The Hague Centre for Strategic Studies

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Reaching breaking point

The semiconductor and critical raw material ecosystem at a time of great power rivalry

Joris Teer, Mattia Bertolini

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Executive summary

Both semiconductors and critical raw materials (CRM) have been described as *the oil of the 21st century*. Semiconductors play an indispensable role in powering the modern digital economy. Computers, smartphones, smart grids, automobiles and jetfighters all require chips. Notably, semiconductors play a key role in the energy transition, for instance, in new energy solutions such as solar and wind power. Without semiconductors no new semiconductors can be produced, as the design labs, foundries and equipment tools used to produce semiconductors require semiconductors as well. The semiconductor production process in turn relies on a wide variety of CRM. Prices of various CRM are on the rise, with some even becoming scarce. The move from oil and gas production to green energy, including solar panels and wind turbines, can be boiled down to "a shift from [reliance on] fossil fuels to metals".[1] Not only the energy transition, but also the digital transition, as well as defence-related manufacturing and other factors are pushing demand for CRM. The interlinking semiconductor and CRM ecosystem hence are the foundation of today's world economy.

The interlinking semiconductor and CRM ecosystem are the foundation of today's world economy.

As great power rivalry heats up, semiconductor and CRM value chains are in an early stage of being weaponised, similar to how the Organisation of Arab Petroleum Exporting Companies (OAPEC) used oil as a lever of power in 1973.[2] The semiconductor value chain is dominated by the technologically advanced democracies of the world, including Taiwan, South Korea, the US, Japan and European states. It is highly globalised, highly consolidated, depends on exceptionally high-levels of investment in research and development (R&D) and has a high division of labour across continents.[3] Even though the majority of activities in the supply chain take part in Taiwan, South Korea, the United States and China, one company in the Netherlands functions as an irreplaceable node. The Netherlands-based lithography giant Advanced Semiconductor Materials Lithography (ASML) is the sole provider of Extreme Ultra-Violet (EUV) lithography equipment, an essential tool used by semiconductor manufacturing companies, such as Taiwan Semiconductor Manufacturing Company (TSMC) and Samsung, to produce the world's most advanced chips.[4] NXP and ASM International, two additional innovative companies involved in the semiconductor value chain, are headquartered in the Netherlands too.

1 René Kleijn, "Leiden-Delft-Erasmus White Paper: Critical Materials, Green Energy and Geopolitics," Leiden-Delft-Erasmus Universities, June 21, 2022, 8, https://www.leiden-delft-erasmus.nl/en/news/the-energy-transition-a-monumental-shift-in-resources-and-policies#:~:text=The%20energy%20transition%3A%20a%20monumental%20shift%20in%20resources%20and%20policies,-21%20Jun%202022&text=For%20dr%20Ren%C3%A9%20Kleijn%20time,than%202025%2C%E2%80%9D%20he%20says.

2 Even though deposits for many CRM around the world are widespread, at the moment production, refining and conversion and processing of CRM for semiconductors is only done in a limited amount of states. Diversification of production cannot be easily done, especially for the mining phase, as the International Energy Agency (IEA) estimates the time from early exploration of a mine to full production to take anywhere between seven and 20 years (see chapter 1). At the same time, US-led attempts to impose limits on exports of semiconductor technology to China as well as a comprehensive ban on exporting semiconductors to Russia contribute to the weaponisation of the semiconductor supply chain (see Chapter 3).

3 Antonio Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era" (BCG, SIA, April 2021), https://www.semiconductors.org/strengthening-the-global-semiconductor-supply-chain-in-an-uncertain-era/.; Jan-Peter Kleinhans and Nurzat Baisakova, "The Global Semiconductor Value Chain: A Technology Primer for Policy Makers" (Stiftung Neue Verantwortung, October 2020), https://www.stiftung-nv.de/sites/default/files/the_global_semiconductor_value_chain.pdf; John Lee and Jan-Peter Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context" (Berlin: *MERICS*, June 2021), https://merics.org/sites/default/files/2021-06/China%E2%80%99s%20Semiconductor%20Ecosystem_0.pdf.

4 "ASML," ASML, 2022, https://www.asml.com/en.

Nowadays, supplies of the refined and processed CRM used to manufacture semiconductors are (indirectly) imported from the European Union's (EU) rivals, specifically China and Russia, and African countries with complicated political-economic or military contexts, such as the Democratic Republic of the Congo (DRC) and other states in Southern Africa. Today's cost efficient, global supply chains, increasingly come with security of supply risks, as trust between the large industrialised blocs of the world is rapidly eroding.

How sustainable will these dependencies prove to be in the next five and ten years? Throughout the previous decade, relations between the Netherlands, the EU and their partners in semiconductor production on the one hand, and Russia and China on the other, have deteriorated rapidly. Yet, as of September 2022, only relations with Russia have reached breaking point. A breaking point is reached when friction in an interstate relationship, often related to military-strategic tensions, becomes so overwhelming that states are no longer willing to supply all or some vital resources on which the economies of their rivals depend. European-Russian trade in vital resources survived the annexation of Crimea, the downing of MH17, and all other contentious events before February 2022. However, European-Russian relations reached breaking point following Russia's invasion of Ukraine and European retaliatory sanctions including a comprehensive ban on the export of semiconductors to Russia. Russia reduced the supply of natural gas to Europe to 25% of 2019 levels, freezing the export of neon gas altogether until the end of 2023. The continuation of palladium exports from Russia, a CRM used in the fabrication of semiconductors, throughout 2022 should not be taken for granted, as relations between Europe and Russia are still in decline.

European-Russian relations have reached breaking point.

Sino-European relations, unlike European-Russian relations, have not yet reached breaking point, but are similarly characterised by a downward trajectory over the course of the past decade. China's supply of silicon, gallium, germanium, cobalt and rare earth elements (REE) survived the EU designating Beijing as a *systemic rival*,[5] the Dutch House of Representatives becoming the first parliament in Europe to label China's mass-internment of Uyghurs a genocide,[6] EU sanctions against Chinese officials engaged in Xinjiang-related policy-making,[7] and the G7's condemnation of China's live-fire drills around Taiwan in August 2022.[8] So far, it has also survived the United States (US) spurring on allies in Europe and Asia to join its attempts to "freeze" China's technological development over the past years. Since 2019, the Dutch government has withheld a license for ASML to export its EUV system to China. Even though China has a history of weaponising access to its market and greatly limited its supply of REE to the world in 2010, it has not opted to weaponise the resource in the 2020s. Finally, the supply of cobalt survived an uptick in political instability in the DRC and other Southern African states as well as the dominance of Chinese (state-owned) companies in refining and control

5 "EU-China - A Strategic Outlook" (Brussels: European Commission, March 12, 2019).

6 "Motie van het lid Sjoerdsma c.s. over uitspreken dat in China genocide plaatsvindt op de Oeigoerse minderheid," Text, Tweede Kamer, February 25, 2021, https://www.tweedekamer.nl/kamerstukken/detail/2021Z03872/2021D08405.

7 "Chair's Statement of 23 March 2021 on EU Sanctions on Human Rights Violations; Counter-Sanctions by the PRC," European Parliament, March 23, 2021, https://www.europarl.europa.eu/delegations/en/chair-s-statement-of-23-march-2021-on-eu/product-details/20210324DPU29209.

8 U.S. Department of State, "G7 Foreign Ministers' Statement on Preserving Peace and Stability Across the Taiwan Strait," August 3, 2022, https://www.state.gov/g7-foreign-ministers-statement-on-preserving-peace-and-stability-across-the-taiwan-strait/#:~:text=We%20are%20concerned%20by%20recent,activity%20in%20the%20Taiwan%20Strait.

over mines in the DRC.[9] Even though the supply of CRM from or through China to Europe has survived until now, the downward trend in China's relations with technologically advanced democracies comes with realistic risks of reaching breaking point throughout this decade.

In the face of looming breaking points ensuring security of supply is becoming a central motivation behind policies of states and companies. Especially contentious issues such as the status of Ukraine, Taiwan, the South China Sea and the East China Sea, can serve as flashpoints leading Russia or China to upend their supply of CRM to Europe. Whether political stability in Southern Africa and the DRC can be maintained remains an open question. At a time of great power rivalry, opposing camps in the semiconductor and CRM ecosystem try to win interdependence by building on their respective strengths and mitigating their vulnerabilities.

Europe in the semiconductor and CRM ecosystem

Opposing camps in the semiconductor and CRM ecosystem try to win interdependence.

To ensure the unimpeded functioning of the European economy in an effective and efficient manner, the Netherlands and the EU need to strengthen their position in the fragile semiconductor and CRM ecosystem.[10] Much has been written on risks due to the interdependencies in the semiconductor supply chain, with industry players like ASML advocating industrial policies to strengthen Europe's place in the semiconductor ecosystem.[11] The European Chips Act, aiming to invest tens of billions of euros, intends to indigenise a greater share of the semiconductor supply chain.[12] The risks of the Netherlands and the EU's vast CRM dependence on third countries, especially its rivals, is widely acknowledged to be a threat and has been assessed in depth.[13] The European Commission President, in her 2022 state of the union address, announced the preparation of a European Critical Raw Material Act, to achieve greater control over CRM value chains.[14] The Dutch government will present a resource strategy by the end of 2022.

Indigenisation of the semiconductor and CRM value chain comes, however, at a cost. The Semiconductor Industry Association, the voice of the US semiconductor industry, has

9 Tsisilile A Igogo et al., "Supply Chain of Raw Materials Used in the Manufacturing of Light-Duty Vehicle Lithium-Ion Batteries" (CEMAC, August 30, 2019), https://doi.org/10.2172/1560124; Eric Lipton and Dionne Searcey, "Chinese Company Removed as Operator of Cobalt Mine in Congo," *The New York Times*, February 28, 2022, sec. World, https://www.nytimes.com/2022/02/28/world/congo-cobalt-mining-china.html; Dionne Searcey et al., "A Power Struggle Over Cobalt Rattles the Clean Energy Revolution," *The New York Times*, November 20, 2021, sec. World, https://www.nytimes.com/2021/11/20/world/china-congo-cobalt.html.

10 See Dutch Ministry of Justice and Security, "National Security Strategy" (Dutch Central Government, 2019), 12, https://english.nctv.nl/topics/national-security-strategy.

11 "ASML Position Paper on EU Chips Act" (ASML, February 2022), https://www.asml.com/-/media/asml/files/news/2022/asml-position-paper-on-eu-chips-act.pdf?rev=cc4554892d7a4304bee8b056b96e4dee.

12 European Commission, "A Chips Act for Europe" (Brussels: European Commission, February 8, 2022), https://digital-strategy.ec.europa.eu/en/library/european-chips-act-staff-working-document.

13 Irina Patrahau et al., "Securing Critical Materials for Critical Sectors" (The Hague Centre for Strategic Studies, 2020), https://hcss.nl/report/securing-critical-materials-for-critical-sectors-policy-options-for-the-netherlands-and-the-european-union/.; Magnus Gislev and Milan Grohol, "Report on Critical Raw Materials and the Circular Economy" (European Commission, 2018), https://op.europa.eu/en/publication-detail/-/publication/d1be1b43-e18f-11e8-b690-01aa75ed71a1. ; European Commission, "Communication from the Commission to the EU Parliament and the European Council: Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability" (European Commission, 2020), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474.

14 European Commission, State of the Union Speech by President von Der Leyen, 2022, https://www.youtube.com/watch?v=K8LzZ2vgnwA.

highlighted the enormous added value of the global, sophisticated semiconductor supply chain, pointing out the way in which it supports "the industry's continuous technology innovation" and "how it ultimately benefits consumers and enables better technology and lower prices."[15] The pandemic-induced chip shortage inhibited the production of anything ranging from cars to essential medical devices, highlighting the costs of even just a temporary disruption to the ecosystem.[16] Similarly, re-shoring CRM production comes at a cost too, as for decades value chains were outsourced for reasons of cost efficiency and environmental pollution.[17] Strengthening Europe's place in the semiconductor and CRM fragile balance is a necessity, but disrupting the ecosystem entirely comes with great threats to economic security too.

Indigenisation of the semiconductor and CRM value chain comes at a cost.

This report covers new ground by specifically outlining pending disruptions in CRM value chains on which the EU relies for its access to semiconductors in the next five and ten years. The report also highlights key green technologies that rely on the same CRM value chains, as disruptions to these chains will also inhibit the energy transition. By doing so, an action plan is proposed for the Netherlands and the EU to deal with the risks and opportunities associated with the dependencies of the CRM needed for semiconductor production and green technologies. The action plan also outlines options to seize the opportunities related to the strengths of the Netherlands, the European Union and other technologically advanced democracies in the semiconductor value chain.

15 Antonio Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era" (BCG, SIA, April 2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf.

16 Frans van Houten, "Global Chip Shortages Put Life-Saving Medical Devices at Risk," World Economic Forum, 2022, https://www.weforum.org/agenda/2022/05/global-chip-shortages-put-life-saving-medical-devices-at-risk/.

17 During a visit to Inner-Mongolia in 1992, Deng Xiaoping outlined his "reform-and-open-up" policy further explicating the role he already envisioned in 1987 for Inner-Mongolia. He proclaimed "The Middle East has Oil. China has rare earth" (中东有石油；中国有稀土), China Broadcasting Network, "Deng Xiaoping pointed out during his southern tour: "The Middle East has oil, and China has rare earths"", CNR, August 16, 2007, http://nm.cnr.cn/nmzt/60dq/tjnmg/200704/t20070412_504442760.html; Dian L. Chu, "Seventeen Metals: 'The Middle East Has Oil, China Has Rare Earth,'" Business Insider, November 11, 2010, https://www.businessinsider.com/seventeen-metals-the-middle-east-has-oil-china-has-rare-earth-2011-1.

1. A fragile balance: the semiconductor and critical raw material ecosystem

The semiconductor value chain and the critical raw material supply chain balance each other out: whereas the semiconductor value chain is dominated by technologically advanced democracies allied to the United States, the supply chains of crucial CRM for the production of semiconductors is dominated by rival states, including China and Russia.

The semiconductor supply chain is highly globalised, interdependent, and dependent on constant large-scale investment in R&D. Each step in the main supply chain is concentrated in different geographical regions of the world, has its own distinct market characteristics, and relies on its very own chain of suppliers. Whilst chip design is concentrated in the United States and Taiwan, high-end chip fabrication is located in Taiwan, South Korea, and the United States, and assembly, test, and packaging is mostly done in Taiwan, the United States and China.

The Netherlands plays a small yet indispensable role in the semiconductor supply chain.

The Netherlands plays a small yet indispensable role in the semiconductor supply chain, in which Dutch supplies of semiconductor manufacturing equipment forms a major chokepoint in the entire value chain. Dutch industries are crucial both in specific markets, such as NXP in the automotive industry, as well as across the entire semiconductor industry, such as ASML and ASM International. The role of ASML in particular, as the key and even sole provider of crucial equipment necessary for advanced chip manufacturing provides the Netherlands and Europe with an irreplaceable node in the network to produce the oil of the 21st century. Europe's role in the rest of the semiconductor value chain, however, is modest.

CRM, such as palladium, cobalt, gallium, germanium, REE and silicon, constitute the foundation upon which the entire semiconductor supply chain rests, including essential supplies of anything ranging from equipment and wafers (see Table 1). Geological and economic limitations, the time needed to set up mining, refining and processing capacity, and its polluting and disruptive nature, complicate relocating the industry elsewhere.[18] Reliance on geopolitical rivals such as China and Russia in various steps of the CRM supply chain, poses a profound threat to the semiconductor industry as great power rivalry is heating up. At the same time, reliance on countries mired in political and social instability, such as the DRC, can also significantly disrupt the supply of CRM for the production of semiconductors.

18 "The Role of Critical Minerals in Clean Energy Transitions" (Paris: IEA, 2021), https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary; Rebekah Daunt, "Portugal's Government Approves Lithium Mining despite Growing Concerns," Euronews, May 2, 2022, https://www.euronews.com/2022/02/05/portugal-s-government-approves-lithium-mining-despite-protests-concerns; Darko Lagunas and Luuk van der Sterren, "De weg naar groene energie is een smerige zaak," Follow the Money - Platform voor onderzoeksjournalistiek, June 11, 2022, https://www.ftm.nl/artikelen/zeldzame-aard-metalen-energietransitie-china.

A fragile supply chain balance

The semiconductor and critical raw material ecosystem

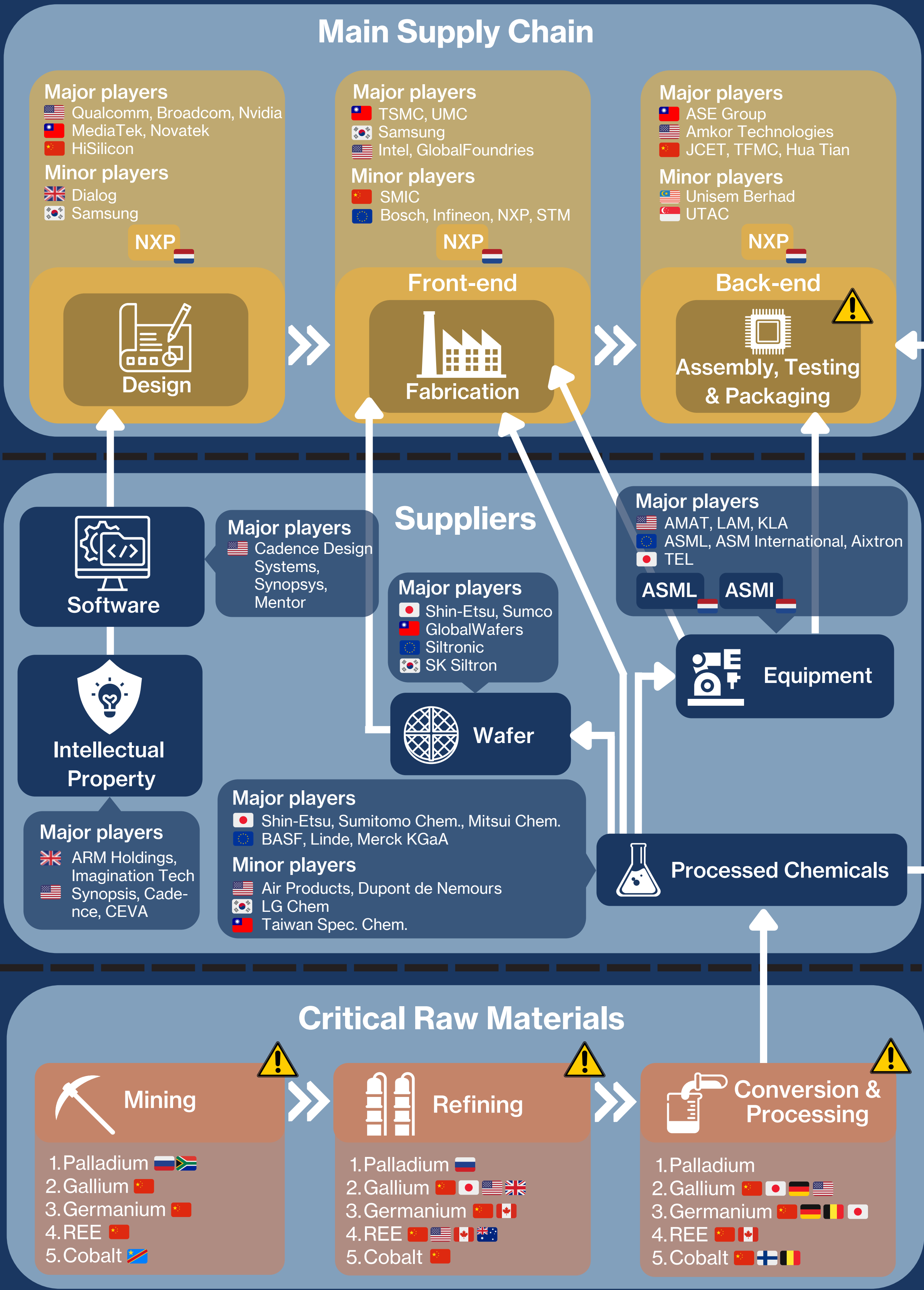


Table 1. Stranglehold: China and Russia's control over six key CRM for the fabrication of semiconductors and green applications

CRM	Function in fabrication semiconductors[19]	Function in green applications[20]	Production (mining) per country (total/share of global production) in 2020[21]
Palladium	A component of a multilayer metallisation structure, improving adhesion	Semiconductors	In kilograms and share 1. Russia: 93,000; 43% 2. South Africa: 73,500; 34% 3. Canada: 20,000; 9% 4. US: 14,600; 7% 5. Zimbabwe: 12,900; 6%
Cobalt	To help copper make better circuits in the latest-generation of semiconductors	Electric Vehicle Batteries (EVB); Carbon Caputure and Storage (CCS); Semiconductors	In metric tons and share 1. DRC*: 98,000; 69% 2. Russia: 9,000; 6% 3. Australia: 5,630; 4% 4. Philippines: 4,500; 3% * Majority of mines owned by China, and refining operations in China
Gallium	A preferred material used in semiconductor manufacturing due to its high breakdown strength, fast switching speed, high thermal conductivity, and lower on-resistance	Solar-Photovoltaic (PV); EVs; Semiconductors	In kilograms and share 1. China: 317,000; 97% 2. Russia: 5,000; 2% 3. Japan: 3,000; 1% 4. South Korea: 2,000; 1%
Germanium	Alloyed with silicon in chip manufacturing for use in certain high-speed devices, including in the automotive industry	Solar PV; EVs; Semiconductors	In kilograms and share 1. China: 95,000; 68% 2. Russia: 5,000; 4% 3. Other countries incl. Belgium, Canada, Germany, Japan, Ukraine: 40,000; 29%
REE	A set of 17 closely-related metals that have applications in various subsets of semiconductor fabrication	Wind Turbines; EVs; Semiconductors	In metric tons and share 1. China: 140,000; 58% 2. US: 39,000; 16% 3. Burma: 31,000; 13% 4. Australia: 21,000; 9%
Silicon	Used to produce the wafers which are used to print patterns on and then sliced up to produce semiconductors.	Solar PV; Semiconductors	In thousand metric tons and share 1. China: 5,600; 69% 2. Russia: 576; 7% 3. Brazil: 404; 5% 4. Norway: 345; 4% 5. US: 277; 3%

19 S. Bobba et al., Critical Raw Materials for Strategic Technologies and Sectors in the EU; Patrahau et al., 'Securing Critical Materials'.

20 Patrahau et al., 'Securing Critical Materials for Critical Sectors', p. 27 and p. 111-112.

21 'Platinum-Group Metals'; 'Cobalt'; 'Gallium'; 'Germanium'; 'Rare Earth Elements'; USGS, 'Silicon'.

2. Threats to the supply of CRM for semiconductors

The breakdown of European-Russian trade in vital resources following Russia's invasion of Ukraine shows that economic ties between rival states, even if mutually beneficial and on the surface solely commercial, cannot be guaranteed. Warning signs of a structural decline in Russia's relations with Europe, characterised by contentious events such as the annexation of Crimea and the downing of MH-17, preceded this breakdown. Today similar early indications of looming disruptions can be observed, showing that specific threats are likely to cause high impact disruptions in the supply of CRM to Europe or its semiconductor manufacturing partners such as Taiwan throughout this decade (see Table 2).

Economic ties between rival states, even if mutually beneficial and on the surface solely commercial, cannot be guaranteed.

Ten pending threats, selected on the basis of a wide variety of data inputs, deserve special attention. Eight threats were identified by drawing lessons from how Russia's war in Ukraine led European-Russian relations to reach breaking point (see *ii. Case study Reaching breaking point: Weaponisation of European-Russian trade in vital commodities following Russia's invasion of Ukraine*). The supply of vital resources, primarily natural gas and neon but also temporarily palladium, to Europe was disrupted by an export embargo by Russia (a geopolitical threat), warfighting in Ukraine (a military threat) and European retaliatory sanctions (a legal threat). As a result, the looming risk of CRM embargoes by rival states, interstate and intrastate war-related disruptions in Asia and Africa, and European and American sanctions disrupting the supply of CRM should be assessed carefully (see Table 2). These eight threats were then verified on the basis of a literature review, prior research and expert interviews with both regional and thematic experts from academia, think tanks, government, and industry (see Appendix 1). Two additional threats, namely structural geoeconomic factors, were identified on the basis of a limited data analysis of CRM prices, demand projections and supply chain disruptions, primarily caused by China's COVID-19 lockdown policies.

Table 2. Pending threats to the critical raw material for semiconductor supply chain

	Theme	Region	Threat
1	Geopolitical	Eastern-Europe	Palladium export embargo by Russia
2	Geopolitical	East Asia	Gallium, Germanium, Cobalt, Rare Earth Element export embargo by China
3	Military	East Asia	People's Liberation Army naval blockade and/or invasion of Taiwan
4	Military	East Asia	Regional naval war in the East China Sea between China and Japan, South Korea and/or the US
5	Military	Southeast Asia	Regional naval war in the South China Sea between China and a Southeast Asian country and/or the US
6	Military	Southeast Asia and Persian Gulf	US blockade halting Chinese oil and gas imports (e.g., Malacca Strait or Strait of Hormuz)
7	Military	Southern Africa	Political instability or civil war in the DRC (or along transportation routes in Southern Africa)
8	Legal	Southern Africa and East Asia	Increasingly stringent EU and US ESG-regulation (e.g., disrupting imports from DRC-mined cobalt and China-mined Silicon)
9	Geo-economic	Global	Demand-induced resource shortage due to the energy transition and increase in semiconductor manufacturing
10	Geo-economic	East Asia	Events inside China such as pandemic-related lockdowns or work stoppages

Finally, a ranking of these threats was brought about through a foresight survey filled out by 49 experts. The survey finds that the supply of semiconductors and end-products to the EU is likely to be strongly, negatively impacted by CRM supply disruptions, already in the next five but even more so in the next ten years. The most important threats to the supply of CRM for semiconductors in the next ten years are demand-induced CRM shortages due to the energy transition, a People's Liberation Army (PLA) invasion or maritime blockade of Taiwan and a CRM embargo by China.[22]

2.1. Ranking risks: CRM-related threats to the supply of semiconductors survey outcome

The seriousness of the identified risks was gauged by experts, ranking the ten threats both in terms of probability of occurrence and level of impact (see Infographics Critical Raw Material Risks and Figure 1 and 2). Seven key findings can be derived from the survey:

The respondents found that there is a higher than 50% change that Taiwan will face a PLA maritime blockade or invasion before 2032.

1. **The supply of semiconductors and end-products to the EU is likely to be strongly, negatively impacted by CRM supply disruptions, already in the next five but even more so in the next ten years**. A demand-induced shortage due to the energy transition, a CRM export embargo by China, and a People's Liberation Army naval blockade/invasion of Taiwan are deemed the top risks in the next ten years. It is likely that one or more risks materialises before 2032 and possibly even before 2027, as five risks were awarded a higher than 50% probability to materialise in the next five years and seven in the next ten years. Out of all risks, seven are expected to have a "high impact"[23] and three to have a "very high impact" (see Figure 2).[24] If even just one of these risks materialises, the respondents expect that this will have either a "high impact" or "very high impact" on the supply of semiconductors and end-products to the EU and, hence, the bloc's overall economic security.

2. **A demand-induced CRM shortage due to the energy transition is the threat that is deemed most likely to materialise in both the next five and ten years.** A demand-induced shortage due to the energy transition is a structural, "high impact" challenge facing the CRM landscape. Five out of six CRM assessed in this report have important functions in both semiconductor production and the transition to green energy, meaning the energy transition will put pressure on their availability for semiconductor production.

3. **The respondents fear that CRM embargoes enacted by China and Russia then aggravate these shortages (see Figure 2), similarly to the imposition of a natural gas and neon gas (partial-)embargo by Russia in 2022.** As prices rise due to increased demand, the "more likely than not" risk of a palladium export embargo by Russia in both the next five and ten years, and the "more likely than not/likely" risk of a CRM embargo by China in the next ten years, are expected to aggravate disruptions in the supply of semiconductors and end-products to the European Union.

22 Needless to say that since the Russia-Ukraine conflict is highly dynamic and shrouded in the fog of war, the findings below may not be exhaustive. These are based on open sources and expert interviews with among other experts a palladium trader. Brijesh Patel, "Palladium Tops $3,000/Oz as Supply Fears Grow, Gold Jumps over 1%," *Reuters*, March 4, 2022, sec. European Markets, https://www.reuters.com/markets/europe/gold-gains-after-russia-attacks-europes-largest-nuclear-plant-2022-03-04/; Peter Hobson, "Palladium Propelled to Record Highs by Russia Supply Concerns," *Reuters*, March 7, 2022, sec. Business, https://www.reuters.com/business/palladium-propelled-record-highs-by-russia-supply-concerns-2022-03-07/. Alexandra Alper, "Exclusive: Russia's Attack on Ukraine Halts Half of World's Neon Output for Chips," *Reuters*, March 11, 2022, sec. Technology, https://www.reuters.com/technology/exclusive-ukraine-halts-half-worlds-neon-output-chips-clouding-outlook-2022-03-11/.

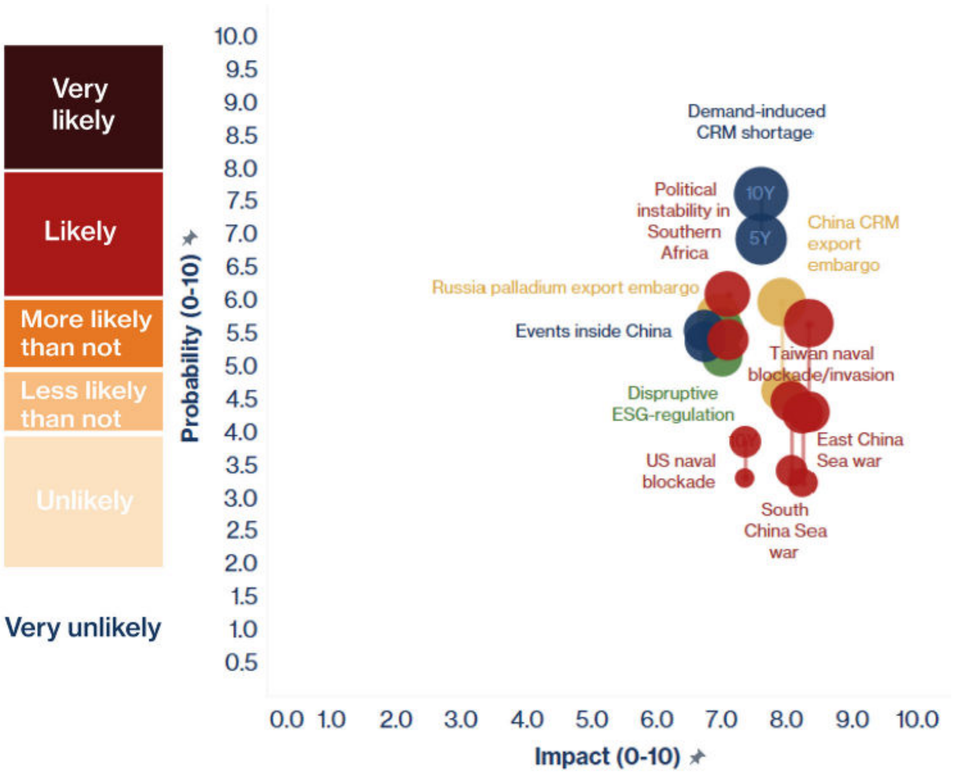
23 Threat 1, 2,3,4,6,9,10

24 Threat 5, 7, 8

4. **Military risks in the Indo-Pacific involving China and possibly the United States are considered the highest impact risks. They are, however, mostly still considered "unlikely" in the next five years and "less likely than not" in the next ten years – with the exception of a naval blockade/invasion of Taiwan.** Military risks involving China, such as 1. A naval blockade and/or invasion of Taiwan, 2. War in the East-China Sea, and 3. War in the South-China Sea are deemed the highest impact events by the overall respondents.[25] Whereas war in either the East-China Sea or South-China Sea is deemed to be "less likely than not" in both the next five and ten years, the odds of a naval blockade and/or invasion of Taiwan passes the respondents' threshold from "less likely than not" in the next five years to "more likely than not" in the next ten years – meaning a higher than 50% chance of occurrence. A PLA naval blockade or invasion of Taiwan is expected to have the greatest impact on the supply of semiconductors or end products to the European Union out of all the risks that were surveyed.

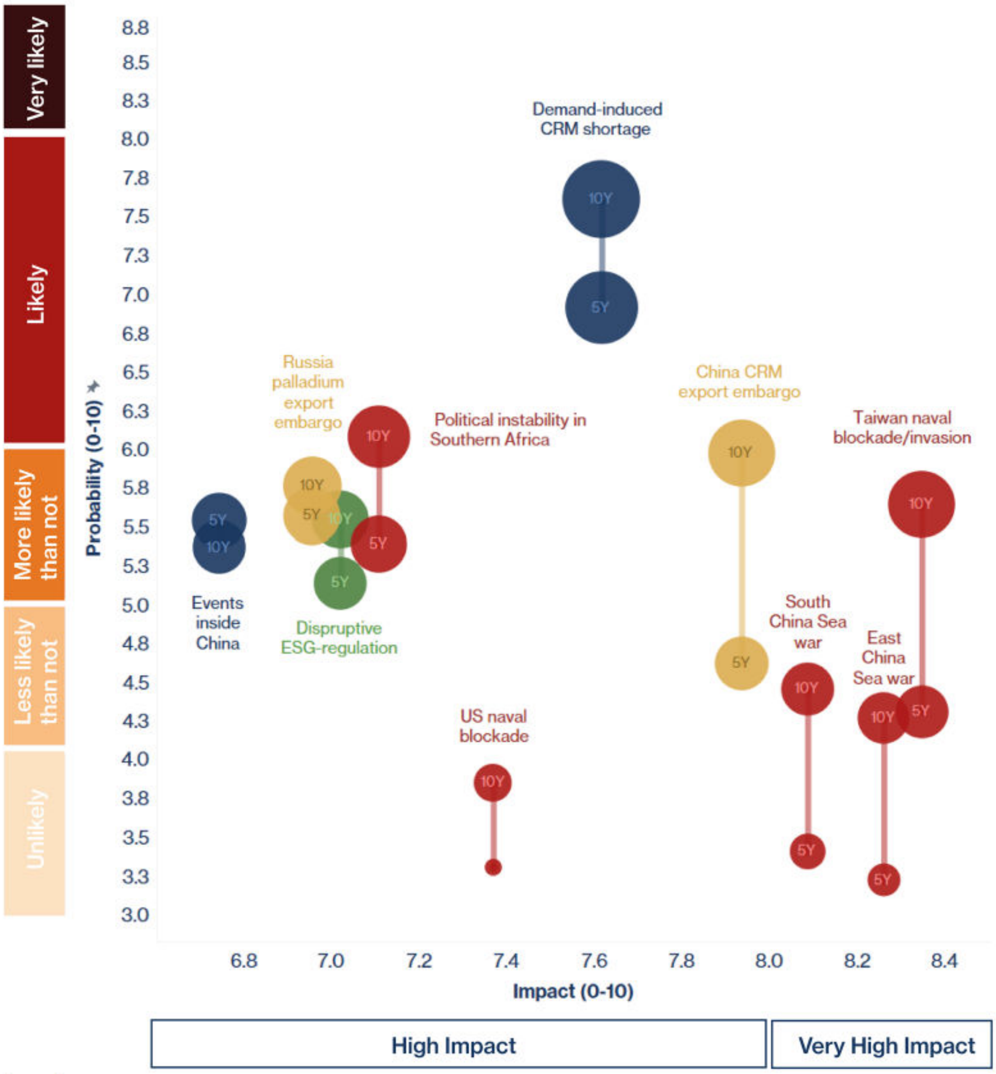
5. **Political unrest or even intrastate conflict in Southern African states are likely to disrupt the supply of cobalt (see Figure 2)**. Political unrest in Southern Africa, another military threat, is deemed "more likely than not" to disrupt the supply of CRM for semiconductors in the next five years, and "likely" to do so in the next ten years. This would have a "high impact" on the supply of semiconductors and end-products to the EU and hence the EU's economic security.

Figure 1. Survey outcome: All CRM-related semiconductor risks are either "high" or "very high" impact



25 All expected to have a "very high impact".

Figure 2. Survey outcome: Seven out of ten threats are considered (at least) "more likely than not" to materialise over the next ten years



6. **ESG-related regulation and sanctions by the United States and the European Union were awarded a higher than 50% probability of causing a "high impact" disruption in the supply of CRM for semiconductor production.**

7. **Finally, events inside China such as pandemic related lockdowns are deemed "more likely than not" to disrupt the supply of CRM already in the next five years, and are expected to have a "high impact" on the supply of semiconductors and end-products to the European Union.**

3. Winning interdependence: semiconductor and CRM rivalry in a de-globalising world

The current semiconductor and CRM equilibrium is not static: various Western governments, led by the US, have undertaken attempts to strengthen and leverage the West's collective dominance in the semiconductor value chain against Russia and China[26], whilst at the same time attempting to mitigate their CRM dependence.[27] However, current European efforts to mitigate CRM reliance are not on-track to bear fruit at a large-scale before the risks related to CRM dependence are expected to materialise.[28]

Bloc formation and intensifying technology competition risk upending the fragile CRM and semiconductor balance.

Bloc formation and intensifying technology competition risk upending the fragile CRM and semiconductor balance. Since 2019, the US has imposed restrictions on the export of vital American semiconductor manufacturing equipment to Chinese chip manufacturers, spurring on allies in Europe and Asia to do the same (see Infographic Sabotaging Xi).[29] Following Russia's 2022 invasion of Ukraine, the US and its allies, including Taiwan, South Korea and Japan, have banned the exports of semiconductors to Russia altogether.[30] This grants China and Russia, the rivals of Europe and its partners in semiconductor production (e.g., Taiwan), greater incentive to weaponise CRM dependence. The place of the Netherlands in this fragile balance is largely shaped by ASML, a key industry player bringing plentiful employment and economic benefits, as well as great power interest, to the Netherlands. However, ASML's EUV and Deep Ultra-Violet (DUV) lithography equipment has also put the Netherlands in an awkward position with both superpowers – the US and China – placing conflicting demands on the Netherlands, and China issuing a barely veiled threat of punishment.[31]

Policy-making efforts in the Netherlands and the European Union to reduce risks in the CRM supply chain are well underway, but translating plans into concrete action remains a problem.

[26] See for example: Jenny Leonard, Ian King, and Debby Wu, "China's Chipmaking Power Grows Despite US Effort to Counter It," *Bloomberg*, June 13, 2022, https://www.bloomberg.com/news/articles/2022-06-13/china-s-growing-clout-in-global-chip-market-rings-alarm-bells-in-washington; John Lee and Jan-Peter Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context" (*MERICS*, June 2021); Ana Swanson, John Ismay, and Edward Wong, "U.S. Technology, a Longtime Tool for Russia, Becomes a Vulnerability," *The New York Times*, June 2, 2022, sec. Business, https://www.nytimes.com/2022/06/02/business/economy/russia-weapons-american-technology.html; Yang Jie and Jiyoung Sohn, "Chip Sanctions Challenge Russia's Tech Ambitions," Wall Street Journal, March 19, 2022, sec. Tech, https://www.wsj.com/articles/chip-sanctions-challenge-russias-tech-ambitions-11647682202; "America Has a Plan to Throttle Chinese Chipmakers," The Economist, April 25, 2022, https://www.economist.com/business/america-has-a-plan-to-throttle-chinese-chipmakers/21808959.

[27] European Commission, "Commission Announces Actions on Critical Raw Materials," Text, European Commission, September 3, 2022, https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1542.; The White House, "Fact Sheet Securing a Made in America Supply Chain for Critical Minerals," The White House, February 22, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/22/fact-sheet-securing-a-made-in-america-supply-chain-for-critical-minerals/.

[28] S. Bobba et al., Critical Raw Materials for Strategic Technologies and Sectors in the EU: A Foresight Study. (LU: European Commission, 2020), https://data.europa.eu/doi/10.2873/58081.

[29] The Economist, "America Has a Plan to Throttle Chinese Chipmakers," The Economist, 2022, https://www.economist.com/business/america-has-a-plan-to-throttle-chinese-chipmakers/21808959.; Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context," June 2021.; Jenny Leonard, Ian King, and Debby Wu, "China's Chipmaking Power Grows Despite US Effort to Counter It."

[30] "Remarks by President Biden on Russia's Unprovoked and Unjustified Attack on Ukraine," The White House, February 24, 2022, https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/02/24/remarks-by-president-biden-on-russias-unprovoked-and-unjustified-attack-on-ukraine/.

[31] Johan Leupen and Sandra Olsthoorn, "'We zouden niet willen dat Nederland zwicht onder de druk van de VS,'" FD.nl, January 15, 2020, https://fd.nl/economie-politiek/1330711/we-zouden-niet-willen-dat-nederland-zwicht-onder-de-politieke-druk-van-de-amerikanen.

These plans include reshoring of mining, refining, and processing operations, CRM cooperation with third-parties such as Japan, Canada, Australia, the US but also non-rival autocracies, recycling, reducing demand, deep-sea mining, and stockpiling.[32] These initiatives either come with challenges, such as *Not In My Backyard-protests* (NIMBY), environmental concerns, technological and economic limitations, limited alternative sourcing countries, or only provide short-term solutions.[33] If only current initiatives are executed, the EU's economic security is likely to be strongly, negatively affected by the disruptions in the supply of CRM that are likely to take place in the next ten years. Both the production of semiconductors and other means necessary to complete the transition to green energy will be affected, if these disruptions occur.

4. Policy implications, opportunities and recommendations

The Netherlands and EU would be advised to take a host of measures to strengthen resilience in the increasingly fragile and contested semiconductor and CRM ecosystem. The semiconductor and CRM ecosystem is, when simplified, best understood as a fragile geopolitical balance held up by American, European and Asian advanced, semiconductor-fabricating, democracies and CRM-producing rival states, namely Russia and China, and non-rival states, meaning the DRC (see Chapter 1: A fragile supply chain balance). This fragile balance may very well be upset in similar ways as Russia's invasion of Ukraine led to a chain reaction that disrupted the supply of essential commodities, namely natural gas, neon gas and temporarily palladium to Europe (see Chapter 2: Threats to the supply of CRM for semiconductors). Current European efforts to mitigate CRM reliance are not on-track to bear fruit at a large-scale before the risks related to CRM dependence are expected to materialise (see Chapter 3: Winning interdependence).

To address these challenges policy-makers are advised to appreciate five high-level policy implication themes, which come with specific policy opportunities and recommendations.[34]

1. Prioritise security of supply in a world where hard competition between great powers structurally threatens European economic security, including disruptions in the near future supply of CRM.
2. Accept that the US-China tech rivalry is likely to put the supply of semiconductors, digital end-products, and products needed for the energy transition to the EU at risk.
3. Work with other technologically advanced democracies to mitigate semiconductor and CRM ecosystem risks *vis-à-vis* Russia and China.

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32 "Commission Announces Actions on Critical Raw Materials," Text, European Commission, September 3, 2020, https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1542; European Commission, "EU and Canada Set up a Strategic Partnership on Raw Materials," European Commission, June 21, 2021, https://ec.europa.eu/growth/news/eu-and-canada-set-strategic-partnership-raw-materials-2021-06-21_en.

33 Jeff Amrish Ritoe, "The New Great Game: Securing Critical Minerals Today for a Clean Energy System Tomorrow," HCSS Geo-Economics (Bangkok: The Hague Centre for Strategic Studies, July 2021), https://hcss.nl/wp-content/uploads/2021/08/The-New-Great-Game-August-2021.pdf; Lagunas and Sterren, "De weg naar groene energie is een smerige zaak"; Rebekah Daunt, "Portugal's Government Approves Lithium Mining despite Growing Concerns," May 2, 2022.

34 These policy implications, opportunities and recommendations were formulated on the basis of a global expert consultation with representatives from academia, think tanks, government and industry (see appendix 1) and a literature review.

4. Expand European leverage in the semiconductor and CRM ecosystem *vis-à-vis* other technologically advanced democracies such as the US, Taiwan, South Korea and Japan.
5. Formulate a strategy to reduce dependence on China and Russia more broadly, as dependence for many other end-products for purposes such as the digital and energy transition remains.[35]

Table 3. Overview of high-level policy implications, policy opportunities and policy recommendations (full list in Chapter 4)

Security implication	Policy recommendation
1. Prioritise security of supply in a world in which hard competition between great powers structurally threatens European economic security, including disruptions in the near future supply of CRM.	1.1 Prepare for persistent pressure on Dutch and broader European prosperity, which will go hand-in-hand with shortages, delays in delivery of products, and constant inflationary pressure due to geopolitical fracturing.
	1.2 The 2022 Dutch Ministry for Foreign Trade and Development Cooperation (BHOS) natural resource strategy is advised to take a "worst-case-scenario" approach to preventing, mitigating, and preparing for the consequences of severe CRM supply disruptions.
	1.3 The government should engage in stress testing to identify the effects of likely and impactful CRM supply disruptions.
	1.4 Institute a top-down approach to reducing strategic dependencies, for instance through the establishment of a National Security Council and an Energy Council, an advisory body for energy affordability, robustness of the energy system and security of supply.
2. Accept that the US-China tech rivalry is likely to put the supply of semiconductors, digital end-products and products needed for the energy transition to the EU at risk.	2.1 Address the adverse (un)intended consequences of the US-China tech rivalry. European policy-makers are advised to anticipate that Europe's enormous strategic dependence on Washington will increasingly impel the EU to participate in the US-China tech rivalry on the side of the US.
	2.2 The Dutch government and its semiconductor companies are advised to explore new approaches to get more in return for participating in the US-led tech-showdown with China.
3. Work with other technologically advanced democracies and non-rival CRM-producing autocracies to mitigate semiconductor and CRM ecosystem risks vis-à-vis Russia and China.	3.1. Make use of the opportunities provided by the dominance of technologically advanced democracies in the semiconductor value chain, for instance in order to deter destabilising acts by rivals.
	3.2. Start policy-initiatives to mitigate CRM-related dependencies and risks now to achieve results in the medium-term.
4. Expand European leverage in the semiconductor and CRM ecosystem vis-à-vis other democracies such as the US, Taiwan, South Korea and Japan.	4.1 Invest in CRM mitigation efforts first and foremost in Canada and Australia, but also the US, as soon as possible, as these states are making the most serious gains to address the CRM issue.
	4.2 Increase the European part of the technologically advanced democracy-dominated semiconductor ecosystem
5. Formulate and execute a broader strategy to reduce dependence on China and Russia.	5.1 The Netherlands and the EU should look for synergies between semiconductor production and large-scale efforts to mitigate dependence that are starting to achieve successes already.
	5.2 The Dutch government's National Security Council, announced in the Coalition Agreement of Rutte IV in January 2022, should be established as soon as possible.
	5.3 Invest in strengths, in line with the advice given by ASML CEO Peter Wennink on how to compete with China: "This is what you do: relentless investment in innovation".[36]
	5.4 Avoid fatalism. If appropriate measures are taken and costs are accepted, taking back control over larger parts of the supply chain is a political decision that the Netherlands and the EU can take.

[35] NPO, 'Het geheim van ASML gemist? Start met kijken op NPO Start', www.npostart.nl, accessed 28 September 2022, https://www.npostart.nl/vpro-tegenlicht/12-09-2022/VPWON_1335235.

Lexicon

A2/AD = Anti Access/Area Denial

ADIZ = Air Defence Identification Zone

ASML = Advanced Semiconductor Materials Lithography

ATP = Assembly, testing, processing

BHOS = Ministry for Foreign Trade and Development Cooperation of the Kingdom of the Netherlands

CCP = Chinese Communist Party

CRM = Critical raw materials

DRC = Democratic Republic of the Congo

DUV = Deep ultraviolet

EEZ = Exclusive Economic Zone

ERMA = European Raw Materials Alliance

ESG = Environmental, Social and Governance

EU = European Union

EUV = Extreme ultraviolet

EU-US TTC = EU–US Trade & Technology Council

EVB = Electric vehicle batteries

HREE = Heavy rare earth elements

IDM = Integrated Device Manufacturer

IEA = International Energy Agency

IP = Intellectual Property

IPCEI = Important Project of Common European Interest

JOGMEC = Japan Oil, Gas and Metals National Corporation

LNG = Liquified Natural Gas

LREE = Light rare earth elements

NATO = North Atlantic Treaty Organisation

NIMBY = Not In My Backyard

OAPEC = Organisation of Arab Petroleum Exporting Countries

OECD = Organisation for Economic Co-operation and Development

OPCW = Organisation for the Prohibition of Chemical Weapons

PGM = Platinum-Group Metals

PLA = People's Liberation Army

PV = Photovoltaic

R&D = Research and development

REE = Rare earth elements

RMIS = Raw Materials Information System

SMIC = Semiconductor Manufacturing International Cooperation

THAAD = Terminal High Altitude Area Defense system

US = United States

Introduction

"God decided where the oil reserves are. We can decide where the fabs [for semiconductor manufacturing] are."

Pat Gelsinger, CEO of Intel, 2021[36]

"The Middle East has its oil. China has rare earth."

Deng Xiaoping, China's Paramount Leader, Southern Tour 1992[37]

The interlinking semiconductor and CRM ecosystem are the foundation of today's world economy.

Both semiconductors and CRM have been described as *the oil of the 21st century*. Oil products have been central in mechanising the economy. Containerships that transport goods around the world, cars that people use to commute to work, and trucks that deliver products to local convenience stores all rely on oil. Semiconductors play an indispensable role in powering the modern digital economy. Computers, smartphones, smart grids, automobiles and jetfighters all require chips. Notably, semiconductors play a key role in the energy transition, for instance, in new energy solutions such as solar and wind power. Without semiconductors no new semiconductors can be produced, as the design labs, foundries and equipment tools used to produce semiconductors require semiconductors as well. The semiconductor production process in turn relies on a wide variety of CRM. Prices of various CRM are on the rise, with some even becoming scarce. The move from oil and gas production to green energy, including solar panels and wind turbines, can be boiled down to "a shift from [reliance on] fossil fuels to metals".[38] Not only the energy transition, but also the digital transition, as well as defence-related manufacturing and other factors are pushing demand for CRM. The interlinking semiconductor and CRM ecosystem hence are the foundation of today's world economy.

36 Ina Fried, 'Intel Pressures the U.S. Government to Help Subsidize Chip Manufacturing', Axios, 18 October 2021, https://www.axios.com/intel-semiconductor-chips-national-security-4ffc8949-4bc7-4460-932c-2c95bebf1daa.html. Ina Fried, 'Intel Pressures the U.S. Government to Help Subsidize Chip Manufacturing', Axios, 18 October 2021, https://www.axios.com/intel-semiconductor-chips-national-security-4ffc8949-4bc7-4460-932c-2c95bebf1daa.html.

37 During a visit to Inner-Mongolia in 1992, Deng Xiaoping outlined his "reform-and-open-up" policy further explicating the role he already envisioned in 1987 for Inner-Mongolia. He proclaimed "The Middle East has Oil. China has rare earth" (中东有石油；中国有稀土), China Broadcasting Network, "Deng Xiaoping pointed out during his southern tour: "The Middle East has oil, and China has rare earths"", CNR, August 16, 2007, http://nm.cnr.cn/nmzt/60dq/tjnmg/200704/t20070412_504442760.html; Dian L. Chu, "Seventeen Metals: 'The Middle East Has Oil, China Has Rare Earth,'" Business Insider, November 11, 2010, https://www.businessinsider.com/seventeen-metals-the-middle-east-has-oil-china-has-rare-earth-2011-1. China has rare earth" (中东有石油；中国有稀土).

38 René Kleijn, "Critical Materials, Green Energy and Geopolitics: A Complex Mix (White Paper)" (Leiden-Delft-Erasmus Universities, June 21, 2022), https://www.leiden-delft-erasmus.nl/en/news/the-energy-transition-a-monumental-shift-in-resources-and-policies#:~:text=The%20energy%20transition%3A%20a%20monumental%20shift%20in%20resources%20and%20policies,-21%20Jun%202022&text=For%20dr%20Ren%C3%A9%20Kleijn%20time,than%202025%2C%E2%80%9D%20he%20says.

As great power rivalry heats up, semiconductor and CRM value chains are in an early stage of being weaponised, similar to how the OAPEC used oil as a lever of power in 1973.[39] The semiconductor value chain is dominated by the technologically advanced democracies of the world, meaning Taiwan, South Korea, the US, Japan and European states. It is highly globalized, highly consolidated, depends on exceptionally high levels of investment in R&D and has a high division of labour across continents.[40] The leading companies along the value chain try to keep up with steadily rising demand for semiconductors and are characterized by their highly specialized activities. This makes them highly dependent on hundreds of suppliers around the world and usually very profitable. The semiconductor supply shortage of 2020, in large part caused by the COVID-19 pandemic, slowed down the production of many products, especially cars but also vital medical equipment.[41] This shows that the semiconductor supply chain lacks "resilience" as its international, *just-in-time* character leaves it vulnerable to disruptive global events.[42] Recognising the risk, China and the US, but also the EU, South Korea, Taiwan (via TSMC) and Japan are in the process of investing unprecedented sums of money to indigenise larger parts of the supply chain to expand security of supply.[43] China has put in considerable efforts, indigenising shares of the global manufacturing of more mature semiconductors, and is also making increasingly advanced semiconductors.[44]

As great power rivalry heats up, semiconductor and CRM value chains are in an early stage of being weaponised, similar to how the OAPEC used oil as a lever of power in 1973.

Even though the majority of activities in the supply chain take part in Taiwan, South Korea, the US and China, one company in the Netherlands functions as an irreplaceable node. The Netherlands-based lithography giant ASML is the sole provider of EUV lithography equipment, an essential tool used by semiconductor manufacturing companies, such as Taiwan Semiconductor Manufacturing Company (TSMC) and Samsung, to produce the world's most

39 Even though deposits for many CRM around the world are widespread, at the moment production, refining and conversion and processing of CRM for semiconductors is only done in a limited amount of states. Diversification of production cannot be easily done, especially for the mining phase, as the International Energy Agency (IEA) estimates the time from early exploration of a mine to full production to take anywhere between seven and 20 years (see Chapter 1). At the same time, US-led attempts to impose limits on exports of semiconductor technology to China as well as a comprehensive ban on exporting semiconductors to Russia contribute to the weaponisation of the semiconductor supply chain (see Chapter 3).

40 Antonio Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era", https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf. Jan-Peter Kleinhans and Nurzat Baisakova, "The Global Semiconductor Value Chain: A Technology Primer for Policy Makers" (Stiftung Neue Verantwortung, October 2020), https://www.stiftung-nv.de/sites/default/files/the_global_semiconductor_value_chain.pdf; John Lee and Jan-Peter Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context" (Berlin: *MERICS*, June 2021), https://merics.org/sites/default/files/2021-06/China%E2%80%99s%20Semiconductor%20Ecosystem_0.pdf.

41 van Houten, "Global Chip Shortages."

42 Jenny Leonard and Ian King, "Biden Team Says Global Chip Shortage to Stretch Through 2022," *Bloomberg*, January 25, 2022, https://www.bloomberg.com/news/articles/2022-01-25/biden-team-says-global-chip-shortage-to-stretch-through-2022?leadSource=uverify%20wall.

43 See, for example: European Commission, "A Chips Act for Europe."; Gregory Arcuri, "The CHIPS for America Act: Why It Is Necessary and What It Does," CSIS, January 31, 2022, https://www.csis.org/blogs/perspectives-innovation/chips-america-act-why-it-necessary-and-what-it-does.; Yuki Furukawa and Takashi Mochizuki, "Japan Approves $6.8 Billion Boost for Domestic Chip Industry," *Bloomberg*, November 26, 2021, https://www.bloomberg.com/news/articles/2021-11-26/japan-approves-6-8-billion-boost-for-domestic-chip-industry.; Kim Jaewon, "South Korea Plans to Invest $450bn to Become Chip 'Powerhouse,'" *Nikkei Asia*, May 13, 2021, https://asia.nikkei.com/Business/Tech/Semiconductors/South-Korea-plans-to-invest-450bn-to-become-chip-powerhouse.; Son Ji-hyoung, "[Korea Chips Act] Korea Sets out Own Chips Act, in Less Ambitious Fashion," The Korea Herald, January 24, 2022, http://www.koreaherald.com/view.php?ud=20220124000671.

44 "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's," SIA, January 10, 2022, https://www.semiconductors.org/chinas-share-of-global-chip-sales-now-surpasses-taiwan-closing-in-on-europe-and-japan/ https://www.semiconductors.org/chinas-share-of-global-chip-sales-now-surpasses-taiwan-closing-in-on-europe-and-japan/; Jan-Peter Kleinhans and Nurzat Baisakova, 'The Global Semiconductor Value Chain: A Technology Primer for Policy Makers', p. 11; 'Chinese Companies Hold Only 5% of Global IC Marketshare', IC Insights, 13 April 2021, https://www.icinsights.com/news/bulletins/Chinese-Companies-Hold-Only-5-Of-Global-IC-Marketshare/.

advanced chips.[45] NXP and ASM International, two additional innovative companies involved in the semiconductor value chain, are headquartered in the Netherlands too.

Nowadays, supplies of the refined and processed CRM used to manufacture semiconductors are (indirectly) imported from the EU's rivals, specifically China and Russia, and African countries with complicated political-economic or military contexts, such as the DRC and other states in Southern Africa. CRM value chains are bound by geography and geology for the mining phase, an often polluting enterprise that adds relatively little monetary value and comes with great health risks for workers. Subsequently, the mined material is refined, converted, and processed in specific localities based on where the right technological processes can be applied. Europe and to a lesser extent, the US fell out of love with mining over the last few decades.[46] Production of REE in the US, once the industry's undisputed leader, shifted to China already during the early stages of Deng Xiaoping's *reform-and-open-up*-policy in the 1980s.[47] Drawn by low environmental and labour standards, companies moved production of CRM to the Global South more broadly. Notably, technologically advanced democracies also rely on rivals and other autocratic states for the energy transition: the production of permanent magnets for wind turbines, batteries for electronic vehicles and solar panels relies on some of the same CRM that are used in semiconductors.[48]

European-Russian relations have reached breaking point.

How sustainable will these dependencies prove to be in the next five and ten years? Throughout the previous decade, relations between the Netherlands, the EU and their partners in semiconductor production on the one hand, and Russia and China on the other, have deteriorated rapidly. Yet, as of September 2022, only relations with Russia have reached breaking point. A breaking point is reached when friction in an interstate relationship, often related to military-strategic tensions, becomes so overwhelming that states are no longer willing to supply all or some vital resources on which the economies of their rivals depend. European-Russian trade in vital resources survived the annexation of Crimea, the downing of MH17, and all other contentious events before February 2022. However, European-Russian relations reached breaking point following Russia's invasion of Ukraine and European retaliatory sanctions including a comprehensive ban on the export of semiconductors to Russia. Russia reduced the supply of natural gas to Europe to 25% of 2019 levels, freezing the export of neon gas altogether until the end of 2023 (see ii. *Case study Reaching breaking point: Weaponisation of European-Russian trade in vital commodities following Russia's invasion of Ukraine*). The continuation of palladium exports from Russia, a CRM used in the fabrication of semiconductors, throughout 2022 should not be taken for granted, as relations between Europe and Russia are still in decline.

Sino-European relations, unlike European-Russian relations, have not yet reached breaking point, but are similarly characterised by a downward trajectory over the course of the past decade. China's supply of silicon, gallium, germanium, cobalt and REE survived the EU

45 "ASML," ASML, 2022, https://www.asml.com/en.

46 Jeff Amrish Ritoe, "The New Great Game: Securing Critical Minerals Today for a Clean Energy System Tomorrow," HCSS Geo-Economics (Bangkok: The Hague Centre for Strategic Studies, July 2021), https://hcss.nl/wp-content/uploads/2021/08/The-New-Great-Game-August-2021.pdf.

47 During a visit to Inner-Mongolia in 1992, Deng Xiaoping outlined his "reform-and-open-up" policy further explicating the role he already envisioned in 1987 for Inner-Mongolia. He proclaimed "The Middle East has Oil. China has rare earth" (中东有石油；中国有稀土), China Broadcasting Network, "Deng Xiaoping pointed out during his southern tour: "The Middle East has oil, and China has rare earths"", CNR, August 16, 2007, http://nm.cnr.cn/nmzt/60dq/tjnmg/200704/t20070412_504442760.html; Chu, "Seventeen Metals." Chu, "Seventeen Metals."

48 Irina Patrahau et al., "Securing Critical Materials for Critical Sectors" (The Hague Centre for Strategic Studies, 2020), 27, https://hcss.nl/report/securing-critical-materials-for-critical-sectors-policy-options-for-the-netherlands-and-the-european-union/.

designating Beijing as a *systemic rival*,[49] the Dutch House of Representatives becoming the first parliament in Europe to label China's mass-internment of Uyghurs a genocide,[50] EU sanctions against Chinese officials engaged in Xinjiang-related policy-making,[51] and the G7's condemnation of China's live-fire drills around Taiwan in August 2022.[52] So far, it has also survived the US spurring on allies in Europe and Asia to join its attempts to "freeze" China's technological development over the past years. Since 2019, the Dutch government has withheld a license for ASML to export its EUV system to China. Even though China has a history of weaponising access to its market and greatly limited its supply of REE to the world in 2010, it has not opted to weaponise the resource in the 2020s. Finally, the supply of cobalt survived an uptick in political instability in the DRC and other Southern African states as well as the dominance of Chinese (state-owned) companies in refining and control over mines in the DRC.[53] Even though the supply of CRM from or through China to Europe has survived until now, the downward trend in China's relations with technologically advanced democracies comes with realistic risks of reaching breaking point throughout this decade.

Opposing camps in the semiconductor and CRM ecosystem try to win interdependence.

In the face of looming breaking points ensuring security of supply is becoming a central motivation behind policies of states and companies, whereas from the 80s and especially the 90s onwards cost-efficiency determined where industrial processes were located worldwide. Especially contentious issues such as the status of Ukraine, Taiwan, the South China Sea and the East China Sea, can serve as flashpoints leading Russia or China to upend their supply of CRM to Europe. Whether political stability in Southern Africa and the DRC can be maintained remains an open question. At a time of great power rivalry, opposing camps in the semiconductor and CRM ecosystem try to win interdependence by building on their respective strengths and mitigate their vulnerabilities.

Europe in the semiconductor and CRM ecosystem

To ensure the unimpeded functioning of the European economy in an effective and efficient manner, the Netherlands and the EU need to strengthen their position in the fragile semiconductor and CRM ecosystem.[54] Much has been written on risks due to the interdependencies in the semiconductor supply chain, with industry players like ASML advocating industrial

[49] European Commission, "EU-China - A Strategic Outlook" (European Commission, March 12, 2019), https://ec.europa.eu/info/sites/default/files/communication-eu-china-a-strategic-outlook.pdf.

[50] "Motie van het lid Sjoerdsma c.s. over uitspreken dat in China genocide plaatsvindt op de Oeigoerse minderheid."

[51] European Parliament, "Chair's Statement of 23 March 2021 on EU Sanctions on Human Rights Violations; Counter-Sanctions by the PRC," March 23, 2021, https://www.europarl.europa.eu/delegations/en/chair-s-statement-of-23-march-2021-on-eu/product-details/20210324DPU29209.

[52] U.S. Department of State, "G7 Foreign Ministers' Statement on Preserving Peace and Stability Across the Taiwan Strait," August 3, 2022, https://www.state.gov/g7-foreign-ministers-statement-on-preserving-peace-and-stability-across-the-taiwan-strait/#:~:text=We%20are%20concerned%20by%20recent,activity%20in%20the%20Taiwan%20Strait.

[53] Igogo et al., "Supply Chain of Raw Materials Used in the Manufacturing of Light-Duty Vehicle Lithium-Ion Batteries," August 30, 2019; Lipton and Searcey, "Chinese Company Removed as Operator of Cobalt Mine in Congo," February 28, 2022; Searcey et al., "A Power Struggle Over Cobalt Rattles the Clean Energy Revolution," November 20, 2021.

[54] See Dutch Ministry of Justice and Security, "National Security Strategy," 12. Economic Security is defined by the government of the Netherlands as "The unimpeded functioning of the Dutch economy in an effective and efficient manner."

policies to strengthen Europe's place in the semiconductor ecosystem.[55] The European Chips Act, aiming to invest tens of billions of euros, intends to indigenise a greater share of the semiconductor supply chain.[56] The risks of the Netherlands and the EU's vast CRM dependence on third countries, especially its rivals, is widely acknowledged to be a threat and has been assessed in depth.[57] The European Commission President, in her 2022 state of the union address, announced the preparation of a European Critical Raw Material Act, to achieve greater control over CRM value chains.[58] The Dutch government will present a resource strategy by the end of 2022.

Indigenisation of the semiconductor and CRM value chain comes at a cost.

Indigenisation of the semiconductor and CRM value chain comes, however, at a cost. The Semiconductor Industry Association, the voice of the US semiconductor industry, has highlighted the enormous added value of the global, sophisticated semiconductor supply chain, pointing out the way in which it supports "the industry's continuous technology innovation" and "how it ultimately benefits consumers and enables better technology and lower prices."[59] The pandemic-induced chip shortage inhibited the production of anything ranging from cars to essential medical devices, highlighting the costs of even just a temporary disruption to the ecosystem.[60] Similarly, re-shoring CRM production comes at a cost too, as for decades value chains were outsourced for reasons of cost efficiency and environmental pollution.[61] Strengthening Europe's place in the semiconductor and CRM fragile balance is a necessity, but disrupting the ecosystem entirely comes with great threats to economic security too.

This report covers new ground by specifically outlining pending disruptions in CRM value chains on which the EU relies for its access to semiconductors in the next five and ten years. The report also highlights key green technologies that rely on the same CRM value chains, as disruptions to these chains will also inhibit the energy transition. By doing so, an action plan is proposed for the Netherlands and the EU to deal with the risks and opportunities associated with the dependencies of the CRM needed for semiconductor production and green technologies. The action plan also outlines options to seize the opportunities related to the strengths of the Netherlands, the European Union and other technologically advanced democracies in the semiconductor value chain. A more extensive version of the action plan can be found in the long-version of this report.

- Chapter 1 shows that the semiconductor and CRM value chains together make up a single highly complex ecosystem, characterised by interdependencies between technologically advanced democracies on the one hand and both rival and non-rival autocracies on the other. The chapter relies on a literature review, desk research, prior research, stakeholder

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55 ASML, "ASML Position Paper on EU Chips Act" (ASML, February 2022), https://www.asml.com/en/news/press-releases/2022/asml-position-paper-on-eu-chips-act.

56 European Commission, "A Chips Act for Europe."

57 Patrahau et al., "Securing Critical Materials." European Commission, "Communication from the Commission to the EU Parliament and the European Council: Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability."

58 State of the Union Speech by President von Der Leyen, 2022, https://www.youtube.com/watch?v=K8LzZ-2vgnwA.

59 Antonio Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era" (BCG, SIA, April 2021), https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf.

60 van Houten, "Global Chip Shortages."

61 During a visit to Inner-Mongolia in 1992, Deng Xiaoping outlined his "reform-and-open-up" policy further explicating the role he already envisioned in 1987 for Inner-Mongolia. He proclaimed "The Middle East has Oil. China has rare earth" (中东有石油；中国有稀土), China Broadcasting Network, "Deng Xiaoping pointed out during his southern tour: "The Middle East has oil, and China has rare earths"", CNR, August 16, 2007, http://nm.cnr.cn/nmzt/60dq/tjnmg/200704/t20070412_504442760.html; Chu, "Seventeen Metals."

interviews, and expert interviews with both regional and thematic experts from academia, think tanks, government, and the CRM and semiconductor industry.[62]

- Chapter 2 maps and ranks ten threats that may well disrupt the supply of CRM to Europe or its partners in semiconductor manufacturing (e.g., Taiwan) in both the next five and ten years. Eight threats are identified on the basis of a case study into how Russia's war in Ukraine led to a breaking point, meaning the near total collapse of European-Russian trade in natural and neon gas. Two additional structural threats are identified and all threats are verified on the basis of a literature review, prior research, expert interviews with both regional and thematic experts from academia, think tanks, government, and industry, a limited data analysis of CRM prices and demand projections and a historical analogy of Imperial Japan's route to war with the US following the American oil embargo. Ranking of the threats (*probability * impact*) was done on the basis of a foresight survey in which 49 experts participated (see Appendix 2).

- Chapter 3 maps the measures that technologically advanced democracies and autocracies already took in order to "win" interdependence in a de-globalising world, specifically focusing on semiconductor and CRM rivalry. Special attention is paid to how US-led attempts to sabotage China's development of a domestic semiconductor industry and the imposition of a comprehensive semiconductor export ban on Russia enhances incentives for Moscow and Beijing to weaponise CRM exports in the near future. This chapter relies on a literature review, desk research, expert interviews and stakeholder interviews.

- Chapter 4 proposes an action plan that the Netherlands and the EU can adopt, in conjunction with other partners, to mitigate geopolitical risk and capitalise on opportunities in the semiconductor and CRM ecosystem.[63] The Netherlands and EU should focus on implementing policies immediately to achieve two main goals. First, to maintain and expand the dominance of technologically advanced democracies in the semiconductor industry in the short-term (i.e., next five years). By doing so, technologically advanced democracies can maintain sufficient leverage *vis-à-vis* Moscow and Beijing not to weaponise CRM. Second, the Netherlands and the EU should seek to achieve mitigation of the vulnerabilities in the CRM value chain in the medium-term (i.e., next ten years), for instance by bringing back or expanding mining, refining and processing in Europe, the US, Canada, Australia or other partner countries.

  The formulation of the policy implications, opportunities and recommendations relies on the findings of the previous chapters, additional desk research, and a global expert consultation consisting of two parts. First, 22 individual interviews were conducted with representatives from academia, thinktanks, government and both the CRM and semiconductor industry from the US, Canada, Australia, Japan and European states (see Appendix 1). Second, a stakeholder consultation session was conducted with representatives of the Ministry of Foreign Affairs and the Ministry of Defence of the Netherlands in July 2022.

62 For prior research by HCSS respectively on vital resources, threats to supply chains in the Indo-Pacific and China's rise, please find the extensive work done by our Energy & Natural Resources initiative, the Europe in the Indo-Pacific Hub (EIPH) and our China Desk.

63 The action plan builds on current policy efforts that have already been implemented. It analyses the challenges these efforts ran into and proposes solutions to overcome these challenges.

Chapter 1. Fragile balance: the semiconductor and critical raw material ecosystem

Key Takeaways

- The semiconductor value chain and the CRM supply chain balance each other out: whereas the semiconductor value chain is dominated by technologically advanced democracies allied to the United States, supply chains of CRM currently used for the production of semiconductors are dominated by rival states, namely China and Russia, and non-rival states, such as the DRC.

- The semiconductor supply chain is global, characterised by a high division of labour and dependent on constant large-scale investments in research and development (R&D). Each step in the main supply chain is concentrated in different geographical regions of the world, has its own distinct market characteristics, and relies on its very own chain of suppliers. Whilst chip design is concentrated in the United States, high-end chip fabrication is predominantly located in Taiwan, as well as South Korea and the United States, while assembly, testing, and packaging (ATP) is mostly done in Taiwan, the United States, and China. The majority of activities in the main semiconductor supply chain, hence, take place in technologically advanced democracies.

- The Netherlands plays a small yet indispensable role in the semiconductor supply chain. Dutch companies are important players in the semiconductor fabrication process, as ASML and ASM International produce important semiconductor manufacturing equipment, as well as in specific markets, such as NXP in the automotive industry. The role of ASML in particular, as the key and even sole provider of crucial equipment necessary for advanced chip manufacturing, provides the Netherlands and Europe with an irreplaceable node in the network to produce the oil of the 21st century. Europe's role in the rest of the semiconductor value chain, however, is modest.

- The EU's rivals, Russia and China, and non-rivals, such as the DRC, dominate the value chains of many CRM that are currently used to produce semiconductors. CRM, such as palladium, cobalt, gallium, germanium, REE and silicon, constitute the foundation upon which the entire semiconductor supply chain is built, including essential supplies of anything ranging from equipment and wafers. Each of these CRM has very specific and specialised functions in current semiconductor manufacturing practices. China and Russia, hence, hold levers of power to disrupt the semiconductor and various other industries.

The semiconductor value chain and the CRM supply chain balance each other out: whereas the semiconductor value chain is dominated by technologically advanced democracies allied to the United States, supply chains of CRM currently used for the production of semiconductors are dominated by rival states, namely China and Russia, and non-rival states, such as the DRC (see Infographic Fragile Balance for an overview of the semiconductor and CRM ecosystem). To substantiate the points above, this chapter outlines the different steps in the semiconductor supply chain, ranging from the design, all the way to the ATP of chips, demonstrating the dominance of technologically advanced democracies. The chapter will also delve into the suppliers that make possible the main semiconductor supply chain. Both major and minor players involved in each step will be identified, specifically highlighting the role Dutch (and European) companies play in the value chain as a whole. The semiconductor supply chain will subsequently be interlinked with the value chain for CRM for chip production, ranging from the mining of raw ore to the conversion and processing of the final chemical product (see Infographic Fragile Balance below).

The EU's rivals, Russia and China, and non-rival autocracies, such as the DRC, dominate the value chains of many CRM that are currently used to produce semiconductors. CRM, such as palladium, cobalt, gallium, germanium, REE and silicon, constitute the foundation upon which the entire semiconductor supply chain rests, including essential supplies of anything ranging from equipment and wafers. Each of these CRM has very specific and specialised functions in current semiconductor manufacturing practices (see Table 5). Green technology applications rely on many of the same CRM either directly, as solar panels are made of polysilicon, or indirectly, as gallium is used to produce the semiconductors used in solar panels.[64] Geological and economic limitations, the time needed to set up mining, refining and processing capacity, and its polluting and disruptive nature, complicate relocating the industry elsewhere.[65] China and Russia, hence, hold levers of power to disrupt the semiconductor and various other industries (see Infographic West's Achilles Heel).

Whereas the semiconductor value chain is dominated by technologically advanced democracies allied to the United States, supply chains of CRM currently used for the production of semiconductors are dominated by rival states, namely China and Russia.

64 Patrahau et al., "Securing Critical Materials."

65 IEA, "The Role of Critical Minerals in Clean Energy Transitions" (Paris: IEA, 2022), https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary.; Rebekah Daunt, "Portugal's Government Approves Lithium Mining despite Growing Concerns," Euronews, May 2, 2022, https://www.euronews.com/2022/02/05/portugal-s-government-approves-lithium-mining-despite-protests-concerns.; Lagunas and Sterren, "De weg naar groene energie is een smerige zaak."

1.1. Semiconductor production: A highly globalised supply chain

The semiconductor supply chain is global, characterised by a high division of labour, dependent on constant large-scale investments in R&D and is mostly concentrated in the world's technologically advanced democracies. The main supply chain can be divided into three distinct steps, namely (1) design, (2) fabrication, and (3) ATP. Companies in the US, particularly Qualcomm, Broadcom and NVIDIA, dominate chip design.[66] For manufacturing of the most advanced chips, the world relies on the Taiwan Semiconductor Manufacturing Company (TSMC) and South Korea-headquartered Samsung. US-based Intel and China-based Semiconductor Manufacturing International Cooperation (SMIC) play a key role in the production of mature (meaning older, well-established) chips, with Chinese parties making considerable gains over the last five years.[67] Assembly of semiconductors mostly takes place in Taiwan, the US, and China.[68] Except for the production of irreplaceable lithography equipment by ASML, Europe's role in the value chain is modest. The majority of activities in the main semiconductor supply chain, hence, take place in technologically advanced democracies (see Infographic Fragile Balance below). It goes without saying, however, that the supply chain is far more complex in reality, as each actor in the supply chain again depends on hundreds of suppliers for the manufacturing of their products.

The majority of activities in the main semiconductor supply chain, hence, take place in technologically advanced democracies

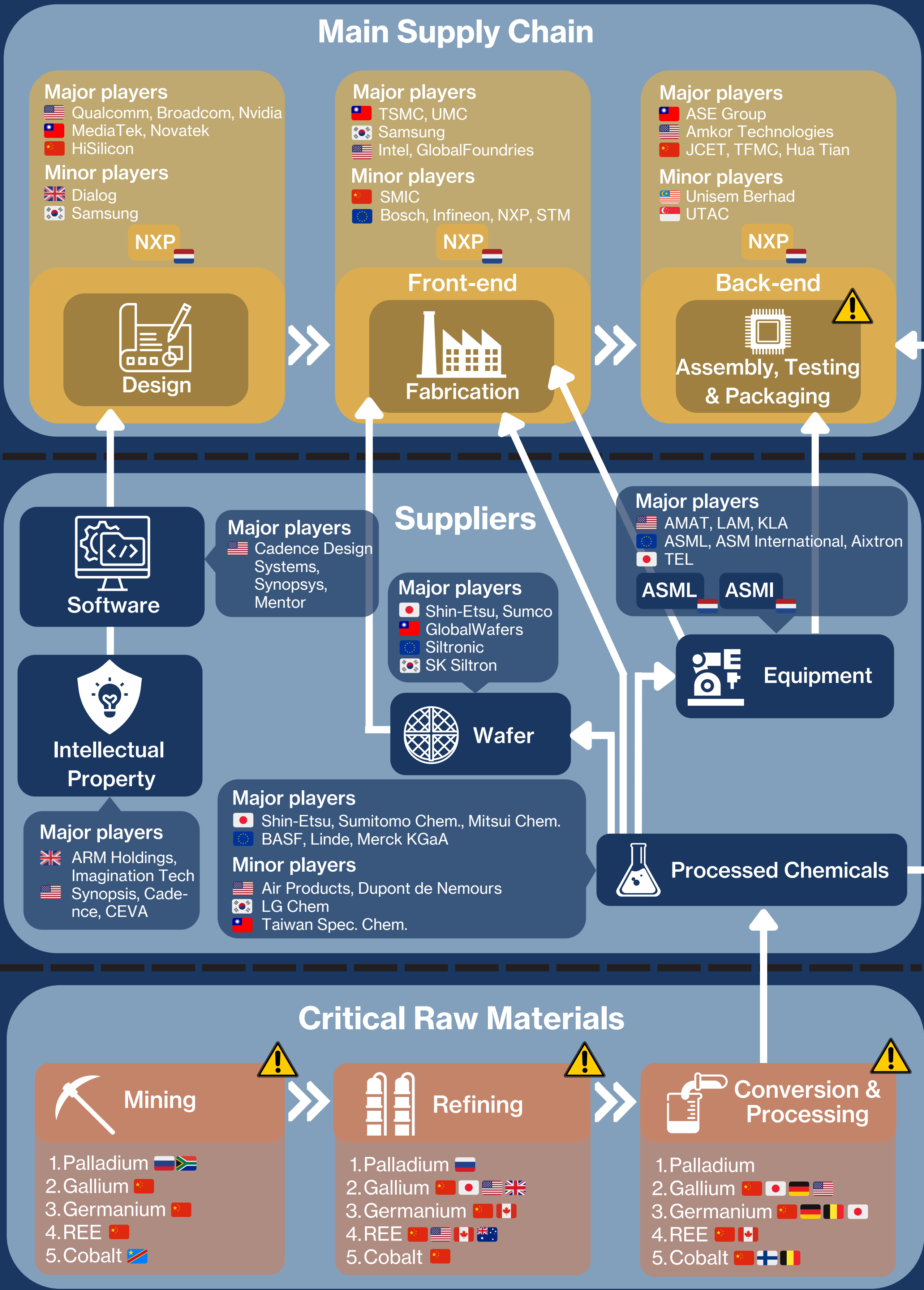
[66] SIA, "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's."; Kleinhans and Baisakova, "Global Semiconductor Value Chain," 11.; IC Insights, "Chinese Companies Hold Only 5% of Global IC Marketshare," IC Insights, April 13, 2021, https://www.icinsights.com/news/bulletins/Chinese-Companies-Hold-Only-5-Of-Global-IC-Marketshare/.

[67] SIA, "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's," SIA, Semiconductor Industry Association (blog), January 10, 2022, https://www.semiconductors.org/chinas-share-of-global-chip-sales-now-surpasses-taiwan-closing-in-on-europe-and-japan/.; Matt Hamblen, "Foundries See Wafer, Chip Demand on Rise," Fierce Electronics, August 24, 2020, https://www.fierceelectronics.com/electronics/foundries-see-wafer-chip-demand-rise.; Ian King, Adrian Leung, and Demetrios Pogkas, "Why Making More Chips Is So Hard," *Bloomberg*, May 6, 2021, https://www.bloomberg.com/graphics/2021-chip-production-why-hard-to-make-semiconductors/.

[68] Alan, "Top 10 OSAT (Outsourced Semiconductor Assembly and Test) Companies," Utmel Electronic, January 10, 2022, https://www.utmel.com/blog/categories/semiconductor/top-10-osat-outsourced-semiconductor-assembly-and-test-companies#3.

A fragile supply chain balance

The semiconductor and critical raw material ecosystem



Chip design is dominated by the United States.

Step one: Design

The first step in the production of chips is the design phase, which is dominated first and foremost by the US but also includes Taiwan as a key player, is characterised by relatively low barriers to market entry, and requires constant R&D to continue innovation.[69] In this stage the design files are produced that are given to semiconductor fabrication plants (commonly called 'fabs' or 'foundries') for chip fabrication. Major companies in this segment are Qualcomm, Broadcom, and NVIDIA in the US, and MediaTek, Novatek, and Realtek in Taiwan. China's HiSilicon also plays a significant role in the design of chips, but predominantly limits its services to its parent company Huawei. Minor players in the design market (each accounting for only about 1% of the market) are Dialog, located in Europe, and Samsung, located in South Korea.[70]

Chip design companies rely on design software and intellectual property (IP), which is again highly concentrated in the US with companies such as Cadence Design Systems, Synopsys, and Mentor dominating the market.[71] The companies that license semiconductor IP are located in both Europe (e.g., ARM Holdings, Imagination Tech) and the US (e.g., Synopsys, Candence, CEVA).[72] China has actively been trying to secure access to this segment of the chip design phase through the acquisition of UK-based Imagination Technologies[73] and the establishment of ARM China, a subsidiary of ARM Holdings, in which Chinese investors have a 51% stake.[74]

Step two: Fabrication

The second step in the semiconductor main supply chain, chip fabrication, is dominated by Taiwan, South Korea and the US, and has nearly insurmountable entry barriers. Fabrication plants (i.e., 'fabs') transfer the chip design onto a wafer. This step is also called the 'front-end' manufacturing phase of chip production and is one of the most complex stages of the entire

69 In fact, "firms focusing on semiconductor design typically invest 12 to 20% of their annual revenues in R&D.", Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," 15. Antonio Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era" (BCG, SIA, April 2021), p.15, https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf; Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context," June 2021, 22.; Kleinhans and Baisakova, "Global Semiconductor Value Chain," 11.; IC Insights, "Chinese Companies Hold Only 5% of Global IC Marketshare."

70 IC Insights, "Chinese Companies Hold Only 5% of Global IC Marketshare." ; Kleinhans and Baisakova, "Global Semiconductor Value Chain," 11. ; TelecomLead, "Qualcomm, Nvidia, Broadcom Are Top IC Design Companies: TrendForce - TelecomLead," accessed October 3, 2022, https://www.telecomlead.com/telecom-chips/qualcomm-nvidia-broadcom-are-top-ic-design-companies-trendforce-105086.

71 Gary Elinoff, 'IC Design Resources Roundup: Mentor, Cadence, and Synopsys', All About Circuits, 5 August 2019, https://www.allaboutcircuits.com/technical-articles/ic-design-resources-roundup-mentor-cadence-synoy/; Jan-Peter Kleinhans and Nurzat Baisakova, 'The Global Semiconductor Value Chain: A Technology Primer for Policy Makers', p. 13; Tzuhsuan Tang, 'China's EDA Venture: Taking on Synopsys and Cadence', EqualOcean, 26 January 2022, https://equalocean.com/analysis/2022012616968.

72 Markets and Markets, "Semiconductor Intellectual Property (IP) Market with COVID-19 Impact Analysis by Design IP (Processor IP, Memory IP, Interface IP, Other IPs), IP Source (Royalty, Licensing), IP Core (Hard IP, Soft IP), Vertical and Geography - Global Forecast to 2026," Markets and Markets, January 2022, https://www.marketsandmarkets.com/Market-Reports/semiconductor-silicon-intellectual-property-ip-market-651.html#:~:text=The%20semiconductor%20IP%20market%20includes%20key%20companies%20such,countries%20across%20Asia%20Pacific%2C%20Europe%2C%20Americas%2C%20and%20RoW.

73 Julia Kollewe, "UK Chip Maker Imagination Bought for £550m by China-Backed Tech Firm," *The Guardian*, September 25, 2017, sec. Business, https://www.theguardian.com/business/2017/sep/25/imagination-technologies-shares-canyon-bridge-takeover.

74 Che Pan, "Controlling Stake in Arm China May Shift to Little-Known Entity as Chip Joint Venture's Ownership Saga Drags On," South China Morning Post, May 20, 2022, https://www.scmp.com/tech/big-tech/article/3178400/controlling-stake-arm-china-may-shift-little-known-entity-chip-joint.

semiconductor value chain. Wafer fabrication is conducted in cleanrooms, which maintain strict sterile conditions, and can consist of up to 1400 production steps that require hundreds of different pieces of equipment, materials, and chemicals.[75]

Not only does building a cutting-edge wafer fabrication plant cost around 20 billion USD, but extensive and highly specialised knowledge of the fabrication process is necessary. Furthermore, Moore's Law stipulates that in recent history the number of transistors on a microchip doubles every two years, whilst its cost is halved. This high-pace and constant innovation in the industry leads to near insurmountable entry barriers for companies wanting to enter the chip fabrication market. Indeed, this segment in the semiconductor value chain is highly concentrated and dominated by just three companies, namely TSMC in Taiwan, Samsung in South Korea, and Intel in the United States. A multitude of minor players are also involved in semiconductor fabrication. SMIC, located in China, is trying to challenge the dominant position held by TSMC for advanced chip manufacturing. Other European players (e.g., Bosch, Infineon, NXP, STM) play an important role in specific segments of the chip-making business, such as the automotive industry (see Infographic Fragile Balance).[76]

The fabrication phase of chip production has nearly insurmountable entry barriers.

So far, Chinese parties, including SMIC, have made considerable gains in capturing market volume through growing chip sales in the mature chip market and by steadily producing more advanced chips. China's total chip sales grew from 3.8% in 2015 to 9% in 2020 of the global market.[77] Meanwhile, SMIC reportedly produced a "quasi-7-nanometer" chip, potentially allowing China to achieve "breakthroughs in AI and high-speed computing."[78] Still, China is far from self-sufficient in chip fabrication. China consumes around 25% of global chip supply.[79] This gives China an overall self-sufficiency rate below 40%, still far under the "self-sufficiency" goal of 75% which the Chinese government set as a goal for the year 2030 in its Made in China 2025 initiative.[80] China is yet to produce the most advanced chips altogether, namely 3nm and 5nm chips.

Semiconductor manufacturers rely on companies, which are also headquartered in technologically advanced democracies, such as Japan, Taiwan, Europe and South Korea, for essential supplies such as wafers, equipment, and processed chemicals and materials.[81] Some of the key equipment needed is provided by AMAT, LAM, and KLA in the US, ASML, ASM International, and Aixtron in Europe, and TEL in Japan.[82] The processed chemicals and mate-

75 Antonio Varas et al., 'Strengthening the Global Semiconductor Supply Chain in an Uncertain Era' (BCG and SIA, April 2021), p. 16.

76 Hamblen, "Foundries See Wafer, Chip Demand on Rise"; King, Leung, and Pogkas, "Why Making More Chips Is So Hard"; Anton Shilov, "SMIC: Advanced Process Technologies and Gov't Funding," EETimes, July 13, 2020, https://www.eetimes.com/smic-advanced-process-technologies-and-govt-funding/; Jan-Peter Kleinhans and Nurzat Baisakova, "The Global Semiconductor Value Chain: A Technology Primer for Policy Makers," October 2020; David Manners, "NXP, Infineon, Renesas, TI, ST Stay Top Five for Auto ICs," Electronics Weekly, May 4, 2020, https://www.electronicsweekly.com/news/business/nxp-infineon-renesas-ti-st-stay-top-five-auto-ics-2020-05/.

77 Hamblen, "Foundries See Wafer, Chip Demand on Rise"; King, Leung, and Pogkas, "Why Making More Chips Is So Hard."

78 Che-Jen Wang, "China's Semiconductor Breakthrough," The Diplomat, August 20, 2022, https://thediplomat.com/2022/08/chinas-semiconductor-breakthrough/.

79 Antonio Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era" (BCG, SIA, April 2021), p.12.

80 Che-Jen Wang, "China's Semiconductor Breakthrough," The Diplomat, August 20, 2022, https://thediplomat.com/2022/08/chinas-semiconductor-breakthrough/.

81 Mark Lapedus, "Mixed Outlook For Silicon Wafer Biz," Semiconductor Engineering, February 21, 2019, https://semiengineering.com/mixed-outlook-for-silicon-wafer-biz/.

82 "2020 Top Semiconductor Equipment Suppliers," VLSI Research, March 11, 2021, https://www.vlsiresearch.com/the-chip-insider/2020-top-semiconductor-equipment-suppliers.

rials, on the other hand, predominantly rely on chemical companies in Japan and Europe.[83] The production of processed chemicals, materials, and equipment, in turn, depends on an extensive and complex supply chain of CRM, which will be discussed in detail in the latter half of this chapter.

Step three: Assembly, test, and packaging

ATP is dominated by Taiwan, the US, and China.

Taiwan and the US are major players in the third step of the main semiconductor supply chain, namely ATP, although China is gaining a significant foothold in this segment. ATP has comparatively fewer barriers to enter the market and is geographically less concentrated. This phase of the semiconductor supply chain is also known as the 'back-end' of chip fabrication. The fabricated silicon wafers are sliced, tested, and packaged. The cost of ATP, as well as the value added is relatively lower than 'front-end' manufacturing.[84] Consequently, ATP production is characterised by comparatively lower market-entry barriers and is more widespread. However, one can observe a steady consolidation of the market throughout the past decade. Major players in ATP are located in Taiwan (ASE Group), the US (Amkor Technologies), and China (JCET, TFMC, Hua Tian), which has gained an increasingly significant portion of the market in this segment. Minor players, amongst others, are Unisem Berhad in Malaysia and UTAC in Singapore.[85] Similar to 'front-end' manufacturing, 'back-end' manufacturing relies on both equipment and processed chemicals and materials. However, these components are easier to acquire as the equipment is relatively inexpensive and lower purity chemicals are required.[86]

Dutch presence in the semiconductor supply chain

The Netherlands plays a small yet indispensable role in the semiconductor supply chain. Dutch companies are important players in the semiconductor fabrication process, as ASML and ASM International produce important semiconductor manufacturing equipment, as well as in specific markets, such as NXP in the automotive industry. Semiconductor fabrication, predominantly done by TSMC, Samsung, and Intel, almost entirely relies on Dutch company ASML to provide them with key equipment. ASML is the main supplier of lithography machines, which burn patterns into materials deposited on the silicon wafers, even holding a monopoly on the most advanced system, namely EUV lithography (see Table 4). Whereas ASML's older lithography systems make use of DUV, EUV lithography makes use of extreme ultraviolet. This is used for the fabrication of the most advanced chips. These machines are extremely complex to produce. Just one machine could cost over 200 million USD and requires multiple jumbo jets to transport.[87]

83 Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era"; Jan-Peter Kleinhans and Nurzat Baisakova, "The Global Semiconductor Value Chain: A Technology Primer for Policy Makers."

84 Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," 19; Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context," June 2021.

85 Utmel Electronic, "Top 10 OSAT (Outsourced Semiconductor Assembly and Test) Companies," Utmel Electronic, January 10, 2022, https://www.utmel.com/blog/categories/semiconductor/top-10-osat-outsourced-semiconductor-assembly-and-test-companies#3.

86 Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context," June 2021, 52.

87 ASML, "ASML"; Buitenhof, CEO ASML | Peter Wennink | Buitenhof, 2020, https://www.youtube.com/watch?v=yII53vpdEMc.

Canon and Nikon, ASML's primary competitors in the DUV lithography market, are based in Japan, another US ally.[88] EUV lithography technology, however, is a technology entirely exclusive to ASML. Thus, cutting-edge chip fabs such as TSMC and Samsung rely entirely on ASML for this equipment, providing ASML with significant leverage in the supply chain. The various components for ASML's lithography systems are manufactured in different localities, such as the US and Taiwan. Assembly into final products is however still done in Europe, namely in Veldhoven, The Netherlands.[89] It could take decades for any other company to catch up given the complexity of the product, ASML's proprietary technology, and because it has built complicated, often exclusive deals with up to 800 suppliers.[90]

Table 4. Dominance of ASML in the lithography market

	DUV Lithography	EUV Lithography	EUV 0.55 NA, High-NA (under development)
ASML market share	80+%[91]	100%[92]	100%[93]

Other Dutch companies that play a smaller, yet important role in the semiconductor supply chain are NXP and ASM International. NXP is a semiconductor manufacturer that holds a key position in chip production for the automotive industry.[94] NXP is a so-called Integrated Device Manufacturer (IDM), a company that performs all three production steps from design to fabrication and ATP. The company follows a fab-lite approach whereby it also relies on other wafer fabrication plants, such as TSMC in Taiwan, to conduct the initial fabrication of its chips.[95] NXP's operations are spread across various countries, ranging from The Netherlands to the United States and China.[96] ASM International, on the other hand, is also a supplier to semiconductor manufacturers. Its core business revolves around wafer processing equipment, specifically atomic layer deposition, epitaxy, and chemical vapor deposition. Unlike ASML, which holds a monopoly in some of its products, ASM International does have competitors.[97] Although ASM International is headquartered in The Netherlands, most of its operations are done in other countries.[98]

88 'ASML 2021 Annual Report' (ASML, 2022), p. 116.

89 ASML, "Inside the World of High-Tech Manufacturing at ASML," ASML, October 23, 2020, https://www.asml.com/en/news/stories/2020/inside-high-tech-manufacturing.

90 CNBC, Why The World Relies On ASML For Machines That Print Chips.

91 Robert Castellano, 'ASML: Not Just A Monopoly In EUV Lithography (NASDAQ:ASML)', Seeking Alpha, 15 June 2020, https://seekingalpha.com/article/4354007-asml-not-just-monopoly-in-euv-lithography, https://seekingalpha.com/article/4354007-asml-not-just-monopoly-in-euv-lithography; René Raaijmakers, '"We Underestimated the Demand for DUV"', Bits & Chips, 4 February 2021, https://bits-chips.nl/artikel/we-underestimated-the-demand-for-duv/.

92 ASML, 'ASML | The World's Supplier to the Semiconductor Industry', 2022, https://www.asml.com/en.

93 ASML is currently the only company developing this new technology, which is based on EUV lithography, see ASML, 'ASML'.

94 "NXP," NXP, 2022, https://www.nxp.com/.

95 "NXP Selects TSMC 5nm Process for Next Generation High Performance Automotive Platform," NXP, June 12, 2020, https://www.nxp.com/company/about-nxp/$AUTOLINK[1622048738274733413442:W]; Jan-Peter Kleinhans and Nurzat Baisakova, "The Global Semiconductor Value Chain: A Technology Primer for Policy Makers," October 2020; "TSMC to Benefit from NXP's Restructuring - Papers," *Reuters*, September 13, 2008, sec. U.S. Regulatory News, https://www.reuters.com/article/nxp-tsmc-idUKTP32703020080913.

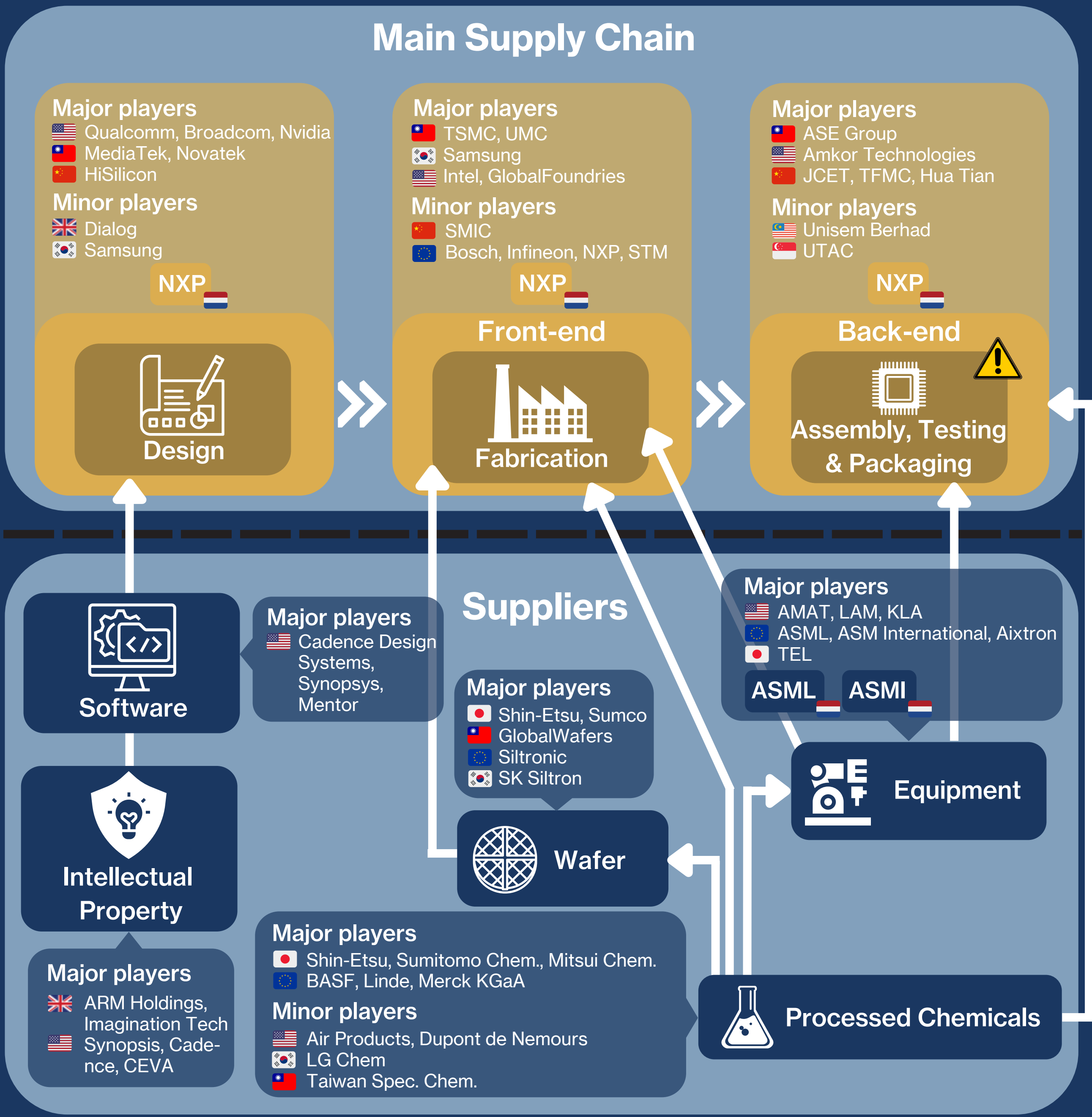
96 "Worldwide Locations | NXP Semiconductors," NXP, 2022, https://www.nxp.com/company/about-nxp/worldwide-locations:GLOBAL_SITES.

97 "ASM International," 2022, https://www.asm.com/.

98 "Locations," ASM, 2022, https://www.asm.com/about/locations.

Advanced democracies dominate the semiconductor value chain

But China invests heavily to improve its position



1.2. Critical raw materials for semiconductor production

Current supply chains of crucial CRM are dominated by rivals, namely China and Russia, and other non-rival autocracies, such as the DRC.

‘Front-end’ and ‘back-end’ chip manufacturers, such as NXP, as well as their suppliers, such as ASML and ASM International, rely on processed chemicals and materials that are produced with various CRM. Even the design labs, foundries and equipment tools that are used to produce semiconductors require semiconductors and in turn the CRM needed to produce semiconductors. The companies that provide these chemicals and materials to the semiconductor supply chain are mostly located in Japan and Europe.[99] However, these processed chemicals and materials are preceded by a complex supply chain consisting of numerous tiers of suppliers, which can be traced all the way back to the mining of raw ores. Technologies for the transition to green energy rely on many of the same CRM value chains, indicating that the problem of CRM dependence goes beyond the semiconductor industry (see Table 5 below). It is of crucial importance to understand the risks and dependencies in this supply chain of CRM as without these foundational CRM, semiconductors, as currently designed, cannot be produced.

Current supply chains of crucial CRM are dominated by rivals, namely China and Russia, and other non-rival autocracies, such as the DRC, while various factors, such as geological limitations, the time required to set up mining operations (which could span over a decade), and its polluting and disruptive nature, complicate relocating the industry elsewhere. The supply chain from ore to processed chemical can be broken down into three main steps, namely (1) mining, (2) refining, and (3) conversion and processing (see Infographic Achilles Heel below). The mining of CRM is geologically bound and the timespan from exploration to production can vary from seven to fifteen years, with the International Energy Agency (IEA) even pointing out it can take up to 20 years.[100] Therefore, it would require significant time and investment to diversify the mining production of CRM. The refining of the raw ores is usually done close to the mine, but can also be outsourced to other countries. Developing a refining facility requires significantly less time than establishing mining operations, but it can still take several years.

As the mining and refining industries have left Europe throughout the decades, the technological know-how and human capital in these sectors have also disappeared to a great extent. Moreover, refining processes can be extremely polluting and disruptive, limiting options to relocate to other places. Lastly, the refined chemicals are converted and processed to provide the final product necessary for semiconductor manufacturing. For example, cobalt is upgraded to cobalt sulphate. Building such a conversion and processing plant requires between one and two years, but the qualification process alone could take up to 18 months.[101] Most of the refining and processing of CRM today take place in China.[102]

99 Antonio Varas et al., ‘Strengthening the Global Semiconductor Supply Chain in an Uncertain Era’; Jan-Peter Kleinhans and Nurzat Baisakova, ‘The Global Semiconductor Value Chain: A Technology Primer for Policy Makers’, p. 18.

100 IEA, “The Role of Critical Minerals in Clean Energy Transition” (IEA, 2021), https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions; Jeff Amrish Ritoe, “The New Great Game: Securing Critical Minerals Today for a Clean Energy System Tomorrow,” HCSS Geo-Economics (Bangkok: The Hague Centre for Strategic Studies, July 2021), https://hcss.nl/wp-content/uploads/2021/08/The-New-Great-Game-August-2021.pdf; Nicholas LePan, “Visualizing the Life Cycle of a Mineral Discovery,” Visual Capitalist, https://www.visualcapitalist.com/visualizing-the-life-cycle-of-a-mineral-discovery/; “Copper Mining and Processing: Life Cycle of a Mine” (The University of Arizona, July 13, 2020), https://superfund.arizona.edu/resources/modules/copper-mining-and-processing/life-cycle-mine.

101 Ritoe, “The New Great Game.”

102 Ritoe, ‘The New Great Game’, 12.

Given the difficulty of relocating the CRM supply chain to other countries, it is of paramount importance to identify the risks and dependencies inherent to the supply chain and address these in a timely manner.

The value chains of five distinct CRM are analysed, from mining to processed chemicals, on which the Dutch and European semiconductor industry and its partners in semiconductor manufacturing (e.g., Taiwan) rely on China, Russia and the DRC, namely palladium, cobalt, gallium, germanium, REE, and silicon. These six CRM have been selected as they are today central in the production of semiconductors, and each come with different risks and dependencies inherent to the supply chain (see Table 5 below). Technologies for the transition to green energy rely on many of the same CRM value chains, showing that the problem of CRM dependence goes beyond the semiconductor industry (see Table 5 below). In addition, the report pays attention to the supply chain of silicon. Silicon takes up the largest share of CRM in semiconductors and is mostly mined in China and is also used for the production of semiconductors. However, almost all solar photovoltaic (PV's) make use of silicon sourced from China whereas the higher-purity semiconductor polysilicon comes from other countries with which the EU is more closely aligned (See Table 5 and infographic Achilles heel below outlining the principal players in every production step of each selected CRM).

Given the difficulty of relocating the CRM supply chain to other countries, it is of paramount importance to identify the risks and dependencies inherent to the supply chain and address these in a timely manner.

Table 5. Stranglehold: China and Russia's control over six key CRM for the fabrication of semiconductors and green applications

CRM	Function in fabrication semiconductors[103]	Function in green applications[104]	Production (mining) per country (total/ share of global production) in 2020[105]
Palladium	A component of a multilayer metallisation structure, improving adhesion	Semiconductors	In kilograms and share 1. Russia: 93,000; 43% 2. South Africa: 73,500; 34% 3. Canada: 20,000; 9% 4. US: 14,600; 7% 5. Zimbabwe: 12,900; 6%
Cobalt	To help copper make better circuits in the latest-generation of semiconductors	Electric Vehicle Batteries (EVB); Carbon Caputure and Storage (CCS); Semiconductors	In metric tons and share 1. DRC*: 98,000; 69% 2. Russia: 9,000; 6% 3. Australia: 5,630; 4% 4. Philippines: 4,500; 3% * Majority of mines owned by China, and refining operations in China
Gallium	A preferred material used in semiconductor manufacturing due to its high breakdown strength, fast switching speed, high thermal conductivity, and lower on-resistance	Solar-Photovoltaic (PV); EVs; Semiconductors	In kilograms and share 1. China: 317,000; 97% 2. Russia: 5,000; 2% 3. Japan: 3,000; 1% 4. South Korea: 2,000; 1%
Germanium	Alloyed with silicon in chip manufacturing for use in certain high-speed devices, including in the automotive industry	Solar PV; EVs; Semiconductors	In kilograms and share 1. China: 95,000; 68% 2. Russia: 5,000; 4% 3. Other countries incl. Belgium, Canada, Germany, Japan, Ukraine: 40,000; 29%
REE	A set of 17 closely-related metals that have applications in various subsets of semiconductor fabrication	Wind Turbines; EVs; Semiconductors	In metric tons and share 1. China: 140,000; 58% 2. US: 39,000; 16% 3. Burma: 31,000; 13% 4. Australia: 21,000; 9%
Silicon	Used to produce the wafers which are used to print patterns on and then sliced up to produce semiconductors.	Solar PV; Semiconductors	In thousand metric tons and share 1. China: 5,600; 69% 2. Russia: 576; 7% 3. Brazil: 404; 5% 4. Norway: 345; 4% 5. US: 277; 3%

103 S. Bobba et al., *Critical Raw Materials for Strategic Technologies and Sectors in the EU*; Patrahau et al., 'Securing Critical Materials'.

104 Patrahau et al., 'Securing Critical Materials for Critical Sectors', p. 27 and p. 111-112.

105 Platinum-Group Metals" (USGS, 2022); "Cobalt" (USGS, 2022); "Gallium" (USGS, 2022); "Germanium" (USGS, 2022); "Rare Earth Elements" (USGS, 2022); USGS, "Silicon" (USGS, 2022), https://www.usgs.gov/centers/national-minerals-information-center/silicon-statistics-and-information.

The West's critical raw material Achilles heel

A supply chain dominated by China, Russia and the DRC

Critical Raw Materials

Mining

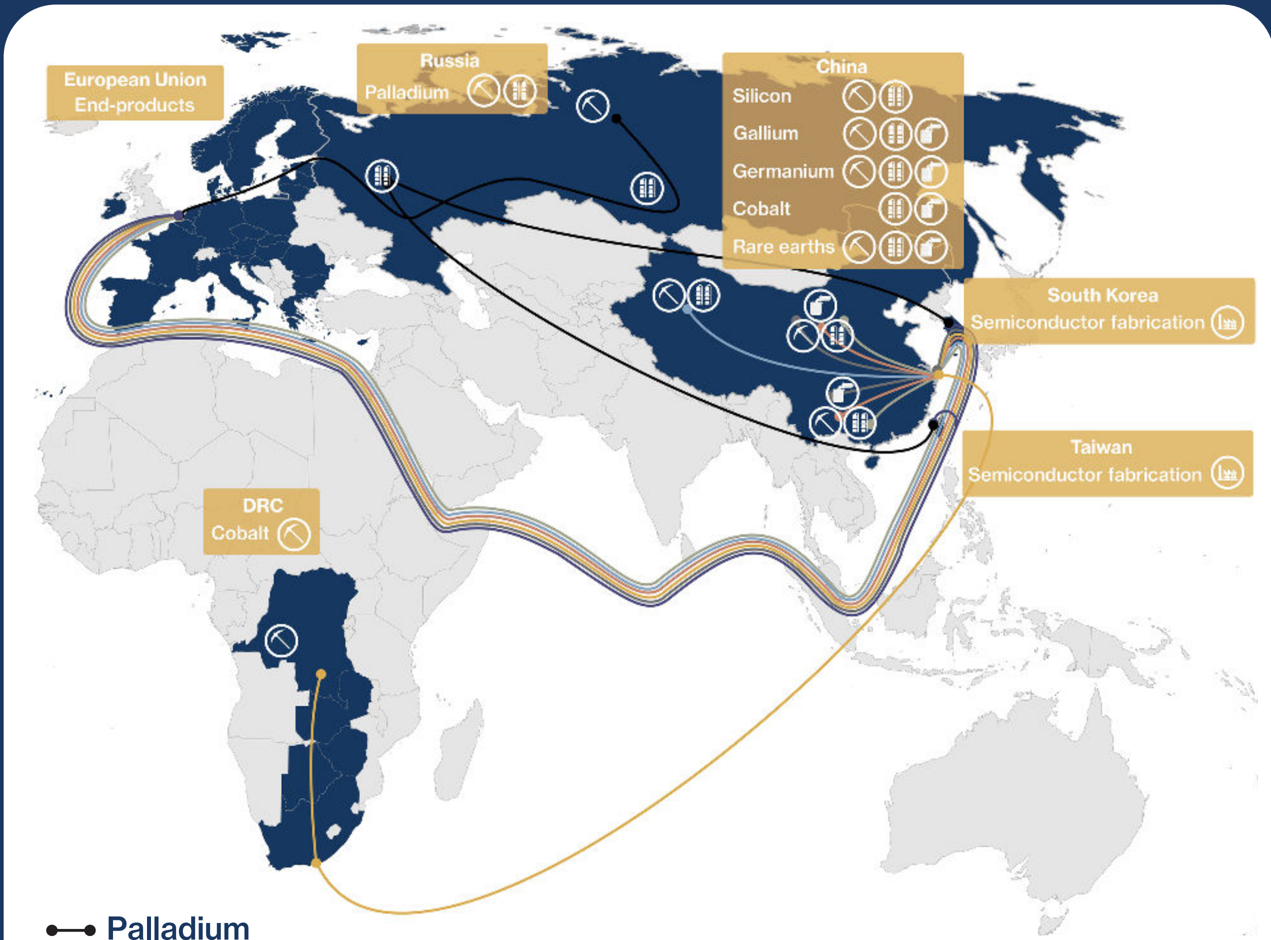
1. Palladium
2. Gallium
3. Germanium
4. REE
5. Cobalt

Refining

1. Palladium
2. Gallium
3. Germanium
4. REE
5. Cobalt

Conversion & Processing

1. Palladium
2. Gallium
3. Germanium
4. REE
5. Cobalt



- Palladium
- Gallium
- Germanium
- REE
- Cobalt
- Silicon
- Semiconductors
- Mining
- Refining
- Conversion & processing
- Fabrication

Palladium

Palladium is used in chip production as a component of a multilayer metallization structure improving adhesion.[106] Palladium is predominantly mined in Russia and South Africa, with Canada, the US, and Zimbabwe playing minor roles. The largest reserves of Platinum-Group Metals (PGM), which include palladium, can be found in the Bushveld Complex in South Africa, while Russia also holds a significant amount of the outstanding world resources.[107] Russia is also an important player in the refining of palladium.[108] European reliance on Russian palladium is unknown but the EU estimates it to be equivalent to the share of global production, which is 40%.[109] Reliance on Russia for the sourcing of palladium has proven to be a risk to the semiconductor supply chain. Most recently, sanctions over the war in Ukraine have negatively impacted the supply of palladium, which will be discussed further in-depth in the following chapter.[110]

Reliance on Russia for the sourcing of palladium has proven to be a risk to the semiconductor supply chain.

Cobalt

Cobalt is used in semiconductor manufacturing to help copper make better circuits in the latest generation of semiconductors. Cobalt is sourced as a by-product of copper ore and nickel ore mining through hydrometallurgy and pyrometallurgy. Around 70% of total cobalt mined around the world is extracted in the DRC.[111] Europe relies for 68% of its cobalt on mining operations in the DRC.[112] This is unlikely to change anytime soon as the vast majority of outstanding world cobalt deposits are found in the DRC, although Australia, Indonesia, and Cuba also hold significant deposits.[113] Moreover, the DRC is one of the only places in the world where cobalt can be extracted on its own and not as a by-product of copper, which is the case in most other locations.

The majority of cobalt mines in the DRC are owned by China. As of 2020, Chinese (state-) owned companies owned or had a financial stake in 15 out of 19 cobalt mines in the DRC.[114] The main Chinese companies operating in the DRC include China Molybdenum, Jinchuan Group, Zhejiang Huayou Cobalt, Shalina Resource, Wanbao Mining, and Nanjing Hanrui Cobalt.[115] After the cobalt is mined and partially refined in these Chinese-owned mines, it

106 D. G. Ivey, "Platinum Metals in Ohmic Contacts to 111-V Semiconductors," *Platinum Metals Review* 43, no. 1 (1999): 2–12.

107 "Platinum-Group Metals" (USGS, 2022).

108 Indrabati Lahiri, "How Will the Russian Refinery Ban Affect Palladium's Price?," Capital, April 12, 2022, https://capital.com/how-will-the-russian-refinery-ban-affect-the-palladium-price.

109 "Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability" (European Commission, 2020), https://ec.europa.eu/docsroom/documents/42849. Quintessentially PGMs, Nornickel, 23 May 2022, Report

110 See for example: Peter Hobson, "Palladium Propelled to Record Highs by Russia Supply Concerns," *Reuters*, March 7, 2022, sec. Business, https://www.reuters.com/business/palladium-propelled-record-highs-by-russia-supply-concerns-2022-03-07/; Yuliya Fedorinova, Eddie Spence, and Ranjeetha Pakiam, "Russia's Palladium Exports Face Disruption From Flight Bans," *Bloomberg*, February 28, 2022, https://www.bloomberg.com/news/articles/2022-02-28/russia-s-palladium-exports-face-disruption-from-flight-bans; Brijesh Patel, "Palladium Tops $3,000/Oz as Supply Fears Grow, Gold Jumps over 1%," *Reuters*, March 4, 2022, sec. European Markets, https://www.reuters.com/markets/europe/gold-gains-after-russia-attacks-europes-largest-nuclear-plant-2022-03-04/.

111 IEA, "The Role of Critical Minerals in Clean Energy Transition" (IEA, 2021), https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions, p. 13.

112 "Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability."

113 "Cobalt" (USGS, 2022).

114 Eric Lipton and Dionne Searcey, "Chinese Company Removed as Operator of Cobalt Mine in Congo," *The New York Times*, February 28, 2022, sec. World, https://www.nytimes.com/2022/02/28/world/congo-cobalt-mining-china.html.

115 Tsisilile A Igogo et al., "Supply Chain of Raw Materials Used in the Manufacturing of Light-Duty Vehicle Lithium-Ion Batteries" (CEMAC, August 30, 2019), http://www.osti.gov/servlets/purl/1560124/.

is subsequently shipped to China, the world's leading producer of refined cobalt.[116] The conversion and processing of cobalt into various metals, as well as cobalt sulphate, is also predominantly done in China. The pivotal role played by China in the cobalt supply chain is unlikely to be challenged anytime soon as competitors in other countries, such as Belgium, Finland, and Canada, are unlikely to catch up before the end of this decade.[117] Cobalt proves to be an interesting case where political and social instability in the DRC, reliance on Chinese (state-)owned companies to mine cobalt, and dependence on refining and processing of cobalt in China pose significant risks to the supply of cobalt for the international semiconductor industry (see Chapter 2). China's dominance in cobalt refining also poses risks to Europe's energy transition, as the production of EV-batteries, semiconductors for the energy transition and CCS requires cobalt too.

Gallium

Reliance on gallium and germanium from China comes with risks for Europe's transition to green energy.

Gallium is a preferred material used in semiconductor manufacturing due to its high breakdown strength, fast switching speed, high thermal conductivity, and lower on-resistance. The vast majority of gallium, including high-purity gallium needed for semiconductors, is mined in China.[118] The EU relies for over a quarter of its gallium on China.[119] However, gallium that is already processed into final products that enter the European market is not taken into account, which points at a significantly higher reliance on China. As 97% of global mining of gallium is done in China, Europe's reliance on China is in reality much greater (see Table 5 above).[120] The refining of gallium is also concentrated in China, with Japan, Slovakia, and the US playing a minor role.[121] The conversion and processing of gallium into gallium arsenide, a key component in chip manufacturing, is geographically spread across different continents, including North America, Europe, and East Asia.[122] The significant reliance on China in all three production steps of gallium serves as a relevant illustration of the dependence on China in the sourcing of key CRM for the semiconductor supply chain.This reliance on China also comes with risks for Europe's transition to green energy, as the production of solar PV, electric vehicles and semiconductors for the energy transition also require gallium.

Germanium

Germanium is alloyed with silicon in chip manufacturing for use in certain high-speed devices, including in the automotive industry.[123] Similar to gallium, germanium is also predominately mined and refined in China, controlling 68% of total production. Russia holds the second-largest germanium mining operation after China.[124] The EU stated that 17% of its germanium

116 "Cobalt," 2022.

117 "Share of Top Three Producing Countries in Total Processing of Selected Minerals and Fossil Fuels, 2019," IEA, 2021, https://www.iea.org/data-and-statistics/charts/share-of-top-three-producing-countries-in-total-processing-of-selected-minerals-and-fossil-fuels-2019; Ritoe, "The New Great Game."

118 "Gallium" (USGS, 2022).

119 European Commission, "Communication from the Commission to the EU Parliament and the European Council: Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability."

120 "Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability."

121 "Gallium"; USGS, "Gallium," Professional Paper, Professional Paper (USGS, 2017).

122 Markets and Research, "Global Gallium Arsenide Market 2020 by Manufacturers, Regions, Type and Application, Forecast to 2026 -," Markets and Research, https://www.marketsandresearch.biz/report/45280/global-gallium-arsenide-market-2020-by-manufacturers-regions-type-and-application-forecast-to-2026.

123 Vanessa Samuel, "What Is Silicon Germanium's Place at the Semiconductor Table?," All About Circuits, June 2, 2020, https://www.allaboutcircuits.com/news/what-is-silicon-germaniums-place-at-the-semiconductor-table/.

124 "Germanium" (USGS, 2022).

is sourced in China.[125] However, germanium that is already processed into final products that enter the European market is not taken into account, which points at a significantly higher reliance on China. Both China and Russia execute large-scale germanium conversion and processing activities, next to Germany, Belgium, Japan, and the US.[126] The significant reliance on China, as well as the presence of Russia in the germanium supply chain, is illustrative of the reliance on geopolitical rivals for the supply of CRM to the semiconductor supply chain (see Infographic Achilles Heel).

Rare earth elements

China has weaponised its rare earth exports in the past, most notably through the temporary and informal imposition of an export ban of REE to Japan in 2010 following a dispute over the contested Senkaku/Diaoyu Islands, as well as an imposed export quota imposed on its rare earths.

REE are a set of 17 closely-related metals, which can be subdivided into light rare earth elements (LREE) and heavy rare earth elements (HREE), and have various applications in semiconductor fabrication. Contrary to what their name suggests, REE can be abundantly found in the Earth's crust. Yet, to date, both LREEs and HREEs are almost exclusively sourced in China.[127] The low economic viability of rare earth mining operations and environmental concerns haves dissuaded other countries from engaging in rare earth mining activities.[128] Similar to gallium and germanium, REE are not only mined in China, but they are also refined, as well as converted and processed in China.[129] However, unlike gallium and germanium, the EU has very few alternative sourcing countries of rare earths as it relies for 99% of its LREEs and 98% of its HREEs on China.[130] Importantly, REE also play an important role in the transition to green energy as they are used to produce EVs and wind turbines.

This heavy reliance on Chinese production has prompted various countries to (re)initiate mining, refining, and conversion and processing operations of REE.[131] China has weaponised its rare earth exports in the past, most notably through the temporary and informal imposition of an export ban of REE to Japan in 2010 following a dispute over the contested Senkaku/Diaoyu Islands, as well as an imposed export quota imposed on its rare earths, which led prices to increase sevenfold.[132] Therefore, REE, due to their heavy reliance on Chinese sourcing, Europe and democratic Asia's declining relationship with China, and Beijing's history of weaponizing economic ties, prove to be of significant illustrative relevance into laying bare the risks and dependencies that strain the supply of CRM for the semiconductor supply chain.

125 European Commission, "Communication from the Commission to the EU Parliament and the European Council: Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability."

126 ENF Solar, "List of Germanium Manufacturers.," ENF Solar, 2022, https://www.enfsolar.com/directory/material/germanium.

127 "Rare-Earth Elements," Professional Paper, Professional Paper (USGS, 2017).

128 Charles Homans, "Are Rare Earth Elements Actually Rare?," *Foreign Policy*, June 15, 2010, https://foreignpolicy.com/2010/06/15/are-rare-earth-elements-actually-rare/.

129 Ross Embleton and David Merriman, "Rare Earth Elements: Frequently Asked Questions," Wood Mackenzie, October 1, 2021, https://www.woodmac.com/news/editorial/rare-earth-elements-frequently-asked-questions/.

130 European Commission, "Communication from the Commission to the EU Parliament and the European Council: Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability."

131 Ross Embleton and David Merriman, "Rare Earth Elements"; Matthew Fulco, "Taiwan Is an Ideal Partner for Canada in the Semiconductor Sector" (Macdonald-Laurier Institute, January 2022).

132 Keith Bradsher, "Amid Tension, China Blocks Vital Exports to Japan," *The New York Times*, September 23, 2010, sec. Business, https://www.nytimes.com/2010/09/23/business/global/23rare.html; "China Abolishes Rare Earth Export Quotas: State Media," *Reuters*, January 5, 2015, https://www.reuters.com/article/us-china-rareearths-idUSKBN0KE07P20150105.

Silicon

Silicon is used to produce the wafers out of which semiconductors are made. China is the largest producer of silicon in the world, with around 40% of global production coming from its Xinjiang-region. However, silicon from China is unlikely to be used in the US semiconductor supply chain as it does not meet "the extreme high levels of purity required", according to the US Semiconductor Industry Association.[133] Instead, semiconductor grade polysilicon is sourced from the Unites States, Brazil, Malaysia, France, Germany, Norway, Australia, and South Korea and supplied by German, American, Japanese and Norwegian companies.[134] Xinjiang silicon is mostly used in solar panels and other products related to the energy transition.[135] Silicon is not geologically scarce, but few countries have the technologies and made the investments to mine the material. Unlike other CRM, silicon is the odd one out, as the semiconductor industry as far as is known does not directly rely on silicon from China, but Europe's green transition does depend on it. As China is almost the only producer of the silicon required for solar panels, large-scale disruption in the supply of silicon from China could lead to price hikes or even put pressure on silicon availability across the rest of the world. Silicon prices have proven to be volatile, as electricity curbs in China led to a production cut in the second half of 2021. This led the price of the material to jump by 300% within two months, "threatening everything from car parts to computer chips."[136]

China is the largest producer of silicon in the world, with around 40% of global production coming from its Xinjiang-region.

Infographic Levers of power (below) illustrates the fragile balance of CRM and semiconductors: whereas an technologically advanced democracy-initiated disruption to semiconductor supply would greatly hurt China and Russia, a CRM boycott risks halting nearly all operations in the semiconductor supply chain and Europe's transition to green energy.

133 SIA, "SIA Comments to DHS on UFLPA" (SIA, March 10, 2022), https://www.semiconductors.org/wp-content/uploads/2022/04/SIA-Comments-to-DHS-on-UFLPA.pdf.

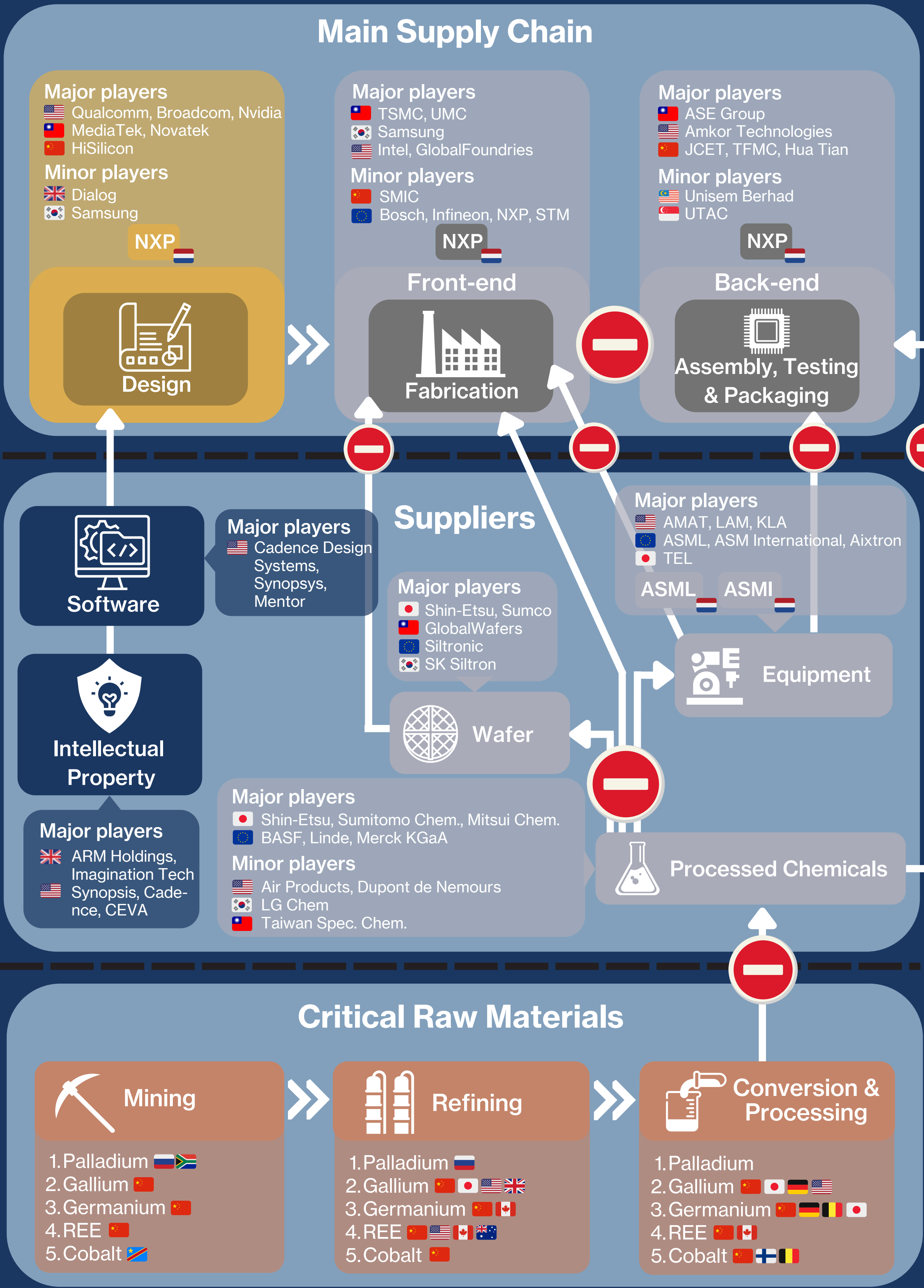
134 The US Semiconductor Industry Association said US supply-chains are at "low risk" of sourcing silicon from China, including Xinjiang. They explained: "though the UFLPA designates polysilicon as a high-priority enforcement sector, the polysilicon produced in Xinjiang, and elsewhere in China, currently does not meet the extremely high levels of purity required for semiconductor-grade polysilicon. Thus, as far as we are aware, polysilicon produced in Xinjiang or elsewhere in China currently is not used by the semiconductor industry. Further, the global production of semiconductor-grade polysilicon is concentrated amongst five major manufacturers (Wacker Chemie (Germany), Hemlock Semiconductor (USA), Tokuyama Corporation (Japan), Mitsubishi Corporation (Japan), and REC Silicon (based in the U.S., listed in Norway), with Wacker Chemie and Hemlock Semiconductor representing approximately three quarters of the global semiconductor polysilicon supply." SIA.

135 Thomas Kaplan, Chris Buckley, and Brad Plumer, "U.S. Bans Imports of Some Chinese Solar Materials Tied to Forced Labor," *The New York Times*, June 24, 2021, sec. Business, https://www.nytimes.com/2021/06/24/business/economy/china-forced-labor-solar.html; *Bloomberg*, "Solar Energy Boom Could Worsen Forced Labor in Xinjiang, China, Group Says," *Bloomberg*, March 28, 2022, https://www.bloomberg.com/news/articles/2022-03-28/solar-energy-boom-could-worsen-forced-labor-in-china-group-says#xj4y7vzkg.

136 Krystal Chia, Dan Murtaugh, and Mark Burton, "Silicon's 300% Surge Throws Another Price Shock at the World," *Bloomberg*, October 1, 2021, https://www.bloomberg.com/news/articles/2021-10-01/silicon-s-300-surge-throws-another-price-shock-at-the-world.

Beijing and Moscow's levers of power

No critical raw materials = no semiconductors



Legend

Countries

Australia	DRC	Japan	South Africa
Belgium	European Union	Malaysia	South Korea
Canada	Finland	Russia	Taiwan
China	Germany	Singapore	United States

Dutch Companies

ASML	Advanced Semiconductors Materials Lithography
ASMI	Advanced Semiconductors Materials International
NXP	NXP Semiconductors

Icons

- Risk
- Blocked

Conclusion

Together, the semiconductor value chain and the CRM supply chain balance each other out: whereas the semiconductor value chain is dominated by technologically advanced democracies allied to the US, the supply chains of crucial CRM for the production of semiconductors and the transition to green energy are based in rival states, China and Russia, and states with complicated political and economic contexts, like the DRC. Except for ASML, Europe's role in the semiconductor value chain is modest.[137]

The value chains for CRM on which the entire semiconductor supply chain currently relies for production are predominantly located in rival states, such as China and Russia, and in other autocracies, like the DRC. These CRM are also required for the production of products used to produce semiconductors such as wafers and equipment. Moreover, geological and economic limitations, the time needed to set up mining operations, and its polluting and disruptive nature complicate relocating the industry elsewhere. The six CRM expanded on above, which are used in the semiconductor and green technology value chains, all serve as an illustrative example laying bare the various risks and dependencies in the CRM supply chain for the semiconductor industry.

Reliance on geopolitical rivals such as China and Russia for essential resources poses a profound threat to European economic security.

Reliance on geopolitical rivals such as China and Russia for essential resources poses a profound threat to European economic security, as is evidenced by Russia's (partial-)natural gas embargo and neon gas embargo against the EU. Especially China, but also Russia still hold dominant roles in various steps of the CRM for semiconductor supply chain. At the same time, reliance on countries mired in political and social instability, such as the DRC, can also significantly disrupt the supply of CRM for the production of semiconductors. By assessing the chain reactions as a result of which European-Russian relations reached breaking point following the invasion of Ukraine, threats can be identified that - throughout the next decade - may well disrupt the CRM value chains on which Europe relies. The next chapter delves deeper into these actors and discusses the threats that could upend or reduce the supply of CRM to Europe or its partners in semiconductor manufacturing. Subsequently, chapter three assesses the various initiatives by the EU and partners to seize the opportunities of semiconductor dominance, as well as to mitigate the risks and dependencies inherent in the supply of CRM for the semiconductor supply chain.

137 Ina Fried, "Intel Pressures the U.S. Government to Help Subsidize Chip Manufacturing," Axios, October 18, 2021, https://www.axios.com/intel-semiconductor-chips-national-security-4ffc8949-4bc7-4460-932c-2c95bebf1daa.html.

Chapter 2. Threats to the supply of CRM for semiconductors

No critical raw materials = no semiconductors

Key Takeaways

- The breakdown of European-Russian trade in vital resources following Russia's invasion of Ukraine shows that economic ties between rival states, even if mutually beneficial and on the surface solely commercial, cannot be guaranteed. Warning signs of a structural decline in Russia's relations with Europe, characterised by contentious events such as the annexation of Crimea and the downing of MH-17, preceded this breakdown.
- Today similar early indications of looming disruptions can be observed, showing that specific threats are likely to cause high impact disruptions in the supply of CRM to Europe or its semiconductor manufacturing partners such a Taiwan (see Table 3) throughout this decade. Actions that weaponise CRM against the European Union's partners in semiconductor production, such as the United States and Taiwan, threaten European economic security in similar ways as direct CRM threats against the Union, as the CRM for semiconductor ecosystem is highly globalised. In addition, CRM weaponisation risks inhibiting the transition to green energy.
- The war in Ukraine and Europe's sanctions against Russia after 15 years of deteriorating relations finally led European-Russian relations to reach breaking point, meaning the moment when military-strategic challenges in the relationship became so overwhelming that
  - Russia became unwilling to deliver the vital resources on which European economies depend (i.e., natural gas and neon embargo),
  - Military action by Russia in Ukraine became so consequential that the supply of an essential resource to Europe has been disrupted (i.e., neon gas) and,
  - European sanctions against Russia (temporarily) inhibited the trade of a critical CRM for the production of semiconductors (i.e., palladium).
- 49 surveyed experts found that the supply of semiconductors and end-products to the EU is likely to be strongly, negatively impacted by CRM supply disruptions in similar ways as the war in Ukraine disrupted European-Russian trade, already in the next five but even more so in the next ten years.
  - A demand-induced CRM shortage due to the energy transition is the threat that is deemed most likely to materialise in both the next five and ten years.
  - The respondents fear that CRM embargoes enacted by China and Russia then aggravate these shortages.
  - Military risks in the Indo-Pacific involving China and possibly the United States are considered the highest impact risks. They are, however, mostly still considered "unlikely" in the next five years and "less likely than not" in the next ten years – with the exception of a naval blockade/invasion of Taiwan.
  - Political unrest or even intrastate conflict in Southern African states is deemed likely to disrupt the supply of cobalt.
  - ESG-related regulation and sanctions by the United States and the European Union were awarded a higher than 50% probability of causing a "high impact" disruption in the supply of CRM for semiconductor production.
  - Events inside China such as pandemic related lockdowns are deemed "more likely than not" to disrupt the supply of CRM already in the next five years, and is expected to have a "high impact" on the supply of semiconductors and end-products to the European Union.

"Undoubtedly, the U.S. side wants to use the products made by China's exported rare earths to counter and suppress China's development. The Chinese people will never accept this! [...] The US is doomed to be met with a slap in the face after it wakes up and stops dreaming."

Wu Yuehu, Commentator for China state newspaper the People's Daily, on 31 May 2019.[138]

"The unimpeded functioning of the Dutch economy in an effective and efficient manner."

The government of the Netherlands' definition of Economic Security.[139]

The supply of semiconductors and end-products to the EU is likely to be strongly, negatively impacted by CRM supply disruptions, already in the next five but even more so in the next ten years.

Europe has a high level of dependence predominantly on China, but also on Russia and the DRC, for the supply of the CRM necessary for domestic production and imports of semiconductors and for its transition to green energy. The breakdown of European-Russian trade in vital resources following Russia's invasion of Ukraine shows that economic ties between rival states, even if mutually beneficial and on the surface solely commercial, cannot be guaranteed. Warning signs of a structural decline in Russia's relations with Europe, characterised by contentious events such as the annexation of Crimea and the downing of MH-17, preceded this breakdown. Today similar early indications of looming disruptions can be observed, showing that specific threats are likely to cause high impact disruptions in the supply of CRM to Europe or its semiconductor manufacturing partners throughout this decade (see Table 6).

Ranking of threats

A ranking of these threats was brought about through a foresight survey filled out by 49 experts. The survey finds that the supply of semiconductors and end-products to the EU is likely to be strongly, negatively impacted by CRM supply disruptions, already in the next five but even more so in the next ten years. The most important threats to the supply of CRM for semiconductors in the next ten years are demand-induced CRM shortages due to the energy transition, a PLA invasion or maritime blockade of Taiwan and a CRM embargo by China.

138 Wu Yuehe, "United States, Don't Underestimate China's Ability to Strike Back," The People's Daily Online, May 31, 2019, http://en.people.cn/n3/2019/0531/c202936-9583292.html.

139 "National Security Strategy" (Dutch Central Government, 2019), p.12.

Table 6. Threats to the critical raw material for semiconductor supply chain

	Theme	Region	Threat
1	Geopolitical	Eastern-Europe	Palladium export embargo by Russia
2	Geopolitical	East Asia	Gallium, Germanium, Cobalt, Rare Earth Element export embargo by China
3	Military	East Asia	People's Liberation Army naval blockade and/or invasion of Taiwan
4	Military	East Asia	Regional naval war in the East China Sea between China and Japan, South Korea and/or the US
5	Military	Southeast Asia	Regional naval war in the South China Sea between China and a Southeast Asian country and/or the US
6	Military	Southeast Asia and Persian Gulf	US blockade halting Chinese oil and gas imports (e.g., Malacca Strait or Strait of Hormuz)
7	Military	Southern Africa	Political instability or civil war in the DRC (or along transportation routes in Southern Africa)
8	Geo-economic	Global	Demand-induced resource shortage due to the energy transition and increase in semiconductor manufacturing
9	Geo-economic	East Asia	Events inside China such as pandemic-related lockdowns or work stoppages
10	Legal	Southern Africa and East Asia	Increasingly stringent EU and US ESG-regulation (e.g., disrupting imports from DRC-mined cobalt and China-mined Silicon)

Selection of the threats

Eight threats were identified by drawing lessons from how Russia's war in Ukraine led European-Russian relations to reach breaking point (see Case Study 1 under Threat 1: A palladium embargo by Russia). Measures by the Russian government, namely [1.] export squeezes/embargoes, have severely disrupted the supply vital resources like neon gas and natural gas to the European Union, but did not affect palladium exports. [2.] War-fighting in Ukraine has severely disrupted the supply of neon gas to the EU as half of the world's semiconductor-grade neon is produced in the country, including at the besieged Azovstal steel plant in Mariupol. The European sanction packages have evaded sanctioning essential commodities from Russia, including palladium, neon extract, and natural gas. However, [3.] European and partner sanctions, specifically the closure of European airspace for Russia, have temporarily disrupted palladium imports, as direct flights from Moscow to European capitals are now rerouted via Doha and Istanbul.[140] As a result, the looming risk of CRM embargoes by rival states, interstate and intrastate war-related disruptions in Asia and Africa, and European and American sanctions disrupting the supply of CRM in the next ten years should be assessed carefully (see Table 6).

These eight threats were then verified on the basis of a literature review, prior research and expert interviews with both regional and thematic experts from academia, think tanks, government, and industry (see Appendix 1). Two additional threats, namely structural geoeconomic factors, were identified on the basis of a limited data analysis of CRM prices, demand projections and supply chain disruptions, primarily caused by China's COVID-19 lockdown policies.

140 Needless to say that since the Russia-Ukraine conflict is highly dynamic and shrouded in the fog of war, the findings below may not be exhaustive. These are based on open sources and expert interviews with among other experts a palladium trader. Patel, "Palladium Tops $3,000/Oz as Supply Fears Grow, Gold Jumps over 1%," March 4, 2022; Hobson, "Palladium Propelled to Record Highs by Russia Supply Concerns," March 7, 2022. Alper, "Exclusive," March 11, 2022.

2.1. Ranking risks: CRM-related threats to the supply of semiconductors survey outcome

The respondents judge the probability of a maritima blockade/ invasion of Taiwan in the next ten years to be above 50%

The seriousness of the identified risks was gauged by experts, ranking the ten threats both in terms of probability of occurrence and level of impact (see Infographics Critical Raw Material Risks and Figure 3 and 4). Seven key findings can be derived from the survey:

1. **The supply of semiconductors and end-products to the EU is likely to be strongly, negatively impacted by CRM supply disruptions, already in the next five but even more so in the next ten years.** A demand-induced shortage due to the energy transition, a CRM export embargo by China, and a People's Liberation Army naval blockade/ invasion of Taiwan are deemed the top risks in the next ten years. It is likely that one or more risks materialises before 2032 and possibly even before 2027, as five risks were awarded a higher than 50% probability to materialise in the next five years and seven in the next ten years. Out of all risks, seven are expected to have a "high impact"[141] and three to have a "very high impact" (see Figure 3).[142] If even just one of these risks materialises, the respondents expect that this will have either a "high impact" or "very high impact" on the supply of semiconductors and end-products to the EU and, hence, the bloc's overall economic security.

2. **A demand-induced CRM shortage due to the energy transition is the threat that is deemed most likely to materialise in both the next five and ten years.** A demand-induced shortage due to the energy transition is a structural, "high impact" challenge facing the CRM landscape. Five out of six CRM assessed in this report have important functions in both semiconductor production and the transition to green energy, meaning the energy transition will put pressure on their availability for semiconductor production.

3. **The respondents fear that CRM embargoes enacted by China and Russia then aggravate these shortages (see Figure 4), not unlike how Russia already imposed a natural gas and neon gas (partial-)embargo in 2022.** As prices rise due to increased demand, the "more likely than not" risk of a palladium export embargo by Russia in both the next five and ten years, and the "more likely than not/likely" risk of a CRM embargo by China in the next ten years, are expected to aggravate disruptions in the supply of semiconductors and end-products to the European Union. The respondents with economic security expertise ranked a CRM embargo by China as the highest impact threat out of all the risks appreciated, whereas China, Japan, East Asia, and international security experts maintained that a Chinese CRM embargo is only a "high impact risk".

4. **Military risks in the Indo-Pacific involving China and possibly the United States are considered the highest impact risks. They are, however, mostly still considered "unlikely" in the next five years and "less likely than not" in the next ten years – with the exception of a naval blockade/invasion of Taiwan.** Military risks involving China, such as 1. A naval blockade and/or invasion of Taiwan, 2. War in the East-China Sea, and 3. War in the South-China Sea are deemed the highest impact events by the overall respondents.[143]

141 Threat 1, 2,3,4,6,9,10

142 Threat 5, 7, 8

143 All expected to have a "very high impact".

Events inside China such as pandemic related lockdowns are deemed "more likely than not" to disrupt the supply of CRM already in the next five years.

Whereas war in either the East-China Sea or South-China Sea is deemed to be "less likely than not" in both the next five and ten years, the odds of a naval blockade and/or invasion of Taiwan passes the respondents' threshold from "less likely than not" in the next five years to "more likely than not" in the next ten years – meaning a higher than 50% chance of occurrence. A People's Liberation Army naval blockade or invasion of Taiwan is expected to have the greatest impact on the supply of semiconductors or end products to the European Union out of all the risks that were surveyed. However, the judgment of respondents with East Asia expertise differs from the overall group as they maintain that the risk of an invasion of Taiwan is "unlikely" before 2027 and still "less likely than not" before 2032. An American maritime blockade of the Strait of Hormuz or the Strait of Malacca to choke China's supply of petrochemical products is, unlike a Taiwan scenario, considered an "unlikely" event by the overall respondents, both before 2027 and 2032.

5. **Political unrest or even intrastate conflict in Southern African states are likely to disrupt the supply of cobalt (see Figure 3).** Political unrest in Southern Africa, another military threat, is deemed "more likely than not" to disrupt the supply of CRM for semiconductors in the next five years, and "likely" to do so in the next ten years. This would have a "high impact" on the supply of semiconductors and end-products to the EU and hence the EU's economic security.

Figure 3. Survey outcome: All CRM-related semiconductor risks are either "high" or "very high" impact

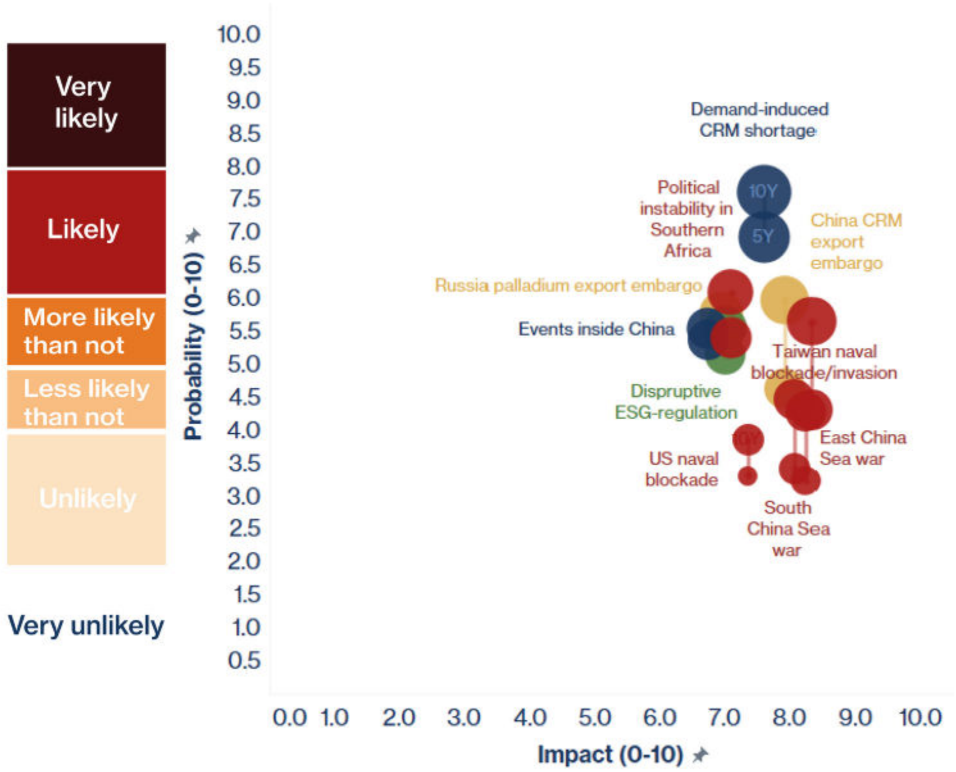
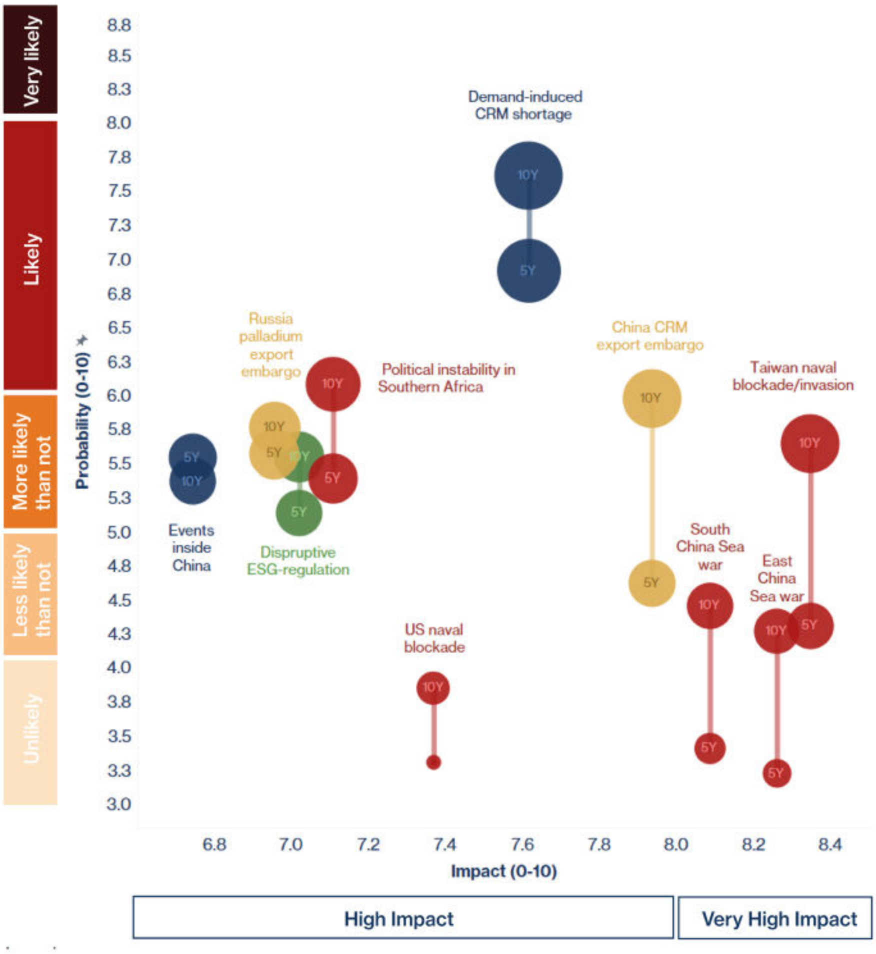
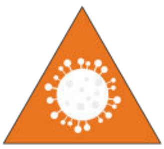


Figure 4. Survey outcome: Seven out of ten threats are considered (at least) "more likely than not" to materialise over the next ten years



6. **ESG-related regulation and sanctions by the United States and the European Union were awarded a higher than 50% probability of causing a "high impact" disruption in the supply of CRM for semiconductor production.** Economic security experts found that ESG-related regulation was "less likely than not" to affect the supply of CRM to Europe in both the next five and ten years. International security and China, Japan, and East Asia experts, however, found the risk to be "more likely than not" to materialise in the next five and ten years.[144]

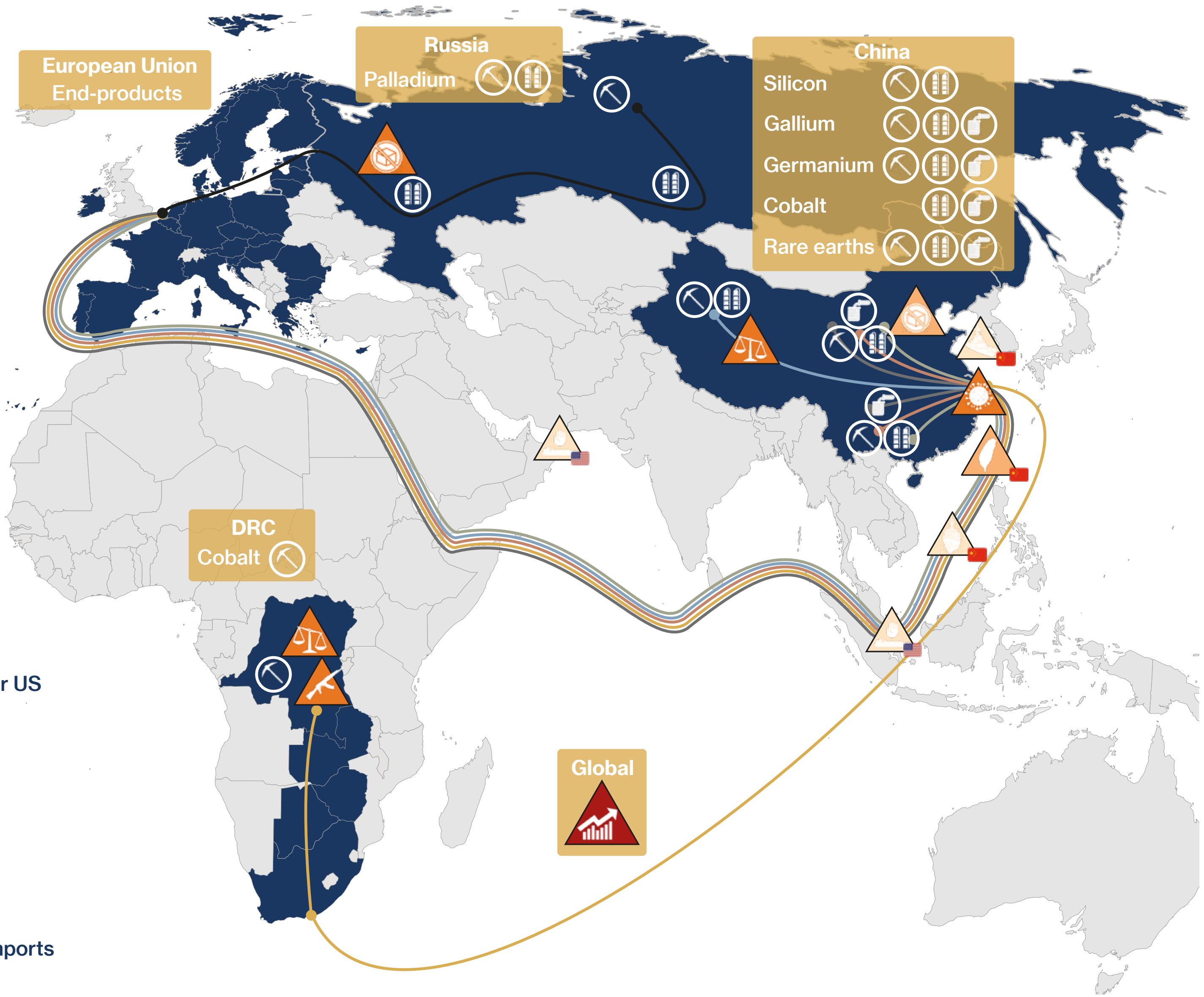


7. **Finally, events inside China such as pandemic related lockdowns are deemed "more likely than not" to disrupt the supply of CRM already in the next five years, and is expected to have a "high impact" on the supply of semiconductors and end-products to the European Union.** Economic security experts on average ranked the probability and impact of events inside China disrupting the supply of CRM both before 2027 and 2032 higher than international security experts and East Asia experts.

144 The Netherlands and the EU are working on increasingly stringent Environmental, Social and Governance (ESG) guidelines, rules and regulations. Child labour has been a problem in DRC cobalt mines. Around 40 to 50% of the world's silicon metal, a material used for the production of semiconductors, is mined in Xinjiang. On June 21, 2022, the Uygur Forced Labor Prevention Act entered into force in the US with more human rights related regulation in the making.

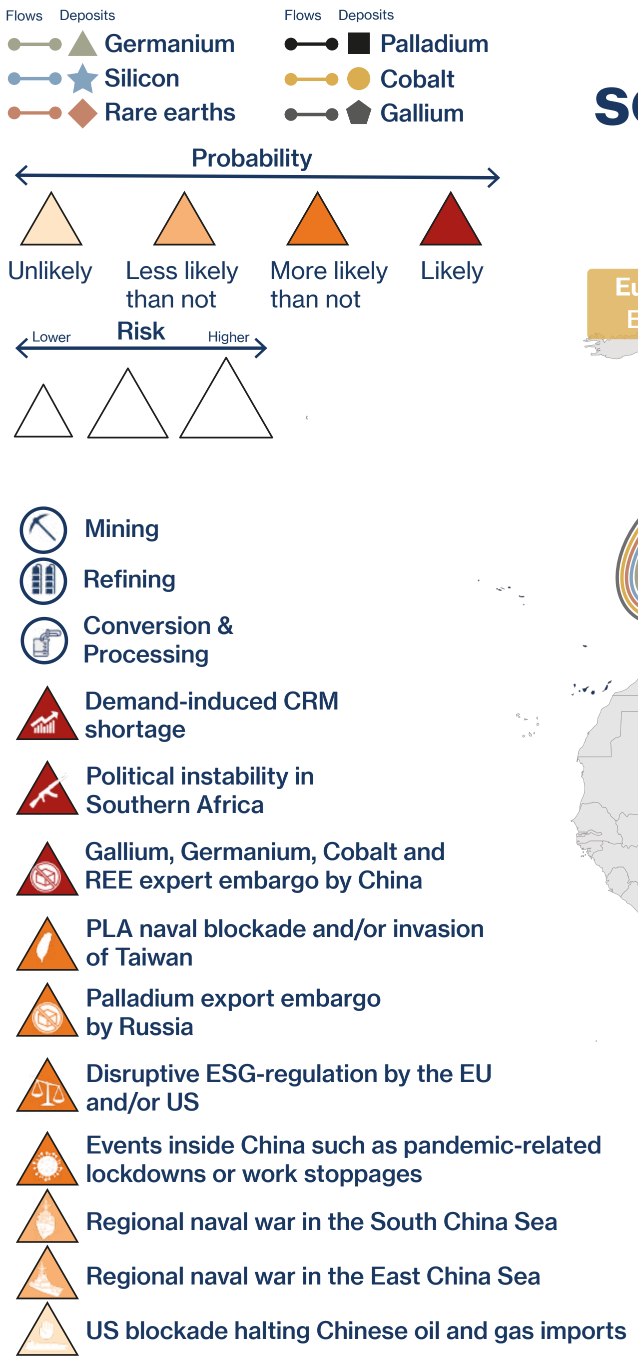
Critical Raw Material risks for semiconductor supply next five years

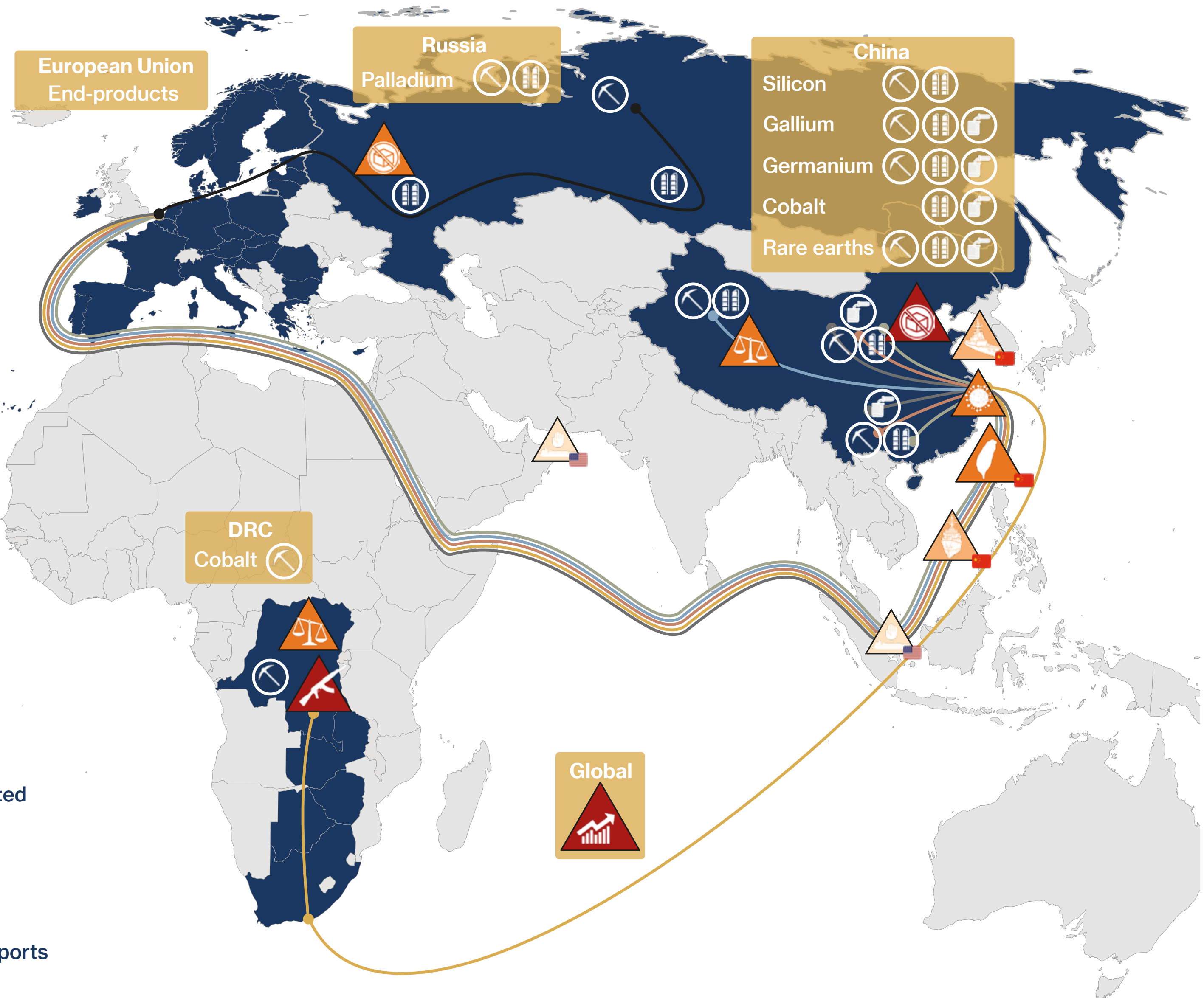
According to 49 experts surveyed in 2022



Critical Raw Material risks for semiconductor supply next ten years

According to 49 experts surveyed in 2022





Survey methodology

The ranking of the risks (i.e., *probability * impact*) was brought about through a foresight survey filled out by a group of 49 experts from different fields of expertise and work, of whom 29 are named (see Appendix 2). Respondents ranked the identified ten risks in terms of probability of occurrence in both the next five and ten years. Respondents were also asked to assess the impact that these scenarios would have on the supply of semiconductors and end-products to Europe (see section Survey Outcome).

Respondents filled out 30 questions ranking the probability in five years, the probability in ten years, and the impact for each of the ten threats (see Figure 3 and 4). 'Probability' is defined as the chance of an event occurring. 'Impact' is defined as the impact an event would have on the supply of CRM to the EU or its partners in semiconductor manufacturing (e.g., Taiwan), and therefore also the supply of semiconductors to the EU.

For each question, respondents scored probability or impact on a scale from zero to ten. Zero indicated "extremely unlikely" or "extremely low impact", while ten indicated "extremely likely" or "extremely high impact". The numerical probability responses were categorised in six categories, namely very unlikely (0.0-2.0), unlikely (2.01-4.0), less likely than not (4.01-5.0), more likely than not (5.01-6.0), likely (6.01-8.0), and very likely (8.01-10.0). The numerical impact responses were similarly categorised in five categories, namely very low impact (0.0-2.0), low impact (2.01-4.0), medium impact (4.01-6.0), high impact (6.01-8.0), and very high impact (8.01-10.0).

Ranges	Probability	Impact
0,0 - 2,00	Very unlikely	Very low impact
2,01 - 4,00	Unlikely	Low impact
4,01 - 5,00	Less likely than not	Medium impact
5,01 - 6,00	More likely than not	Medium impact
6,01 - 8,00	Likely	High impact
8,01 - 10.0	Very Likely	Very high impact

Responses were excluded when a respondent mentioned not to have the expertise needed to answer a specific question. The survey was conducted from the last week of May until the end of June 2022.

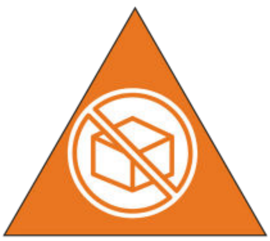
2.2. Selecting risks: Ten CRM-related threats to the supply of semiconductors

2.2.1. Geopolitical risks: Embargoes

When do relations with rivals reach "breaking-point" via the first avenue, meaning the moment when challenges in the relationship, especially highly contentious military-strategic challenges, become so problematic that rivals are no longer willing to supply essential commodities (such as CRM) on which our economies depend? The below analysis of Dutch and European relations with two rivals, Russia and China, over the past ten-to-fifteen years show a clear downward trend, marked and accelerated by specific contentious events such as Russia's annexation of Crimea in 2014 and European sanctions and Chinese countersanctions over the mass-internment of Uyghurs in Xinjiang in 2021. However, this has not led to an embargo of palladium supplies by Russia to the EU or its partners in semiconductor production, nor to the EU sanctioning imports of Russian palladium, nor to a CRM embargo by China against the EU or its partners as of 2022.

Dutch and European relations with two rivals, Russia and China, show a clear downward trend over the past ten-to-fifteen years.

Russia-EU relations did however reach "breaking point" following the 2022 Russian invasion of Ukraine : natural gas and neon supplies are now being fully weaponised by Russia against the European Union. A case study on the supply of essential commodities from Russia to Europe following the war in Ukraine (see ii. Reaching breaking point: Weaponisation of European-Russian trade in vital commodities following Russia's invasion of Ukraine) is incorporated in the analysis of recent European-Russian relations. European-Chinese relations have not reached a breaking point as of yet. As the downward trend in relations between Europe and its partners in semiconductor production (e.g., Taiwan and the US) on the one hand and China and Russia on the other is likely to continue towards 2027 and then to 2032, the experts surveyed in the previous section consider reaching a "breaking point" via CRM embargoes enacted by China and Russia to have a more than 50% chance of materialising in the next ten years.



Threat 1: Palladium export embargo by Russia

i. Fifteen years of contentious Dutch and European relations with Russia (2007-2022)

Russian palladium exports to the Netherlands, the rest of Europe and its partners in semiconductor manufacturing (e.g., Taiwan) have survived a rapidly and structurally deteriorating relationship characterised by a wide range of contentious and even lethal events, which continue at the time of writing.[145] In 2012, Dutch, European and American relations with Russia had already run into difficulties for many years following a speech by Putin at the Munich Security Conference in 2007 in which he decried American unilateralism ("the US has overstepped its national borders in every way"), as he accused the US of "hyper use of [...] military force [...] plunging the world into an abyss of permanent conflicts" and lamented the Eastward expansion of the North Atlantic Treaty Organisation (NATO).[146] In 2022, Russia's relations with the EU and the Netherlands hit a new post-Cold War low as Russia invaded Ukraine and the

145 The time of writing is mid-August 2022.

146 "Transcript: 2007 Putin Speech and the Following Discussion at the Munich Conference on Security Policy," Johnson's Russia List, March 10, 2007, https://russialist.org/transcript-putin-speech-and-the-following-discussion-at-the-munich-conference-on-security-policy/.

Figure 5. From low to lower: fifteen years of deterioration in Dutch and EU relations with Russia

EU enacted a series of sanction packages. Curiously, European-Russian trade in palladium has proceeded, suffering only some disruptions, as Russia has not embargoed its supply of palladium and the EU has exempted palladium from its sanctions against Russia.[147]

Crisis events: Crimea, MH17, and OPCW

The EU, its member states, and the US imposed sanctions on Russia in response to its *fait accompli* annexation of Crimea in February and March 2014. Amongst other measures, the EU-Russia Summit was cancelled, Russia was disinvited from G8 meetings, and negotiations on Russian entry into the Organisation for Economic Cooperation and Development (OECD) and the IEA were suspended.[148] In July 2014, Russian-backed separatists in Eastern Ukraine downed the Malaysia-bound MH17 flight from Amsterdam, killing nearly 200 Dutch nationals. In 2018, the Dutch and Australian governments officially held Russia responsible for the tragedy.[149] In that same year, the Dutch Minister of Defense Ank Bijleveld stated that the Netherlands is engaged in a "cyber war" with Russia after the GROE, Russia's intelligence service, tried to hack into the Organisation for the Prohibition of Chemical Weapons (OPCW).[150]

Adjusting strategy: A policy memo and a Russia strategy

The Netherlands also formally changed its outlook on Russia in a 2015 policy memo, sustaining this more negative position in its 2019 Russia Strategy. In the Dutch government's 2015 Policy Memo *Reorientation in relations with Russia*, the Dutch government called MH17 a "watershed" moment and accordingly revised its official policy on and approach to Russia, warning about the external assertiveness and internal repression of the Russian state.[151] The memo concluded that Dutch-Russian relations, as a consequence, have entered "a new phase", within which "almost all aspects of the relationship" have become more difficult. In 2019, the Netherlands doubled down on its new approach to relations with Russia, arguing that "the government will continue its efforts to invest in protection and defense of the Netherlands and its allies and partners whilst continuously putting

[147] Olof Konig and Fredric Ericsson, "The EU Adopts a Fifth Package of Sectoral and Individual Measures Targeting Russia and Belarus," Baker McKenzie, April 11, 2022, https://sanctionsnews.bakermckenzie.com/the-eu-adopts-a-fifth-package-of-sectoral-and-individual-measures-targeting-russia-and-belarus/.

[148] "EU Restrictive Measures in Response to the Crisis in Ukraine," European Council, March 25, 2022, https://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-ukraine-crisis/.

[149] Stef Blok, "Ruslandstrategie," Rijksoverheid (Ministerie van Algemene Zaken, December 23, 2019), https://www.rijksoverheid.nl/documenten/kamerstukken/2019/12/23/ruslandstrategie.

[150] Tweede Kamer, "Debat over spionage door Rusland," Text, Tweede Kamer, December 21, 2018, https://www.tweedekamer.nl/kamerstukken/plenaire_verslagen/kamer_in_het_kort/debat-over-spionage-door-rusland.

[151] A. G. Koenders, "Beleidsbrief betrekkingen met Rusland," officiële publicatie, Tweede Kamer, May 13, 2015, https://zoek.officielebekendmakingen.nl/kst-34000-V-69.html.

pressure on Russia."[152] Even though the government does not expect Russia to return to the "European security order" that NATO and Russia "together built" after the Cold War, the strategy does acknowledge that Russia is "a key geostrategic player on the European continent" and calls for "sustaining dialogue" as it is crucial to still explore "areas of shared interest".[153]

ii. Case study Reaching breaking point: Weaponisation of European-Russian trade in vital commodities following Russia's invasion of Ukraine

EU and partner sanctions have inhibited the supply of palladium, among other resources.

Russia's invasion of Ukraine in early 2022, responded to by technologically advanced democracies with sanctions such as a ban on semiconductor exports to the country, and large-scale weapon deliveries to Ukraine, have led to a breaking-point in European-Russian relations. Since the invasion began, the supply of palladium, neon gas and natural gas, commodities essential to the European economy and the production of semiconductors, have experienced disruptions. What follows is an assessment of the causes and severity of the disruptions in the supply of these essential commodities since 24 February 2022. The effect of three risks, namely (1) war-fighting in Ukraine, (2) a Russian export embargo or squeeze, and (3) EU and partner sanctions, are assessed. Developments within these categories show that Russian-EU relations finally reached a "breaking point" after 15 years of deteriorating relations and intensifying hostility, as Russia enacted a *de facto* natural gas and neon gas embargo against the EU. The production of neon in Ukraine has been disrupted and EU and partner sanctions have inhibited the supply of palladium, among other resources. Table 7 below provides an overview of the severity of disruption caused by the different measures indicated through high, medium, or low disruption.[154]

Table 7. Reaching breaking-point? Disruptions in the supply of essential energy supplies and natural resources from Ukraine and Russia since 24 February 2022

	Palladium	Neon Gas	Natural Gas
War-fighting in Ukraine	No disruption	High disruption	Medium disruption
Russian export squeeze or embargo	No disruption	High disruption	High disruption
EU and partner sanctions	Low disruption	No disruption	Low disruption

1. **War-fighting in Ukraine**

The war-fighting in Ukraine has severely disrupted the supply of neon gas to the EU as half of the world's semiconductor-grade neon is produced in the country, including at the infamous Azovstal steel plant in Mariupol. A large part of the neon extract used for the production of semiconductors is a byproduct of Russian steel manufacturing, which is subsequently purified and processed in Ukraine, after which it is shipped to semiconductor manufacturers

152 Stef Blok, 'Ruslandstrategie', p. 2.

153 Stef Blok, p. 13.

154 Needless to say that since the Russia-Ukraine conflict is highly dynamic and shrouded in the fog of war, the findings below may not be exhaustive.

Russian natural gas exports have been severely weaponised by the Russian government.

across the globe.[155] Originally, over 90% of global neon production came from Ukraine, but since the annexation of Crimea in 2014 a significant part of production has shifted to China.[156] An investigation by market-research firm Techcet CA LLC found that currently 45% to 54% of neon used for semiconductor manufacturing is produced by just two Ukrainian companies, namely Ingas and Cryoin, which were both forced to indefinitely suspend their operations following the Russian invasion of Ukraine.[157] While Ingas is based in Mariupol, Cryoin is located in Odessa, both places that have been severely disrupted by the heavy war-fighting between Russian and Ukrainian forces.[158] Azovstal, the infamously besieged steel plant in Mariupol, was one of the few facilities in the world that can produce the neon necessary for semiconductor production.[159] Various major players in the semiconductor supply chain have tried to mitigate the disruption. Whilst South Korea swiftly removed its import tariffs on neon, ASML shifted its neon sourcing to other locations in the world.[160]

To a lesser degree, the war-fighting in Ukraine has also directly disrupted Russian natural gas supply to the EU. Russian gas is supplied to the EU through an intricate network of pipelines, including pipelines that run through Ukraine. In May of 2022, Russian gas supply through Ukraine fell by a quarter, as Kyiv was forced to halt gas supply through a major transit point, citing interference by Russian forces.[161] This Ukrainian gas corridor usually supplies 8% of total Russian natural gas to the EU, predominantly to Austria, Italy, and Slovakia.[162] This further strains the limited supply of natural gas to Europe.

2. **Russia export squeeze or embargo**

Russia has restricted the export of neon gas to Europe, whilst there is still no sign of a palladium export ban, though plausible in the near future. In June 2022, the Russian Ministry of Trade and Industry announced it would restrict the export of noble gases, including neon, until the end of the year. Neon gas exporters are required to receive a special state permission until December 31st.[163] This puts further strain on the materials essential for semiconductor manufacturing. The Russian government has also repeatedly warned of further sanctions against the West, including restricting raw material exports. President Putin signed a broad decree in May of this year forbidding the export of products and raw materials for various people and entities on Russia's sanctions list.[164] However, to date there has been no sign of a palladium export ban. Yet, the repeated threats by the Russian government could indicate a

155 Suman Bhattacharyya, "Russian Attack on Ukraine Could Dent Chip-Maker Supply Lines," *The Wall Street Journal*, February 25, 2022, sec. C Suite, https://www.wsj.com/articles/russian-attack-on-ukraine-could-dent-chip-maker-supply-lines-11645837830.

156 Izabella Kaminska, "Noble Gases Are Suffering From Putin's War in Ukraine," *Bloomberg*, May 19, 2022, https://www.bloomberg.com/opinion/articles/2022-05-19/ukraine-war-mariupol-noble-gases-neon-helium-are-suffering-from-putin-s-war.

157 Alexandra Alper, "Exclusive: Russia's Attack on Ukraine Halts Half of World's Neon Output for Chips," *Reuters*, March 11, 2022, sec. Technology, https://www.reuters.com/technology/exclusive-ukraine-halts-half-worlds-neon-output-chips-clouding-outlook-2022-03-11/.

158 Alper, "Russia's attack on Ukraine".

159 Izabella Kaminska, "Noble Gases Are Suffering From Putin's War in Ukraine."

160 Alper, "Exclusive," March 11, 2022.

161 Nina Chestney, "Russian Gas Flows to Europe via Ukraine Fall after Kyiv Shuts One Route," *Reuters*, May 11, 2022, sec. Energy, https://www.reuters.com/business/energy/requests-russian-gas-via-key-ukraine-transit-point-fall-zero-data-shows-2022-05-11/.

162 Chestney.

163 Mary Villareal, "Russia Responds to Another Round of EU Sanctions by Restricting Exports of Noble Gases like Neon, Which Is Essential for Making Computer Chips," Supply Chain Warning, June 7, 2022, https://www.supplychainwarning.com/2022-06-07-russia-responds-eu-sanctions-limits-neon-exports.html.

164 Guy Faulconbridge, "Putin Puts West on Notice: Moscow Can Terminate Exports and Deals," *Reuters*, May 3, 2022, sec. World, https://www.reuters.com/world/putin-signs-decree-new-retaliatory-sanctions-against-west-kremlin-2022-05-03/.

potential weaponization of its raw material resources in the near future and has incentivised palladium importers to increase their palladium imports from Russia to prepare for a possible future squeeze.[165]

Russian natural gas exports have been severely weaponised by the Russian government through repeated reductions and restrictions of natural gas flows to Europe, which will continue for the foreseeable future. In the early stages of the war, Russia enforced a ruble payment scheme for gas, obstructing Russian gas purchases by the EU.[166] This was followed by cutting gas supplies to various countries across the EU, including Poland, Bulgaria, Finland, the Netherlands, Greece and Denmark, a list which is bound to grow.[167] Following Europe's imposition of a partial ban on Russian oil in June 2022, Moscow also reduced gas supplies to more countries, namely Germany, Italy, France, the Czech Republic, Slovakia, and Austria.[168] For example, in June Russian energy supplier Gazprom had reduced the gas flows of Nordstream 1, an undersea gas pipeline to the EU, to just 40% of capacity.[169] Overall Russia's share of gas supplies to the EU has dropped from 40% in 2021 to just 20% in June 2022, in response to the EU's partial ban on Russian oil and complete ban on coal imports.[170]

EU sanctions have indirectly (and partially inadvertently) disrupted the supply of essential commodities to Europe, including palladium.

3. **EU and partner sanctions**

The EU's six sanctions packages have not directly sanctioned the Russian supply of palladium, neon gas, and natural gas. Since the start of the Russian invasion of Ukraine, the EU has imposed extensive sanctions against Russia, including individual sanctions against members of the Russia State Duma, as well as Vladimir Putin and Sergey Lavrov, the closure of EU airspace to all Russian aircraft, the exclusion of various Russian banks from the SWIFT banking system, and a partial ban on Russian oil imports.[171] However, essential commodities, such as palladium and natural gas have been exempted. The European commission has stated that "the competent national authority may authorise the award and continued execution of contracts related to: [...] natural gas and oil, including refined petroleum products, as well as titanium, aluminum, copper, nickel, palladium, iron ore and coal until August 10,

165 "Europe Scrambles for Palladium as Russia Threatens Supply," Automotive Logistics, July 1, 2022, https://www.automotivelogistics.media/trade-and-customs/europe-scrambles-for-palladium-as-russia-threatens-supply/43189.article.

166 *Al Jazeera*, "Putin: Russia Will Enforce Rouble Payments for Gas from Friday," *Al Jazeera*, March 31, 2022, https://www.aljazeera.com/economy/2022/3/31/putin-russia-will-enforce-rouble-payments-for-gas-from-friday.

167 Tsvetelia Tsolova and Anna Koper, "Europe Decries 'blackmail' as Russia Cuts Gas to Poland, Bulgaria," *Reuters*, April 27, 2022, sec. Energy, https://www.reuters.com/business/energy/gazprom-says-it-halts-gas-supplies-poland-bulgaria-payments-row-2022-04-27/; *BBC News*, "Russia Halts Gas Supplies to Finland," *BBC News*, May 21, 2022, sec. Europe, https://www.bbc.com/news/world-europe-61524933; America Hernandez, "Russia Halts Gas Supply to the Netherlands," Politico, May 31, 2022, https://www.politico.eu/article/russia-halts-gas-supply-to-the-netherlands/; Jan M. Olsen, "Russia Cuts off Natural Gas Supply to Denmark, Company Says | AP News," AP News, June 1, 2022, https://apnews.com/article/russia-ukraine-putin-government-and-politics-netherlands-10923b26194d11c555f6176799465dd2.

168 Ben McWilliams and Georg Zachmann, "European Union Demand Reduction Needs to Cope with Russian Gas Cuts," Bruegel, July 7, 2022, https://www.bruegel.org/2022/07/european-union-demand-reduction-needs-to-cope-with-russian-gas-cuts. Ben Cahill, "European Union Imposes Partial Ban on Russian Oil," CSIS, 2022, https://www.csis.org/analysis/european-union-imposes-partial-ban-russian-oil.;

169 *Reuters*, "Exclusive: Russia Likely to Restart Gas Exports from Nord Stream 1 on Schedule - Russian Sources," *Reuters*, July 20, 2022, sec. Energy, https://www.reuters.com/business/energy/exclusive-russia-seen-restarting-gas-exports-nord-stream-1-schedule-2022-07-19/.

170 Ben McWilliams and Georg Zachmann, "European Union Demand Reduction Needs to Cope with Russian Gas Cuts."

171 European Council, "EU Sanctions against Russia Explained.""EU Sanctions against Russia Explained," European Council, July 22, 2022, https://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-against-russia-over-ukraine/sanctions-against-russia-explained/.

2022".[172] It is likely that EU sanctions will continue to avoid directly curbing the flow of these essential goods in the short-term, whilst Europe seeks alternative suppliers.

However, EU sanctions have already indirectly (and partially inadvertently) disrupted the supply of essential commodities to Europe, including palladium. Following the closure of EU airspace to all Russian aircraft, palladium supply routes have been temporarily disrupted. Whereas palladium was originally transported via air directly to European airports, palladium is now flown in from Moscow to Doha or Istanbul and then to Europe.[173] Moreover, sanctions have prompted handlers and shippers to stop the handling of Russian goods in fear of sanctions.[174] These indirect disruptions have led palladium prices to spike.[175] In addition, the EU sanctions packages have targeted shareholders of mining companies, which has thus complicated the payment of foreign debt. This, in turn, made it more difficult for Russian mining companies to import foreign equipment necessary for their mining operations.[176]This could be disruptive to palladium mining operations in Russia in the medium term.[177] Last, measures by partner countries, including the United Kingdom, Canada, and the US have also either directly or indirectly disrupted the supply of essential commodities to the EU and have the potential to do so going forward. For example, in May of 2022 the UK announced to increase its tariffs on palladium imports from Russia and Belarus.[178] This caused palladium prices to jump, disrupting trade of the metal.[179]

Russia-EU relations have reached a "breaking point" following the 2022 Russian invasion of Ukraine.

Conclusion

Russia-EU relations have reached a "breaking point" following the 2022 Russian invasion of Ukraine : military-strategic considerations in the relationship are starting to severely affect the supply of essential commodities from Russia to the EU, although differences between the supply of neon and natural gas, on the one hand, and palladium, on the other hand, stand out. Whilst natural gas and neon extract supplies are now being fully weaponised by Russia against the EU, the supply of palladium has largely remained untouched. The war fighting in Ukraine has caused high disruption of neon gas supply and medium disruption of natural gas flows from Russia. Measures by the Russian government, such as export squeezes or embargoes, have severely disrupted the supply of neon gas and natural gas to the EU, whilst palladium exports have largely been unaffected. The European sanctions packages have avoided sanctioning essential commodities from Russia, including palladium, neon extract, and natural gas. However, European and partner sanctions have indirectly disrupted palladium imports.

172 European Commission, "Consolidated Version of the Frequently Asked Questions Concerning Sanctions Adopted Following Russia's Military Aggression against Ukraine" (European Commission, June 22, 2022), 197, https://finance.ec.europa.eu/publications/consolidated-version_en. 'Commission Consolidated FAQs' (European Commission, 22 June 2022), p. 197.

173 "Russia's Palladium Exports Face Disruption From Flight Bans."

174 Hobson, "Palladium Propelled to Record Highs by Russia Supply Concerns," March 7, 2022.

175 Patel, "Palladium Tops $3,000/Oz as Supply Fears Grow, Gold Jumps over 1%," March 4, 2022.

176 Mining.com, "Putin Wants Russia to Boost Its Use of Metals to Counter Sanctions," Mining.Com (blog), April 20, 2022, https://www.mining.com/web/putin-wants-russia-to-boost-its-use-of-metals-to-counter-sanctions/.

177 Ibid.

178 *Reuters*, "Britain to Increase Tariffs on Russian Platinum, Palladium in New Sanctions," *Reuters*, May 8, 2022, sec. United Kingdom, https://www.reuters.com/world/uk/britain-increase-tariffs-russian-platinum-palladium-new-sanctions-2022-05-08/.

179 Joe Wallace, "U.K. Tariffs on Russian Palladium Briefly Send Prices Higher," *The Wall Street Journal*, May 9, 2022, https://www.wsj.com/livecoverage/russia-ukraine-latest-news-2022-05-09/card/u-k-tariffs-on-russian-palladium-briefly-send-prices-higher-a5xHWTfpwyNSttUH2ALP.

It remains to be seen whether the breaking point will further degenerate, to the point that Russia will put an outright full ban on the export of all essential materials, including palladium, needed to keep both the European economy and the production of semiconductors running. The War in Ukraine has, however, led to steep price rises also for palladium and the supply of neon gas, needed by both producers of lithography equipment and by semiconductor manufacturers, has been disrupted by the fighting.[180] The continuation of human rights and security disputes between NATO and Russia, the War in Ukraine and the ensuing sanctions will further inflate problems in the relationship. Respondents to the expert survey claim that a Russian embargo of palladium supply to Europe and its partners in semiconductor manufacturing in both the next five and ten years is therefore a “more likely than not” scenario.

Threat 2: Gallium, Germanium, Cobalt, Rare Earth Element export embargo by China

i. Dutch and European relations with China (2012-2022)

China’s supply of gallium, germanium, cobalt and REE survived a whole range of contentious issues throughout the past ten years. Unlike Russia’s interactions, China’s interactions with the Netherlands and the EU were predominantly positive as of 2012.[181] Since then, however, Dutch and European relations with China have rapidly deteriorated, as concerns about China’s trade and technology policies, severe human rights violations including the mass-internment in Xinjiang, and the abolishment of democracy in Hongkong and political issues came to dominate the relationship. In 2022, security issues such as China’s rhetorical support for Russia’s war in Ukraine,[182] and increased PLA assertiveness around Taiwan have dominated the relationship. However, the trade of essential commodities between China and the EU does not seem to have been impacted to date.

The trade of essential commodities between China and the EU does not seem to have been impacted to date.

The early-2010s: Business, business, and business

Throughout the first part of the 2010s, Dutch and European relations with China were mostly positive, as shown by two key visits. The state visit of President Xi Jinping to the Netherlands in March 2014 included a lavish dinner hosted by King Willem-Alexander and led to the establishment of a “Partnership for Comprehensive Cooperation”, highlighting “the intention of both countries to work together in a broad framework, focusing on political and economic

180 Alper, “Exclusive,” March 11, 2022. Peter Hobson, “Palladium Propelled to Record Highs by Russia Supply Concerns,” *Reuters*, March 7, 2022, sec. Business, https://www.reuters.com/business/palladium-propelled-record-highs-by-russia-supply-concerns-2022-03-07/. Patel, “Palladium Tops $3,000/Oz as Supply Fears Grow, Gold Jumps over 1%,” March 4, 2022; Hobson, “Palladium Propelled to Record Highs by Russia Supply Concerns,” March 7, 2022.

181 See, for example: “Het Nederlandse China-Beleid: Investeren in Waarden En Zaken” (Government of The Netherlands, May 16, 2013), https://www.parlementairemonitor.nl/9353000/1/j4nvgs5kjg27kof_j9vvij5epm-j1ey0/vjeqk6qdzhyh/f=/kst3362559.pdf; “Joint Statement between the People’s Republic of China and the Kingdom of the Netherlands on the Establishment of an Open and Pragmatic Partnership for Comprehensive Cooperation | Report | Government.Nl,” September 4, 2019, https://web.archive.org/web/20190904211633/https://www.government.nl/documents/reports/2014/03/24/joint-statement-between-the-people-s-republic-of-china-and-the-kingdom-of-the-netherlands-on-the-establishment-of-an-open-and-p; “Handelsmissie naar China,” CGCB International B.V., March 21, 2015, https://www.cgcb.nl/nl/handelsmissie-naar-china-maart-2015/.

182 John Feng, “NATO Coalition Calls on China to Oppose Russia’s War in Ukraine,” Newsweek, March 24, 2022, https://www.newsweek.com/nato-china-russia-ukraine-war-oppose-stop-assistance-1691429; “EU-China Summit: Restoring Peace and Stability in Ukraine Is a Shared Responsibility,” European Council, April 1, 2022, https://www.consilium.europa.eu/en/press/press-releases/2022/04/01/eu-china-summit-restoring-peace-and-stability-in-ukraine-is-a-shared-responsibility/.

issues, international developments and security, culture and science, and exchange visits."[183] One year later, Prime Minister Rutte led a trade mission that included 70 Dutch companies to Beijing in order to deepen the economic dimension of the relationship.[184]

Change of direction: human rights concerns and political scrutiny

In the latter half of the 2010s, both the Netherlands and the EU adjusted their relationship with China significantly. In the EU's 2016 strategy paper towards China, the EU took a more pragmatic, realistic, and assertive approach to its relationship with China.[185] This course of action was reconfirmed in the EU's 2019 strategy paper on China. Most notably, the EU coined China a "systemic rival promoting alternative forms of governance",[186] marking the shift from seeing China as a partner to seeing it also as a competitor and rival. Concerns about Chinese trade and technology policy, human rights violations, and other political issues, have started to take center stage in the relationship. The EU increasingly voices its dissatisfaction in China-EU economic relations, noting unfair competition and lack of reciprocity.[187] In 2021, the Dutch parliament voted in favor of calling the suppression of Uyghurs in China a "genocide".[188] Over the same issue the EU imposed sanctions on China, followed by retaliatory sanctions by Beijing.[189] Both the Netherlands and the EU expressed explicit support for Taiwan, thus angering China.[190] The China-EU Comprehensive Agreement on Investment, originally a key component of the 'strategic partnership' between China and the EU, was shelved after the European Parliament voted to freeze it.[191] The G7, which includes two important EU member-states, criticised China's live-fire drills around Taiwan following Nancy Pelosi's visit to the self-governing island republic in August 2022, calling it "an escalatory response."[192]

183 "China and the Netherlands Strengthen Bilateral Relations | News Item | Government.Nl," September 5, 2019, https://web.archive.org/web/20190905184924/https://www.government.nl/latest/news/2014/03/24/china-and-the-netherlands-strengthen-bilateral-relations.

184 "Handelsmissie naar China."

185 "Elements for a New EU Strategy on China" (Brussels: European Commission, June 22, 2016).

186 European Commission, "EU-China - A Strategic Outlook," 1. 'EU-China - A Strategic Outlook' (Brussels: European Commission, 12 March 2019), p. 1.

187 "European Chamber Calls on China to Demonstrate Its Commitment to Economic Globalisation and Openness," European Chamber of Commerce, September 19, 2017, https://www.europeanchamber.com.cn/en/press-releases/2579/european_chamber_calls_on_china_to_demonstrate_its_commitment_to_economic_globalisation_and_openness; Dana Heide et al., "China First: EU Ambassadors Band Together against Silk Road," Handelsblatt, April 17, 2018, https://www.handelsblatt.com/english/politics/china-first-eu-ambassadors-band-together-against-silk-road/23581860.html.

188 Tweede Kamer, "Motie van het lid Sjoerdsma c.s. over uitspreken dat in China genocide plaatsvindt op de Oeigoerse minderheid," Text, Tweede Kamer, February 25, 2021, https://www.tweedekamer.nl/kamerstukken/detail?id=2021Z03872&did=2021D08405.

189 "Chair's Statement of 23 March 2021 on EU Sanctions on Human Rights Violations; Counter-Sanctions by the PRC." European Parliament, "Chair's Statement of 23 March 2021 on EU Sanctions on Human Rights Violations; Counter-Sanctions by the PRC."

190 "European Parliament Delegation Ends Visit to Taiwan," European Parliament, November 5, 2021, https://www.europarl.europa.eu/news/en/press-room/20211104IPR16624/european-parliament-delegation-ends-visit-to-taiwan; "Motie van het lid De Roon over uitdragen dat eenzijdige stappen met betrekking tot de status van Taiwan onaanvaardbaar zijn," Text, Tweede Kamer, 2021, https://www.tweedekamer.nl/kamerstukken/moties/detail/2021Z21366/2021D45602.

191 "MEPs Refuse Any Agreement with China Whilst Sanctions Are in Place," European Parliament, May 20, 2021, https://www.europarl.europa.eu/news/en/press-room/20210517IPR04123/meps-refuse-any-agreement-with-china-whilst-sanctions-are-in-place.

192 United States Department of State, "G7 Foreign Ministers' Statement on Preserving Peace and Stability Across the Taiwan Strait," August 3, 2022, https://www.state.gov/g7-foreign-ministers-statement-on-preserving-peace-and-stability-across-the-taiwan-strait/#:~:text=We%20are%20concerned%20by%20recent,activity%20in%20the%20Taiwan%20Strait.

Figure 6. Falling off a cliff: Dutch and European relations with China since 2012

China's pro-Russian neutrality in the Ukraine War

China's response to the war in Ukraine has further negatively impacted its relationship with the EU. EU member states and NATO have repeatedly called on China to oppose Russia's war in Ukraine and communicated their dissatisfaction with China's pro-Russian neutrality in the war. In the most recent EU-China summit, Commission President von der Leyen noted that "no European citizen would understand any support to Russia's ability to wage war".[193] Moreover, European concerns following Chinese FK-3 missile systems to the Serbian military[194], an increased threat perception of a Chinese invasion of Taiwan,[195] as well as the continuation of joint air patrol's together with Russia in spite of its invasion of Ukraine,[196] have further strained the relationship. At the same time, the invasion of Ukraine has bolstered the EU-US transatlantic partnership, as evidenced by the unprecedented sanctions, including a ban on semiconductor exports, that both sides implemented against Russia in cooperation with partners in Asia, such as with Japan, South-Korea, Taiwan, and Australia. The war also strengthened their resolve to cooperate in their opposition to China, jointly stating that "support [for Russia's aggression against Ukraine] would have consequences for our respective relationships with China".[197]

As the US and China are engaged in intensifying superpower competition, Russia's war in Ukraine has made EU dependence on the US for its military acute and, as China's relations with the EU keep deteriorating, China may find itself increasingly in a position where it could consider launching an export embargo of CRM against the EU or its partners in semiconductor partners. The previous decade has shown that China on several occasions launched boycotts and embargoes against states when relations deteriorated.

193 John Feng, "NATO Coalition Calls on China to Oppose Russia's War in Ukraine," Newsweek, March 24, 2022, https://www.newsweek.com/nato-china-russia-ukraine-war-oppose-stop-assistance-1691429.; Lenka Ponikelska, "Czechs Warn China Its Endorsement of Russia Will Erode EU Ties," *Bloomberg*, April 21, 2022, https://www.bloomberg.com/news/articles/2022-04-21/czechs-warn-china-its-endorsement-of-russia-will-erode-eu-ties.

194 Jack Lau and Finbarr Bermingham, "China Delivered FK-3 Missile System to Serbian Military, State Media Says," South China Morning Post, April 11, 2022, https://www.scmp.com/news/china/military/article/3173904/china-delivered-fk-3-missile-system-serbian-military-state.

195 *Reuters*, "Taiwan Says Hopes World Would Sanction China If It Invades," *Reuters*, May 7, 2022, sec. Asia Pacific, https://www.reuters.com/world/asia-pacific/taiwan-says-hopes-world-would-sanction-china-if-it-invades-2022-05-07/; *Reuters*, "Chinese Calculations on Taiwan Affected by Ukraine Conflict, Says CIA Director," *Reuters*, May 7, 2022, sec. World, https://www.reuters.com/world/chinese-calculations-taiwan-affected-by-ukraine-conflict-says-cia-director-2022-05-07/.

196 Tony Munroe, "China Says Air Patrol with Russia Not Directed at Any Country," *Reuters*, May 25, 2022, https://www.reuters.com/world/china-says-air-patrol-with-russia-not-directed-any-country-2022-05-25/.

197 "EU-U.S.: Consultations between EEAS Secretary General Stefano Sannino and United States Deputy Secretary Wendy Sherman," EEAS, April 22, 2022, https://www.eeas.europa.eu/eeas/eu-us-consultations-between-eeas-secretary-general-stefano-sannino-and-united-states-deputy_en.

ii. China's economic coercion since 2010

Since 2010, China has on several occasions weaponised access to its gigantic market and its dominance in specific resources against states with which China has a diplomatic dispute centered around China's "core interests" (see Table 8). In 2009, during the first meeting of the US-China Strategic and Economic Dialogue, State Councilor Dai Bingguo made explicit Beijing's view of its "core interests", of which the two most important are:

- "upholding its basic systems, our national security", meaning the supremacy of the Chinese Communist Party (CCP),
- "the sovereignty and territorial integrity", meaning its claims to rule not just territories under its control like Xinjiang, Tibet and Hong Kong, but also disputed islands in the East China Sea and South China Sea and Taiwan, and its "economic and social sustained development".[198]

China has on several occasions weaponised access to its gigantic market and its dominance in specific resources.

Import bans, export embargoes and dissuading tourists' visits were the weapons of choice used to force other states not to hurt these interests.

In the Indo-Pacific, China wielded these tools (temporarily) against Japan, against South Korea and Australia. In 2010, international media reported that China had cut off exports of rare earths to Japan, following an incident in which the captain of a Chinese trawler was arrested by the Japanese Coast Guard in the area of the disputed Senkaku/Diaoyu Islands, an issue that China finds harmful to its second core interest, namely its territorial sovereignty.[199] Although no official embargo of Chinese rare earths to Japan was ever announced, China significantly slowed and obstructed its exports to Japan through a series of administrative and bureaucratic measures.[200] This disruption led prices to rise tenfold, in spite of customs data from China and Japan showing that rare earths "continued to be shipped to Japan throughout the fall of 2010."[201] Chinese-installed export quotas in the same year, reducing its overall export of rare earths by 40%, led prices to rise sevenfold. These quotas were finally suspended in 2015 "following a trade dispute settlement at the WTO" initiated by the US in 2012, after also Japan and the EU had complained about China's policies.[202] Japan has reduced its rare earth dependence on China from 90% to 58% within a decade, aiming to bring that number to under 50% by 2025.[203] Individual companies are also taking measures.

198 Bingguo Dai, "Closing Remarks for U.S.-China Strategic and Economic Dialogue," //2009-2017.state.gov/secretary/20092013clinton/rm/2009a/july/126599.htm.

199 Keith Bradsher, "Amid Tension, China Blocks Vital Exports to Japan," *The New York Times*, September 23, 2010, sec. Business, https://www.nytimes.com/2010/09/23/business/global/23rare.html. ; Larry Wortzel and Kate Selley, "Breaking China's Stranglehold on the Rare Earth Elements Supply Chain | JAPAN Forward," April 28, 2021, https://japan-forward.com/breaking-chinas-stranglehold-on-the-rare-earth-elements-supply-chain/. 'China Abolishes Rare Earth Export Quotas: State Media', *Reuters*, 5 January 2015, https://www.reuters.com/article/us-china-rareearths-idUSKBN0KE07P20150105.

200 Bradsher, "Amid Tension, China Blocks Vital Exports to Japan," September 23, 2010. Bradsher, "Amid Tension, China Blocks Vital Exports to Japan," September 23, 2010.

201 Lucy Hornby and Henry Sanderson, "Rare Earths: Beijing Threatens a New Front in the Trade War," *Financial Times*, June 4, 2019, sec. China Rivalry, https://www.ft.com/content/3cd18372-85e0-11e9-a028-86cea8523dc2.

202 "China Abolishes Rare Earth Export Quotas: State Media," January 5, 2015. https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds431_e.htm

203 Mary Hui, "Japan's Global Rare Earths Quest Holds Lessons for the US and Europe," Quartz, April 23, 2021, https://qz.com/1998773/japans-rare-earths-strategy-has-lessons-for-us-europe/. https://asia.nikkei.com/Business/Markets/Commodities/China-tightens-rare-earth-regulations-policing-entire-supply-chain

Toyota designed new magnets for electric vehicles with lower concentrations of REE to limit the geopolitical risks of its dependence on China.[204]

In response to the joint deployment of the US Terminal High Altitude Area Defense system (THAAD), first announced by South Korean and American military officials in February 2016, China enacted a host of punitive measures.[205] These included the closure of 74 Lotte supermarkets in China "for fire safety violations" and a comprehensive stop on "all outbound group tourism to South Korea". In addition, South Korea's EV battery and motorcycle industry as well as cultural exports were also affected.[206] In 2020, China banned the imports of Australian wine, a 1.2$ billion market in 2020, altogether and put tariffs and restrictions on other commodities "including barley, beef, timber, cotton, lobsters and coal." Banned coal, however, was partly released from Chinese ports subsequent to shortages and blackouts in China. Iron ore was exempted altogether.[207]

Throughout the past decade, China also targeted European states. In retaliation for awarding the 2010 Nobel Peace Prize to Liu Xiaobo, a Chinese democracy advocate and dissident, China banned the import of Norwegian salmon on the Chinese market.[208] In the fall of 2021, China downgraded relations with Lithuania after the country allowed for the opening of a "Taiwanese Representative Office" instead of a "Taipei Representative Office" in Vilnius.[209] China's retribution went further, as Beijing restricted trade of Lithuanian companies and other European companies that incorporate Lithuanian-made parts in its products on its domestic market.[210] Chinese economic coercion of European companies also manifests itself informally, for example through popular boycotts.[211]

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204 Numbers are based on UN Comtrade Data. Robert Ferris, "Toyota Is Trying to Make Electrified Vehicles Less Dependent on Chinese Minerals," CNBC, February 20, 2018, https://www.cnbc.com/2018/02/20/toyota-is-trying-to-make-electric-vehicles-less-dependent-on-chinese-minerals.html.

205 Michael D. Swaine, "Chinese Views on South Korea's Deployment of THAAD," China Leadership Monitor (Carnegie Endowment for International Peace, February 14, 2017), 1–2, https://carnegieendowment.org/files/CLM52MS.pdf. Beijing did this, in spite of American insistence that THAAD was solely aimed at protecting South-Korea from North-Korean attacks. Missy Ryan, "Pentagon to Deploy Anti-Missile System in South Korea," Washington Post, June 7, 2016, https://www.washingtonpost.com/news/checkpoint/wp/2016/07/07/pentagon-to-deploy-anti-missile-system-in-south-korea/.

206 About 40% of South Korea's economy depended on exports at the time. China has for a long time been South Korea's largest trading partner. Darren J. Lim and Victor A. Ferguson, "Informal Economic Sanctions: The Political Economy of Chinese Coercion during the THAAD Dispute," Review of International Political Economy 0, no. 0 (May 26, 2021): 3, 5–8, https://doi.org/10.1080/09692290.2021.1918746.

207 Samuel Yang, "Will the Change of Government in Australia End the Trade War with China?," ABC News, June 1, 2022, https://www.abc.net.au/news/2022-06-02/trade-war-between-australia-china-labor-government/101109164. Su-Lin Tan, "Australian Iron Imports to China Slow but 'Roaring' Demand Likely to Return," South China Morning Post, February 4, 2022, https://www.scmp.com/week-asia/economics/article/3165730/australian-iron-imports-china-slow-roaring-demand-likely-return.

208 The effectiveness of the export ban, however, remains unclear as "official statistics record a reduced Norwegian market share and decreased Norway–China salmon trade despite an expansion of the volume of Chinese imports. However, official data do not record Norwegian salmon entering illegally, which some stakeholders estimate at between 50 and 70 per cent of the market. " Xianwen Chen and Roberto Javier Garcia, "Economic Sanctions and Trade Diplomacy: Sanction-Busting Strategies, Market Distortion and Efficacy of China's Restrictions on Norwegian Salmon Imports," *China Information* 30, no. 1 (March 2016): 29–57, https://doi.org/10.1177/0920203X15625061.

209 John O'Donnell and Andrius Sytas, "Exclusive: Lithuania Braces for China-Led Corporate Boycott," *Reuters*, December 9, 2021, sec. China, https://www.reuters.com/world/china/exclusive-lithuania-braces-china-led-corporate-boycott-2021-12-09/.

210 Joshua Nevett, "Lithuania: The European State That Dared to Defy China Then Wobbled," *BBC News*, January 7, 2022, sec. Europe, https://www.bbc.com/news/world-europe-59879762.

211 Aya Adachi, Alexander Brown, and Max J. Zenglein, "Fasten Your Seatbelts: How to Manage China's Economic Coercion" (*MERICS*, August 25, 2022), https://merics.org/en/report/fasten-your-seatbelts-how-manage-chinas-economic-coercion.

Table 8. China's weaponization of trade: a sample of coercive action over the last decade

Target state	Good/ Commodity	Kind	Year of initiation	Cause	Effect
Norway	Salmon	Import ban	2010	Nobel Peace Prize awarded to Chinese dissident	Disruption of (legal) sales of Norwegian salmon into China
Japan	Rare Earth Elements; Same year 40% export cut in REE is enacted	Export embargo/ quota	2010	Arrest of Chinese Fishing Trawler in disputed waters East-China Sea	Price-hikes; Japan enacts state-driven policies to slash dependence on REE from China almost by half in 2025
South-Korea	Lotte super-markets; tourist groups; EV/ Motorcycle and cultural exports	Import ban; Tourism ban	2016-2017	Deployment of US THAAD missile system in South-Korea	Closure of Lotte supermarkets in China, Tourist boycott and damage to EV and motorcycle sector and cultural exports
Australia	Wine, barley, beef, timber, cotton, lobsters and coal	Import ban	2020	Call for independent inquiry in COVID-19 origin	Too early to tell
Lithuania	All goods	Import-ban	2021	Vilnius' upgrading of relations with Taiwan	Too early to tell

Conclusion

China-EU/NL relations have witnessed a deteriorating trend and Beijing has weaponised access to its domestic market and the export of key commodities to Asian and European democracies several times over the past decade.

In short, China-EU/NL relations have witnessed a deteriorating trend and Beijing has weaponised access to its domestic market and the export of key commodities to Asian and European democracies several times over the past decade. The first trend is likely to continue given the EU's hardening stance towards China, and China's increasing assertiveness in international relations. To date, trade in essential commodities has remained unaffected by the deteriorating relationship between China and the EU. A credible risk exists that China will weaponise its CRM exports and affect the semiconductor supply chain, given China's history of weaponising trade to its advantage and a further deteriorating trend in the relationship. While the surveyed experts expect an export embargo by China against the EU or its partners in semiconductor manufacturing (e.g., Taiwan) still "less likely than not" to occur until July 2027, they do find that a CRM export embargo by China before July 2032 is "likely" to be enacted.

2.2.2. Military risks: War-related disruption

At what point does interstate military conflict, both high intensity war (e.g., regional war or great power war) and low intensity war (e.g., naval blockades), disrupt the economic foundation that underpins the EU and its partners in semiconductor production's relationship with rivals and third countries? When does intrastate political instability reach the point at which the exports of vital commodities are upended? Military action by Russia in Ukraine became so large-scale after its invasion of 2022 that the supply of an essential commodity, namely neon gas, to Europe has been disrupted (see Case Study above). Meanwhile, as the EU together with the US, Taiwan, South-Korea, and Japan imposed sanctions on Russia, politically supported Ukraine, and provided the country with heavy armament, Russia in retaliation restricted the export of neon gas "for the rest of the year" from June 2022 onwards.[212]

212 Mary Villareal, "Russia Responds to Another Round of EU Sanctions by Restricting Exports of Noble Gases like Neon, Which Is Essential for Making Computer Chips."

This shows that parties not directly involved in the war may also be affected by retaliatory boycotts as a result of their political support.

The analysis below of four interstate war threats in the Indo-Pacific, involving China and the US, and finally a political instability/intrastate war threat, involving the DRC and transit route states in Southern Africa, through which DRC-cobalt is exported, highlight avenues for conflict to disrupt the supply of essential CRM. The analysis shows that "breaking-point" through an active war has not been reached, as military competition between the US (and its allies) and China around Taiwan, in the East China Sea, in the South China Sea, and, albeit to a lesser extent around the Malacca Strait has not yet involved open conflict (despite heating up significantly). At the same time, political instability in the DRC has so far not disrupted the mining, refining, and export of cobalt, and China has not weaponised its control over DRC-cobalt.

Respondents judge the chance of a naval blockade and/or invasion of Taiwan to be higher than 50% in the next ten years.

This state of relative normalcy should not be taken for granted, however, as superpower rivalry is heating up with the PLA's live-fire drills around Taiwan in August 2022 serving as the latest example. The stakes for both China and for the US are sky high. China inherited a "claustrophobic nautical setting", which is characterised by its constraint position within the US-dominated first island chain and its reliance on the East China Sea, the Taiwan Strait, and the South China Sea. Enforcing sovereignty over the territories China claims as its own is one of the CCP's stated "core interests", just behind maintaining the supremacy of the CCP.[213] At the same time, China depends on the Strait of Hormuz and especially the Strait of Malacca for its petrochemical imports such as crude oil and liquified natural gas (LNG). In a conflict with China, the US will ask for the support of its allies. Considering Europe's vast dependence on US military might in NATO to deter Russia, including the deployment of 100.000 US personnel, forces a diabolical dilemma onto European states: supporting the US and upsetting China, on which the EU relies for CRM or staying out of confrontation and upsetting the guarantor of its security.[214] Hence, if military conflict does occur, the US and its allies may face similar embargoes by China, as the neon and natural gas embargoes already imposed by Russia in 2022.

Not coincidentally, the surveyed experts expect security of CRM supply will be breached as a result of military action. The respondents find that before July 2032 a naval blockade or an invasion of Taiwan is "more likely than not" to occur, and that political instability in Southern Africa is "likely" to disrupt the supply of cobalt. In fact, they find that the supply of cobalt to the EU and partners in semiconductor production is already "more likely than not" to be disrupted before July 2027.

Threat 3: People's Liberation Army naval blockade and/or invasion of Taiwan

The rapid and ongoing modernization of the PLA, especially of its Navy, Air Force, and Rocket Force, have given the CCP new means to force a military solution and "unify" the mainland with Taiwan, seen by the CCP leadership as a renegade province.[215] China's live fire drills around Taiwan in August 2022, following an uptick in PLA jets crossing into China's Air-Defense Identification Zone (ADIZ), take place in a radically different geopolitical context than the Third

213 Bingguo Dai, "Closing Remarks for U.S.-China Strategic and Economic Dialogue," U.S. Department of State, accessed October 3, 2022, //2009-2017.state.gov/secretary/20092013clinton/rm/2009a/july/126599.htm.

214 Joris Teer et al., "China's Military Rise and the Implications for European Security" (The Hague Centre for Strategic Studies, 2021), 109, https://hcss.nl/report/chinas-military-rise/.

215 Ibid.

Taiwan Strait Crisis.[216] In 1995-6, President Clinton was still able to deploy two Carrier Strike Groups in the Taiwan Strait, in order to effectively end a PRC intimidation campaign of Taiwan. In 2022, China's Anti-Access and Area-Denial (A2/AD) capabilities, especially its guided missiles, mines, and submarines make any American intervention to thwart a PLA naval blockade or amphibious invasion of Taiwan extremely costly.[217] US ability to deter a PLA naval blockade of Taiwan or a complete invasion has strongly decreased since 1995/6.[218]

The shifting balance of power and Taiwan's unwillingness to cede to China's demands have led China to take some bold moves over the past years, to which not just the US but also Japan and Australia have responded. The PLA Airforce has expanded its number of incursions into Taiwan's ADIZ in 2021 and 2022.[219] In June 2022, President Xi signed "trial orders" allowing "military operations other than war" beyond China's borders which would "safeguard China's national sovereignty, security, and development interests.[220] The outlines of the policy remain unpublished, but the phraseology bears striking resemblance to Russia's Special Military Operation in Ukraine, which the Kremlin has refused to call a war since it was announced.[221] President Biden has now four times pledged to defend Taiwan if it were attacked by China.[222] In November 2021, the then Australian Minister of Defense said it was "inconceivable" that Australia "wouldn't support the US in an action if the US chose not take that action", seemingly describing the scenario if US forces moved to repel a Chinese attack on Taiwan.[223]

Economic security reasons involving semiconductors may also move Beijing to consider an attack on Taiwan. One Chinese top economist "at a government-run research group" has stressed that TSMC's dominance in semiconductor manufacturing is a reason to "recover" Taiwan, if the West imposes similar sanctions on China as it did against Russia -effectively

216 Chris Buckley and Steven Lee Myers, "'Starting a Fire': U.S. and China Enter Dangerous Territory Over Taiwan," *The New York Times*, October 9, 2021, sec. World, https://www.nytimes.com/2021/10/09/world/asia/united-states-china-taiwan.html.

217 A naval blockade would isolate Taiwan militarily from the US navy, economically from essential supplies of food and energy resources, and perhaps even digitally from its online connection to the rest of the world as the telecommunication cables on which Taiwan relies may be cut. Chris Buckley et al., "How China Could Choke Taiwan," *The New York Times*, August 25, 2022, sec. World, https://www.nytimes.com/interactive/2022/08/25/world/asia/china-taiwan-conflict-blockade.html.; Rush Doshi, *The Long Game: China's Grand Strategy to Displace American Order* (Oxford University Press, 2021), 68–100, 183–207.

218 Amti Vorndick, "China's Reach Has Grown; So Should the Island Chains," Asia Maritime Transparency Initiative, October 22, 2018, https://amti.csis.org/chinas-reach-grown-island-chains/.

219 Katharina Buchholz, "Infographic: Taiwan's Airspace: Chinese Incursions Remain on High Level," Statista Infographics, May 24, 2022, https://www.statista.com/chart/24620/chinese-military-aircraft-entering-taiwans-adiz/.

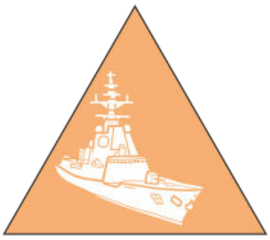
220 Helen Davidson, "Tensions Heighten in Taiwan Strait as China Acts to Extend Military Operations," *The Guardian*, June 15, 2022, sec. World news, https://www.theguardian.com/world/2022/jun/15/tensions-heighten-in-taiwan-strait-as-china-acts-to-extend-military-operations.

221 Vladimir Putin, "Full Text of Vladimir Putin's Speech Announcing 'Special Military Operation' in Ukraine," https://theprint.in/world/full-text-of-vladimir-putins-speech-announcing-special-military-operation-in-ukraine/845714/.

222 Even though White House spokespersons have stated every time that US Taiwan policy remains "unchanged." The first time was in August 2021 during the chaotic withdrawal from Afghanistan. The third time in Japan, during a trip to the Indo-Pacific, on May 23 President Biden made a similar pledge. https://www.nytimes.com/2022/05/23/world/asia/biden-taiwan-china.html

223 The Australian, "Defending Taiwan against China Is a Must, Says Peter Dutton," The Australian, November 12, 2021, https://www.theaustralian.com.au/subscribe/news/1/?sourceCode=TAWEB_WRE170_a&dest=https%3A%2F%2Fwww.theaustralian.com.au%2Fnation%2Fdefence%2Fdefending-taiwan-against-beijing-is-a-must-says-peter-dutton%2Fnews-story%2Fef9dd7fd56515afbdc90021760d1d344&memtype=anonymous&mode=premium&v21=dynamic-groupa-test-noscore&V21spcbehaviour=append; Demetri Sevastopulo, "Australia Vows to Help US Defend Taiwan from Chinese Attacks," *Financial Times*, November 13, 2021, https://www.ft.com/content/231df882-6667-4145-bc92-d1a54bccf333.

cutting-off semiconductor supply to Russia- following its invasion of Ukraine.[224] Such an attack would not be without historical precedent, as Imperial Japan's military rush for oil resources in Indonesia and its attack on Pearl Harbor were a response to the US imposed oil embargo.[225] However, unlike oil, semiconductor production fabs are not commodities that can be easily taken over as they rely on highly specialised teams of engineers and careful conditions to operate.[226] Mark Liu, Chair of TSMC stated that if China were to occupy Taiwan this would render its fabs "not operable."[227]



Threat 4: Regional naval war in the East China Sea between China and Japan, South Korea and/or the US

The East China Sea is of great importance to China, Japan, and South Korea for a variety of reasons. First of all, it is the second out of four arenas in East-Asia where Chinese-US strategic competition unfolds: While the East China Sea holds great strategic importance for China to consolidate its claims to the First Island Chain, it is also highly relevant for the US' main ally in the region and second regional power, Japan, to maintain its grip over the contested Senkaku/Diaoyu islands. The East China Sea is central to security in the Indo-Pacific, and whoever achieves dominance over it, will ultimately shape at the very least the regional order. Should Japan manage to assert its claims to the islands, the Indo-Pacific order driven by the US-Japan alliance would only be reaffirmed, but if China successfully claims the islands, it may indicate an end of the US order in the region.[228]

Japan views China as its principal challenger, especially citing the rapid modernisation of the PLA Navy.[229] Tokyo increasingly comes to see Beijing's moves as attempts to change the status quo through coercion.[230] China follows a maritime strategy shaped by coexistence, deterrence, and active defence in the East China Sea.[231] Enforcing sovereignty over the territories China claims as its own is one of the CCP's stated "core interests", just behind maintaining the supremacy of the CCP.[232] For China, asserting control over the East China Sea is informed by the century of humiliation at the hands of foreigners and the US presence through patrolling shipping lanes on which Chinese economic growth is dependent. This vulnerability is seen as a key driver to establish a ring of maritime control around its periphery.[233] The East China Sea is one of China's most important maritime regions due to its economic center in

224 *Bloomberg*, "Top Economist Urges China to Seize TSMC If US Ramps Up Sanctions," *Bloomberg*, June 7, 2022, https://www.bloomberg.com/news/articles/2022-06-07/top-economist-urges-china-to-seize-tsmc-if-us-ramps-up-sanctions.

225 Ian Kershaw, *Fateful Choices: Ten Decisions That Changed the World, 1940-1941* (Allen Lane, 2007), 331–81.

226 "What Happens Without Taiwan's Chips?," China Talk, https://podcasts.google.com/feed/aHR0cHM6Ly9ja-GluYWVjb250YWxrLmxpYnN5bi5jb20vcnNz/episode/NGZmMGY1NTItMTgwYy0xMWVkLWJhM2YtY-WY2MDAyMjFmMjgz?hl=en-NL&ved=2ahUKEwikxI38-cr5AhXCGuwKHSS5C90QieUEegQIBBAI&ep=6.

227 Fareed Zakaria, "On GPS: Can China Afford to Attack Taiwan?," CNN, n.d., https://edition.cnn.com/videos/tv/2022/07/31/exp-gps-0731-mark-liu-taiwan-semiconductors.cnn.

228 Nabel Akram, "Geostrategic Importance and Natural Reserves of East China Sea," Modern Diplomacy February 14, 2022, https://moderndiplomacy.eu/2022/02/14/geostrategic-importance-and-natural-reserves-of-east-china-sea/.

229 Japan Ministry of Defense, "Defense of Japan 2022 (White Paper)" (Japan Ministry of Defense, 2022), https://www.mod.go.jp/en/.

230 Jeffey W. Hornung, "Japan's Potential Contributions in an East China Sea Contingency," Research Reports (RAND Corporation, 2020).

231 "China's Maritime Strategy in the East China Sea," The Wilson Center, September 24, 2013, https://www.wilsoncenter.org/event/chinas-maritime-strategy-the-east-china-sea.

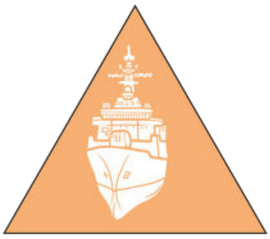
232 Dai, "Closing Remarks for U.S.-China Strategic and Economic Dialogue," July 28, 2009.

233 Linda Jakobson and Rory Medcalf, "The Perception Gap: Reading China's Maritime Objectives in Indo-Pacific Asia," Lowy Institute, June 23, 2015, https://www.lowyinstitute.org/publications/perception-gap-reading-chinas-maritime-objectives-indo-pacific-asia.

the east, its densely populated coastal cities and vulnerability to an attack. Access to the East China Sea is also essential for Beijing to deter Taiwan from making a formal independence declaration and Beijing's dependence on international seaborne trade.[234]

The South China Sea presents another key region of strategic US-China competition.

South Korea is mainly interested in securing Socotra Rock as a maritime boundary issue for its Exclusive Economic Zone (EEZ) claims and has overlapping claims of ADIZs in the East China Sea[235], all of which are the source of less tension than between Japan and China in this sea. A potential conflict scenario could involve naval warfare or an aerial confrontation, due to the patrols flown through the East China Sea to secure the respective claims to ADIZs. The overlapping ADIZ claims of China, Japan, and South Korea in the East China Sea as well as unsettled territorial dispute over Senkaku/Diaoyu between China and Japan and the ongoing maritime boundary dispute between China and South Korea, allow for a variety of tensions to flare up in the region. Meanwhile, deployment of the first US-THAAD missile system in 2017 led to an economic campaign by China against South-Korea.[236] In 2022, the Yoon administration is considering the deployment of a second system. Due to the dependence of the world economy on the East China Sea for trade with China, Japan, and South-Korea, a conflict scenario played out on this stage is not only a regional matter, but a global one.



Threat 5: Regional naval war in the South China Sea between China and a Southeast Asian country and/or the US

The South China Sea presents another key region of strategic US-China competition. A variety of overlapping territorial claims make the South China Sea even more dangerous waters than the East China Sea to navigate. The significant amount of natural resources and fishing areas makes it an especially attractive area for various littoral countries. Competing claims of Brunei, Indonesia, Malaysia, the Philippines, Taiwan, and Vietnam about the Spratly Islands, the Paracel Islands and Scarborough Shoal,[237] have been a source of tension for decades. Besides disputed claims, the South China Sea is also relevant for shipping routes, as Japan, South Korea, and Australia are heavily dependent on the latter for supplying fuels and for their trade with Europe and the states around the Indian Ocean, but also as an export route.[238]

China has taken assertive attempts at claiming the South China Sea through physically expanding the size of the islands, building new islands and constructing military

234 Michael McDevitt et al., "The Long Littoral Project: East China and Yellow Seas. A Maritime Perspective on Indo-Paciifc Security" (CNA, September 2012), https://www.cna.org/archive/CNA_Files/pdf/iop-2012-u-002207-final.pdf.

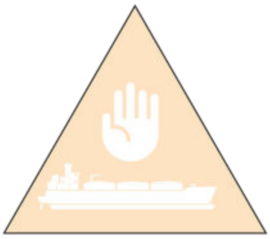
235 Rebecca Strating, "Maritime and Sovereignty Disputes in the East China Sea," The National Bureau of Asian Research, February 9, 2021, https://www.nbr.org/publication/maritime-and-sovereignty-disputes-in-the-east-china-sea/; Young-jin Kim, "Why Ieodo Matters," The Korea Times, September 19, 2012, https://www.koreatimes.co.kr/www/news/nation/2012/09/117_120266.html.

236 Michael D. Swaine, "Chinese Views on South Korea's Deployment of THAAD," Hoover Institution, 2017, 1–2, https://www.hoover.org/research/chinese-views-south-koreas-deployment-thaad. Beijing did this, in spite of American insistence that THAAD was solely aimed at protecting South-Korea from North-Korean attacks. Ryan, "Pentagon to Deploy Anti-Missile System in South Korea."

237 "Territorial Disputes in the South China Sea," Global Conflict Tracker May 4, 2022, https://cfr.org/global-conflict-tracker/conflict/territorial-disputes-south-china-sea. Council on Foreign Relations Center for Preventive Action, "Territorial Disputes in the South China Sea," Global Conflict Tracker, accessed October 3, 2022, https://cfr.org/global-conflict-tracker/conflict/territorial-disputes-south-china-sea.

238 "South China Sea," The Lowy Institute, accessed July 11, 2022, https://www.lowyinstitute.org/issues/south-china-sea. "South China Sea," The Lowy Institute, accessed July 11, 2022, https://www.lowyinstitute.org/issues/south-china-sea.

installations.[239] China bases its claims on a 1948 map which marked the Chinese territorial claims to the rocks and reefs of the South China Sea through the so-called nine-dash-line, which the Chinese Coast Guard as well as other government agencies have used as a maritime boundary and claim to the sea.[240] The US maintains a defense treaty with the Philippines, meaning that it could get involved within a conflict with China.[241]



Threat 6: US blockade halting Chinese oil and gas imports (e.g., Malacca Strait or Strait of Hormuz)

To counter or deter China from starting the above-listed military conflicts or to preemptively coerce China to achieve other objectives, the US may choose to target China's reliance on enormous supplies of essential overseas oil through a naval blockade. The effectiveness of such a measure is clear. Access to oil is of central importance to military warfare. China still relies on the supply of oil via these waterways (even though the share has gradually been reduced). The US has the military means to take such an action (outside of what China considers its "near-seas"). Finally, some analysts have deemed an oil-embargo to be a relatively low-risk military action to take against China.

The US may choose to target China's reliance on enormous supplies of essential overseas oil through a naval blockade.

Without oil, modern warfare cannot be fought "because mobility in the age of mechanised warfare depends almost completely on oil."[242] China also relies economically on foreign oil, as in 2018 China was "the largest single-country importer of crude oil ever, importing roughly 9.3 million barrels of crude per day, about half being imported from the Middle East via the Indian Ocean and the Persian Gulf."[243] The US Navy, with its eleven nuclear-powered mega-aircraft carriers versus Beijing's three diesel-powered and relatively small carriers, will most likely remain the dominant military power near the Strait of Hormuz and even near the Strait of Malacca for another decade. This advantage is maintained in spite of China's successful leaps in developing a "world-class" navy and its expected ability to be able to "project power extra-regionally in the next 10 years" and the success of China's A2/AD strategy closer to home, namely within the first island chain.[244]

The US is aware of China's vast reliance on the Straits, has used control over oil against a rival in the past, and knows China is fearful of its reliance on these shipping routes. In fact, the Pentagon noted that in 2019, China's total crude oil imports "met approximately 77 percent" of its total oil consumption of which in turn "77% transited the South-China Sea and the Malacca Strait" (see Figure 7).[245] One analysis showed that an "interception-style blockade" is one

239 "Territorial Disputes in the South China Sea," Global Conflict Tracker, May 4, 2022, https://cfr.org/global-conflict-tracker/conflict/territorial-disputes-south-china-sea.

240 Bill Hayton, "New Alignments Are Looming in the South China Sea," Chatham House – International Affairs Think Tank, January 12, 2022, https://www.chathamhouse.org/2022/01/new-alignments-are-looming-south-china-sea; "South China Sea."

241 "Territorial Disputes in the South China Sea."

242 Rosemary A. Kelanic, "The Petroleum Paradox: Oil, Coercive Vulnerability, and Great Power Behavior," Security Studies 25, no. 2 (April 2, 2016): 187, https://doi.org/10.1080/09636412.2016.1171966. ; China's Military Rise and the Implications for European Security, p. 76

243 Source Annual Report to Congress: Military Power of the People's Republic of China, 2020 ||China's Military Rise and the Implications for European Security, p.77.

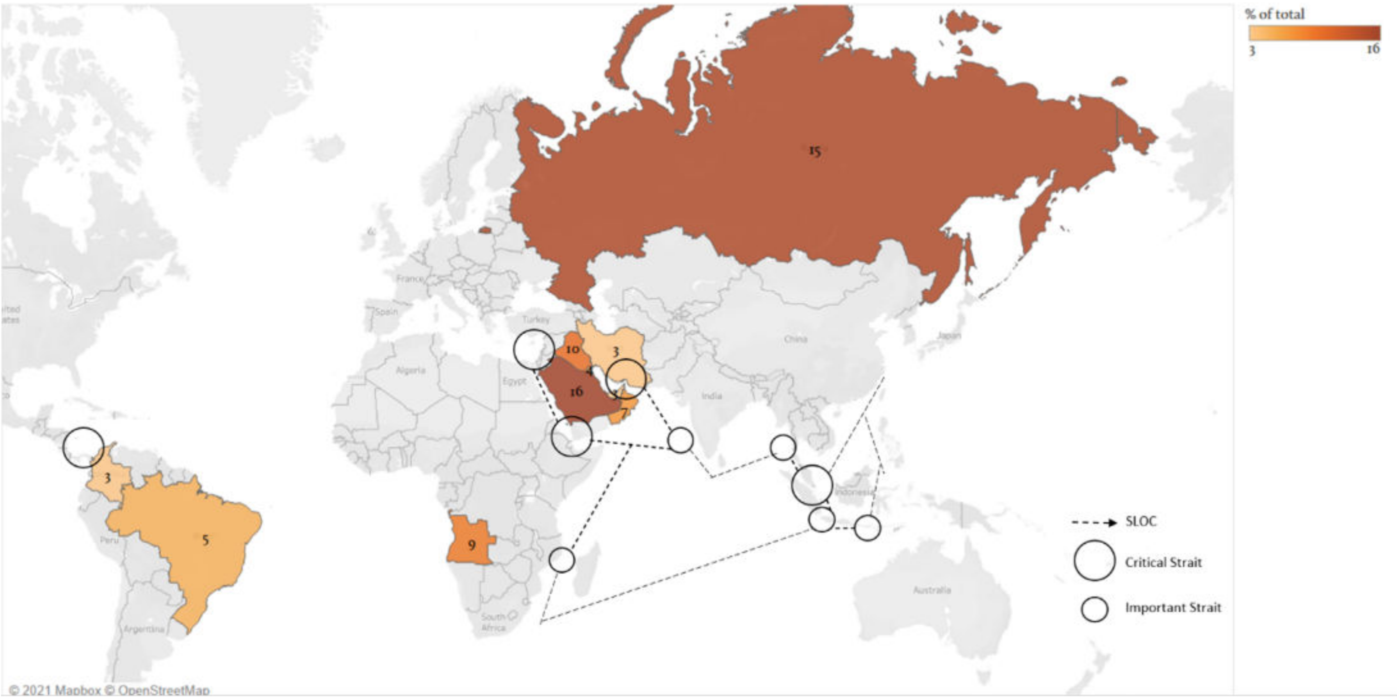
244 Joris Teer, Tim Sweijs, Paul van Hooft, Lotje Boswinkel, and Jack Thompson, "China's Military Rise and the Implications for European Security" (The Hague Centre for Strategic Studies, 2021), 38, https://hcss.nl/report/chinas-military-rise/.; Rush Doshi, The Long Game: China's Grand Strategy to Displace American Order (Oxford University Press, 2021), 68–100, 183–207.

245 Department of Defense, Military and Security Developments Involving the People's Republic of China 2020 Annual Report to Congress (Ocotillo Press, 2021), 133, https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF.

In June 2022 Russia overtook Saudi Arabia as China's top supplier of crude oil.

military tactic Washington can opt for that is least likely to lead to nuclear threats by China (or even worse: a nuclear confrontation).[246] In the past, US efforts to weaponise oil did lead to military conflict as the American oil-embargo against Imperial Japan eventually moved Tokyo to attack Pearl Harbour.[247] Beijing has long feared that its reliance on important waterways can be used against China. "The Malacca Dilemma", a phrase coined by President Hu Jintao at the closing of the CCP Economic Work Conference in November 2003, features prominently in the strategic thinking of the CCP. President Hu warned that "certain powers have all along encroached on and tried to control navigation through the strait", calling for energy diversification.[248] China has been moving towards that end, as in June 2022 Russia overtook Saudi Arabia as China's top supplier of crude oil.[249]

Figure 7. Chinese oil imports per country.
Source Annual Report to Congress: Military Power of the People's Republic of China, 2020



246 Fiona S. Cunningham, "The Maritime Rung on the Escalation Ladder: Naval Blockades in a US-China Conflict," Security Studies 29, no. 4 (August 7, 2020): 730–68, https://doi.org/1 0.1080/09636412.2020.1811462.

247 Ian Kershaw, *Fateful Choices: Ten Decisions That Changed the World, 1940-1941* (Allen Lane, 2007), 331–81.

248 Marc Lanteigne, "China's Maritime Security and the 'Malacca Dilemma,'" Asian Security 4, no. 2 (April 29, 2008): 144, https://doi.org/10.1080/14799850802006555.

249 Part of Russia's supply of oil to China is transported via pipeline. Chen Aizhu, "Russia Is China's Top Oil Supplier for 2nd Month, Saudi Volumes Tumble - Data," *Reuters*, July 20, 2022, sec. Energy, https://www.reuters.com/business/energy/russia-is-chinas-top-oil-supplier-2nd-month-saudi-volumes-tumble-data-2022-07-20/.

Threat 7: Political instability or civil war in the Democratic Republic of Congo (or along transportation routes in Southern Africa)

The DRC has been subject to continued conflict since the turn of the century. Armed conflict between the military of the DRC and various militant groups have been centered in the Kivu and Ituri regions in the eastern part of Congo. Other conflicts have lit up in the Kasai region, in central-southern Congo.[250] The existing conflicts and unstable environment have been exacerbated by continued political instability after President Joseph Kabila's 11-year term ended in 2016 and multiple health crises, such as the Ebola virus and COVID-19.[251]

The growing dominance of China in cobalt mining operations in the DRC has led to concerns in both Europe and the US.

As of 2020, Chinese (state-)owned companies came to control 15 out of the 19 cobalt mines in the DRC.[252] The growing dominance of China in cobalt mining operations in the DRC, which came to be known as the China-Cong-Cobalt nexus, has led to concerns in both Europe and the US. Tiffin Caverly, a vice president at the Export-Import Bank of the US, stated that "China has a sort of stranglehold on the supply chain".[253] The US has now been pushing for access to cobalt in other countries, such as Australia and Canada.[254] However, Chinese ownership of mines has recently come under scrutiny by the Congolese government. Officials have accused China of breaking its mining contracts, which has led to a broad review of Chinese mining activities in the country.[255]

The broader Southern African region has also proven to be an unstable and disruptive region for the supply of CRM. Cobalt mined in the DRC depends on a limited set of export routes through Southern Africa, which makes it vulnerable to disruptions. Frequent miners' strikes and work stoppages in South Africa, deadly rioting at a South African port through which cobalt is exported, power outages, and worsening environmental conditions have repeatedly affected the supply of CRM in the region, including cobalt.[256]

Political and social instability in the DRC and Southern Africa has persisted throughout the years. The region is expected to continue to be a disruptive environment for the supply of CRM to Europe and semiconductor manufacturing partners. Although cobalt mining in the southern DRC has mostly remained unaffected by the continued conflict in the eastern regions of Congo, future political and social instability, compounded by other factors such as health crises and worsening environmental conditions, could potentially disrupt the supply of CRM, in particular cobalt. Moreover, the China-Congo-Cobalt nexus poses as threat to the ability of Europe and semiconductor manufacturing partners to source cobalt from the DRC.

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250 RULAC, "DRC: A Mapping of Non-International Armed Conflicts in Kivu, Kasai and Ituri," RULAC, February 5, 2019, https://www.rulac.org/news/democratic-republic-of-the-congo-a-mapping-of-non-international-armed-confl.

251 Concern Worldwide, "Timeline: Democratic Republic of Congo's Crisis at a Glance," Concern Worldwide, February 8, 2020, https://www.concernusa.org/story/drc-crisis-timeline/.

252 Dionne Searcey et al., "A Power Struggle Over Cobalt Rattles the Clean Energy Revolution," *The New York Times*, November 20, 2021, sec. World, https://www.nytimes.com/2021/11/20/world/china-congo-cobalt.html.

253 Lipton and Searcey, "Chinese Company Removed as Operator of Cobalt Mine in Congo," February 28, 2022.

254 Searcey et al., "A Power Struggle Over Cobalt Rattles the Clean Energy Revolution," November 20, 2021.

255 New York Today, "What to Know About the Frantic Quest for Cobalt," New York Today (blog), November 20, 2021, https://thenewyorktoday.com/what-to-know-about-the-frantic-quest-for-cobalt/.

256 See, for example: Mining.com, "Palladium Market Deficit to Narrow Significantly in 2020," Mining.Com (blog), September 16, 2020, https://www.mining.com/palladium-market-deficit-to-narrow-significantly-in-2020-report/; Teboho Sebetlela, "Cobalt contagion: The effects of Covid-19 on cobalt supply chain risk," May 3, 2020, https://www.linkedin.com/pulse/effects-covid-19-cobalt-supply-chain-risk-teboho-sebetlela; Searcey et al., "A Power Struggle Over Cobalt Rattles the Clean Energy Revolution," November 20, 2021; IEA, "The Role of Critical Minerals in Clean Energy Transitions"; USGS, "Platinum-Group Elements," Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply (USGS, 2017), https://www.usgs.gov/centers/national-minerals-information-center/platinum-group-metals-statistics-and-information.

2.2.3. Geo-economic risk: Shortage due to exploding demand or inhibited supply

Demand-induced CRM shortage due to the energy transition is likely to put pressure on the supply of those CRM that also have green applications.

The assessed geopolitical and military threats that may upend the supply of CRM for semiconductors to semiconductor-producing countries and hence the supply of semiconductors and end-products to the EU are compounded by two geo-economic challenges. First, the structural problem of a looming demand-induced CRM shortage due to skyrocketing-demand (for the most part caused by the energy transition) is likely to put pressure on the supply of those CRM that also have green applications, such as cobalt, REE, and silicon. For example, cobalt is not only a key material necessary for semiconductor production but is also used in various other technological applications of the energy transition, most notably electric vehicle batteries (EVB). An increased demand for these different technologies will put an increased strain on cobalt supplies. Second, events inside China such as pandemic related lockdowns have proven to be highly disruptive for trade between China and the rest of the world. Since China is not likely to move away from Xi Jinping's "Dynamic Zero-COVID" policy anytime soon,[257] "Events inside China" is another important risk that may upend the supply of CRM for semiconductor production in Europe, Taiwan, the US, and South-Korea in the next five and ten years.

In fact, a demand-induced shortage is the only threat to the supply of CRM for semiconductors that the experts expect to "likely" materialise already before June 2027. Events inside China, such as pandemic related lockdowns, are "more likely than not" to disrupt the CRM for semiconductor supply both in the next five and the next ten years.

Threat 8: Demand-induced resource shortage due to the energy transition and increase in semiconductor manufacturing

The energy transition, in particular, but also the digital transition, defense-related manufacturing, and the 2015 "diesel emissions scandal" have led to skyrocketing demand for specific CRM that is only expected to rise further as the energy and digital transition pick up pace.[258] Price rises are a good indication of how demand has already grown. Cobalt is both required for the energy transition and for semiconductor production. Notably, price rises for CRM such as lithium, cobalt, and nickel risk inhibiting the energy transition as they work against the established trend of reduced costs for clean energy technologies, such as solar PV and batteries through innovation. Price rises for CRM partially caused a reversal of the trend, as prices rose for solar panels and wind turbines in 2021.[259] They put pressure on suppliers to semiconductor manufacturers as well.

The price of cobalt, needed for both the energy transition and the production of semiconductors and other digital technologies, has more than doubled since 2012 (see Figure 8).[260] Between January 2021 and March 2022 alone, cobalt prices rose by 156%.[261] Gallium, mostly sourced from China, has seen a 150% price rise as compared to pre-pandemic levels.[262]

257 Or formerly "Zero-COVID"-policy.

258 Kirsten Hund et al., "Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition" (International Bank for Reconstruction and Development, 2020).

259 Kim Tae-Yoon, "Critical Minerals Threaten a Decades-Long Trend of Cost Declines for Clean Energy Technologies – Analysis" (International Energy Agency, May 18, 2022), https://www.iea.org/commentaries/critical-minerals-threaten-a-decades-long-trend-of-cost-declines-for-clean-energy-technologies.

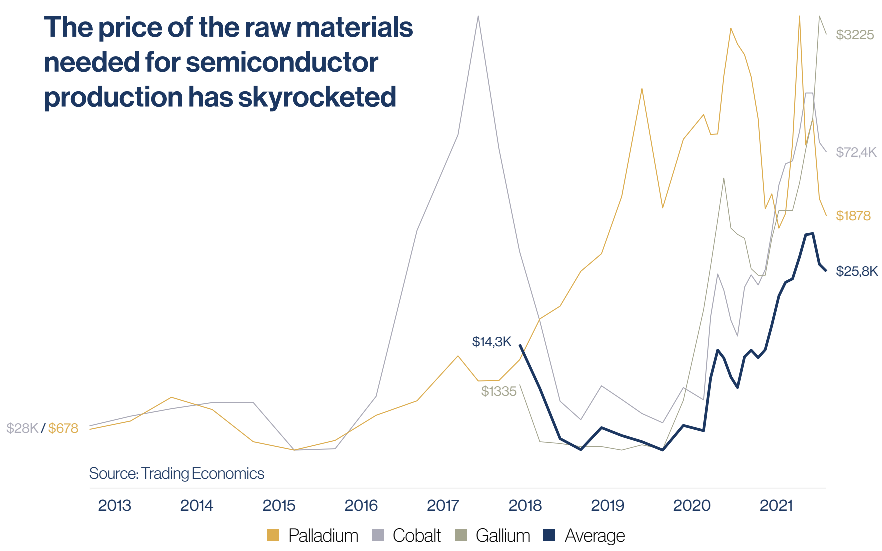
260 Trading Economics, "Cobalt," Trading Economics, 2022, https://tradingeconomics.com/commodity/cobalt.

261 Kim, "Critical Minerals,".

262 Trading Economics, "Gallium," Trading Economics, https://tradingeconomics.com/commodity/gallium.

The price of palladium, a CRM of which about 85% of total supply is used for the production of catalytic converters for light gasoline and hybrid vehicles, has more than tripled since 2012.[263] Following the 2015 diesel emissions scandal, a sharp drop in sales of diesel cars in Europe, which use platinum instead of palladium, led to structural high-demand for palladium.[264] The shift from diesel vehicles using platinum to gasoline or hybrid vehicles using palladium has aggravated the EU's dependence on Russia, as 90% of platinum is mined outside of Russia, but 40% of "global palladium primary production" takes place in Russia.[265] Compared to 2012 levels, Palladium in 2022 even briefly rose to over 400% of the price four days after Russia's invasion of Ukraine started (see Figure 8). Silicon prices have proven volatile, as electricity curbs in China led to a production cut in the second half of 2021. This led the price of the material to jump by 300% in two months, "threatening everything from car parts to computer chips."[266]

Figure 8. Sky rocketing prices as demand for CRM is growing



CRM necessary for both semiconductor production and the energy transition risk becoming increasingly scarce.

Those CRM necessary for the production of semiconductors that are also required for the energy transition, namely cobalt, REE, and silicon, risk becoming increasingly scarce. The CRM required for the production of gasoline cars, palladium, can become more readily available due to the energy transition. In essence, the energy transition is "a shift from [reliance on] fossil fuels to metals" for the world's production of energy.[267] Global demand for cobalt, REE, and silicon is expected to grow annually by respectively 4-to-6%, 5% and 2.2-to-2.6% until 2050 to keep up with the energy transition.[268] The production of EV is the main driver of energy transition metal demand, as estimates are that 50-60% of CRM required by the

263 Trading Economics, "Palladium," Trading Economics, https://tradingeconomics.com/commodity/palladium.

264 Ranjeetha Pakiam and Eddie van der Walt, "How Palladium Became a Really, Really Precious Metal," *Bloomberg*, April 23, 2021, https://www.bloomberg.com/news/articles/2021-04-23/how-palladium-became-a-really-really-precious-metal-quicktake.

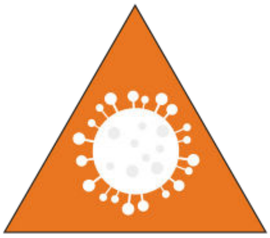
265 Nornickel, "Metals Market Review. Quintessentially PGMs."

266 Chia, Murtaugh, and Burton, "Silicon's 300% Surge Throws Another Price Shock at the World."

267 Kleijn, "Critical Materials, Green Energy and Geopolitics: A Complex Mix (White Paper)," 8.

268 KU Leuven, "Pathways to Solving Europe's Raw Materials Challenge," April 2022, 25, https://www.eurometaux.eu/metals-clean-energy/?5.

energy transition will go into EV.[269] To reach the 2030 required cobalt supply for governments to deliver on their climate pledges on electric vehicles, another 17 cobalt mines should be opened worldwide by 2030.[270] However, as gasoline and then hybrid cars in the EU are phased out from 2030 onwards, recycling can expand access for semiconductor producers to palladium as electric cars do not require this precious metal.



Threat 9: Events inside China such as pandemic-related lockdowns or work stoppages

The vast reliance on CRM mined and refined (e.g., gallium, germanium and REE) or just refined in China, (e.g., cobalt) makes semiconductor production in the EU and in partner states reliant on the whims of CCP-governance. Events inside China, such as its stringent pandemic-related lockdowns throughout cities in various provinces, have since early-2020 led to disruptions in the supply of commodities and products from China to the rest of the world. At least once, an entire container terminal in one of China's leading ports was closed in response to a singular COVID-case.[271] China's official Q2/2022 GDP was 0,4% as a result, with Shanghai's economy contracting by almost 14% after a near-total seven week lockdown of the largest port city in the world.[272] This has led prices of containerised export, for instance from Shanghai, to rise by 300% since pre-pandemic levels (see Figure 9).[273] The President of the European Chamber of Commerce in China (EUCCC) to conclude that "China is losing its credibility as the best sourcing location in the world."[274]

Events inside China such as pandemic-related lockdowns have led to disruptions in the supply of commodities and products from China to the rest of the world.

In spite of the economic pain, lockdowns will likely inhibit the export of commodities and products from China for the foreseeable future. Xi Jinping, China's top leader, maintains that his "dynamic zero-COVID" policy is "correct" and "effective" still as of June 2022.[275] His insistence may be driven by the threat of the original outbreak and cover-up by local officials in late-2019 to CCP rule over China, which is the Party's primary concern.[276] Especially the death of Li Wenliang, a doctor, who warned his colleagues about the virus but was silenced by the

[269] Another 35-45% is estimated to be required for electricity networks and solar panels. Only 5% go into remaining technologies. See KU Leuven, 9.

[270] IEA, "Global Supply Chains of EV Batteries – Analysis" (IEA, 2022), 48, https://www.iea.org/reports/global-supply-chains-of-ev-batteries. This calculation is based on the IEA's "Announced Pledges Scenario (APS)". https://www.iea.org/reports/world-energy-model/announced-pledges-scenario-aps

[271] Costas Paris and Stella Yifan Xie, "Covid-19 Closure at China's Ningbo Port Is Latest Snarl in Global Supply Chains," Wall Street Journal, August 20, 2021, sec. World, https://www.wsj.com/articles/covid-19-closure-at-chinas-ningbo-port-is-latest-snarl-in-global-supply-chains-11629451800.

[272] Kevin Yao, "China's Economy Brakes Sharply in Q2, Global Risks Darken Outlook," *Reuters*, July 15, 2022, sec. China, https://www.reuters.com/world/china/chinas-q2-gdp-growth-slows-sharply-04-yy-missing-fcast-2022-07-15/.

[273] Martin Placek, "Shanghai Containerized Freight Rate Index from January 2019 to June 2022," Statista, August 22, 2022, https://www.statista.com/statistics/1309698/monthly-china-shanghai-container-freight-rate-index/.

[274] Mark Dittli, "«China's Leadership Is Prisoner of Its Own Narrative»," The Market, April 28, 2022, https://themarket.ch/interview/chinas-leadership-is-prisoner-of-its-own-narrative-ld.6545.

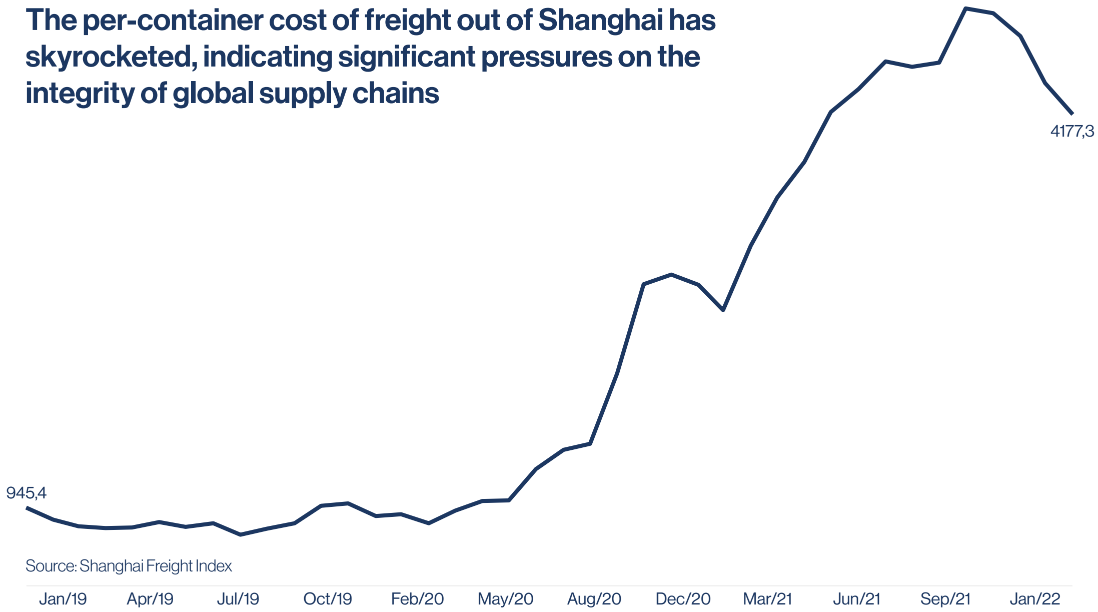
[275] Cao Desheng, "Xi: Dynamic Zero-COVID Policy Works," accessed October 3, 2022, https://www.chinadaily.com.cn/a/202206/30/WS62bcd80ea310fd2b29e6962b.html.

[276] A leading China-expert, Bill Bishop, emphasised the scale of the conundrum for Chinese leaders as he wrote that "The Party's social contract with the people—ensuring the people's wellbeing and providing ever-increasing economic prosperity—is being stressed on a nationwide level in ways I don't recall in the past several decades." Bishop added: "Last Friday I wrote that 'this is as close to an existential crisis for Xi and the Party that I think we have seen since [the Tiananmen massacre of] 1989', and I think it is even more so a week later."Bill Bishop, "Reports of the Death Dr. Li Wenliang Spark Outrage; Internet Media Crackdown," Sinocism, February 6, 2020, https://sinocism.com/p/reports-of-the-death-dr-li-wenliang.; Laurie Garrett, "How China's Incompetence Endangered the World," *Foreign Policy* (blog), accessed October 3, 2022, https://foreignpolicy.com/2020/02/15/coronavirus-xi-jinping-chinas-incompetence-endangered-the-world/.

authorities, led to an outpouring of support on Chinese social media platform Weibo.[277] Fate turned temporarily, as for the next two years hard lockdowns limited the number of infections and deaths in China whilst the rest of the world dealt with mass-infection and far higher casualties. Beijing's *wolf warrior*-diplomats touted China's superior COVID-response, pointing specifically at the chaos in the US. However, as lockdowns and COVID-restrictions were abandoned in the rest of the world in 2022, China is still forcing entire cities into lockdowns in line with the leader's Dynamic-zero COVID-policy. The Party is likely to hand Xi a groundbreaking third term during the 20th Party Congress this autumn, showing that in today's China politics and not technocracy will be leading - whatever the economic cost.

Figure 9. The cost of shipping: Containerised freight

The per-container cost of freight out of Shanghai has skyrocketed, indicating significant pressures on the integrity of global supply chains



Source: Shanghai Freight Index

2.2.4. Legal risk: Shortage due to human rights concerns

The US, the Netherlands, the EU and other G7 members are working on increasingly stringent Environmental, Social and Governance (ESG) guidelines, rules and regulations as well as on human rights-related sanctions. In the current stand-off with Russia, European sanctions against Russia (temporarily) inhibited the trade of a critical CRM for the production of semiconductors, as palladium is imported via plane from Moscow and the EU removed access to its airspace. In the upcoming decade, legal risks can disrupt the supply of CRM from states with poor governance, such as the DRC, and large-scale human rights violations, such as silicon from Xinjiang.

277 Joy Dong, "Li Wenliang, Doctor Who Warned of Covid, Is Still Mourned in China," *The New York Times*, February 7, 2022, https://www.nytimes.com/2022/02/07/world/asia/chinese-doctor-li-wenliang-covid-warning.html.

Threat 10: Increasingly stringent EU and US ESG-regulation disrupting imports from DRC-mined cobalt and China-mined Silicon

The Netherlands and the EU are working on increasingly stringent ESG-related regulation. Child labour and poor labour conditions in general have been a pressing problem in DRC cobalt mines, which deliver over 70% of cobalt supply to global markets.[278] 40 to 50% of the world's silicon metal, a material also used for the production of semiconductors, is mined in Xinjiang. On June 21, 2022, the Uygur Forced Labor Prevention Act will enter into force in the US, risking to impact the supply of silicon to global markets. The silicon from Xinjiang is, reportedly, not used in the US semiconductor supply chain as it does not meet "the extreme high levels of purity required". Instead, semiconductor grade polysilicon is sourced from the Unites States, Brazil, Malaysia, France, Germany, Norway, Australia, and South Korea and is supplied by German, American, Japanese, and Norwegian companies.[279] Xinjiang silicon is mostly used in solar panels and other products relating to the energy transition. An ESG-related boycott of Chinese silicon may lead to price hikes as well as shortages of the material used to create PV-grade or semiconductor-grade polysilicon. The interconnectedness is evidenced by the 300% price hike for silicon in the second half of 2021, as this also "threatened [...] computer chips".[280] In fact, the surveyed experts deemed the risk that "disruptive ESG-regulation by the EU and/or US" would inhibit the supply of CRM to Europe to be "more likely than not" already in the next five years.

Increasingly stringent EU and US ESG-regulation may disrupt imports from DRC-mined cobalt and China-mined Silicon.

[278] IEA, "The Role of Critical Minerals in Clean Energy Transitions," 13.

[279] The US Semiconductor Industry Association said US supply-chains are at "low risk" of sourcing silicon from China, including Xinjiang. They explained: "though the UFLPA designates polysilicon as a high-priority enforcement sector, the polysilicon produced in Xinjiang, and elsewhere in China, currently does not meet the extremely high levels of purity required for semiconductor-grade polysilicon. Thus, as far as we are aware, polysilicon produced in Xinjiang or elsewhere in China currently is not used by the semiconductor industry. Further, the global production of semiconductor-grade polysilicon is concentrated amongst five major manufacturers (Wacker Chemie (Germany), Hemlock Semiconductor (USA), Tokuyama Corporation (Japan), Mitsubishi Corporation (Japan), and REC Silicon (based in the U.S., listed in Norway)), with Wacker Chemie and Hemlock Semiconductor representing approximately three quarters of the global semiconductor polysilicon supply." "SIA Comments to DHS on UFLPA."SIA, "SIA Comments to DHS on UFLPA."

[280] Chia, Murtaugh, and Burton, "Silicon's 300% Surge Throws Another Price Shock at the World."

Chapter 3. Winning interdependence: semiconductor and CRM rivalry in a de-globalising world

Key Takeaways

- The current semiconductor and CRM equilibrium is not static: various Western governments, led by the US, have undertaken attempts to strengthen and leverage the West's collective dominance in the semiconductor value chain against Russia and China, whilst at the same time attempting to mitigate their CRM dependence.

- Bloc formation and intensifying technology competition risk upending the fragile CRM and semiconductor balance. Since 2019, the US has imposed restrictions on the export of vital American semiconductor manufacturing equipment to Chinese chip manufacturers, spurring on allies in Europe and Asia to do the same (see Infographic Sabotaging Xi). Following Russia's 2022 invasion of Ukraine, the US and its allies, including Taiwan, South Korea and Japan, have banned the exports of semiconductors to Russia altogether. This grants China and Russia, the rivals of Europe and its partners in semiconductor production (e.g., Taiwan), greater incentive to weaponise CRM dependence.

- The place of the Netherlands in this fragile balance is largely shaped by ASML, a key industry player bringing plentiful employment and economic benefits, as well as great power interest, to the Netherlands. However, ASML's EUV and DUV lithography equipment has also put the Netherlands in an awkward position with both superpowers – the US and China – placing conflicting demands on the Netherlands, and China issuing a barely veiled threat of punishment.

- Policy-making efforts in the Netherlands and the European Union to reduce risks in the CRM supply chain are well underway, but translating plans into concrete action remains a problem. These plans include reshoring of mining, refining, and processing operations, CRM cooperation with third-parties such as Japan, Canada, Australia, and the US but also non-rival autocracies, recycling, reducing demand, deep-sea mining, and stockpiling.

- These initiatives either come with challenges, such as NIMBY protests, environmental concerns, technological and economic limitations, limited alternative sourcing countries, or only provide short-term solutions. If only current initiatives are executed, the EU's economic security is likely to be strongly, negatively affected by the disruptions in the supply of CRM that are likely to take place in the next ten years. Both the production of semiconductors and other means necessary to complete the transition to green energy will be affected, if these disruptions occur.

> "We have made it very clear to the Dutch: We believe that this kind of sensitive technology does not belong in 'certain places'"
>
> US Ambassador Pete Hoekstra 17 January 2020; on the export of ASML's EUV lithography system to China[281]

> "This is yet another example of the US practice of "coercive diplomacy" by abusing state power and wielding technological hegemony. It is also classic *technological terrorism*."
>
> PRC Foreign Ministry Spokesperson Zhao Lijian June/July 2022, in response to reported US government pressure on the Netherlands and Japan to block exports of ASML and Nikon DUV equipment to China.[282]

The US, in coordination with other countries, has already leveraged the semiconductor supply chain against rival states, namely China and Russia.

The current semiconductor and CRM equilibrium is not static : various Western governments, led by the US, have undertaken attempts to strengthen and leverage the West's collective dominance in the semiconductor value chain against Russia and China, whilst at the same time attempting to mitigate their CRM dependence. Meanwhile, China has invested unprecedented sums of money to indigenise parts of the semiconductor value chain.

In order to formulate policy, a thorough understanding of ongoing policy initiatives – both by partners and rivals – to achieve greater control over the semiconductor and CRM ecosystem is essential. At the same time, this chapter looks at the ongoing policy initiatives in the Netherlands as well as in the EU and other friendly states to mitigate risks related to CRM dependence on China, Russia and the DRC.

3.1. Semiconductor dominance of technologically advanced democracies

The US government, amongst others, has already taken various steps to hinder the supply of semiconductor manufacturing equipment and end-products to China and Russia, which include spurring on the Dutch government to withhold an export license for ASML EUV lithography machines to China, as well as setting up a coordinated, comprehensive ban with the EU, Japan, South-Korea, and Taiwan on semiconductor exports to Russia following its invasion of Ukraine.

281 Sandra Olsthoorn and Johan Leupen, "'ASML-Technologie Hoort Niet Thuis Op Bepaalde Plaatsen,'" FD.nl, January 17, 2020, https://fd.nl/economie-politiek/1331153/asml-technologie-hoort-niet-thuis-op-bepaal-de-plaatsen-org2caw9zGbx.

282 "Foreign Ministry Spokesperson Zhao Lijian's Regular Press Conference on July 6, 2022," Ministry of Foreign Affairs of the People's Republic of China, July 6, 2022, https://www.fmprc.gov.cn/mfa_eng/xwfw_665399/s2510_665401/2511_665403/202207/t20220706_10716417.html.

3.1.1. Leveraging semiconductor dominance

ASML and Sino-American great power rivalry

The US, in coordination with other countries, has already leveraged the semiconductor supply chain against rival states, namely China and Russia. The Chinese government, on the other hand, has set forth ambitious plans to reduce their dependence on foreign countries for their high-end chip supply by radically increasing the domestic production of high-end semiconductors.[283] However, the US has repeatedly tried to hinder this process by denying China access to various essential components and equipment needed for semiconductor manufacturing. In 2020, the US placed SMIC, China's leading chip manufacturer and crucial to China's technology ambitions, on an export blacklist. Consequently, any US company wishing to sell products to SMIC, including key semiconductor manufacturing software, must apply for a special license issued by the US government.[284] In the same year, the US required foreign chip manufacturers that use US chipmaking equipment (e.g., TSMC) to apply for a license from the US Department of Commerce before selling their products to Huawei, essentially cutting off China's biggest smartphone producer from advanced chips produced by TSMC.[285]

The US has also spurred on its allies to deny China essential semiconductor manufacturing equipment, including the indispensable EUV lithography machines produced by Dutch company ASML. The export of this essential piece of equipment for the production of the newest semiconductors was blocked as of late 2019 (see Infographic Sabotaging Xi) partially because it fell under the Wassenaar Agreement.[286] In March of 2022, US lawmakers requested the US Department of Commerce to tighten export controls of technology needed in the Chinese chip industry, specifically mentioning semiconductor manufacturing equipment. This expansion of restrictions would require coordination with US allies, in particular the Netherlands and Japan, whose companies ASML and Tokyo Electron hold key chokepoints in the semiconductor equipment industry.[287] Textbox 1 provides an in-depth analysis of the process leading up to the Dutch government deciding to withhold an export license for ASML's EUV system to China, while Infographic Sabotaging Xi presents a heavy sample of US-led efforts to halt the export of semiconductor manufacturing equipment to China.

283 See, for example: Justin Feng, "The Costs of U.S.-China Semiconductor Decoupling," CSIS, May 25, 2022, https://www.csis.org/blogs/new-perspectives-asia/costs-us-china-semiconductor-decoupling; Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context"; Jan-Peter Kleinhans and John Lee, "China's Rise in Semiconductors and Europe" (SNV & *MERICS*, 2021); Jenny Leonard, Ian King, and Debby Wu, "China's Chipmaking Power Grows Despite US Effort to Counter It," *Bloomberg*, June 13, 2022, https://www.bloomberg.com/news/articles/2022-06-13/china-s-growing-clout-in-global-chip-market-rings-alarm-bells-in-washington; "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's," Semiconductor Industry Association, January 10, 2022, https://www.semiconductors.org/chinas-share-of-global-chip-sales-now-surpasses-taiwan-closing-in-on-europe-and-japan/.

284 "America Has a Plan to Throttle Chinese Chipmakers," The Economist, April 25, 2022, https://www.economist.com/business/america-has-a-plan-to-throttle-chinese-chipmakers/21808959.

285 Arjun Kharpal, "U.S. Sanctions on Chipmaker SMIC Hit at the Very Heart of China's Tech Ambitions," CNBC, September 28, 2020, https://www.cnbc.com/2020/09/28/us-sanctions-against-chipmaker-smic-hit-china-tech-ambitions.html.

286 "We have made it very clear to the Dutch: We believe that this kind of sensitive technology does not belong in 'certain places'" US Ambassador Pete Hoekstra 17 January 2020; on the export of ASML's EUV lithography system to China https://fd.nl/economie-politiek/1331153/asml-technologie-hoort-niet-thuis-op-bepaal-de-plaatsen-org2caw9zGbx

287 "America Has a Plan to Throttle Chinese Chipmakers," The Economist, April 25, 2022, https://www.economist.com/business/america-has-a-plan-to-throttle-chinese-chipmakers/21808959.

Textbox 1. Blocking the export of ASML EUV lithography to China

Blocking the export of ASML EUV lithography to China

Starting in 2018, the Trump administration spurred on the Dutch government to withhold ASML to sell their EUV technology to Chinese costumers. Although no specific export license for EUV technology had been issued at the time, the Dutch government had granted a general export license to ASML, allowing it to export its products to China. Officials from the US Department of Defense met with Dutch officials to stress the security risks attached to the sale. Former US secretary of state Mike Pompeo reportedly even directly asked Dutch Prime Minister Mark Rutte to block the sale of ASML's advanced technology to China. In the Summer of 2019 ASML's export license expired unused and has not been renewed to date.[288] The Biden administration has continued to ask the Dutch government to restrict sales to China because of national security concerns.[289] In its Annual Report, ASML also acknowledges the political pressures the company faces, in particular from the US, stating that "the US government has enacted trade measures, including import tariffs, national security regulations and restrictions on conducting business with certain Chinese entities, restricting our ability to provide certain products and services to such entities without a license."[290] The US is now reportedly pressuring the Dutch government to also restrict the sales of ASML's older DUV lithography technology to China. Estimates are that already 700 to 800 DUV systems are in China. However, they necessitate ongoing ASML support for maintenance.[291] The Dutch government has, however, not yet complied to this request.[292] Henne Schuwer, Former Dutch Ambassador to the US and in office during the negotiations on the EUV-export license, stated that, as far as he knows, the Netherlands nor ASML received anything in return for withholding an export license for ASML to export its EUV lithography system to China.[293]

Under current regulations, the Dutch government stated that it has "sovereign discretion to grant licenses of dual-use technology", including lithography equipment.[294] The US can require a foreign company to need a US license to sell their products to China if US-made components consist of more than 25% of the total value. However, ASML's advanced EUV equipment, although certain key components are produced in the US, does not meet this threshold. The US Department of Commerce is now considering lowering this 25% threshold for certain products.[295] Moreover, the deputy national security advisor under Trump noted

288 Noah Barkin, "Export Controls and the US-China Tech War: Policy Challenges for Europe," *MERICS*, 2020; Alper, Toby Sterling, and Stephen Nellis, "Trump Administration Pressed Dutch Hard to Cancel China Chip-Equipment Sale: Sources," *Reuters*, January 6, 2020, sec. Technology News, https://www.reuters.com/article/us-asml-holding-usa-china-insight-idUSKBN1Z50HN.

289 Stu Woo and Yang Jie, "China Wants a Chip Machine From the Dutch. The U.S. Said No.," *The Wall Street Journal*, July 17, 2021, https://www.wsj.com/articles/china-wants-a-chip-machine-from-the-dutch-the-u-s-said-no-11626514513; *Reuters*, "ASML Still Has No Licence to Ship Newest Machines to China - CEO," *Reuters*, January 19, 2022, sec. Technology, https://www.reuters.com/technology/asml-still-has-no-licence-ship-newest-machines-china-ceo-2022-01-19/.

290 ASML, "ASML 2021 Annual Report" (ASML, 2022), 117, https://www.asml.com/en/investors/annual-report/2021.

291 NRC, "Waar blijft het door de VS zo gewilde techfront tegen China?," NRC, 2022, https://www.nrc.nl/nieuws/2022/09/02/waar-blijft-het-door-de-vs-zo-gewilde-techfront-tegen-china-a4140624.

292 Jillian Deutsch et al., "US Wants Dutch Supplier to Stop Selling Chipmaking Gear to China," *Bloomberg*, July 5, 2022, https://www.bloomberg.com/news/articles/2022-07-05/us-pushing-for-asml-to-stop-selling-key-chipmaking-gear-to-china.

293 Interview by the authors with Hendrik Jan Jurriaan Schuwer, former Dutch ambassador to the US (2015-2019), conducted on 12 May 2022.

294 Alper, Toby Sterling, and Stephen Nellis, "Trump Administration Pressed Dutch Hard to Cancel China Chip-Equipment Sale."

295 Ibid.

that the US government does have the authority to restrict the export of key US-made components needed for the production of ASML's EUV lithography machines.[296] This, consequently, puts both ASML and the Dutch government in a difficult position.

ASML's lithography equipment, a chokepoint in the semiconductor supply chain, has become an important piece in the great power rivalry between the US and China. Withholding the export license for ASML came with considerable risks for Sino-Dutch relations. Former Chinese ambassador to the Netherlands Xu Hong stated in an interview with the Dutch Financial Times that the Netherlands could face problems with China and damage trade relations if it continued to prevent exports of advanced semiconductor equipment to China.[297] Moreover, Chinese Foreign Ministry spokesman Zhao Lijian accused the US of "*technological terrorism*", as Washington reportedly attempts to expand export restrictions to also include ASML and Nikon's DUV equipment to China.[298] ASML CEO, Peter Wennink, has also been critical of export controls, stating that: "as part of a broader national strategy on semiconductor leadership, governments need to think through how these tools, if overused, could slow down innovation in the medium term by reducing R&D".[299] ASML is a key industry player, bringing plentiful employment and economic benefits, as well as great power interest to the Netherlands. At first sight, one would expect the company's presence in Veldhoven to give the Dutch government a geopolitical tool to wield against its rivals. However, ASML's EUV and DUV lithography equipment has also put the Netherlands in an awkward position in the middle of US and Chinese great power competition.

296 Stu Woo and Yang Jie, "China Wants a Chip Machine From the Dutch. The U.S. Said No."

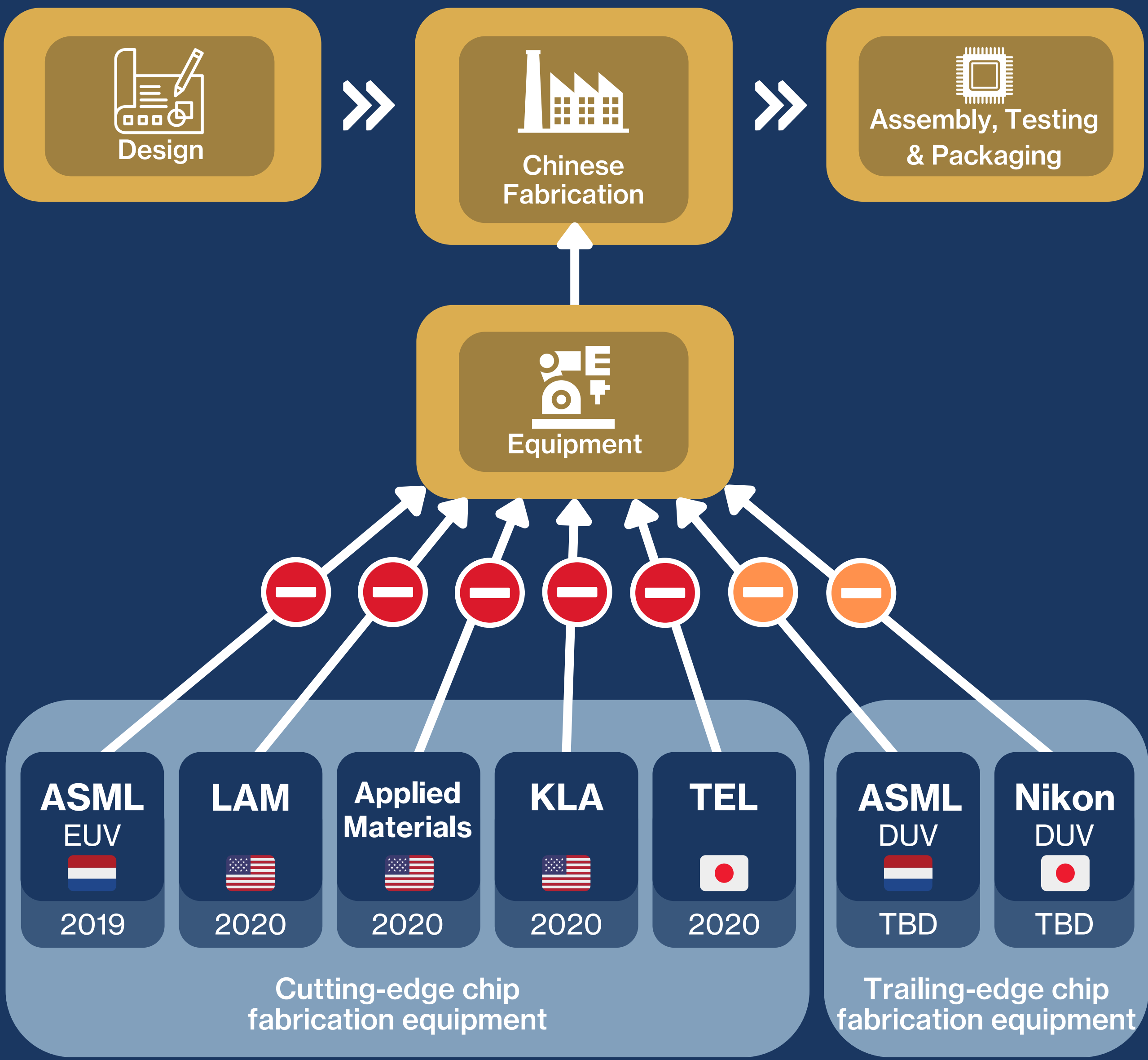
297 Johan Leupen and Sandra Olsthoorn, "'We zouden niet willen dat Nederland zwicht onder de druk van de VS,'" FD.nl, January 15, 2020, https://fd.nl/economie-politiek/1330711/we-zouden-niet-willen-dat-nederland-zwicht-onder-de-politieke-druk-van-de-amerikanen.

298 *Bloomberg*, "China Accuses US of 'Technological Terrorism' as Chip Curbs Grow," *Bloomberg*, July 6, 2022, https://www.bloomberg.com/news/articles/2022-07-06/china-calls-us-pressure-on-chipmakers-technological-terrorism.

299 Stu Woo and Yang Jie, "China Wants a Chip Machine From the Dutch. The U.S. Said No."

Sabotaging Xi's indigenization efforts

The United States imposes more and more restrictions on the export of vital American semiconductor manufacturing equipment to Chinese chip manufacturers, spurring on allies in Europe and Asia to do the same.



Legend

(red sign)	Export blocked	**ASML**	Advanced Semiconductors Materials Lithography
(orange sign)	Ongoing US diplomatic campaign to block export	**LAM**	Lam Research Corporation
EUV	Extreme ultraviolet lithography system	**KLA**	KLA Corporation
DUV	Deep ultraviolet litography system	**TEL**	Tokyo Electron Limited
Applied Materials	Applied Materials, Inc.	**Nikon**	Nikon Corporation

Hamstringing Russia's ability to fight in Ukraine: A full-semiconductor boycott

China has not been the only target of the West in leveraging semiconductor dominance. Following the eruption of the Russia-Ukraine War in 2022, the US imposed an export embargo prohibiting the sale of any chip developed with American technology to Russia. President Biden noted that the move was meant to "impair their ability to compete in a high-tech 21st century economy".[300] Other countries have joined the American effort, including the EU, Japan, South Korea, Taiwan, and Australia.[301] The export controls of semiconductors to Russia are reportedly hampering the country's long-term military industry capacity, since high-end chips are vital in today's most advanced weapon systems.[302] Although Russia can still import lower-end semiconductors from China, it is high-end chips that are key to the development of emerging technologies, produced by TSMC (Taiwan) and Samsung (South Korea). TSMC and Samsung chips specifically include applications that are expected to revolutionise warfare. Both TSMC and Samsung have complied with the American export embargo and halted the sale of all their products to Russia.[303] At the same time, Russia's access to more mature chips, such as the automotive chips produced by NXP (The Netherlands), that were found in Russian weapon systems has been inhibited by the EU joining into the sanction effort.

Following the eruption of the Russia-Ukraine War in 2022, the US imposed an export embargo prohibiting the sale of any chip developed with American technology to Russia.

Conclusion

Technologically advanced democracies, led by the US, have already leveraged their high-end semiconductor dominance against rival states, namely China and Russia. The goal of this tool, against Russia, was to "impair their ability to compete in a high-tech 21st century economy".[304] The Netherlands, home to lithography company ASML, holds a crucial position in this concerted Western effort to leverage semiconductor dominance. Although the Dutch chokepoint in the semiconductor supply chain draws great economic and trade benefits, as well as geopolitical attention from large states, the Netherlands should beware that it does not singularly bare the cost of opposite demands by the US and China.

3.1.2. Expanding the EU's semiconductor ecosystem

Various countries, including the EU, US, Japan, South Korea, India, and China, are proposing legislation to increase their foothold in the semiconductor supply chain given the strategic

300 "Remarks by President Biden on Russia's Unprovoked and Unjustified Attack on Ukraine," The White House, February 24, 2022, https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/02/24/remarks-by-president-biden-on-russias-unprovoked-and-unjustified-attack-on-ukraine/.

301 Ana Swanson, "Chinese Companies That Aid Russia Could Face U.S. Repercussions, Commerce Secretary Warns.," *The New York Times*, March 8, 2022, sec. Technology, https://www.nytimes.com/2022/03/08/technology/chinese-companies-russia-semiconductors.html.

302 Ana Swanson, John Ismay, and Edward Wong, "U.S. Technology, a Longtime Tool for Russia, Becomes a Vulnerability," *The New York Times*, June 2, 2022, sec. Business, https://www.nytimes.com/2022/06/02/business/economy/russia-weapons-american-technology.html.; Other research shows that some of Russia's most modern weapon system relies on Western micro-electronics, including chips from the Dutch semiconductor manufacturing company NXP. https://rusi.org/explore-our-research/publications/special-resources/silicon-lifeline-western-electronics-heart-russias-war-machine Swanson, Ismay, and Wong, "U.S. Technology, a Longtime Tool for Russia, Becomes a Vulnerability." ; Other research shows that some of Russia's most modern weapon system relies on Western micro-electronics, including chips from the Dutch semiconductor manufacturing company NXP. James Byrne et al., "Silicon Lifeline: Western Electronics at the Heart of Russia's War Machine," 2022.https://rusi.org/explore-our-research/publications/special-resources/silicon-lifeline-western-electronics-heart-russias-war-machine

303 Yang Jie and Jiyoung Sohn, "Chip Sanctions Challenge Russia's Tech Ambitions," *The Wall Street Journal*, March 19, 2022, sec. Tech, https://www.wsj.com/articles/chip-sanctions-challenge-russias-tech-ambitions-11647682202.

304 "Remarks by President Biden on Russia's Unprovoked and Unjustified Attack on Ukraine."

importance of the industry. Whilst the US is trying to rally different allied countries to bolster semiconductor dominance[305], the EU wants to radically increase its share of semiconductor manufacturing, growing from a marginal player to producing over 20% of the world's chips by 2030.[306] Meanwhile, China, noting that the West can use the semiconductor supply chain as a geostrategic tool, is trying to bolster the Chinese semiconductor sector to reduce dependence on the West.[307] Table 9 provides an overview of EU policy initiatives and cooperation agreements to increase resilience in the semiconductor supply chain.

Various countries are attempting to increase their foothold in the semiconductor supply chain.

The EU is acutely aware it needs to reinforce its semiconductor ecosystem and reduce dependencies in its supply chain. In February 2022, the EU Commission proposed the European Chips Act, which has the objective to achieve at least 20% of the world's production of cutting-edge semiconductors by 2030. This would strengthen the EU's resilience in the semiconductor supply chain. To this end, it is looking to provide a policy-driven investment in excess of 43 billion euros by 2030 to strengthen and expand the semiconductor industry in the Union.[308] Dutch lithography company ASML published a position paper on the EU Chips Act welcoming the proposal by the European Commission and stating that "if no action is taken, the European semiconductor manufacturing capacity will fall below 4%, making it virtually irrelevant on a global scale and creating a structural threat of insufficient chip supplies to European industries".[309]

Table 9. Heavy sample of EU and partner initiatives to increase semiconductor supply chain leverage

EU initiatives	Cooperation initiatives including the EU	Partner country cooperation initiatives excluding the EU
European Chips Act	EU-US Trade and Technology Council	US-Taiwan Cooperation on Semiconductors
Important Project of Common European Interest (IPCEI)	EU-India Trade and Technology Council	US-ROK Supply Chain Task Force
EU's New Industrial Strategy	EU-Taiwan Trade and Investment Dialogue	The Quad Semiconductor Supply Chain Initiative
2030 Digital Compass		
Joint Declaration on Strategic Investment in Semiconductor Industry		
The Observatory for critical technologies		

Other countries, including the US, Japan, and Korea, have proposed or passed similar acts to bolster their own domestic semiconductor industry.[310] Aside from the European Chips Act, the EU has issued various other legislation in support of the Union's semiconductor

305 'Fact Sheet: Quad Leaders' Summit', The White House, 25 September 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/24/fact-sheet-quad-leaders-summit/; Kleinhans and Lee, 'China's Rise in Semiconductors and Europe', p. 21.

306 "A Chips Act for Europe" (Brussels: European Commission, February 8, 2022).

307 Justin Feng, "The Costs of U.S.-China Semiconductor Decoupling"; Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context," June 2021; Jenny Leonard, Ian King, and Debby Wu, "China's Chipmaking Power Grows Despite US Effort to Counter It"; "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's."

308 European Commission, "A Chips Act for Europe."

309 'ASML Position Paper on EU Chips Act' (ASML, February 2022), p. 2.

310 Gregory Arcuri, "The CHIPS for America Act"; Furukawa and Takashi Mochizuki, "Japan Approves $6.8 Billion Boost for Domestic Chip Industry"; Ji-hyoung, "[Korea Chips Act] Korea Sets out Own Chips Act, in Less Ambitious Fashion."

The EU has also reached out to allies and partners in semiconductor manufacturing to increase its resiliency in the semiconductor supply chain.

industry. These include the Important Project of Common European Interest (IPCEI)[311], which supports the funding for semiconductor fabs and expertise across member states, and a joint declaration by 22 member states in December 2020 announcing strategic investments in the European semiconductor industry.[312] The EU's New Industrial Strategy and 2030 Digital Compass also highlight semiconductors as a key area of focus.[313] Last, in 2022 the EU set up the Observatory for critical technologies, which is meant to "identify, monitor and assess critical technologies for the space, defence and related civil sectors, their potential application and related value and supply chains", including semiconductors.[314]

The EU has also reached out to allies and partners in semiconductor manufacturing to increase its resiliency in the semiconductor supply chain. At the G7-Plus summit in June 2021, European and US policymakers discussed semiconductor manufacturing along with South Korea and Japan, two key partners in the semiconductor supply chain. After the summit, the White House stated that the participants "will consider mechanisms and share best practices to address risks to the resilience of the critical global supply chains, in areas such as critical minerals and semiconductors".[315] This was soon followed by the establishment of an EU-US Trade and Technology Council (EU-US TTC), which serves to build "a partnership on the rebalancing of global supply chains in semiconductors with a view to enhancing respective security of supply as well as their respective capacity to design and produce semiconductors".[316] Besides Trans-Atlantic cooperation, the EU has launched a similar Trade and Technology Council with India in the Spring of 2022 following Russia's invasion of Ukraine. New Delhi plans to invest over 30 billion USD in its tech sector and chip supply chain.[317] Moreover, the EU is in talks with Taiwan to support Brussels' ambitious goal to produce over one-fifth of global chips in the Union by 2030.[318] At their annual Trade and Investment Dialogue, Taiwan and the EU discussed cooperation in the semiconductor industry, including developing semiconductor talent, manufacturing, and research.[319]

Other cooperation initiatives, which the EU is not a participant in, also have the potential to significantly increase the dominance of the EU and partner countries in the semiconductor supply chain. The US is attempting to boost its domestic semiconductor manufacturing industry through strategic decoupling, reshoring, and ringfencing, thus getting various

311 German Federal Ministry for Economic Affairs and Energy, "Important Project of Common European Interest (IPCEI Microelectronics)," VDI/VDE Innovation + Technik GmbH: Projektträger und Dienstleister für Innovationen, accessed June 30, 2022, https://vdivde-it.de/en/node/2283.

312 "Member States Join Forces for a European Initiative on Processors and Semiconductor Technologies," European Commission, December 7, 2020, https://digital-strategy.ec.europa.eu/en/news/member-states-join-forces-european-initiative-processors-and-semiconductor-technologies.

313 'New Industrial Strategy', European Commission, 2020, https://ec.europa.eu/growth/industry/strategy_en; 'Europe's Digital Decade: Digital Targets for 2030', European Commission, 2021, https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en.

314 "Roadmap on Critical Technologies for Security and Defence" (European Commission, February 15, 2022).

315 The White House, "Carbis Bay G7 Summit Communique," The White House, June 13, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/06/13/carbis-bay-g7-summit-communique/.

316 European Commission, "EU-US Trade and Technology Council Inaugural Joint Statement," Text, European Commission, September 29, 2021, https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_21_4951.

317 European Commission, "EU-India: Joint Press Release on Launching the TTC," Text, European Commission, April 25, 2022, https://ec.europa.eu/commission/presscorner/detail/en/IP_22_2643; Cheng Ting-Fang and Lauly Li, "India to Pump $30bn into Tech Sector and Chip Supply Chain," *Nikkei Asia*, June 16, 2022, https://asia.nikkei.com/Spotlight/Supply-Chain/India-to-pump-30bn-into-tech-sector-and-chip-supply-chain.

318 Finbarr Bermingham, "Upgraded Trade Talks with EU on Chips Signal Advance in Taiwan's Standing," South China Morning Post, June 3, 2022, https://www.scmp.com/news/china/diplomacy/article/3180248/upgraded-trade-talks-eu-semiconductors-signal-advance-taiwans.

319 Zsuzsa Anna Ferenczy, "EU-Taiwan Ties: Towards Resilient Global Value Chains," *Chinaobservers* (blog), June 14, 2022, https://chinaobservers.eu/eu-taiwan-ties-towards-resilient-global-value-chains/.

companies to build production facilities in the US.[320] President Biden signed The Chips and Science Act into law in August 2022, allocating 53 billion USD in federal funds to bolster chip manufacturing in the US.[321] In 2021 TSMC, the world's leading cutting-edge chip manufacturer, started the construction of a fab in Arizona worth over 12 billion USD. In addition, Taiwan's GlobalWafers, a leading manufacturer of silicon wafers, will spend 5 billion USD to build a manufacturing plant in Texas in 2022.[322] The US has also sought cooperation with other key partners in the semiconductor industry by engaging in techno-diplomacy and tech-alliances.[323] Currently, the US and South Korea are exploring the creation of a US-ROK Supply Chain Task Force to increase cooperation throughout the entire semiconductor value chain.[324] The Quadrilateral Security Dialogue, a cooperation pact that includes the US, Australia, India, and Japan, has launched a Semiconductor Supply Chain Initiative "to map capacity, identify vulnerabilities, and bolster supply-chain security for semiconductors and their vital components".[325]

China has bolstered its semiconductor sector to reduce dependence on the West throughout the past decade.

China, having experienced that the US and its allies can use American and non-American companies in the semiconductor supply chain as a geostrategic tool against it, has bolstered the Chinese semiconductor sector to reduce dependence on the West throughout the past decade. In a 2009 project initiative, China stated it should break its dependence on imports across the entire semiconductor value chain through heavy investments in R&D.[326] This was followed by a National Integrated Circuit Industry Development Outline in 2014, which set targets for each step in the semiconductor supply chain and incentivised companies to enhance the Chinese semiconductor sector through tax reliefs and investment funds.[327] A specific roadmap for the Chinese semiconductor industry was also included in the Made in China 2025 initiative.[328] Chinese initiatives also include the investment in and buyout of Western companies active in the semiconductor industry.[329] Despite efforts by the US and partners to hinder the development of Chinese semiconductor manufacturing industry, the sector – including the manufacturing of mature and increasingly advanced nodes – seems

320 Alex Capri, 'Techno-Nationalism via Semiconductors': (Hinrich Foundation, June 2021), p. 5.

321 U.S. Senate Committee on Commerce, Science, & Transportation, "The CHIPS and Science Act of 2022," U.S. Senate Committee on Commerce, Science, & Transportation, July 29, 2022, https://www.commerce.senate.gov/2022/8/view-the-chips-legislation.

322 *Reuters*, "Taiwan's GlobalWafers to Invest $5 Bln in New Silicon Wafer Plant in Texas," *Reuters*, June 28, 2022, sec. Technology, https://www.reuters.com/technology/taiwans-globalwafers-invest-5-bln-new-silicon-wafer-plant-texas-2022-06-28/.

323 Capri, 'Techno-Nationalism via Semiconductors', p.5:

324 The White House, "Fact Sheet United States – Republic of Korea Partnership," The White House, May 22, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/05/21/fact-sheet-united-states-republic-of-korea-partnership/.

325 "Quad Leaders' Summit - Fact Sheet," The White House, September 25, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/24/fact-sheet-quad-leaders-summit/.

326 Government of the People's Republic of China, "第六次"极大规模集成电路制造装备"专项会议召开," Government of the People's Republic of China, February 21, 2010, http://www.gov.cn/gzdt/////////2010-02/21/content_1537742.htm; Lee and Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context," June 2021.

327 PKU Law, "国家集成电路产业发展推进纲要: Outline for Advancing the National Integrated Circuit Industry," PKU Law, June 2014, http://www.pkulaw.cn/fulltext_form.aspx?Db=chl&Gid=7f55f84f48a2c3a1bdfb&isFromV6=1.

328 Max J. Zenglein and Anna Holzmann, "Evolving Made in China 2025: China's Industrial Policy in the Quest for Global Tech Leadership," *MERICS* Papers on China (*MERICS*, July 2019).

329 See, for example: Gordon Corera, "China: Buyout of UK's Largest Microchip Plant Raises Concerns," *BBC News*, July 4, 2022, sec. World, https://www.bbc.com/news/world-62014792; Shunsuke Tabeta, "China Takes Wider Aim at Foreign Tech with National Standards Plan," *Nikkei Asia*, July 6, 2022, https://asia.nikkei.com/Business/Technology/China-takes-wider-aim-at-foreign-tech-with-national-standards-plan; Brenda Goh and Sarah Wu, "Germany's Merck to Open Semiconductor Base in China," *Reuters*, May 31, 2022, sec. Technology, https://www.reuters.com/technology/merck-says-it-plans-open-semiconductor-base-china-2022-05-31/.

to be continuously expanding in China.[330] Recent reporting suggests China's top chipmaker, SMIC, may have already started producing advanced 7nm chips.[331]

Conclusion

Competing countries and entities, including the EU, heavily invest in the semiconductor industry to boost resilience and reduce dependencies. Various Western allies, from the Americas to Europe and Asia, are cooperating to expand and secure their dominance over the semiconductor supply chain. Europe is part of many such initiatives and could join other allies and partners in semiconductor manufacturing to increase its foothold in the entire semiconductor value chain. China, on the other hand, being aware of its dependence on the West for the supply of its cutting-edge chips, is attempting to bolster its homegrown chip industry in the face of repeated attempts by the US and allies to obstruct China's ambitions. Fears in Beijing over its dependence have likely been strongly aggravated by the consorted US, EU, South Korea, Japan, and Taiwan comprehensive embargo of the export of semiconductors to Russia, over its war in Ukraine.

The EU and various allies have attempted to mitigate risks and reduce their dependence on CRM from the autocratic and developing world.

3.2. Mitigating dependencies in the CRM supply chain

As the previous chapters have indicated, the mining, refining and processing of the CRM necessary for the production of semiconductors is dominated by rival states, some of which are unstable, and plagued by various threats. The EU and various allies, such as the US, Canada, and Japan, have put forth various policy initiatives to mitigate these risks and reduce their dependence on CRM from rival and non-rival autocracies, running into challenges whilst doing so (see Table 10).

3.2.1. European efforts to mitigate the risks in the CRM supply chain

In recent years, the EU has acknowledged the strategic importance of CRM and sought to increase resilience of their CRM supply and reshore CRM mining inside the Union. The new EU Industrial Strategy, the EU Strategic Compass, and European Green Deal acknowledge that access to CRM is paramount to European security and defence, as well as making the green and digital transformations a success.[332] Consequently, the European Commission announced an Action Plan on Critical Raw Materials to (1) "develop resilient value chains for EU industrial ecosystems", (2) "reduce dependency on primary critical raw materials through circular use of re-sources, sustainable products and innovation", (3) "strengthen domestic sourcing of raw materials in the EU", and (4) "diversify sourcing from third countries and remove distortions to international trade".[333] To this end, the EU set forth various concrete actions to achieve these objectives, including establishing a European Raw Materials Alliance (ERMA), setting up a Raw Materials Information System (RMIS), identifying mining and

330 Jenny Leonard, Ian King, and Debby Wu, "China's Chipmaking Power Grows despite U.S. Effort to Counter It," The Japan Times, June 14, 2022, https://www.japantimes.co.jp/news/2022/06/14/business/tech/china-chip-making-grows-us/.

331 Debby Wu and Jenny Leonard, "China's Top Chipmaker SMIC Achieves Breakthrough Despite US Sanctions," *Bloomberg*, July 21, 2022, https://www.bloomberg.com/news/articles/2022-07-21/china-s-top-chipmaker-makes-big-tech-advances-despite-us-curbs#xj4y7vzkg.

332 "Commission Announces Actions on Critical Raw Materials," Text, European Commission, September 3, 2020, https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1542.

333 Ibid.

processing projects in the EU that can be operational by 2025, and mapping the potential of secondary CRM from existing EU stocks and wastes (i.e., recycling).[334] These initiatives have become all the more important when the EU issued the Declaration of Versailles in the wake of the 2022 Russia-Ukraine war in which it states that Europe should reduce strategic dependencies in sensitive areas, including CRM and semiconductors.[335]

Table 10. Initiatives to reduce the risks and dependencies in the CRM supply chain and their challenges

Current Initiative	Challenges
Reshoring of mining operations to Europe: *European Raw Material Alliance*	(1) NIMBY movements (e.g., from general population or indigenous communities) (2) Environmental concerns (3) Lack of refining and processing operations (4) Lack of capital (5) Lack of skilled workers (6) Dependence on foreign (e.g., Chinese) equipment and expertise
Reshoring of refining and processing operations to Europe	(1) NIMBY movements (e.g., from general population or indigenous communities) (2) Environmental concerns (3) Dependence on foreign (e.g., Chinese) equipment and expertise (4) Dependence on mines nearby refining and processing operations (5) Lack of skilled workers
Diversifying supply chain to partner states	(1) Limited sourcing countries
Diversifying supply chain to third party states (mostly in the Global South other than China)	(1) Limited sourcing countries (2) Uncertain political allegiances (3) Regulatory uncertainty and political instability
Deep sea mining	(1) In early technological stages (exploration, not yet exploitation) (2) Limiting permitting environment as part of UNCLOS (3) Deposits in international waters, to which other countries (e.g., China) can also lay claim. (4) Environmental pollution
Recycling	(1) Scientific limitations (2) Limited economic viability
Reducing demand	(1) Growing demand due to energy transition (2) Limited alternatives to certain CRM
Stockpiling	(1) Only a short-term solution for limited supply of CRM (2) Risks driving-up price (cost of silos and shortage)

However, the EU's efforts to expand mining operations within the Union are mired in a host of challenges, including environmental pollution concerns, NIMBY movements, geological, economic and technological limitations, and the extended timeline needed to develop mining capabilities. Europe does hold deposits of CRM in the ground, including cobalt in Scandinavia, REE in Sweden and Greece, and gallium and germanium in Poland (see Infographic Critical Raw Material Risks).[336] However, these resources would not suffice to fulfil future demand following the green and digital transitions.[337] Besides, the time needed to set up mining operations from exploration to first production can take up to 15 years, greatly reducing the EU's capability to address its CRM dependence on foreign states in the short-term.[338] The mining

334 Ibid.

335 "The Versailles Declaration, 10 and 11 March 2022," European Council, March 10, 2022, https://www.consilium.europa.eu/en/press/press-releases/2022/03/11/the-versailles-declaration-10-11-03-2022/.

336 'Report on Critical Raw Materials and the Circular Economy' (European Union, 2018), p. 26.

337 "*Critical Raw Materials for Strategic Technologies and Sectors in the EU - A Foresight Study*" (European Commission, September 3, 2020).

338 Ritoe, "The New Great Game"; Bobba et al., "The Role of Critical Minerals in Clean Energy Transitions."

projects that have gotten off the ground in Europe have been significantly slowed down by environmental pollution concerns and NIMBY movements, as the case study of mining operation in Portugal and Sweden shows (see Textbox 2).

Textbox 2. Challenges to reshoring CRM mining: operations in Portugal and Sweden

Portugal holds significant deposits of lithium needed for the energy transition, amounting to over 60,000 tones. Since the early 2000s, mining companies and the Portuguese government have explored the potential of lithium mining in the country. In 2022 the environmental regulator of the Portuguese government has given the green light for lithium mining in six different parts of the country. However, the project has been met with severe opposition by environmental groups, as well as local residents. They fear the activities will pollute the area's central irrigation system and pose a threat to the local environment.[339]

Since 2009, Canadian mining company Leading Edge Materials has been trying to commence rare earth mining operations near Norra Kärr, Sweden. The region holds Europe's largest known reserves of REE. However, mining operations have been hindered by severe opposition by environmental organisations and locals in the area. They fear that the mining company would not follow environmental regulations and that radioactive waste will pollute the nearby lake, given that the production of one ton of rare earth metals generates tens of thousands of litres of radioactive wastewater.[340]

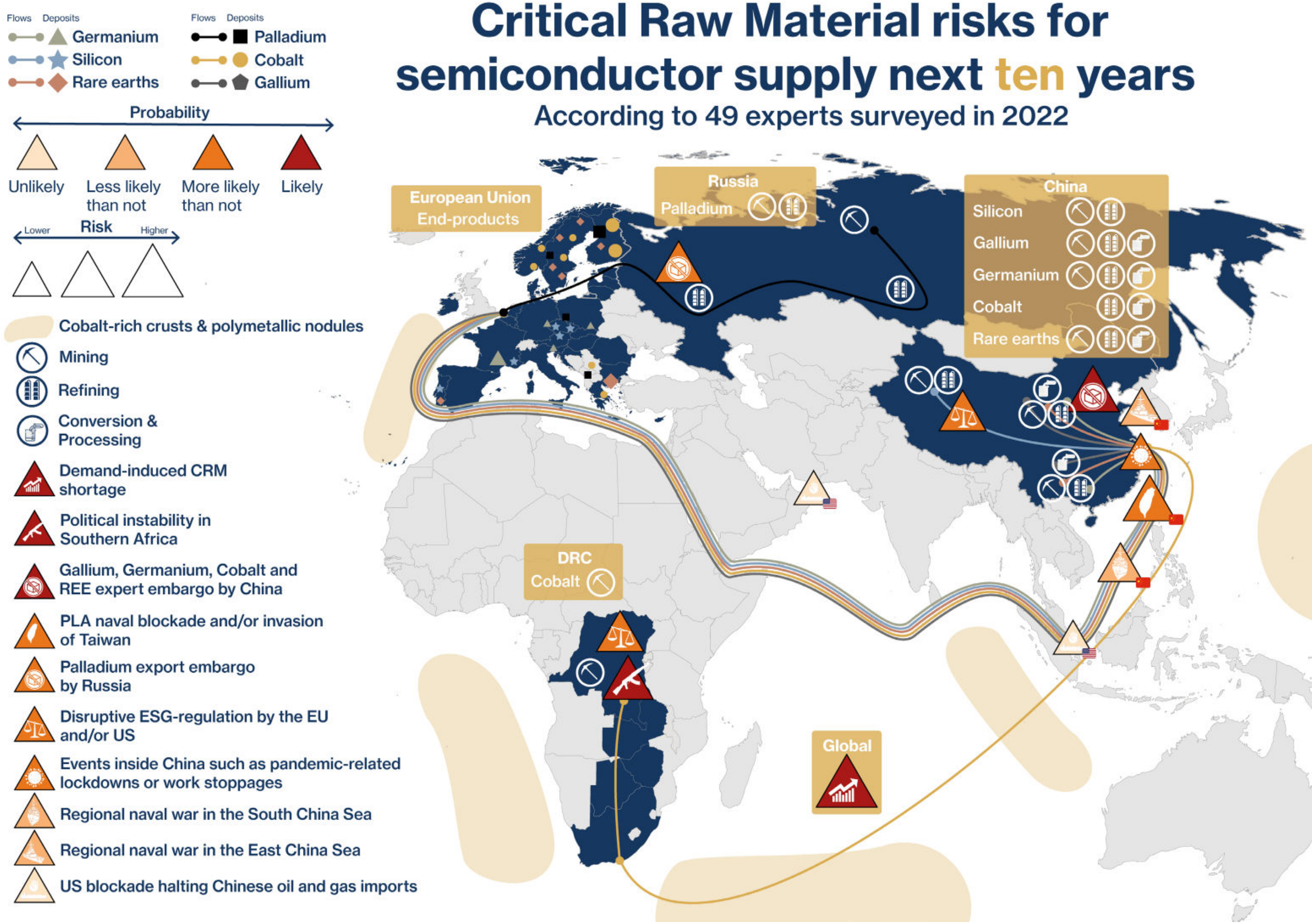
The cases above reveal the various challenges that come with (re)opening mining operations in Europe. The lithium mining project in Portugal and the rare earths mining project in Sweden have taken decades to come off the ground. Moreover, both projects have been confronted with environmental concerns and opposition by local residents, which has slowed both projects. This suggests that the (re)opening of mining operations in the EU cannot be the sole solution to the reduction of dependencies in the CRM supply to Europe.

[339] Rebekah Daunt, "Portugal's Government Approves Lithium Mining despite Growing Concerns," Euronews, May 2, 2022, https://www.euronews.com/2022/02/05/portugal-s-government-approves-lithium-mining-despite-protests-concerns.

[340] Darko Lagunas and Luuk van der Sterren, "De weg naar groene energie is een smerige zaak," Follow the Money - Platform voor onderzoeksjournalistiek, June 11, 2022, https://www.ftm.nl/artikelen/zeldzame-aardmetalen-energietransitie-china.

Critical Raw Material risks for semiconductor supply next ten years

According to 49 experts surveyed in 2022



Aside from CRM mining within the EU, the EU's initiatives to reduce its dependence on foreign countries in the CRM supply chain aims to engage in recycling efforts. Some CRM, such as Tungsten and Vanadium, have high end-of-life recycling rates, 42% and 44% respectively. However, the recycling of many CRM, including those required to produce semiconductors and many products for the energy transition, have both scientific and economic limitations, severely reducing their rate of recycling. Table 11 below provides an overview of the end-of-life recycling rates of the CRM highlighted in this report.

Table 11. Recycling rates of selected CRM in the EU.

Source: Report on Critical Raw Materials and the Circular Economy (EU, 2018)[341]

CRM	Recycling rate	Complications
PGMs (including palladium)	11%*	The high value of PGMs makes their recycling attractive. The majority of the recycling volumes come from the recycling of spent automotive catalysts and electronics, which will be phased out as from 2030 onwards only Electric Vehicles are meant to be sold in the EU.
Cobalt	35%	Cobalt-bearing end-of-life scrap can be in the form of used turbine blades or other used parts from jet engines, used cemented carbide cutting tools, spent rechargeable batteries, magnets that have been removed from industrial or consumer equipment, spent catalysts, etc
Gallium	0%	The rate of recovery of gallium from end-of-life products is close to zero and this is due to the difficulty and cost to recover it from highly dispersed items
Germanium	2%	Only a small amount of germanium is recycled from old scrap of IR optics such as used mobile phones
Rare earth elements (Light and Heavy)	6%/7%* (average values)	Recycling of REEs is often difficult because of the way they are incorporated as small components in complex items or as part of complex materials. The process required for recycling are energy intensive and complex

Given the challenges to source or recycle the CRM needed for semiconductor manufacturing, the EU is also establishing strategic partnerships with other states to diversify its supply chain. In 2021, the EU and Canada set up a strategic partnership on raw materials (see Table 12). The strategic partnership "will focus on the integration of EU-Canada raw material value chains" to allow both sides to "advance trade and investments into a secure, sustainable and resilient raw materials value chain".[342] Moreover, following the war in Ukraine in 2022, the EU launched a strategic partnership on raw materials with Ukraine as well to secure the supply of primary and secondary CRM for both sides.[343] Both partnerships allow the EU to diversify its supply of CRM to friends and allied countries, which are less densely populated and have considerable CRM reserves, thus mitigating the risks inherent to the supply of CRM to Europe.

341 Gislev and Grohol, "Report on Critical Raw Materials and the Circular Economy."

342 "EU and Canada Set up a Strategic Partnership on Raw Materials," European Commission, June 21, 2021, https://ec.europa.eu/growth/news/eu-and-canada-set-strategic-partnership-raw-materials-2021-06-21_en.

343 European Commission, "EU and Ukraine Start Strategic Partnership on Raw Materials," Text, European Commission, 2022, https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3633.

3.2.2. Partner country efforts to mitigate the risks in the CRM supply chain

Other countries have taken similar measures to reduce their dependence on the supply of CRM from the developing and autocratic world, including the US, Japan, Australia, and Canada, which the EU could take note of when devising its own policy initiatives. In 2021 the Biden administration ordered a review of the vulnerabilities inherent to the US supply of CRM. An ensuing assessment of the supply chain found an "over-reliance on foreign sources and adversarial nations for critical minerals and materials, which pose national and economic security threats".[344] This was quickly followed by action. The US invested heavily in boosting the domestic production of CRM through public-private partnerships and the development of recycling initiatives. Moreover, the recently passed Inflation Reduction Act incentivises the use of critical minerals mined in the US or free trade agreement partners (which does not include the EU), boosting the local CRM mining industry.[345] Moreover, in its Defense Production Act, the Biden administration urges to take action to reduce dependence on foreign countries for the sourcing of CRM, including cooperation with partner countries.[346] MP materials was awarded 35 million USD to mine REE in California, a new facility was built to test the viability of mining lithium on the US West Coast, Redwood Materials in partnership with Ford and Volvo is starting a pilot to collect and recycle end-of-life lithium-ion batteries, and the recovery of REE from coal ash and other mine waste is being explored, just to name a few initiatives.[347]

European efforts will not suffice in meeting all current - let alone future - demand for CRM.

However, US policy initiatives do not come without their challenges. Two key challenges stand out. First, these efforts will not suffice in meeting all current – let alone future – demand for CRM.[348] Second, various environmental regulations and unfavorable local political contexts prevent the US from developing refining and processing capacity.[349] Without investing in these capabilities, the US will remain dependent on China to refine and/or process CRM.[350] The US, and for that matter Europe, will continue to be dependent on foreign sources for its CRM supply and must, employ a variety of approaches, including ensuring multiple supply options, diversifying geographically, and reducing demand.

Japan has diversified its supply of rare earths away from China following an alleged export ban of Chinese rare earths to Japan in 2010 and Beijing reducing its general export quota by 40%. Tokyo reduced the share of Chinese rare earths from over 90% of imports to just 58%

344 The White House, "Building Resilient Supply Chains, Revitalizng American Manufacturing, and Fostering Broad-Based Growth" (Washington, D.C.: The White House, June 2021), https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.

345 Reed Blakemore and Paddy Ryan, "The Inflation Reduction Act Places a Big Bet on Alternative Mineral Supply Chains," Atlantic Council, August 8, 2022, https://www.atlanticcouncil.org/blogs/energysource/the-inflation-reduction-act-places-a-big-bet-on-alternative-mineral-supply-chains/.

346 U.S. Department of Defense, "Defense Production Act Title III Presidential Determination for Critical Materials in Larg," U.S. Department of Defense, April 5, 2022, https://www.defense.gov/News/Releases/Release/Article/2989973/defense-production-act-title-iii-presidential-determination-for-critical-materi/https%3A%2F%2Fwww.defense.gov%2FNews%2FReleases%2FRelease%2FArticle%2F2989973%2Fdefense-production-act-title-iii-presidential-determination-for-critical-materi%2F.

347 "Fact Sheet Securing a Made in America Supply Chain for Critical Minerals," The White House, February 22, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/22/fact-sheet-securing-a-made-in-america-supply-chain-for-critical-minerals/.

348 IEA, "The Role of Critical Minerals in Clean Energy Transitions."

349 Peter J Pham, "Securing Supply Chains of Critical Minerals and Materials For" (Krach Institute for Tech Diplomacy, March 24, 2022).

350 Hui, "Japan's Global Rare Earths Quest Holds Lessons for the US and Europe."

within a decade,[351] aiming to bring that amount below 50% by 2025.[352] Japan was able to radically reduce its dependence on China through a concerted, government-led effort that combined multiple strategies, including diversification, cutting demand, increasing recycling, and stockpiling.[353] Key to these Japanese efforts was close cooperation between the public and private sectors. The Japanese government appointed the world's first Economic Security Minister and a department within the National Security Secretariat to address the supply of CRM.[354] Moreover, Japan created a state-backed company named Japan Oil, Gas and Metals National Corporation (JOGMEC), which is managed by the Japanese Ministry of Economy, Trade and Industry. Through JOGMEC, the Japanese government could invest and partner with various mining companies and projects around the world, including in Australia, to secure rare earths. Aside from diversification, Japan also heavily invested in the recycling of rare earths, as well as research to develop alternatives to rare earths, which could significantly reduce demand.[355]

Other allied and friendly countries, Canada and Australia, have also expanded their mining operations of certain CRM. In the medium term, they could become major alternative suppliers of the CRM needed in the semiconductor industry for the partner states. Commercial production of REE was commenced in the Northwest Territories of Canada in 2021. Besides mining operations, Canada has also been investing in CRM refining capacity, for example in Saskatoon, further reducing its reliance on other states, including China, for refining operations.[356] The Australian government has also been financially and legislatively supporting the initiation of rare earth mining operations in the country, including the Arafura Resources' Nolans project and the Iluka Resources' Eneabba refinery. Similar to Canada, Australia has also been reshoring refining operations, for example Lynas' LAMP cracking and leaching facility has been relocated from Malaysia to Western Australia. The company also reached an agreement with the US Department of Defense to establish rare earth refining facilities in Texas.[357] Canada and Australia, two less densely populated states, which have both felt the whip of reliance on China over the past decade, hold options for mitigation and lessons for European states.

351 Aya Adachi and Francesca Ghiretti, "A Japanese Solution to the EU's Economic Security Struggle," *MERICS*, May 2, 2022, https://merics.org/en/short-analysis/japanese-solution-eus-economic-security-struggle.

352 Ryosuke Hanafusa, "Japan to Pour Investment into Non-China Rare-Earth Projects," *Nikkei Asia*, February 15, 2020, https://asia.nikkei.com/Politics/International-relations/Japan-to-pour-investment-into-non-China-rare-earth-projects.

353 European Union Chamber of Commerce in China, "Decoupling: Severed Ties and Patchwork Globalisation" (European Union Chamber of Commerce in China, 2021).

354 Aya Adachi and Francesca Ghiretti, "A Japanese Solution to the EU's Economic Security Struggle."

355 Hui, "Japan's Global Rare Earths Quest Holds Lessons for the US and Europe."

356 Fulco, "Taiwan Is an Ideal Partner for Canada in the Semiconductor Sector."

357 Ross Embleton and David Merriman, "Rare Earth Elements."

Table 12. Heavy sample of initiatives to expand European and partner state access to CRM supply

EU initiatives	Cooperation initiatives including the EU	Partner country cooperation initiatives excluding the EU
New European Industrial Strategy	EU-Canada Strategic Partnership on Raw Materials (part of CETA)	Inflation Reduction Act
European Green Deal	EU-Ukraine Strategic Partnership on Raw Materials	Other US Free Trade Agreements on Critical Raw Materials
European Strategic Compass		
Action Plan on Critical Raw Materials, which includes the European Raw Materials Alliance (ERMA)		
RePowerEU		
Global Gateway		
EU Action Plan on Circular Economy		
2022 EU Declaration of Versailles		
Raw Materials Information System (RMIS)		

Conclusion

The Netherlands and allies have already taken measures to leverage their semiconductor dominance against rival states.

The Netherlands and allies have already taken measures to leverage their semiconductor dominance against rival states, such as China and Russia, as well as put forth various initiatives to mitigate the risks and dependencies in the CRM supply chain. However, both efforts do not come without risks. First, leveraging semiconductor dominance provides the West with a significant geostrategic tool against rival countries. ASML is a key industry player bringing plentiful employment and economic benefits, as well as great power interest to the Netherlands. At first sight, one would expect the company's presence in Veldhoven to give the Dutch government a geopolitical tool to wield against its rivals. However, ASML's EUV and DUV lithography equipment has also put the Netherlands in an awkward position with the great powers of China and the US, demanding conflicting action with the first threatening punishment.

Second, mitigation efforts to reduce risks in the CRM supply chain are being devised at high speed but translating plans into concrete action remains difficult. The EU and allies have put forth various initiatives to reduce dependence on foreign rival states for their supply of CRM, including the reshoring of mining, refining, and processing operations, recycling, reducing demand, diversification of the supply chain, and stockpiling. However, all of these initiatives come with challenges, such as NIMBY and environmental concerns, scientific and economic limitations, limited alternative sourcing countries, or only providing short-term solutions. To be sure, mitigating the risks and dependencies requires going beyond what the EU is currently doing. It requires multiple strategies to be employed at the same time and a whole-of-society effort, in which public sector parties coordinate with private sector actors to play a large role. This is the topic of the next chapter.

Chapter 4. Policy implications, opportunities and recommendations

Key Takeaways

To address the challenges of the semiconductor and CRM ecosystem at a time of great power rivalry, policy-makers are advised to appreciate five high-level policy implication themes, which come with specific policy opportunities and recommendations.

1. Prioritise security of supply in a world in which hard competition between great powers structurally threatens European economic security, including disruptions in the near future supply of CRM.
2. Accept that the US-China tech rivalry is likely to put the supply of semiconductors, digital end-products, and products needed for the energy transition to the EU at risk.
3. Work with other technologically advanced democracies to mitigate semiconductor and CRM ecosystem risks vis-à-vis Russia and China.
    a. Keep intact the fragile balance in the short-term. Make use of the opportunities provided by the dominance of technologically advanced democracies in the semiconductor value chain.
    b. Mitigate CRM-related dependencies and risks in the medium-term. Accept that ensuring security of supply of vital resources such as CRM in the medium-term requires a foreign policy based on “mutual interests”towards non-rival, CRM-producing autocratic states, including sometimes difficult limited compromises in human rights and ESG-policy, and comes with environmental and climate costs in the short-term.
4. Expand European leverage in the semiconductor and CRM ecosystem vis-à-vis other technologically advanced democracies such as the US, Taiwan, South Korea and Japan.
5. Formulate a strategy to reduce dependence on China and Russia more broadly, as dependence for many other end-products for purposes such as the digital and energy transition remains.”

The Netherlands and EU would be advised to take a host of measures to strengthen resilience in the increasingly fragile and contested semiconductor and CRM ecosystem. The semiconductor and CRM ecosystem is, when simplified, best understood as a fragile geopolitical balance held up by American, European and Asian advanced, semiconductor-fabricating, democracies and CRM-producing rival autocracies, namely Russia and China, and non-rival autocracies, meaning the DRC (see Chapter 1: A fragile supply chain balance). This fragile balance may very well be upset in similar ways as Russia's invasion of Ukraine led to a chain reaction that disrupted the supply of essential commodities, namely natural gas, neon gas and temporarily palladium to Europe (see Chapter 2: Threats to the supply of CRM for semiconductors). Current European efforts to mitigate CRM reliance are not on-track to bear fruit at a large-scale before the risks related to CRM dependence are expected to materialise (see Chapter 3: Winning interdependence).

To address these challenges policy-makers are advised to appreciate five high-level policy implication themes, which come with specific policy opportunities and recommendations.[358]

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3. Work with other technologically advanced democracies to mitigate semiconductor and CRM ecosystem risks *vis-à-vis* Russia and China.

    a. Keep intact the fragile balance in the short-term. Make use of the opportunities provided by the dominance of technologically advanced democracies in the semiconductor value chain.

    b. Mitigate CRM-related dependencies and risks in the medium-term. Accept that ensuring security of supply of vital resources such as CRM in the medium-term requires a foreign policy based on "mutual interests"[359] towards non-rival, CRM-producing autocratic states, including sometimes difficult limited compromises in human rights and ESG-policy, and comes with environmental and climate costs in the short-term.

4. Expand European leverage in the semiconductor and CRM ecosystem *vis-à-vis* other technologically advanced democracies such as the US, Taiwan, South Korea and Japan.

5. Formulate a strategy to reduce dependence on China and Russia more broadly, as dependence for many other end-products for purposes such as the digital and energy transition remains.

358 These policy implications, opportunities and recommendations were formulated on the basis of a global expert consultation with representatives from academia, thinktanks, government and industry (see appendix 1) and a literature review.

359 Adviesraad Internationale Vraagstukken, "Urgentie van een nieuwe Nederlandse Afrika-strategie," publicatie (Adviesraad Internationale Vraagstukken, July 14, 2022), 8–9, https://www.adviesraadinternationalevraagstukken.nl/documenten/publicaties/2022/07/14/urgentie-van-een-nieuwe-afrika-strategie.

1. Prioritise security of supply

Prioritise security of supply in a world in which hard competition between great powers structurally threatens European economic security, including disruptions in the near future supply of CRM. Policy-makers should prepare the Netherlands for a world in which "high impact" disruptions to the supply of CRM for semiconductors occur, as the case of Russia's natural and neon gas embargoes against Europe and the outcomes of the expert survey show (see Chapter 2). The risk of Russia weaponising Europe's extensive dependence on Gazprom's gas exports (i.e., around 36% of total consumption in the EU) was only addressed when relations reached "breaking-point", following Russia's invasion of Ukraine and European retaliatory sanctions against Moscow. No mitigative action was taken, in spite of a structural downward trend in European-Russian relations characterised by events such as Russia's 2014 annexation of Crimea and the downing of MH-17 (see Chapter 2). The Dutch government and EU's actions to mitigate natural gas dependence on Russia have been reactive. To solve the crisis, the Minister of International Trade and Development Cooperation of the Netherlands (BHOS) and a German counterpart paid a visit to Qatar in March 2022 to purchase LNG at peak prices.[360] In addition, US companies and Chinese traders supplied LNG to Europe. Partially as a result of this strategic dependence, between 670,000 and 1.2 million Dutch households are at risk of not being able to pay necessary bills, possibly with consequences for public order in the wake of growing social discontent and an increase in homelessness.[361]

Policy-makers should prepare the Netherlands for a world in which "high impact" disruptions to the supply of CRM for semiconductors occur.

At the same time, semiconductor and equipment manufacturers have reduced their dependence on Russia and Ukraine for neon gas following Russia's annexation of Crimea. Peter Hanbury, a research analyst at Bain & Company, gauges their reliance on Russia and Ukraine originally stood at around 90%, but points at greater resilience today due to efforts such as stockpiling and minimising the use of neon gas in production processes.[362] Whereas more than half of the world's neon is still produced by a few companies in Ukraine today,[363] ASML reduced its reliance on "neon sourced from Ukraine to approximately 20% of previous levels".[364] Contrary to the Dutch economy, the company's core functioning was not affected, as far as is publicly known.

1.1. Prepare for persistent pressure on Dutch and broader European prosperity

This will go hand-in-hand with shortages, delays in delivery of products and constant inflationary pressure due to geopolitical fracturing. The acute cost-of-living crisis in Europe, following Russia's invasion of Ukraine, should not be seen as a one-off event. Instead, geopolitical, military, and geo-economic events are likely to consistently put lower and middle economic classes into dire financial circumstances.

360 BNR Webredactie, "Europese Ministers Zoeken Naarstig Naar Alternatieven Voor Russisch Gas," BNR Niewsradio, March 18, 2022, https://www.bnr.nl/nieuws/internationaal/10470645/europese-ministers-naarstig-op-zoek-naar-niet-russische-gasleveranciers.

361 "CPB: Betalingsproblemen Voor 1,2 Miljoen Huishoudens Bij Donker Scenario," NOS, June 9, 2022, https://www.bnr.nl/nieuws/internationaal/10470645/europese-ministers-naarstig-op-zoek-naar-niet-russische-gasleveranciers.

362 Sam Shead, "Chip Industry under Threat with Neon Production Set to Fall off a Cliff Following Russia's Invasion of Ukraine," CNBC, accessed October 3, 2022, https://www.cnbc.com/2022/03/25/russia-ukraine-war-laser-neon-shortage-threatens-semiconductor-industry.html.

363 Morgan Meaker, "Russia's War in Ukraine Could Spur Another Global Chip Shortage," Wired, February 28, 2022, https://www.wired.com/story/ukraine-chip-shortage-neon/.

364 Shead, "Chips Industry under Threat,".

Politicians should communicate clearly to the population that in the post-post-Cold War period, regular geopolitical, economic and likely also military crises will put the prosperity of the electorate under pressure, in order to set more realistic expectations. A key part of this is acknowledging that the past 30-years of low inflation, cheap products and just in time supply chains were the *exception* and not the *rule*. These circumstances were also made possible by populations in the developing world, especially China, doing the polluting, challenging work in poor labour conditions that populations of technologically advanced democracies were not willing to do anymore.

The Dutch BHOS natural resource strategy is advised to take a "worst-case-scenario" approach to preventing, mitigating, and preparing for the consequences of severe CRM supply disruptions.

1.2. The 2022 Dutch Ministry for Foreign Trade and Development Cooperation (BHOS) natural resource strategy should take a "worst-case-scenario" approach.

1.2.1. The Dutch BHOS natural resource strategy, expected in the second part of 2022, is advised to take a "worst-case-scenario" approach to preventing, mitigating, and preparing for the consequences of severe CRM supply disruptions, assuming they will occur.

1.2.2. The government is advised to encourage and, if requested, support companies in the semiconductor value chain to map their supply chains, all the way to where the CRM necessary for their production are processed, refined and even mined. If the analysis of companies goes far beyond their first, second and third tier suppliers, public and private parties can work on the basis of more granular information to ensure that CRM disruptions are kept to a minimum.

1.2.3. Encourage companies to diversify their suppliers on the basis of geopolitical risks that manifest themselves differently in different geographies.

1.3. The government should engage in stress testing to identify the effects of likely and impactful CRM supply disruptions.

The process leading-up to the strategy is advised to include behind-the-scene stress testing, including the effects of different high likelihood and high impact forms of CRM supply disruptions (e.g., demand-induced shortage, a China export embargo of CRM in the form of processed materials, or a PLA naval blockade/invasion of Taiwan). The expected price hikes to Europe in the winter of 2022 due to high gas and oil prices can provide insights into what effects a CRM shortage may have. Economic security experts from academia, think tanks and the private sector, especially those focusing on CRM and semiconductors, can best be included in this exercise.

1.3.1 Private sector companies, like ASML, NXP and ASM International, should be included in these exercises to exchange best practices, for instance on the semiconductor industry's proactive mitigation of dependence on neon gas following Russia's annexation of Crimea. Triangulating approaches to foresight and risk assessment with the private sector and between firms within the private sector, in order to strengthen resilience, is key.

1.3.2. This exercise may be repeated together with EU, NATO and other partners.

1.3.3 Scenario-based stress tests and red-teaming in order to gauge whether the Netherlands and the EU are ready for highly disruptive geopolitical events could be used more broadly in government.

1.4 Institute a top-down approach to reducing strategic dependencies.

Institute a top-down approach to reducing strategic dependencies, for instance through the establishment of a National Security Council, as promised in the 2021 Coalition Agreement, and an Energy Council, an advisory body for energy affordability, robustness of the energy system and security of supply. Both bodies should test if policies in the realm of the energy transition are sufficiently robust to survive high-impact geopolitical events.[365] Parliament similarly called for the establishment of the *Interdepartementale Task Force om strategische afhankelijkheden te verminderen*. This task force, if established, can be included in the above-described stress tests.[366]

> **1.4.1.** Device a system on either a Dutch government or a European level that annually tracks and publishes the current level of access to CRM, distinguishing between the different volumes of CRM needed for the semiconductor ecosystem and the energy transition.

The US-China tech rivalry is likely to intensify, pushing the EU and other American allies to act with Washington against Beijing.

2. Accept that the US-China tech rivalry will put supply lines to the EU at risk

Accept that the US-China tech rivalry is likely to put the supply of semiconductors, digital end-products and products needed for the energy transition to the EU at risk. Anticipate that the EU's severe strategic dependence on the US will likely impel the EU to more openly and explicitly take part in this high-tech competition on the side of Washington. The US-China tech rivalry is likely to intensify, more often pushing the EU and other American allies to act with Washington against Beijing. US attempts to sabotage China's semiconductor indigenisation efforts risk unsettling the semiconductor value chain for two reasons: 1) it risks reducing the total global output of semiconductors (i.e., supply chain resilience) by intended and unintended consequences in a highly complicated ecosystem during a transition period; and 2) it risks unsettling the fragile semiconductor supply balance across rival blocs, as it incentivises China (or Russia) to weaponise parts of the semiconductor value chain under its control, namely the CRM supply chain. At the same time, China is climbing down nodes in semiconductor production (now at quasi 7-nanometers) and claiming semiconductor global market share much faster than technologically advanced democracies are expanding CRM production, diminishing their leverage *vis-à-vis* China.[367]

US-China technological competition, unlike military competition, does not have a natural "ceiling" that both superpowers desperately want to avoid touching. Since 2015, US-China

365 Lucia van Geuns, Strategic Advisor Energy at the Hague Centre for Strategic Studies, advocates this position. She will present on this in the Dutch House of Representatives in September 2022.

366 Ruben Brekelmans, "Hierbij Mijn Motie Samen Met @AgnesMulderCDA (2/2)," *Twitter*, July 8, 2022, https://twitter.com/rubenbrekelmans/status/1545416829488742401.

367 "And while the ability to produce a small number of chips using the next level of production technique signals that a company is making technological progress, what determines economic viability -- under normal circumstances -- is yield, or the percentage of every production run that's successful." Debby Wu and Jenny Leonard, "China's Top Chipmaker SMIC Achieves Breakthrough Despite US Sanctions."; SIA, "China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's."

competition has intensified, both deepening and broadening.[368] In the next ten years, the pursuit of relative instead of absolute gains, bloc formation, and ideological competition between the great powers, is likely to intensify irrespective of who the occupant of the White House is. Unlike military competition, economic and technological competition is not restrained by an ultimate fear by both great powers of Armageddon: a debilitating conventional or even nuclear war between them. Therefore, strategic management, and hence compromise between the superpowers, is more likely to occur in those critical junctures of the relationship in which risks are highest, namely the military domain.[369] Within these circumstances of deep distrust between the great powers and the relatively low risk of intensifying their competition in the technological sphere, competition is likely to lead to at least partial technological decoupling between the US and China. During this process, the US will continue to leverage the pressure points it has on Europe and other allies to spur on governments and companies to curtail technology transfers to China. Ongoing US efforts to block the exports of DUV-machines to China are an example of this.[370]

The Netherlands' and the EU's space to carve out an independent position in the intensifying US-China tech and trade competition remains limited.

The Netherlands' and the EU's space to carve out an independent position in the intensifying US-China tech and trade competition remains limited, as ASML and other companies in the semiconductor value chain are reliant on production facilities in the US as well as dependent on access to the US market and trade in dollars. Tellingly, Trump's reimposition of sanctions on Iran in 2018 led all major European oil giants to leave the country within months. In the all-or-nothing realm of territorial security, European reliance on the US military to deter Russia is even more consequential. This is best exemplified by the conventional deterrence 100.000 troops that the US provides in Central Europe's NATO member-states and the American nuclear umbrella under which Europe still shelters.[371]Europe should, therefore, anticipate greater and greater pressures to participate in the American-led tech showdown with Beijing.

2.1. Address the adverse (un)intended consequences of the US-China tech rivalry

European policy-makers are advised to anticipate that Europe's enormous strategic dependence on Washington will increasingly impel the EU to participate in the US-China tech rivalry on the side of the US. To craft realistic European and Dutch policy, to strengthen semiconductor and CRM resilience policy-makers are advised to take this strategic context into account.

368 As competition moved from China's militarization of its man-made islands in the South-China Sea, to a trade war during initiated by the Trump administration, to an ideological conflict over superiority of governmental systems during COVID-19, to a tech decoupling focusing on dominance in among other sectors the semiconductor ecosystem and now to increasingly intense military moves around Taiwan, as China expands its aerial incursions, steps-up its maritime presence and the US increasingly delivers arms to Taiwan and President Biden has made the US-security guarantee to Taiwan more explicit.

369 Strategic dampening of military tensions could follow a similar logic as the US-USSR agreements on arms control following the spiraling out of control of super power competition during the Cuban Missile Crisis in 1962, after competition structurally heated up in the 1950s. For an account of what managed competition may look like, see Kevin Rudd, The Avoidable War: The Dangers of a Catastrophic Conflict between the US and XI Jinping's China (New York: PublicAffairs, 2022).

370 NRC, "In twee weken kunnen de chips op zijn, waarschuwt Eurocommissaris Breton," NRC, accessed September 28, 2022, https://www.nrc.nl/nieuws/2022/09/06/eurocommissaris-breton-vreest-blokkade-taiwanese-chips-en-dan-hebben-we-in-twee-weken-tijd-geen-chips-meer-2-a4140942.

371 Russia's war in Ukraine has made Europe's reliance on the US even more acute for two reasons. The invasion revealed the lengths Russia is willing to go to enforce what it sees as its historical prerogatives and European states. In addition, European states are very unlikely to have any realistic alternative for the US security guarantee to Europe for at least another 10-to-15 years.

2.2. The Dutch government and its semiconductor companies are advised to explore new approaches to get more in return for participating in the US-led tech-showdown with China.[372]

2.2.1. Government ministries are advised to explore if ASML's outstanding order list, consisting of orders of the top semiconductor manufacturing companies like TSMC, Samsung, Intel and SMIC for 100s of lithography systems, can be employed in closer coordination with the government to achieve Dutch national and European policy goals.

2.2.2. The Dutch government is advised to explore if leverage would increase if export licensing are on other regulatory levels for instance the European level instead of the national level.

Work with other technologically advanced democracies and non-rival CRM-producing autocracies to mitigate semiconductor and CRM ecosystem risks.

3. Work with others to mitigate risks

Work with other technologically advanced democracies and non-rival CRM-producing autocracies to mitigate semiconductor and CRM ecosystem risks *vis-à-vis* Russia and China. Even though its partnership with the US may force the Netherlands and Europe occasionally in awkward positions, the solutions to creating greater security of supply (i.e., resilience) and mitigate threats to the CRM for semiconductor ecosystem can only be achieved together with allies and partners. A fully indigenous European semiconductor and European CRM value chain is entirely impossible, certainly in the near and medium-term future. In the medium-to-long term (10 to 15 years), the mineral wealth and technological skill necessary to create a semiconductor supply chain without China and Russia may be achievable if the EU works with the US, Canada, Australia, Japan, South Korea, India and countries in the Global South.[373] The steps the Netherlands and the EU can take are outlined below to [2.1] keep intact the fragile semiconductor and CRM ecosystem in the short-term by capitalising on semiconductor strengths and [2.2] to mitigate CRM-related dependencies in the medium-term.

3.1. Make use of the opportunities provided by the dominance of technologically advanced democracies in the semiconductor value chain.

Already before CRM mitigation efforts are likely to bear fruit, the EU and its partners in semi-conductor production (e.g., Taiwan) are advised to strengthen efforts to maintain and build on their advantages in the semiconductor and CRM ecosystem. In the short term, mitigating dependence on Russia, China and the DRC for the CRM for semiconductor supply chain at just one of its key stages (i.e., mining, refining or conversion and processing) is unrealistic, in spite of CRM deposits in Europe, Canada, Australia, the US, parts of the Global South not controlled by Chinese mining companies and the deep-sea. For example, starting up a mine all the way from receiving a permit, the exploration phase to full production, if at all possible, in technologically advanced democracies takes a decade or longer. The time needed to

372 "To my knowledge, neither the Dutch state nor ASML received anything in return for withholding the EUV export license to China." Expert interview with Henne Schuwer, Former Dutch Ambassador to the US.

373 However, also these geopolitical mitigation efforts take place against a non-geopolitical structural factor that continually threatens security of supply, namely growing demand for CRM as a result of the energy transition.

reshore refining and conversion and processing capabilities also can take up-to a decade. Considering that the surveyed experts expect disruptions in the supply of CRM for semiconductors already to take place in the next five and ten years, the EU needs to take action now to achieve results in the short-term. Dominance in the semiconductor value chain brings forth opportunities to do this.

In the short-term, maintaining and strengthening key leverage that technologically advanced democracies have *vis-à-vis* China and Russia on the semiconductor side of the semiconductor-CRM ecosystem is essential to keep China and Russia in check, especially at a time when US technological action against China risks upsetting the balance. Key points of strength, such as Taiwan's TSMC and the Netherlands' ASML, should therefore be protected and expanded upon. The Eindhoven Brainport region has many practical needs the government can help satisfy, such as 70.000 vacancies in engineering-related fields. ASML, in need of "mechanics and top-level STEM talent" is expected to double its personnel file in the upcoming years.[374] Meanwhile, efforts should be made to make hostile acts, such as China enacting a CRM boycott against the EU or its partners in semiconductor production (e.g., Taiwan) or the PLA taking military action against Taiwan, as unappealing as possible.

In the short-term, maintaining and strengthening key leverage that technologically advanced democracies have is essential to keep China and Russia in check.

3.1.1. Invest in capacity, both human resources and technologies, to continuously screen Chinese advances in the semiconductor value chain. China's level of success in indigenising this technology enabling sector will partially determine the strategic space it has to act disruptively (e.g., enact a CRM export embargo or take military action against Taiwan).[375]

- Invest in economic security knowledge, both inside and outside the Dutch government, with a focus on China.
- Establish partnerships throughout Asia with knowledge institutes specialising in technology and China-analysis, for instance in South Korea, Japan and Taiwan.

3.1.2. Advanced democracies should invest in better protection of IP to protect the technological edge that advanced democracies hold in semiconductor production. The Dutch government, making use of its great cyber security ecosystem consisting of both the intelligence services and world-leading private companies such as Fox-IT, may help strengthen the defensive cyber capabilities of key Dutch, South-Korean, Taiwanese and American companies like ASML, Samsung, TSMC and Intel.

- The Dutch government is advised to expand its knowledge security agenda, as concerning examples of unwanted knowledge transfer also in the military realm, have occurred over recent years.[376] The government is advised in its establishment of a "toetsingskader" for universities and "investeringstoets" for companies to (1) produce an overview of Dutch business and university collaborations with China

374 NRC, "In twee weken kunnen de chips op zijn, waarschuwt Eurocommissaris Breton."

375 The importance of tracking China's semiconductor indigenisation efforts can hardly be overstated. The former Prime-Minister of Australia, Kevin Rudd, argues that "whether China can succeed in closing the semiconductor manufacturing gap between itself and the US and its allies, given that silicon chips underpin the future drivers of the global digital economy and military technology, including the unfolding artificial intelligence revolution" is one of five factors determining much of "the great strategic race between Washington and Beijing over the course of the next decade". Rudd, The Avoidable War, 354.

376 Annebelle de Bruijn et al., "Drones and Concrete to Withstand Bullets: Collaboration with 'Ordinary' Chinese Universities Also Poses Risks," Follow the Money - Platform for investigative journalism, May 26, 2022, https://www.ftm.eu/articles/collaborating-with-ordinary-chinese-universities-also-poses-risks.; Teer, Sweijs, van Hooft, Boswinkel, and Thompson, "China's Military Rise and the Implications for European Security."

in high-risk fields by instituting an obligation to notify the government, (2) define "high-risk fields" based on the military-technological gaps geopolitical rivals, such as China, struggle with and the technologies they want to use to master the warfare of the future, and (3) mandate a specialised and central government body with a clear vision of the Dutch national interest to - if necessary - block corporate takeovers and commercial and university collaborations.[377]

- The Dutch government is advised to closely study Taiwan's new legislative measures that aim to put a stop to technology transfer to the Chinese Mainland. This includes a host of measure to limit brain drain via employees in Taiwan's semiconductor industry taking positions at Chinese semiconductor companies.[378]

Accept that bringing semiconductor production to Europe, which will necessarily require lots of electricity, is a vital step to in the end ensure the security of supply necessary for digitalization and greening the economy.

3.1.3. Strengthening the technological edge of advanced democracies. Maintain an active conversation with leading semiconductor firms, both European and non-European, on their needs and drivers behind decisions on starting new fabs or expanding existing ones in specific localities.

a. Make available more Dutch and European funds along the semiconductor supply chain that come closer to the sums provided by the US, Japan or South Korea.
b. Use funds from InvestNL, NXTGEN High Tech and FMO to help contribute to this aim. Encourage these funds to ensure that geopolitical risk is sufficiently accounted for in their investment strategies.
c. Provide tax incentives for semiconductor design, manufacturing and ATP companies to open offices in Europe.
d. Speed-up permitting for enlargement or the development new fabs in the Netherlands and other European states. Support the completion and enactment of the European Chip Act, whilst looking actively to how central, eastern-, and southern- European member-states can benefit from reshoring CRM value chains.
e. Accept that bringing semiconductor production to Europe, which will necessarily require lots of electricity, is a vital step to in the end ensure the security of supply necessary for digitalization and greening the economy.[379] For instance, the production of New Energy Vehicles relies on chips produced by semiconductor companies active in the automotive industry such as NXP. The modeling of wind turbines is done on supercomputers, which require incredibly advanced chips.
f. Accept that semiconductor manufacturers rely on digital infrastructure, such as data centers, that require a lot of energy. Accept that this is a vital step to ensure the security of supply necessary for digitalization and greening the economy.
g. Expand funding broadly for pre-competitive research along the semiconductor and CRM value chain. Expand government subsidies to enable university and other research teams to commercialise their products.
h. Expand funding for companies who do research on how to make semiconductors more energy-efficient.

377 Joris Teer, "China's Military Rise and European Technology: The Policy Debate in the Netherlands" (The Hague Centre for Strategic Studies, 2022), 7–8, https://hcss.nl/report/chinas-military-rise-and-european-technology/.

378 Erin Hale, "Taiwan Cracks down on China Poaching Tech Talent," *Al Jazeera*, May 4, 2022, https://www.aljazeera.com/economy/2022/5/4/taiwan-is-trying-to-thwart-chinas-efforts-to-poach-tech-talent.

379 Betty Hou and Stephen Stapczynski, "Chipmaking's Next Big Thing Guzzles as Much Power as Entire Countries," *Bloomberg*.Com, August 25, 2022, https://www.bloomberg.com/news/articles/2022-08-25/energy-efficient-computer-chips-need-lots-of-power-to-make.

3.1.4. Anticipate that both in the semiconductor and CRM industries engineering talent and other skilled workers are a bottleneck resource, by:

a. Providing tax incentives for semiconductor talent to study, work and live in the Netherlands, for instance by at least maintaining (and not shortening) the 30% tax benefit rule.[380]
b. Pursue visa liberalization for countries that train engineers on a large scale, such as India, a country in which high numbers of engineers graduate every year.
c. Promote STEM fields among high school students, including by offering financial incentives.[381] Similarly, try to grow the pool of mechanics by promoting relevant education in trade schools.
d. Invest in large-scale housing in the Netherlands, first-and-foremost in Eindhoven, the brain port of the Netherlands.
e. Expand student exchanges with technologically advanced democracies active in the semiconductor value chain. Use the model of the Netherlands-Asia Honours Summer School, a public-private initiative that sets out to familiarise 100 Dutch honours students annually with China, to set-up an exchange program in semiconductor research and China analysis with Taiwan, South Korea and Japan. Advocate that European companies active in the semiconductor industry, ministries and universities all contribute to setting-up this program.
f. Pursue the expansion of traineeship schemes at companies throughout the semiconductor value chain.

Invest in large-scale housing in the Netherlands, first-and-foremost in Eindhoven, the Brainport of the Netherlands.

3.1.5. Expand cooperation with Indo-Pacific states on CRM and semiconductors.

a. Assess the added value of founding a EU-South Korea Trade and Technology Council focusing on strengthening the semiconductor ecosystems. Do the same for a EU-Japan Trade and Technology Council, focusing on Japan's great success in decreasing its reliance on Chinese CRM. The semiconductor mission to South-Korea (5-7 October 2022) organized by the Dutch government is a good effort.
b. Join the QUAD-working group on semiconductors.

3.1.6. Continue to sell semiconductor end-products on the Chinese market, as long as this does not aid the development of China's PLA. Sales of end-products on China's market, in total 25% of global semiconductor consumption, can help maintain the enormous R&D costs that semiconductor companies require to maintain successful.

3.1.7. Leverage newfound post-Ukraine unity among technologically advanced democracies to disincentivise China from enacting a CRM export embargo or putting a naval blockade around/invading Taiwan. Technologically advanced democracies should communicate to China what the consequences would be if Beijing takes action to disrupt the supply of CRM to Europe and its partners in semiconductor production before such an event occurs. To disincentivise China from taking "high impact" action, for instance enacting a CRM embargo against the EU or its partners in semiconductor production or a naval blockade/invasion of Taiwan, technologically advanced democracies should act collectively and proactively. In fact, a CRM embargo

[380] Ministerie van Algemene Zaken, "Expat Tax Break to Be Shortened - Income Tax - Government.Nl," onderwerp (Ministerie van Algemene Zaken, July 6, 2018), https://www.government.nl/topics/income-tax/shortening-30-percent-ruling.

[381] Beatrijs Ritsema, "Goed plan: gratis exact studeren," HP/De Tijd (blog), June 2, 2012, https://www.hpdetijd.nl/2012-06-02/goed-plan-gratis-exact-studeren/.

merely focused against Taiwan would already greatly disrupt European economic security, as even European semiconductor companies like NXP partially rely on TSMC's foundries for its chip production. A successful economic deterrence effort by technologically advanced democracies entails communicating privately the willingness to take retaliatory measures against China. EU, G7, South Korean, Taiwanese and Australian punishment of Russia was hinted on by the European Council already in December 2021 in broad terms, as the Council warned of "massive consequences" and "severe cost" that would be imposed and "coordinated with partners" to deter Russia from "any further military aggression" Ukraine.[382] The cohesion coming out of that crisis should be maintained and used to inform Beijing, at moments of high tension, what collective economic consequences technologically advanced democracies would inflict on China. In addition, technologically advanced democracies are advised to communicate to China that Taiwan's semiconductor industry will be inoperable, if China decides to invade.

Accept that ensuring security of supply of vital resources such as CRM in the medium-term requires a foreign policy based on "mutual interests".

a. The Dutch government is advised to acknowledge that Cross-Strait peace and stability is a key European interest, as it is a necessary condition to preserve European economic security.
b. Behind closed-doors, the Dutch government, its EU partners, the US and its partners in Asia could assess together what economic tools they are willing to leverage against China in the event of an attack on Taiwan. Considering the reliance on China for production and export markets of various partners, such as South Korea and to a lesser extent Germany, the willingness to take action may be smaller than against Russia following its 2022 invasion of Ukraine.
c. Behind closed-doors, assess the viability and desirability, including scenario-based stress-tests, of a *NATO for Trade*-like arrangement with technologically advanced democracies in Europe, the Americas, Asia and Oceania. Include other European strengths in this, such as the Agri-food industry. The purpose is to deter China from continuing to weaponise access to its market and install export embargoes. If one of the parties faces an embargo, then there should be a collective response.
d. Put together a comprehensive overview of pressure points technologically advanced democracies have *vis-à-vis* China and evaluate to what extent each party is willing to use these pressure points to deter China.
e. Engage in deterrence in the area of trade. Strengthen and further develop the EU anti-coercion instrument.

3.2. Mitigate CRM-related dependencies and risks in the medium-term.

Accept that ensuring security of supply of vital resources such as CRM in the medium-term requires a foreign policy based on "mutual interests" towards non-rival, CRM-producing autocratic states, including sometimes difficult limited strategic compromises in human rights and good-governance policy, and comes with environmental and climate costs in the short-term. Many fruitful efforts are ongoing to maintain and strengthen the advantages of technologically advanced democracies in the semiconductor supply chain. Much less, however, has been

[382] European Council, "European Council Conclusions, 16 December 2021," accessed October 3, 2022, https://www.consilium.europa.eu/en/press/press-releases/2021/12/17/european-council-conclusions-16-december-2021/., Conclusion 2.3

achieved in mitigating dependence on China, Russia and the DRC for CRM. The overarching theme is the following:

3.2.1. Note that the current security of supply efforts, especially in the realm of CRM, in technologically advanced democracies, especially in the EU and the US, are not going fast enough to mitigate these risks. Canada and Australia are notable exceptions. Japan has achieved the greatest success in reducing dependence on China, specifically in terms of REE dependence.

3.2.2. Mind the gap. Policies implemented, for instance building refining and processing capacity in Europe, can take up-to a decade to implement. Mining-related policies will likely take even longer.

3.2.3. Embed security of supply goals better in the national government's set-up:

a. Establish an Energy Council, an advisory body for energy affordability, robustness of the energy system and security of supply. This body should test if policies in the realm of the energy transition are sufficiently robust to survive high-impact geopolitical events.[383] The Energy Council can be part of the National Security Council, which the government promised to establish in its coalition agreement in 2021.
b. Broaden the mandate of the Minister of Energy and Climate to become the Minister of Energy, Security of Supply and Climate.

Mind the gap. CRM mitigation policies implemented, for instance building refining and processing capacity in Europe, can take up-to a decade to implement.

3.2.4. All other things being equal, it is better to rely on non-rival autocracies than on rival autocracies for the supply of vital resources such as CRM, LNG and oil. Expanding security of supply through dealings with states such as the DRC, Qatar or Saudi Arabia requires a formulation of resource policy in terms of "mutual-interests",[384] including sometimes difficult limited compromises in human rights and good-governance policy. Pitting a values-driven Dutch and EU foreign policy against the pragmatic and strategic trade policies of China and Russia, often perceived as less intrusive by non-rival energy-producing autocracies, risks putting European efforts to mitigate CRM dependence at a disadvantage from the start.

3.2.5. The EU should accept that there will be environmental and climate costs, which have been exported overseas in the past. The EU cannot just export polluting industries to the developing world like it did first and foremost to China over the past 30 years. The EU should accept there will be environmental and climate costs in the short-term to bring mining, refining and conversion, and processing back. EU policy-makers should acknowledge that this was just pollution emitted elsewhere before. As both CRM and semiconductors are essential for the energy transition, expanding mining, refining and conversion, and processing produces necessary carbonization in order to reach larger-scale decarbonization results. At the same time, efforts to make CRM production more energy-efficient, clean and sustainable should be made along the entire value chain.

383 Lucia van Geuns, Strategic Advisor Energy at the Hague Centre for Strategic Studies, advocates this position. She will present on this in the Dutch House of Representatives in September 2022.

384 Adviesraad Internationale Vraagstukken, "Urgentie van een nieuwe Nederlandse Afrika-strategie," 8.

Mobilise the CRM-reliant private sector, including green transition, semiconductor, defense and car companies, to mitigate CRM dependence conjointly.

3.2.6. Accept that mitigating dependence on CRM from China, Russia, and the DRC cannot be done without the private sector, nor without governments coordinating industrial policy.

3.2.7. Mobilise the CRM-reliant private sector, including green transition, semiconductor, defense and car companies, to mitigate CRM dependence conjointly. These capital-intensive industries require many of the same CRM to produce their products. After all, REE are used in semiconductors, wind turbines, catalytic converters and have many defense applications.

3.2.8. The semiconductor industry should consider prioritising stockpiling and recycling in the short-term. The semiconductor industry, using lower volumes of CRM, is in a better position to prioritise stockpiling and recycling in the short-term to fulfil its needs. The defense industry, in turn, should consider stockpiling for semiconductors and products reliant on CRM to produce the tools necessary to preserve European security.

The more detailed policy recommendations (see overview in Table 13 below) build on current policy initiatives like the *EU Action Plan on Raw Materials* and the challenges they encountered, in order to propose solutions to the challenges they face.[385]

Table 13. Policy recommendations to overcome the challenges to expanding CRM security of supply

Current Initiative	Challenges	Policy Recommendation
Reshoring of mining operations to Europe:	(1) NIMBY movements (2) Environmental concerns (3) Lack of refining and processing operations (4) Lack of capital (5) Lack of skilled workers (6) Dependence on foreign (e.g., Chinese) equipment and expertise	(1) Create a political support base in wider society to address NIMBY and environmental concerns by communicating the need to reshore mining operations to Europe for decarbonization and digitalization efforts to be successful. Learn lessons from gas production in Groningen and compensate affected communities generously and early. Communicate the need for R&D efforts to make mining more sustainable and attract talent from around the world, with financial incentives and increased investment in education, to expand mining. (2) Build capabilities along the entire CRM supply chain, including mining, refining, and conversion and processing (not just mining operations) (3) Assess the equipment and expertise needed to reshore/onshore CRM mining operations in Europe. Seek alternatives to reliance on systemic rivals (e.g., China) (4) Engage in public-private partnerships, focusing on affluent companies in the semiconductor (e.g., ASML and NXP), EV-supply chains (e.g., Volkswagen), financial institutions (e.g., ABN AMRO) and the defence industry (e.g., Thales) to reshore refining, processing and where possible mining operations to Europe. Include key policy-industrialists councils in this, such as the Brussels-based Egmont Beraad and VNO-NCW. • Organise a round-table with all the aforementioned parties, including CRM mining, refining and processing companies. (5) Advocate the inclusion of mining, refining and processing of those CRM required for the green transition and those needed for semiconductor production on the "green list" of the European sustainable finance taxonomy, provided that mining companies work on making the industry more sustainable and implement policies to "do no significant harm". (6) Simultaneously, significant investment in human capital should be made. The current gap in expertise regarding mining, refining and other processes within CRM supply chains should be filled by encouraging universities to take a more active role in teaching and researching new advanced industrial practices.

385 An overview of all European semiconductor and CRM initiatives is included in chapter 3.

Current Initiative	Challenges	Policy Recommendation
Reshoring of refining and processing operations to Europe	(1) NIMBY movements (2) Environmental concerns (3) Dependence on foreign (e.g., Chinese) equipment and expertise (4) Dependence on mines nearby refining and processing operations (5) Lack of skilled workers	(1) Create a political support base in wider society to address NIMBY and environmental concerns by communicating the need to reshore refining and C&P operations to Europe for de-carbonization and digitalization efforts to be successful. Learn lessons from gas production in Groningen and compensate affected communities generously and early. Communicate the need for R&D efforts to make refining and C&P more sustainable and attract talent from around the world, with financial incentives and increased investment in education, to expand mining. (2) Assess the equipment and expertise needed to reshore/onshore CRM operations in Europe. Seek alternatives to reliance on systemic rivals (e.g., China); and send trade mission to especially South-Korea, Japan, Canada and Australia for these purposes. Consider setting up a EU-Japan Trade and Technology Council with specific appreciation for CRM-dependence reduction efforts. (3) Make the Port of Rotterdam the CRM refining and processing hub of Europe, by leveraging us the Port of Rotterdam's technological expertise build up due to its centrality in the EU economy, as well as its function as a fossil-fuel hub. • Expanding refining capacity can improve access to cobalt sulphate, as cobalt is predominantly refined in China but mined in the DRC. Creating a reliable new customer for DRC-cobalt, beyond Glencore and Chinese customers, may give European parties greater security of supply as well as leverage to make demands on DRC-governance and human rights policies. Currently, Europe also relies on DRC-cobalt in the end-products it buys from states such as China.
Diversifying supply chain to partner states	(1) Limited sourcing countries	(1) Expand strategic partnerships for raw materials with other states to diversify the supply chain (e.g., Australia, Canada, Japan) (2) Engage in close cooperation between the public and private sector to identify and invest in foreign mining, refining and C&P operations. (3) Similar to Japan's JOGMEC, create a state-led company that coordinates and invests in overseas projects in partner states.
Diversifying supply chain to third party states (mostly in the Global South other than China)	(1) Limited sourcing countries (2) Uncertain political allegiances (3) Regulatory uncertainty and political instability	(1) Expand strategic partnerships for raw materials with other states to diversify the supply chain (e.g., Turkey, DRC). The CRM work group as part of the CETA agreement is a good example. (2) Acknowledge that China's disinterest in including human rights and good governance clauses gives it short-term advantages in obtaining access to CRM in dictatorships (e.g., China Moly's dominance in the DRC). Appreciate global competition with China when devising ESG-related regulation and offer alternatives (such as investment opportunities in parts of the supply chain that add greater value, such as semiconductor production and battery-making) to companies and governments in the Global South to compete with China. ESG-related guidelines, especially those obliging companies to take responsibility for their entire supply-chain, now risk pushing out European companies. This runs counter to the goal of creating greater security of supply *vis-à-vis* China and Russia. (3) Engage in close cooperation between the public and private sector to identify and invest in foreign mining operations. (4) To mimic Japan's great success in limiting CRM-dependence on China, create a state-led company, like Japan's JOGMEC, that coordinates and invests in overseas CRM projects in third countries. • Tools like InvestNL, NXTGEN High Tech and FMO may also prove suitable to expand access to CRM in third-party states.
Deep sea mining	(1) In early technological stages (exploration, not yet exploitation) (2) Limiting permitting environment as part of UNCLOS (3) Deposits in international waters, to which other countries (e.g., China) can also lay claim. (4) Environmental pollution	(1) Sponsor environmental impact studies of deep-sea mining. (2) Insist that permit-procedure for Deep Sea Mining licenses is speeded-up at the relevant sub-body within International Seabed Authority, within UNCLOS. (3) Invest early in companies with deep-sea mining expertise. (4) Sponsor companies as the Netherlands government in order to already lay claim to particular deposits now under discussion at UNCLOS. (5) Do not install a one-sided EU moratorium on Deep-Sea Mining. This risks strengthening China's position in the CRM value chain. If in time the environmental risks around deep-sea mining turn out to be too extreme, advocate global measures to minimise externalities.

Current Initiative	Challenges	Policy Recommendation
Recycling	(1) Scientific limitations (2) Limited economic viability	(1) Financially incentivise CRM recycling operations through subsidies etc. to increase economic viability (2) Invest in R&D of CRM recycling. In particular, those on which the EU depends most on foreign sourcing. • As gasoline and then hybrid cars in the EU are phased out from 2030 onwards, recycling can expand access for semiconductor producers to palladium as EV cars do not require this precious metal.
Reducing demand	(1) Growing demand due to energy transition (2) Limited alternatives to certain CRM	(1) In the energy transition, take into account the CRM needed for each course of action. (2) Invest in R&D to find viable alternatives to certain especially problematic CRM for products (3) Fund research on making more efficient use of CRM in energy and digital applications.
Stockpiling	(1) Only a short-term solution for limited supply of CRM (2) Risks driving-up price (cost of silos and shortage)	(1) Create a network of secure storage locations. Especially the semiconductor industry may benefit from more CRM storage, as they make use of relatively small quantities of CRM. Expand private partnerships to combine private and public storage locations (see Strategic Petroleum Reserves USA). In addition, stockpile to guarantee defense production for reasons of national security.

4. Expand European leverage in the semiconductor and CRM ecosystem *vis-à-vis* other democracies

Dependence on fellow technologically advanced democracies in the CRM and semiconductor ecosystem comes with risks too.

This report has mostly focused on the risks that threaten the fragile semiconductor and CRM balance, stemming from Russia, China and the DRC. However, among technologically advanced democracies interests also diverge. Therefore, risks to the semiconductor and CRM ecosystem are also present, albeit to a much smaller extent than *vis-à-vis* China and Russia. First, de-democratization in the US best exemplified by the January 6th riots in 2021 and the looming return of a Trump-like America First figure to the Presidency in 2024 can lead to a more unilaterally-acting US again.[386] Second, Taiwan faces a realistic risk of Chinese military action against it. Third, military tensions between the US and its allies, on the one hand, and China, on the other, threaten freedom of navigation in the South China Sea and the East China Sea, even making access to Japan and South Korea no longer a given in a worst case scenario. Therefore, the EU should within the camp of technologically advanced democracies seize on opportunities to achieve an indispensable position in both the semiconductor and the CRM value chain.

4.1. Invest in CRM mitigation efforts in first and foremost Canada and Australia, but also the US, as soon as possible

These states are making the most serious gains among technologically advanced democracies to address the CRM issue. A US, Canada or Australia dominated CRM supply chain risks leaving the EU vulnerable to pressure campaigns that may not necessarily be in our interests (e.g., ASML DUV case).

386 These unilateral acts include imposing steel tariffs against the EU and the secondary sanctions on Iran blocking almost all European-Iranian trade following the US-withdrawal from the Iran-nuclear deal.

4.2. Increase the European part of the advanced democracy-dominated semiconductor and CRM ecosystem

This can be achieved through further expansion of dominance in strong sectors (automotive), in lithography equipment, and by investing in vertically integrated chip manufacturing with industries that Europe is strong in. Try to diversify away from the heavy reliance of semiconductor fabrication taking place in Taiwan. Continue to make a push for TSMC to set up a fab in Europe, as TSMC currently already does both in the US and Japan.

5. Formulate and execute a strategy to reduce dependence on China and Russia more broadly

Mitigating CRM dependence is not a silver bullet.

Mitigating dependence in the CRM for semiconductor ecosystem on China and Russia is not a silver bullet, as dependence for many end-products for purposes such as the digital and energy transition remains. Acknowledge that CRM mitigation for the semiconductor supply chain is not a silver-bullet. A broader industrial policy to protect the EU against geopolitical fracture is necessary to safeguard economic security. The fragile semiconductor and CRM balance is a limited conceptualization of just one essential layer of the global economy. This ecosystem is part of a much larger ecosystem containing a wide range of products, including electric vehicles, smartphones and defense-products. In fact, cobalt mined in the DRC, refined in China, fabricated into a semiconductor in Taiwan, is then exported to China for Foxconn to manufacture iPhones. In short, even if full mitigation of CRM-related risks could be achieved in several decades, this still leaves the world reliant on China for the production of over half a million iPhones per day and over a hundred different product categories.[387] The proposed solutions to improve the position of technologically advanced democracies in the semiconductor and CRM ecosystem could be an essential part of a larger European industrial policy, aiming to reduce dependence on China across critical sectors.[388]

5.1. The Netherlands and the EU should look for synergies between semiconductor production and large-scale efforts to mitigate dependence

Many initiatives are already starting to achieve successes. These include the construction of giga factories for battery production around Europe and the possibilities around growing demand for solar panels. 40% of China's supply of silicon for production comes from Xinjiang and is hence at risk of making use of large-scale forced labour. Both battery production for EVs and high demand for solar panels create strong demand for mining, refining and conversion, and processing of CRM, which are also needed for semiconductor production.

387 David Barboza, "How China Built 'IPhone City' With Billions in Perks for Apple's Partner," *The New York Times*, December 29, 2016, sec. Technology, https://www.nytimes.com/2016/12/29/technology/apple-iphone-china-foxconn.html.

388 Adviesraad Internationale Vraagstukken, "Slimme Industriepolitiek: een opdracht voor Nederland in de EU," publicatie (Adviesraad Internationale Vraagstukken, April 1, 2022), https://www.adviesraadinternationalevraagstukken.nl/documenten/publicaties/2022/03/18/slimme-industriepolitiek.

5.2. The Dutch government's National Security Council, announced in the Coalition Agreement of Rutte IV in January 2022, should be established as soon as possible

Taking back control over larger parts of the supply chain, if appropriate measures are taken and costs are accepted, is a political decision the Netherlands and the EU can take.

This body can make security of supply a top priority and oversee as well as coordinate the strategic dimension of all these dependencies.

5.3. Invest in strengths

Invest in strengths, in line with the advice given by ASML CEO Peter Wennink on how to compete with China: "This is what you do: relentless investment in innovation"[389]

5.4. Avoid fatalism

The world's reliance on China only came about during the last 40-years following Deng Xiaoping's political decision to reform and open-up the country. Industries largely moved to China, with its low labour costs and environmental standards, in an era driven by cost-efficiency. Taking back control over larger parts of the supply chain, if appropriate measures are taken and costs are accepted, is a political decision the Netherlands and the EU can take.

[389] NPO, "Het geheim van ASML gemist? Start met kijken op NPO Start," www.npostart.nl, accessed September 28, 2022, https://www.npostart.nl/vpro-tegenlicht/12-09-2022/VPWON_1335235.

Table 14. Overview of high-level policy implications, policy opportunities and policy recommendations

Security implication	Policy recommendation
1. Prioritise security of supply in a world in which hard competition between great powers structurally threatens European economic security, including disruptions in the near future supply of CRM.	1.1 Prepare for persistent pressure on Dutch and broader European prosperity, which will go hand-in-hand with shortages, delays in delivery of products, and constant inflationary pressure due to geopolitical fracturing.
	1.2 The 2022 Dutch Ministry for Foreign Trade and Development Cooperation (BHOS) natural resource strategy is advised to take a "worst-case-scenario" approach to preventing, mitigating, and preparing for the consequences of severe CRM supply disruptions.
	1.3 The government should engage in stress testing to identify the effects of likely and impactful CRM supply disruptions.
	1.4 Institute a top-down approach to reducing strategic dependencies, for instance through the establishment of a National Security Council and an Energy Council, an advisory body for energy affordability, robustness of the energy system and security of supply.
2. Accept that the US-China tech rivalry is likely to put the supply of semiconductors, digital end-products and products needed for the energy transition to the EU at risk.	2.1 European policy-makers are advised to anticipate that Europe's enormous strategic dependence on Washington will increasingly impel the EU to participate in the US-China tech rivalry on the side of the US.
	2.2 The Dutch government and its semiconductor companies are advised to explore new approaches to get more in return for participating in the US-led tech-showdown with China.
3. Work with other technologically advanced democracies and non-rival CRM-producing autocracies to mitigate semiconductor and CRM ecosystem risks *vis-à-vis* Russia and China.	3.1. Make use of the opportunities provided by the dominance of technologically advanced democracies in the semiconductor value chain.
	3.2. Start policy-initiatives to mitigate CRM-related dependencies and risks now to achieve results in the medium-term.
4. Expand European leverage in the semiconductor and CRM ecosystem *vis-à-vis* other democracies such as the US, Taiwan, South Korea and Japan.	4.1 Invest in CRM mitigation efforts first and foremost in Canada and Australia, but also the US, as soon as possible, as these states are making the most serious gains to address the CRM issue.
	4.2 Increase the European part of the technologically advanced democracy-dominated semiconductor ecosystem
5. Formulate and execute a strategy to reduce dependence on China and Russia more broadly.	5.1 The Netherlands and the EU should look for synergies between semiconductor production and large-scale efforts to mitigate dependence that are starting to achieve successes already.
	5.2 The Dutch government's National Security Council, announced in the Coalition Agreement of Rutte IV in January 2022, should be established as soon as possible.
	5.3 Invest in strengths, in line with the advice given by ASML CEO Peter Wennink on how to compete with China: "This is what you do: relentless investment in innovation".[390]
	5.4 Avoid fatalism. The world's reliance on China only came about in the last 40-years following Deng Xiaoping's political decision to reform and open up the country. Industries largely moved to China in an era driven by cost-efficiency. If appropriate measures are taken and costs are accepted, taking back control over larger parts of the supply chain is a political decision that the Netherlands and the EU can take.

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Annex

Appendix 1. Expert Interview List

Note: This list is not exhaustive. Only the expert and stakeholder interviewees that stated they were willing to be mentioned in the report are listed. It does contain the majority of people interviewed (17 out of 22).

1. David Bekkers, Senior Innovation, Technology & Science Officer at the Dutch Consulate in Shanghai
2. Sebastiaan Bennink, Export Control Lawyer at BenninkAmar Advocaten
3. Rutger Bosland, Project Manager Deep Sea Mining at Allseas
4. Rogier Creemers, Assistant professor in the Law and Governance of China at Leiden University
5. Tom Diederen, Dutch representative at the International Seabed Authority and Legal Council at the Ministry of Foreign Affairs (Minbuza)
6. Peter Flory, Senior Fellow and Director, at SAFE's American Semiconductor Center
7. Fergus Hunter, Analyst at the Australian Strategic Policy Institute (ASPI)'s Cyber Policy Centre
8. Muriel van der Klei, Senior Policy Advisor at the Division "Topsectoren en industriebeleid" (i.e., High-value sectors and industrial policy) at the Ministry of Economic Affairs and Climate (MinEZK)
9. Linda Lengowski, Vice-President Strategy, Geopolitics and ESG at NXP Semiconductors
10. Jonathan Miller, Director of the Indo-Pacific Program at the MacDonald Laurier Institute
11. Stephen Nagy, Senior Associate Professor at the International Christian University in Japan
12. Michel Rademaker, Deputy Director of HCSS and Subject Matter Expert on Critical Raw Materials
13. Jeff Amrish Ritoe, HCSS Subject Matter Expert on Energy & Raw Materials
14. Henne Schuwer, Former Dutch Ambassador to the United States
15. Philip Shetler-Jones, James Cook Associate Fellow in Indo-Pacific Geopolitics at the Council on Geostrategy and Japan Expert
16. Martijn Vlaskamp, Juan de la Cierva Incorporación Research Fellow at Barcelona Institute of International Studies and natural resource expert
17. Abigail Wolf, Director of the Ambassador Alfred Hoffman, Jr. Center for Critical Minerals Strategy at SAFE

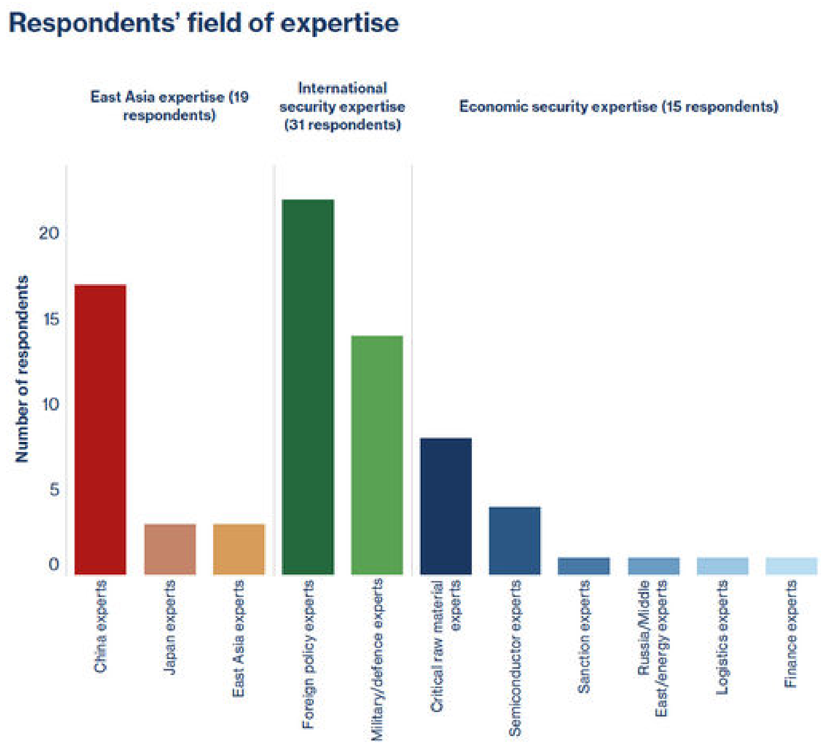
Appendix 2.
Expert Survey Respondents

Note: This list is not exhaustive. Only the participants that stated they were willing to be mentioned in the report are listed. It does contain the majority of respondents (29 out of 49).

1. Ties Dams, Research Fellow at the Clingendael Institute
2. Tom Middendorp, Former General of the Royal Netherlands Army
3. Fons Stoelinga, Former Dutch Ambassador to India
4. Ed Kronenburg, Former Dutch Ambassador to China
5. Jagannath Panda, Director Indo-Pacific ISDP in Sweden
6. Henne Schuwer, Former Dutch Ambassador to the US
7. Michel Rademaker, Deputy Director at HCSS
8. Jonathan Berkshire Miller, Senior Fellow on the Indo-Pacific at the Macdonald Laurier Institute
9. Stephen Nagy, Senior Associate Professor at the International Christian University in Japan
10. Philip Geurts, Oil analyst at BloombergNEF
11. Frank Bekkers, Program Director at HCSS
12. Tim Sweijs, Director of Research at HCSS
13. Irina Patrahau, Strategic Analyst at HCSS
14. Maurice Fremont, Former Business Europe Political Secretary at the European Parliament
15. Zsuzsa Anna Ferenczy, Assistant Professor at National Dong Hwa University
16. Valérie Hoeks, Managing Partner at China Inroads
17. Martijn Vlaskamp, Juan de la Cierva Incorporación Research Fellow at Barcelona Institute of International Studies
18. Giliam Bresser, Military Advisor at the Dutch Ministry of Foreign Affairs
19. Jeroen de Jonge, Business Director Naval and Maritime at TNO
20. Wendela Haringhuizen, Strategic Advisor Security Policy at the Dutch Ministry of Foreign Affairs
21. Josanne van Gorkum, Strategic Policy Advisor at the Dutch Ministry of Defense
22. Julian Kamasa, Senior Researcher at the Center for Security Studies
23. Tobias Gehrke, CRM Expert Research Fellow at the Egmont Institute
24. Jan van der Putten, Former China Correspondent at Volkskrant and Current China Editor at De Groene Amsterdammer
25. Benjamin Sprecher, CRM Expert and Guest Researcher at Leiden University
26. Jeff Amrish Ritoe, HCSS Subject Matter Expert on Energy and Raw Materials
27. Henk Schölte Nordholt, Professor at Leiden University
28. Paul Verhagen, HCSS Subject Matter Expert
29. Friso Stevens, HCSS China and East Asia Affairs Specialist

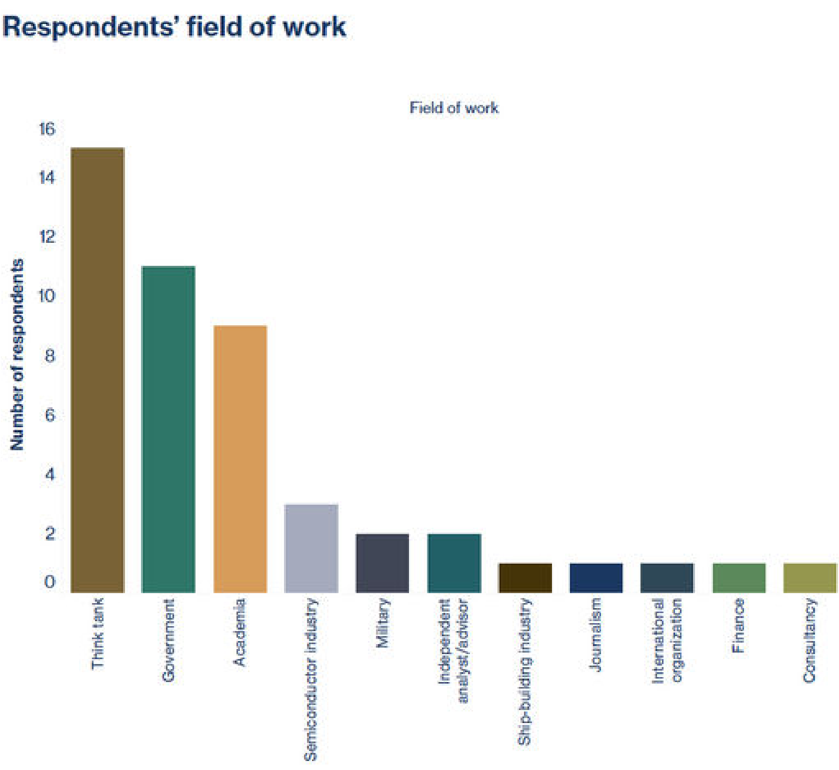
The Critical Raw Material risks for semiconductor supply foresight survey

The 49 respondents



The foresight survey was filled out by 49 experts, who were asked to choose the area(s) of knowledge that best describe(s) their expertise, their sector of current/former employment and whether their names could be mentioned in the report (without connecting their identities to their answers). The group of respondents is diverse, as it contains respondents with expertise on China, Japan, Russia, military/defense, critical raw materials, semiconductors and other topics. The respondents come from a variety of sectors of employment such as the thinktank world, government, academia, industry and the military.

The respondents have different levels of seniority: some are early/mid-career specialists whilst others are (retired) senior diplomats (e.g., former Dutch ambassadors to China, India and the United States), thinktank directors and military commanders (e.g., a former Netherlands Chief of Defence). The full list of the experts who indicated they could be mentioned as respondents (29 out of 49) can be found in the annex. The respondents are mostly Dutch nationals, but some experts from other European states, the Americas and the Indo-Pacific region also participated.



Appendix 3.
Survey Outcome – Raw Data

Overall Outcome

Geopolitical risks

Geoeconomic risks

Military risks

Legal risks

Question	Impact	Years	Probability	Total
Palladium export embargo by Russia	6,957	5	5,574	38,779
Gallium, Germanium, Cobalt REE export embargo by China	7,936	5	4,625	36,705
Demand-induced resource shortage	7,617	5	6,918	52,697
Events inside China	6,745	5	5,542	37,377
PLA naval blockade/invasion of Taiwan	8,348	5	4,313	36
Political instability in DRC	7,109	5	5,396	38,357
War in East China Sea	8,261	5	3,229	26,676
War in South China Sea	8,087	5	3,417	27,630
US blockade halting Chinese oil and gas imports	7,370	5	3,313	24,412
Stringent ESG-regulation	7,021	5	5,143	36,109
Palladium export embargo by Russia	6,957	10	5,766	40,111
Gallium, Germanium, Cobalt REE export embargo by China	7,936	10	5,979	47,452
Demand-induced resource shortage	7,617	10	7,612	57,983
Events inside China	6,745	10	5,375	36,253
PLA naval blockade/invasion of Taiwan	8,348	10	5,646	47,130
Political instability in DRC	7,109	10	6,083	43,245
War in East China Sea	8,261	10	4,271	35,281
War in South China Sea	8,087	10	4,458	36,054
US blockade halting Chinese oil and gas imports	7,370	10	3,854	28,404
Stringent ESG-regulation	7,021	10	5,551	38,975

China, Japan, East-Asia Experts

- Geopolitical risks
- Geoeconomic risks
- Military risks
- Legal risks

Question	Impact	Years	Probability	Total
Palladium export embargo by Russia	6,611	5	4,778	31,586
Gallium, Germanium, Cobalt REE export embargo by China	7,684	5	4,474	34,377
Demand-induced resource shortage	7,158	5	6,737	48,222
Events inside China	6,263	5	5,316	33,294
PLA naval blockade/invasion of Taiwan	8,684	5	3,842	33,366
Political instability in DRC	6,944	5	5,111	35,494
War in East China Sea	8,579	5	4,125	35,388
War in South China Sea	8,474	5	3,263	27,651
US blockade halting Chinese oil and gas imports	6,842	5	3,579	24,488
Stringent ESG-regulation	6,684	5	5,105	34,125
Palladium export embargo by Russia	6,611	10	5,389	35,627
Gallium, Germanium, Cobalt REE export embargo by China	7,684	10	5,684	43,679
Demand-induced resource shortage	7,158	10	7,316	52,366
Events inside China	6,263	10	5,211	32,634
PLA naval blockade/invasion of Taiwan	8,684	10	4,789	41,593
Political instability in DRC	6,944	10	5,778	40,123
War in East China Sea	8,579	10	3,947	33,864
War in South China Sea	8,474	10	4,158	35,233
US blockade halting Chinese oil and gas imports	6,842	10	3,632	24,848
Stringent ESG-regulation	6,684	10	5,684	37,994

International Security Experts

Geopolitical risks

Geoeconomic risks

Military risks

Legal risks

Question	Impact	Years	Probability	Total
Palladium export embargo by Russia	7,207	5	5,633	40,599
Gallium, Germanium, Cobalt REE export embargo by China	7,931	5	4,667	37,011
Demand-induced resource shortage	7,759	5	7,065	54,811
Events inside China	6,966	5	5,600	39,007
PLA naval blockade/invasion of Taiwan	8,464	5	4,333	36,679
Political instability in DRC	7,379	5	5,452	40,229
War in East China Sea	8,250	5	2,933	24,200
War in South China Sea	8,286	5	3,200	26,514
US blockade halting Chinese oil and gas imports	7,321	5	2,967	21,720
Stringent ESG-regulation	6,793	5	5,258	35,719
Palladium export embargo by Russia	7,207	10	5,967	43,001
Gallium, Germanium, Cobalt REE export embargo by China	7,931	10	6,000	47,586
Demand-induced resource shortage	7,759	10	7,710	59,816
Events inside China	6,966	10	5,467	38,078
PLA naval blockade/invasion of Taiwan	8,464	10	5,667	47,964
Political instability in DRC	7,379	10	6,355	46,894
War in East China Sea	8,250	10	3,867	31,900
War in South China Sea	8,286	10	4,357	36,102
US blockade halting Chinese oil and gas imports	7,321	10	3,857	28,240
Stringent ESG-regulation	6,793	10	4,867	33,060

Economic Security Experts

Geopolitical risks

Geoeconomic risks

Military risks

Legal risks

Question	Impact	Years	Probability	Total
Palladium export embargo by Russia	6,929	5	5,154	35,709
Gallium, Germanium, Cobalt REE export embargo by China	8,533	5	4,643	39,619
Demand-induced resource shortage	7,400	5	6,733	49,827
Events inside China	7,133	5	6,000	42,800
PLA naval blockade/invasion of Taiwan	8,214	5	3,786	31,097
Political instability in DRC	7,286	5	5,214	37,990
War in East China Sea	8,143	5	3,357	27,337
War in South China Sea	7,714	5	3,357	25,898
US blockade halting Chinese oil and gas imports	7,000	5	3,857	27,000
Stringent ESG-regulation	7,600	5	4,400	33,440
Palladium export embargo by Russia	6,929	10	4,615	31,978
Gallium, Germanium, Cobalt REE export embargo by China	8,533	10	6,214	53,029
Demand-induced resource shortage	7,400	10	7,600	56,240
Events inside China	7,133	10	5,500	39,233
PLA naval blockade/invasion of Taiwan	8,214	10	5,143	42,245
Political instability in DRC	7,286	10	6,214	45,276
War in East China Sea	8,143	10	4,286	34,898
War in South China Sea	7,714	10	4,357	33,612
US blockade halting Chinese oil and gas imports	7,000	10	3,857	27,000
Stringent ESG-regulation	7,600	10	4,867	36,987

Raw Data

	Geopolitical risks						Geoeconomic risks						Legal risks		
Respondent #	Probability 5: Palladium export embargo by Russia	Probability 10: Palladium export embargo by Russia	Impact: Palladium export embargo by Russia	Probability 5: Gallium, Germanium, Cobalt REE export embargo by China	Probability 10: Gallium, Germanium, Cobalt REE export embargo by China	Impact: Gallium, Germanium, Cobalt REE export embargo by China	Probability 5: Demand-induced resource shortage	Probability 10: Demand-induced resource shortage	Impact: Demand-induced resource shortage	Probability 5: Events inside China	Probability 10: Events inside China	Impact: Events inside China	Probability 5: Stringent ESG-regulation	Probability 10: Stringent ESG-regulation	Impact: Stringent ESG-regulation
1	5	5	3	3	3	7	8	8	3	3	3	3	3	3	3
2	4	5	5	1	2	7	6	8	7	5	3	5	3	4	3
3	2	3	6	2	4	8	7	7	6	8	5	7	6	6	7
4	7	7	7	7	7	7	7	7	7	5	7	7	6	6	8
5	7	7	9	6	7	9	7	9	9	5	6	8	7	8	8
6	2	2	3	3	4	7	8	8	8	3	2	2	2	2	7
7	3	4		2	3		6	6		2	2		2	2	
8	8	8		5	5		9	9		5	5		7	7	
9	3	3	5	6	9	8	3	8	9	9	9	9	5	5	9
10	8	9	8	5	6	8	6	7	8	5	7	8	7	8	6
11	2	2	7	2	3	8	8	9	9	10	10	4	3	5	6
12	8	7	8	6	7	9	9	8	6	8	7	8	6	6	6
13	8	4	7	3	5	8	8	9	7	5	5	8	0	0	7
14	7	8	10	5	7	9	8	8	10	4	7	7	6	5	8
15	2	3	4	3	7	10	6	6	4	2	3	7	2	5	7
16	5	5	7	3	4	8	6	7	8	7	6	8	7	6	6
17	4	3	8	5	7	8	5	8	8	4	3	8	3	3	6
18	3	5	8	4	5	8	6	7	7	4	3	3	7	8	8
19	6	6	7	6	6	7	6	6	7	7	7	6	4	2	8
20	7	7	6	3	4	7	9	10	9	3	3	5	4	5	7
21	4	8	7	3	6	9	10	10	10	7	2	8	10	7	9
22	3	2	2	2	3	4	4	5	4	0	0	0	2	2	3
23	6	7	8	5	8	8	8	7	7	6	6	6	8	8	6
24	5	7	8	6	8	9	7	8	9	7	7	8	4	5	9

	Geopolitical risks						Geoeconomic risks						Legal risks		
Respondent #	Probability 5: Palladium export embargo by Russia	Probability 10: Palladium export embargo by Russia	Impact: Palladium export embargo by Russia	Probability 5: Gallium, Germanium, Cobalt REE export embargo by China	Probability 10: Gallium, Germanium, Cobalt REE export embargo by China	Impact: Gallium, Germanium, Cobalt REE export embargo by China	Probability 5: Demand-induced resource shortage	Probability 10: Demand-induced resource shortage	Impact: Demand-induced resource shortage	Probability 5: Events inside China	Probability 10: Events inside China	Impact: Events inside China	Probability 5: Stringent ESG-regulation	Probability 10: Stringent ESG-regulation	Impact: Stringent ESG-regulation
25	8	8	8	6	7	7	7	7	7	8	8	8	8	7	7
26	7	9	4	4	5	8	8	7	9	4	3	7	7	7	8
27	8	9	9	8	8	8	8	8	9	9	9	8	8	8	8
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30	4	2	4	2	4	7	7	9	8	5	8	8	2	4	7
31	8	8	9	5	8	8	5	8	8	7	5	8	8	9	8
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45	5	5	5	6	7	7	5	5	5	6	6	6	8	9	5
46	1	7	9	6	8	7	7	7	8	4	4	4	1	1	2
47	8	7	5	7	8	8	7	6	6	7	7	7	3	5	5
48	5	5	9	7	7	9	8	8	9	8	8	9	4	4	9
49	6	4	10	3	3	9	7	7	8	9	9	9	9	9	10

	Military risks														
Respondent #	Probability 5: PLA naval blockade/ invasion of Taiwan	Probability 10: PLA naval blockade/ invasion of Taiwan	Impact: PLA naval blockade/ invasion of Taiwan	Probability 5: Political instability in DRC	Probability 10: Political instability in DRC	Impact: Political instability in DRC	Probability 5: War in East China Sea	Probability 10: War in East China Sea	Impact: War in East China Sea	Probability 5: War in South China Sea	Probability 10: War in South China Sea	Impact: War in South China Sea	Probability 5: US blockade halting Chinese oil and gas imports	Probability 10: US blockade halting Chinese oil and gas imports	Impact: US blockade halting Chinese oil and gas imports
1	4	5	3	3	3	3	3	6	3	4	5	3	3	3	3
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3	3	5	8	8	9	7	2	2	5	3	3	6	3	3	8
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15	1	3	10	4	8	6	1	1	10	1	1	10	2	3	2
16	4	5	9	7	7	6	4	5	8	5	6	8	3	4	8
17	1	2	8	6	7	9	1	2	8	1	2	7	1	1	2
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23	3	6	10	6	7	6	1	3	9	2	4	8	1	1	7
24	6	8	9	3	4	7	1	2	9	2	3	10	2	4	8

	Military risks														
Respondent #	Probability 5: PLA naval blockade/ invasion of Taiwan	Probability 10: PLA naval blockade/ invasion of Taiwan	Impact: PLA naval blockade/ invasion of Taiwan	Probability 5: Political instability in DRC	Probability 10: Political instability in DRC	Impact: Political instability in DRC	Probability 5: War in East China Sea	Probability 10: War in East China Sea	Impact: War in East China Sea	Probability 5: War in South China Sea	Probability 10: War in South China Sea	Impact: War in South China Sea	Probability 5: US blockade halting Chinese oil and gas imports	Probability 10: US blockade halting Chinese oil and gas imports	Impact: US blockade halting Chinese oil and gas imports
25	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
26	6	7	9	5	5	7	3	4	8	3	4	8	3	4	8
27	8	8	9	7	7	8	6	6	8	8	8	8	8	8	8
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36	5	8	8	6	8	7	4	6	6	5	7	8	7	5	7
37	4	5	8	6	5	7	8	6	8	6	7	9	6	5	8
38	8	9	9	5	5	5	5	8	9	6	9	9	3	7	9
39				7	8	8									
40	1	5	8	6	7	8	1	2	8	1	2	8	1	1	8
41	3	7	10	8	8	6	2	6	10	2	6	10	2	6	9
42	6	7	10				6	7	10	6	7	10	6	6	8
43	2	2	8	8	8	9	0	0	9	0	0	9	2	2	8
44	3	4	7	6	7	6	4	5	7	3	4	6	3	5	6
45	2	3	10	5	5	5	2	3	8	2	3	8	1	2	8
46	0	0	9	3	3	8	0	0	8	0	0	9	1	1	9
47	7	8	7	6	6	6	4	6	7	7	7	6	6	6	6
48	6	8	8	8	8	9	8	8	9	8	8	9	6	6	9
49	2	1	10	5	5	8	1	1	10	3	4	10	8	1	9

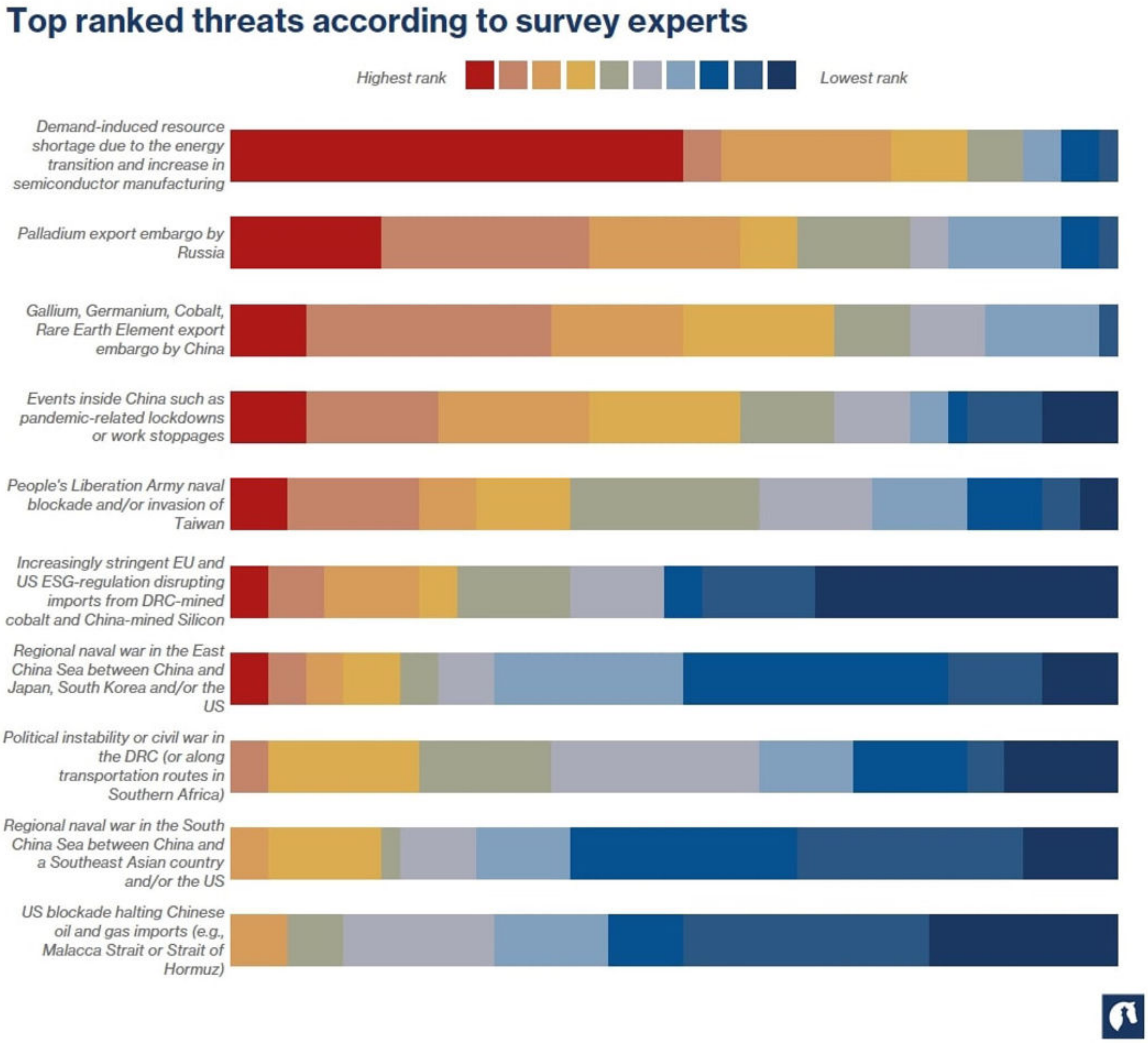
Appendix 4.

Answers to additional questions

Question A: If a particular threat was not listed in the previous question but would make your top 3 threats, please use the question box below to add:

Most important is the complete ownership of value chains. That is in most of the value chain already the case with China
natural disaster
Supply-induced shortage of CRM due to Chinese ESG-regulation
mercantilisation of free trade; end to free trade: decoupling and geopoliticalisation of supply chain security in CRM leading to supply chain interruptions and structural shortages
Globalisation will not stop, but the globalised world will be compartmentlised: if the West with its sanctions will -continue to- threat vital economic interests of CRM exporting nations (mainly Russia and China) these countries will retaliate with embargos on their CRM exports to the West. That is the biggest threat.
Increasing political securitization of the semiconductor supply chain leading to breakdown of integrated supply chains.
Magnesium
Ukraine (two Ukrainian companies, Ingas in Mariupol and Cryoin) produces about 45-55% of the global supply of neon used in semiconductor manufacturing. With the uncertainty caused by the war, in addition to the challenges in the post-pandemic recovery context, this can become a major threat on the output of chips, both short- and medium-term - not suggesting it to be a top threat, but given the high uncertainty of the outcome of Russia's invasion, it deserves more attention.
Good blockade due to use of Forced and Prison Labor in China and Southeast Asia
Other weaponised interdependence like blockage of CRM exports from Ukraine
Chinese standards
The Ukraine-RF conflict
Steel supply for vessel building in the Netherlands. China intentionally raise the prices of steel and we are dependent on Ukraine steel. shipbuilding industry in Europe will disappear because of this dependence on Chinees steel for vessel building.
Political ignorance about this issue while dealing with an accelleration in electrification of our societies induced by the Ukrainian crisis
These are mostly overt, aggressive moves. China doesn't prefer that. China creates dominance, economic leverage below the radar.
Booming demand because of doubling world population + regional frictions around access to minerals
Russia sanctions fall out causing disruption
North Korea nuclear threat
Most relevant threats are listed
return of Trump
sourcing of skilled labour ex China to set up a European / US supply chain for critical raw materials needed for semiconductor supply chain
C4F6 from Russia and Rare gas from Ukraine

Question B: Which of the below scenarios are, in your opinion, the most important threats to the supply of CRM needed for the semiconductor value chain in the next 10 years



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