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US Critical Mineral Supply Chain Vulnerabilities

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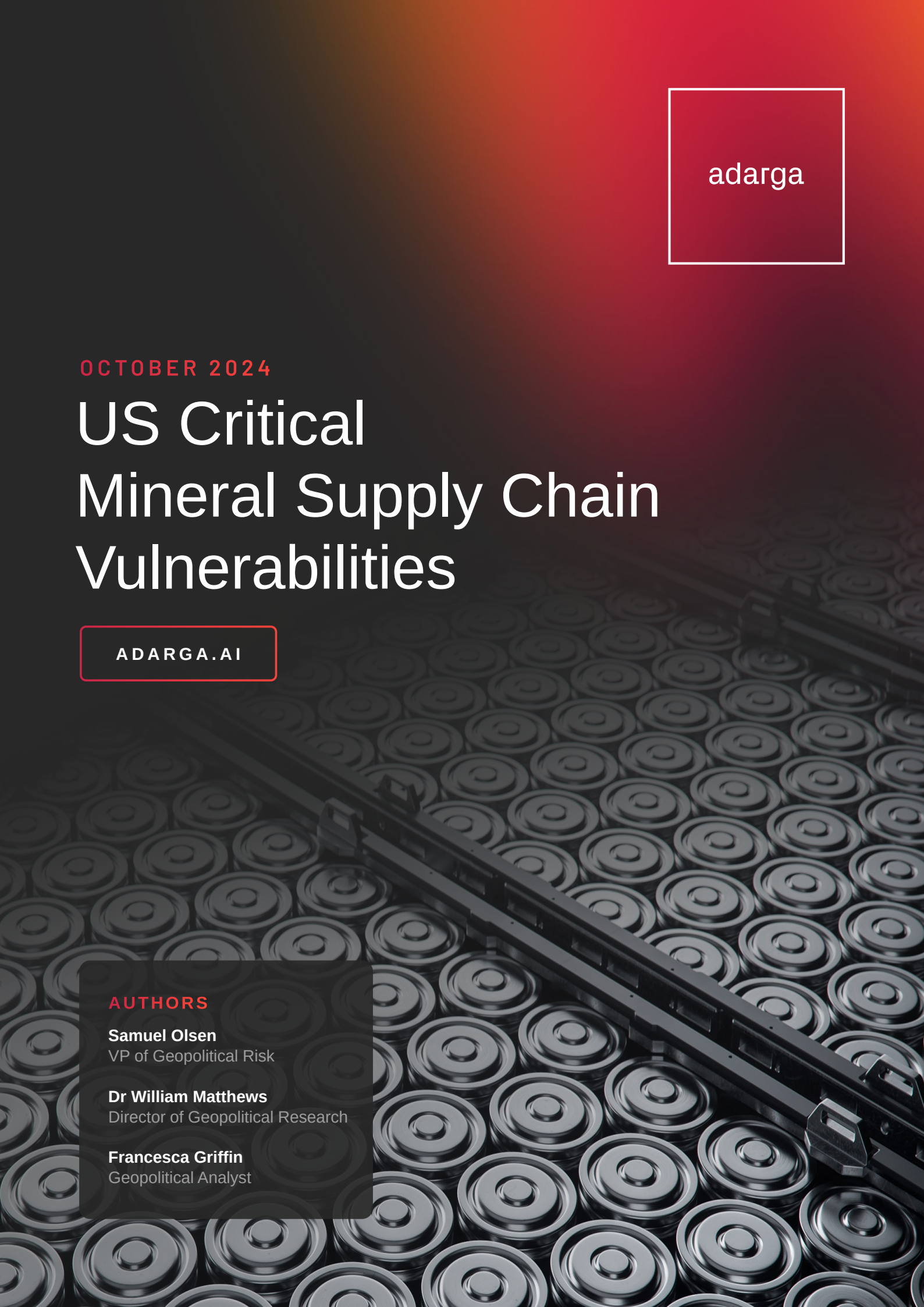

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About Adarga

Adarga is a leader in AI-driven information intelligence for defense, national security, and commercial organizations.

Our team includes geopolitical and geoeconomic experts who are dedicated to delivering in-depth analysis that is enriched by our AI software and proprietary data models. This research report was supported by Adarga Vantage, which is designed to increase the quality, speed, and breadth of intelligence outputs through cutting-edge AI tools to derive key insights from huge volumes of information.

01.
Report Summary

This report reveals the extent of supply chain vulnerability for three critical minerals: **cobalt, copper,** and **nickel**. We use Adarga's **Supply Chain Vulnerability Index (SCVI)** to measure and understand these vulnerabilities, both from a global perspective, and from a US perspective.

Adarga's SCVI scores reveal that the global nickel supply chain is substantially vulnerable to disruption (with a score of 3.75 / 5.00, where 5.00 is the most vulnerable). The vulnerability of the global copper supply chain is only moderate (2.08 / 5.00).

From a US perspective this vulnerability increases for nickel and copper, stemming from the deep involvement of Chinese companies across the supply chains of these metals. The US National Score is severe for nickel (4.13), and substantial for copper (3.58).

The situation for cobalt is slightly different. The global cobalt supply chain is severely vulnerable to disruption, with a score of 4.25 / 5.00, because of the dominance of the Democratic Republic of Congo over reserves and mine production, and China over cobalt refining. However, the US sources most of its cobalt from allied nations such as Norway and Finland, and so the US National Score is currently low at 1.56 / 5.00. Due to the opacity of the market, it is unclear to what degree, if any, these allies rely on China or China-dominated supply chains for this cobalt in the first place. In addition, if US cobalt consumption increases, as expected, then it is likely to draw more on Chinese-controlled supply chains and so increase its risk.

The vulnerability of these supply chains to geopolitical interruption creates a potential threat for the US. China has developed mechanisms for export restrictions that can enable its strong position in mineral supply chains to be used as a weapon. Even if Beijing does not restrict the supply, it can (and does) use its weight to manipulate the price of commodities, which can have serious ramifications for the US and its allies.

Moreover, a severe degree of vulnerability indicates a significant obstacle to reshoring efforts; capacity is concentrated in the hands of a single country and structured in the interests of that country, meaning that alternatives often need to be created from a low starting point. In addition, China's outsized presence in these supply chains makes them vulnerable to domestic events in China (such as lockdown policies or natural disasters affecting production), quite apart from active manipulation in the context of China-US strategic rivalry.

One way to reduce this vulnerability is through ally-shoring. The US' vulnerability to China could in theory substantially decrease if it was able to bring its allies together to better protect their supply chains. Efforts in this are already being made, for example with the US-led Mineral Security Partnership, but more is needed.

Our research shows that although the US is not a major player in the supply chains of the metals analyzed in this paper, some of its allies are. If a proper ally-shoring framework was created for these and other critical minerals, then this would generate two benefits. First, the US would have less strategic vulnerability in these minerals; second, the combined weight of a properly coordinated ally-shoring framework would act as a counterbalance to China, and restrict its ability to manipulate the market.

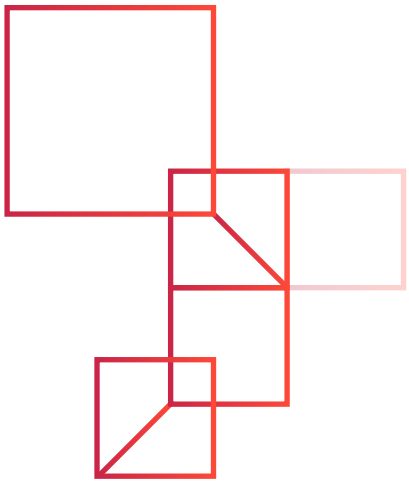
Ally-shoring is, however, difficult in practice: it requires thorough data analysis of trade flows that are not always transparent, and the ability to politically and economically coordinate a response that provides equal benefits to all the allies.

This requires comprehensive understanding of the supply chain vulnerabilities of allies and other key partners as well as that of the US. It also demands clarity on China's structural influence over the different supply chains and the countries and companies involved, which is made harder by opacity surrounding Beijing's actions.

Availability of company-level data likewise presents an obstacle; this report highlights how, when available, such information provides vital context for geopolitical risk analysis not discernible by trade data alone.

This report aims to show how the use of the SCVI can actively support the discussions about supply chain vulnerability and help steer the response.

02.
Introduction



Critical minerals are elements crucial to modern day technologies, including the renewable energy transition, semiconductor manufacturing, and the defense and aerospace industries. Given their importance, being able to control the value chains of these minerals could in theory give a country a significant strategic advantage.

According to the US Geological Survey, there are 50 critical minerals, plus another list of 18 specific to the energy industry, ranging from aluminum and antimony to zinc and zirconium. These lists include all the rare earths too. What these minerals have in common, aside from their criticality to technologies, is that their restricted value chains make them more vulnerable to supply chain disruption than major commodities such as coal or iron.

2.1
China's Dominance of Critical Minerals

Inconveniently for the US, it is China that has the strongest influence on the supply chain of many of these minerals. Although it is unclear if this is a deliberate policy for all of these elements, it is worth noting that its control of rare earths, for instance, was deliberate: Deng Xiaoping, the then leader of China, said in 1987 that "the Middle East has oil, China has rare earths".[1] Since then the country has developed a near monopoly on the production of rare earths, processing around 90% of global output.[2]

Beijing's influence extends across the supply chain. Upstream, nine out of the top fifty mining companies are Chinese.[3] The PRC also has a significant advantage at the midstream stage – where metals and other minerals are used in components – as the country is responsible for around a third of total manufacturing production.[4] This is more than the US, Japan, Germany, and the UK combined.

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China's control of critical mineral supply chains presents a potential threat to the US and its allies because Beijing has a track record of using this control as a strategic weapon. Research by the Organisation for Economic Co-operation and Development (OECD) reveals that between 2009 and 2020 Beijing increased the number of export restrictions on critical minerals by a factor of nine, to become the country with the most amount of restrictions in the world (accounting for a fifth of the total).[5] This is in line with statements made by Beijing about the need for critical mineral security, such as a press release by the Ministry of State Security in 2023.[6]

These restrictions – in the form of the introduction of export licenses – give Beijing the option to restrict exports. Although they have not often done so, there are exceptions, including the control of rare earths to Japan in 2010, export restrictions on gallium and germanium in response to US-led tech controls on semiconductor technology in 2023, and unannounced restrictions on exports of graphite (another critical mineral) imposed on Sweden starting around 2020.[7] [8] That the last appears to have been lifted, again without explanation, is indicative of China's potentially disruptive approach to critical mineral trade. Even where there is not a deliberate policy on the interruption of critical mineral flows, the fact that there are bottlenecks in supply around China presents risks of non-deliberate supply chain disruption.

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2.2
About this Report

In this document we examine the geopolitical vulnerability of three critical minerals (cobalt, copper, and nickel) using Adarga's proprietary Supply Chain Vulnerability Index. The vulnerability is analyzed at both the global level and at the US national level. We then root this analysis in the concept of ally-shoring – the process by which countries rework critical supply chains so that they are held by trusted allies and partners (in this case, allies of the US).

03.
Project Scope & Methodology

3.1
About the Supply Chain Vulnerability Index

Adarga has developed a methodology for examining the exposure of supply chains in general to geopolitical disruption. We have used this methodology – the Supply Chain Vulnerability Index (SCVI) – to examine how vulnerable three critical minerals are to disruption. A high score in the index reflects the elevated potential for disruption.

This disruption might be caused by events such as conflict or the deliberate restriction of supply chain flows, as well as to other phenomena such as natural disasters.

In this report we will focus on the vulnerabilities of three critical mineral supply chains to geopolitical tensions:

The Supply Chain Vulnerability Index uses two types of score, one global and one national. Both use a scale from 0.0 (least vulnerable to disruption) to 5.0 (most vulnerable to disruption).

COBALT
Used in many critical industrial and military technologies, the leading use for cobalt is in rechargeable battery electrodes such as for electric vehicles.

COPPER
The third most used industrial metal (after iron and aluminum) because of its high electrical conductivity and natural resistance to corrosion, copper is vital for almost all technologies.

NICKEL
Although 65% of nickel is used for stainless steel, its ability to improve storage capacity at low cost has been instrumental in developing modern battery technology.[9]

GLOBAL SUPPLY CHAIN VULNERABILITY SCORE

This describes how vulnerable the global supply chains of cobalt, copper, and nickel are to disruption. The calculations include analysis on the reserves for each, as well as mine production data, and where possible, refining data.[10] [11]

NATIONAL SUPPLY CHAIN VULNERABILITY SCORE

The National Score describes how vulnerable a particular country's supply chain is to disruption (including geopolitical disruption) from the perspective of that country. In this report we have calculated the National Scores for the US to show how vulnerable its access to cobalt, copper, and nickel is to disruptions – for example because of geopolitical action by China.

3.2
The SCVI and Ally-Shoring

Adarga is a thought leader on ally-shoring, a concept developed by Elaine Dezenski at the Foundation for Defense of Democracies and John Austin, non-resident fellow at the Brookings Institution. For the purposes of this report, we have used a strategic list of different geopolitical alignments to establish parameters for the vulnerability of US supply chains. These three geopolitical alignments are as follows:[12]

- US & Allies. These are countries that are official treaty allies of the US, including all NATO countries, plus nineteen Major Non-NATO Allies (MNNAs). This includes various countries which play key roles in the cobalt, copper, and nickel supply chains such as Australia, Brazil, Canada, and the Philippines.

- Counter Aligned Countries. This includes countries considered to be adversaries by the US, and which are actively seeking to disrupt or transform the US-led international order through strategic alignment with one another against US interests. This includes China, Russia, Iran, and North Korea, alongside countries which consistently align politically against the US (such as Cuba and Venezuela).

- Unaligned Countries. This comprises countries which do not fit into the above two categories. Note that it is distinct from the 'Non-aligned Movement' and includes countries which pursue partnerships with both the US and China, such as Saudi Arabia. An important example in the nickel supply chain is Indonesia.

Note that this classification is necessarily broad; it is intended to reflect the priorities of the country whose supply chains are being analyzed (here the US). It is assumed that formal allies of the US are more likely to cooperate with the US in aligning supply chains than other countries.

04.
Supply Chain Vulnerability Index Findings by Critical Mineral

4.1
Findings Summaries

4.1.1
Global Supply Chain Vulnerability Analysis

The **Global SCVI** scores for the three minerals present a picture of differing levels of vulnerability in their supply chains. Cobalt is the most vulnerable as it has two distinct bottlenecks. Reserves (55% of the global total, 2023 figures) and mine production (74%) are located in the Democratic Republic of Congo; and cobalt refining is mainly centered on China (76%). The overall Global Score for cobalt of 4.25 / 5.00 shows severe vulnerability. The Global Scores are informed by US Geological Survey data.

Nickel is also vulnerable, although not quite as much as cobalt. Indonesia dominates its reserves (42%) and mine production (50%) but not quite to the same extent as the DRC dominates the cobalt supply chain. There are also substantial reserves in Australia and Brazil, and strong mine production in the Philippines and several other countries. The Global Score for nickel of 3.75 / 5.00 reflects that there is substantial vulnerability, but it is less than cobalt.

Copper is of the least concern, with a widespread holding of reserves and mine production. Chile has the most reserves (19%) with many countries having less than 10%. This picture is mirrored in mine production. There is though a distinct concentration of copper refining in China, which has 44% of the global market. The Global Score of 2.08 indicates moderate vulnerability in the copper supply chain.

	Cobalt	Copper	Nickel
Global Supply Chain Vulnerability Score	4.25 / 5.00	2.08 / 5.00	3.75 / 5.00
US National Supply Chain Vulnerability Score	1.56 / 5.00	3.58 / 5.00	4.13 / 5.00

4.1.2
US National Supply Chain Vulnerability Analysis

The SCVI analysis reveals that the country's potential access to nickel is severely vulnerable, with a National Score of 4.13 / 5.00. The figure is higher than the Global Score, reflecting the level of control that China and fellow Counter Aligned Countries have over the mineral's supply chains at both the national and company level. US access to copper is of substantial vulnerability (3.58 / 5.00), again mainly because of major Chinese presence in the supply chain. However, US access to cobalt is less vulnerable, with a score of 1.56 / 5.00. This lower figure is due to diverse import origins, in particular from allied nations. The score is however likely to change if US cobalt demand increases, for example through the expansion of domestic EV battery manufacturing.

If we expand the scope to look at US Treaty Allies then the picture is better, but not by much.

4.2 Cobalt

Global Supply Chain Vulnerability Score:	4.25 / 5.00
US National Supply Chain Vulnerability Score:	1.56 / 5.00

4.2.1 Cobalt Global Supply Chain Vulnerability Score Analysis

COBALT RESERVES

According to the US Geological Survey, more than half (55%) of all reserves of cobalt are found in the Democratic Republic of Congo (DRC), with 15% in Australia, and the rest in small amounts in other countries.[13]

Almost all cobalt is mined as a by-product of other metal mining. 60% of the global cobalt supply is from copper mining, 38% from nickel mining, and only 2% from direct cobalt mining.[14]

COBALT MINE PRODUCTION

In terms of production, the DRC is responsible for 70% of output and will continue to be a major player for some time to come, unless alternative reserves are found and developed.[15]

The country with the second highest cobalt production is Indonesia (7% in 2023). Production there has surged in the last few years because of the construction of new cobalt refining facilities, a result of the 2019 ban on the export of raw nickel which saw Chinese firms invest heavily in the country's battery metals supply chain.[16] Reports indicate that Indonesia has the potential to increase its cobalt output tenfold by 2030, and it is likely that Chinese investment will be involved in this growth.[17]

In third place for cobalt output is Russia, with just less than 4% share. Output is mainly from the company Norilsk Nickel, which is among the top five producers of the mineral. Note that the US and UK have placed sanctions on Russian cobalt following the invasion of Ukraine, although the EU has not.[18] [19]

COBALT REFINING

Most cobalt is refined during the refinement of copper and nickel. China is the biggest refiner, accounting for 76% of global refined production (2022), followed by Finland (10%), Canada (4%), and Norway (2%).[20]

THE GLOBAL VULNERABILITY SCORE FOR COBALT

The Global Vulnerability Score for cobalt is 4.25 / 5.00, reflecting its high concentration at the extraction and refining stages of the supply chain. This makes the cobalt supply chain highly vulnerable to disruption. At extraction, the current quasi-monopoly of the DRC increases the vulnerability of the supply chains, as few known alternative reserves exist. Additionally, the refining bottleneck in China is particularly significant in the context of China-US geoeconomic competition due to the leverage it could grant China over the supply chain.

4.2.2 The US Vulnerability Score for Cobalt

The US National Score is lower than the Global Score because it has a diverse range of cobalt import partners.[21] These imports are primarily in the form of cobalt metal for superalloys used in the aerospace and defense industries (50%), chemical applications (25%), metallic applications (15%) and other purposes (10%). From 2019-2022, the US imported cobalt metal, oxides, and salts from: Norway (25%), Canada (15%), Finland (13%), Japan (12%) and others (35%).[22] China accounts for only 1.69% of US cobalt imports in 2022 in the two categories analyzed.

This import data suggests that China's role in direct imports to the US is minimal. However, further

upstream, data on the flows of raw cobalt is difficult to accurately assess. Standard sources of trade data such as UN Comtrade and IMF World Integrated Trade Statistics (WITS) do not provide full coverage of cobalt exports from the DRC and Indonesia, the two largest producers of raw cobalt.

While Norway and Finland process a large amount of cobalt, 2021 data suggests that the amount of refined cobalt produced by Finnish and Norwegian smelters significantly exceeded that derived from Finnish and/or Norwegian mines. Umicore, a Belgian company which operates cobalt smelters in Finland, reported that 75% of its cobalt inputs to its European operations originated in the DRC.[23] UNComtrade data, meanwhile, indicates significant Finnish imports of cobalt ore from Austria, where mining operations exist, as reflected in a study by the British Geological Survey.[24] [25]

The Observatory of Economic Complexity (OEC) records DRC cobalt exports of USD5.99 billion in 2022, 96% of which went to China; most of the remainder is accounted for by Singapore, South Korea, and the UAE.[26] UN Comtrade data for 2023 indicates that 58% of China's cobalt oxide and hydroxide exports go to South Korea, and 10% to Belgium. Only around 1% go to the US, but other European countries such as the Netherlands and Spain also import from China. At the same time, OECD data for 2023 indicates that some of the top importers of cobalt oxides and hydroxides are South Korea (USD247 million), and Finland (USD158 million).

Taken together, this suggests that the US is not currently vulnerable to China via direct imports, but there is opacity regarding the cobalt supply chain within Europe. Chinese exports to Belgium, the Netherlands, and Spain are likely to rely on cobalt from the DRC, where China Molybdenum Company (CMOC) is the largest cobalt producer, accounting for 30% of the global market by production volume. It is unclear whether any cobalt refined in Norway, Finland and elsewhere originates in the DRC.[27]

The variable nature of coverage brings home the importance of supply chain transparency and efforts to achieve it. It is not clear from the available data to what extent European refined cobalt production relies on the DRC upstream. Mapping this complexity for cobalt and other minerals should be a priority as part of ally-shoring policies.

This is especially important given the US' investments so far of USD92 billion in building a domestic battery supply chain.[28] The US company EVelution Energy estimates that this will result in massively increased US demand for imports of cobalt metal (11 thousand tonnes per year) and cobalt hydroxide and cobalt sulfate (35 thousand tonnes contained cobalt per year). This could dramatically change the picture given by the current SCVI score, and result in ongoing dependency on cobalt from the DRC.

4.2.3
The Geopolitics of Cobalt from a US & Allies Perspective

The majority of cobalt reserves are held by Unaligned Countries, although US allies (especially Australia) hold about a fifth of the global total.

	Cobalt (2023)		
Geopolitical Alignment	**Reserves**	**Mine Production**	**Refining**
US & Allies	21%	7%	22%
Counter Aligned Countries	7%	5%	76%
Unaligned Countries	60%	84%	1%

Cobalt Reserves (2023) by Geopolitical Alignment

Cobalt mine production is even more heavily weighted towards Unaligned Countries (84% of the global total) with China and the Counter Aligned Countries controlling just 5%; 7% is produced by the US & Allies.

The DRC is the most important of the Unaligned Countries for cobalt reserves and mine production. It is thus not surprisingly the scene of intense geopolitical rivalry in the mining sector. Around 80% of the country's cobalt is mined by Chinese companies like CMOC and Sicomines.[30] [31] [32] However, the new President, Felix Tshisekedi, is pushing back on many of the deals that the former President Joseph Kabila signed with them.[33] At the same time, Western pressure is increasing under the auspices of the US-led Mineral Security Partnership (MSP), a grouping of 14 advanced economy countries.[34] In February 2024 the MSP announced a collaboration deal between the DRC state-owned company GECAMINES and the Japanese firm JOGMEC in minerals exploration, production, and processing with specific focus on cobalt and copper.[35]

Cobalt Mine Production (2023) by Geopolitical Alignment

Although Unaligned Countries, mainly the DRC, control cobalt reserves and mine production it is a different story with cobalt refining. China and Counter Aligned Countries are responsible for the majority of output (76%), compared to the 22% for the US & Allies. Unaligned Countries barely feature. There are initiatives to counter China's hold here, for example the launch of a cobalt processing facility in Arizona by the US firm EVelution Energy.[36]

Cobalt Refining (2023) by Geopolitical Alignment

4.3 Copper

Global Supply Chain Vulnerability Score:	2.08 / 5.00
US National Supply Chain Vulnerability Score:	3.58 / 5.00[37]

4.3.1 Global Supply Chain Vulnerability Score Analysis

COPPER RESERVES

Copper is an abundant mineral, with plentiful reserves and estimated identified resources numbering 2.1 billion tons.[38] Reserves of copper are also relatively well diversified. The largest known (19% of the global total) are in Chile, followed by Peru (12%) and Australia (10%).

COPPER REFINING

China dominates copper refining (2023 figures), with 44% of the market, followed by Chile and the Democratic Republic of Congo (both 7%).[40] Beijing is currently building out its copper refining capacity, with 12 expansion or construction projects scheduled for completion from 2023 to 2026.[41] There are though recent signs of oversupply there, with copper stockpiles in Shanghai Futures Exchange warehouses having grown to their highest levels since 2020 following stagnant demand and a rise in the price of copper.[42]

COPPER MINE PRODUCTION

World copper production has grown since 2020, with refined copper output climbing from 24.66 million metric tons in 2020 to 27.63 million metric tons in 2023.[39] 23% of mine production comes from Chile, followed by Peru (12%) and the DRC (11%).

THE GLOBAL VULNERABILITY SCORE FOR COPPER

The relative ubiquity of copper means that its supply chain is less vulnerable. There is more of a challenge with refining given China's dominance, but these operations mainly service the domestic China market. If the Chinese market is able to absorb this production, then this is unlikely to prove a potential source of leverage for China amid geopolitical tensions with the US and its allies. However, if oversupply is a problem and the Chinese market cannot absorb production, this could lead to China exporting it and thus creating leverage over importer countries. Ultimately, this depends on whether global production exceeds or falls short of global demand, and whether China offers lower prices to encourage trade partners to favor it over other producers.

4.3.2 The US Vulnerability Score for Copper

The US does not rely on China or the other Counter Aligned Countries for reserves of copper, nor in mine production where the US and Australia combined produce more than China. In terms of imports, the US receives more than 90% of its copper ores (HS-6 code 260300) from Canada, which holds just 1% of worldwide reserves.[43] UN Comtrade data indicates that 80% of US imports of refined copper come from Japan, which accounts for 6% of global refinery production. Both of these flows are vulnerable because of concentration, but at least these countries are close US allies.

At the company level, only one out of the top 10 copper miners is from a Counter Aligned Country, and that is Norilsk Nickel from Russia, lying in tenth place.[44] Six are headquartered in the US, Australia, UK, Poland, or Canada, with the other three in Switzerland, Chile, and Mexico. Where China does have a strong grip is in refining; together with Russia, they control almost half of global refinery output. Even though the US does not have direct major exposure to China in copper, this refining dominance does have an impact on the US. In March 2024 Chinese copper refiners announced more cooperation in output, which led to a rally in the long-suffering price of copper. This proved Beijing's ability to use its dominance in copper refining to impact the global market.[45]

In sum, the US has a moderate vulnerability score for copper. It does however have exposure to the ability for China to use its hold on the refined copper market to manipulate global prices.

4.3.3

The Geopolitics of Copper from a US & Allies Perspective

A fifth of global copper reserves are held by the US & Allies, and about half by Unaligned Countries, especially in South America (notably Chile and Peru). The US has stable relations with these countries, but China is making active efforts to court them, for example building a port in Peru at Chancay at a cost of USD3.5 billion.[46]

	Copper (2023)		
Geopolitical Alignment	**Reserves**	**Mine Production**	**Refining**
US & Allies	19%	13%	18%
Counter Aligned Countries	12%	12%	48%
Unaligned Countries	51%	59%	21%

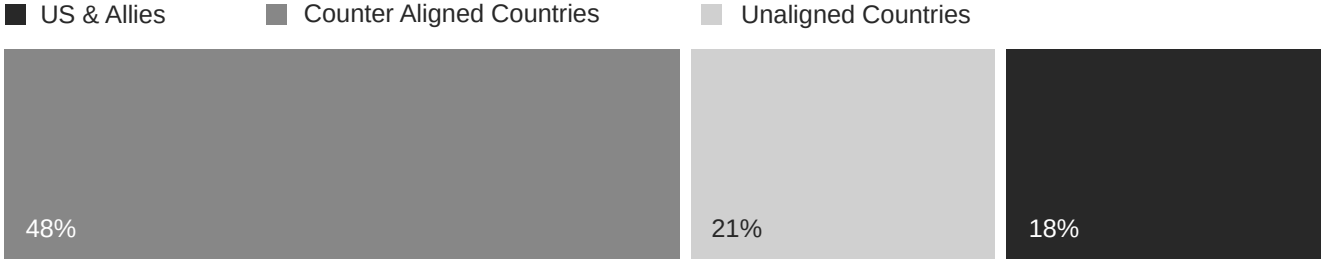
Copper Reserves (2023) by Geopolitical Alignment

Copper mine production is also dominated by Unaligned Countries (59%), with Counter Aligned Countries holding about 12% of the total (the same proportion as copper reserves). The US & Allies holdings are dominated by Australia, which has 4% of total mine production for copper.

Copper Mine Production (2023) by Geopolitical Alignment

Copper refining is dominated by China, with 44% of the total. Russia has 4%, more than the US (3%), Australia (2%) and Canada (1%). Unaligned copper refining is mainly undertaken by Chile and the DRC (7% each).

Copper Refining (2023) by Geopolitical Alignment



4.4 Nickel

Global Supply Chain Vulnerability Score:	3.25 / 5.00
US National Supply Chain Vulnerability Score:	4.13 / 5.00

4.4.1 The Global Supply Chain Vulnerability Score for Nickel

The global nickel supply chain is moderately vulnerable to disruption. Reserves and mining are relatively concentrated, but processing is less so in terms of national distribution.

NICKEL RESERVES

Although there is plenty of nickel in the world, its reserves are concentrated. As of 2023, 42% of global nickel reserves are found in Indonesia, followed by Australia (18%) and Brazil (12%).[47]

NICKEL MINE PRODUCTION

Indonesia produces 50% of the world's nickel, with other major players including the Philippines (11%), New Caledonia (6%), Russia (6%), Canada (5%), and Australia (4%).[48]

NICKEL REFINING

28% of nickel refining takes place in China, while 37% takes place in Indonesia.[49] Chinese companies play a major role in nickel refining. Even though 37% of refining occurs in Indonesia, 80% of this is conducted by Chinese companies.[50] One of these, Tsingshan Group, is responsible for 31% of global refined nickel production, followed by Russia's Norilsk Nickel at 6%.[51] As of 2023, Tsingshan Group has begun refined nickel production in Indonesia.[52]

4.4.2 The US Supply Chain Vulnerability Score for Nickel

The US is highly reliant on China for nickel imports. In 2023, the share of imports of nickel from China grew from approximately 65% to approximately 80%.[53] The outsized role of China's Tsingshan Group, and the broader role of China in nickel refining, mean that China's influence over the US supply chain is significant.

While China itself imports large amounts of refined nickel oxides and hydroxides (USD47 million in 2023) these are massively outweighed by exports (USD1.2 billion in 2023).[54] Of these, over USD1 billion worth go to South Korea, followed distantly by the US at USD47 million. Taken together with China's exports of cobalt to South Korea, this is particularly important from an ally-shoring perspective given the close trade relationship between the US and South Korea.

The US is now South Korea's top export market, and South Korea plays a key role in supply chains reliant on critical minerals (such as EV batteries).[55] [56]

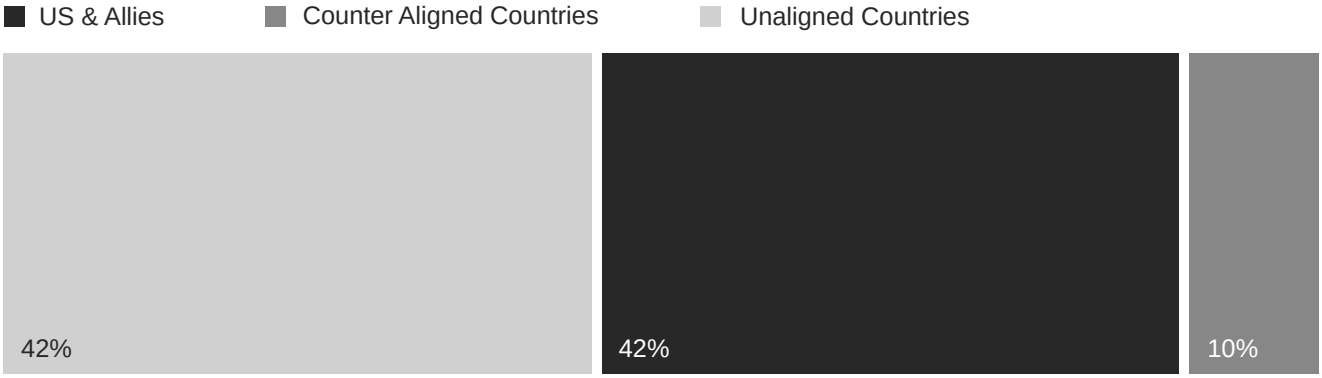
4.4.3 The Geopolitics of Nickel from a US & Allies Perspective

	Nickel	
Geopolitical Alignment	**Reserves**	**Mine Production**
US & Allies	42%	30%
Counter Aligned Countries	10%	9%
Unaligned Countries	42%	50%

(Note that there is not enough reliable data to make a full analysis in this report for nickel refining per geopolitical alignment).

The US & Allies have good representation in nickel reserves. A fifth are found in Five Eyes countries Australia and Canada, and the Philippines and Brazil have substantial reserves too. The fourth largest reserves are in New Caledonia, an overseas territory of France, which was America's "first ally" as President Biden reminded the world in June 2024.[57] New Caledonia has been wracked by pro-independence riots so far in 2024, and there is suspicion in Paris that Beijing is in some way linked to this; if the territory became fully independent then it (and its nickel) would fall into China's hands "like ripe fruit", said a French Senator.[58]

Nickel Reserves (2023) by Geopolitical Alignment

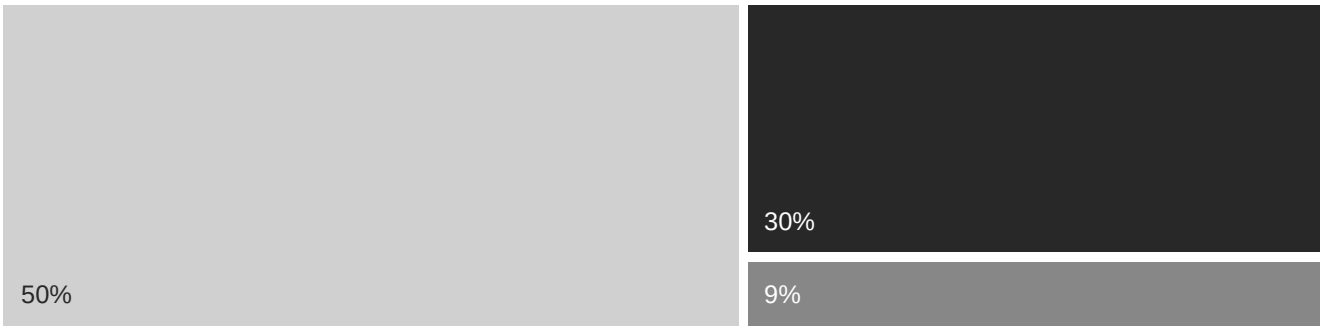


In terms of nickel mine production, the Philippines (11% of global share) dominates US & Allies representation, with Australia and Canada making up less than 10% of output between them. Indonesia makes up half of all nickel output and given that much of this is dominated by Chinese companies, there is a potential threat to the US here.

However, the most significant challenge for the US is the dominance of Chinese companies in the nickel supply chain. The example of Indonesian nickel production confirms that both trade data and company-level data are important for assessing the vulnerability of a supply chain. Indonesia's role in refined nickel production is in fact largely due to the activities of Chinese companies, in particular Tsingshan Group. Notably it owns shares in the Morowali Industrial Park - a nickel processing facility with at least 20 smelters in Morowali Regency, Sulawesi, and which is a prominent part of the Belt and Road Initiative. Tsingshan's role is especially important given Indonesia's 2014 nickel ore export ban, which was extended in 2020; this has allowed Chinese companies already active prior to the ban to expand their operations, while competitors from US-friendly countries remain excluded from the largest nickel-producing country.[59]

The US is also vulnerable to price fluctuations caused by Chinese action in the supply chain. Such has been the increase in nickel production from Chinese operations in Indonesia that it has contributed to a steep drop in the metal's price, from USD48,000 per tonne in 2022 to USD17,000 per tonne in June 2024.[60] As with copper, this shows how the US and its allies are vulnerable to Chinese action on their supply chains beyond export controls.

Nickel Mine Production (2023) by Geopolitical Alignment



05.
Overall Discussion on SCVI and Ally-Shoring Implications

The Scale of US Vulnerability in Cobalt, Copper, and Nickel

Cobalt, copper, and nickel are all vital for modern technologies and the economy more broadly. Without them, globally significant initiatives like the renewable energy transition and the development of advanced defense technologies would be impossible.

The US has recognized that it has significant exposure and therefore potential vulnerability in its mineral supply chains. This report has set out the scale of this vulnerability for copper and nickel, and the potential vulnerabilities for cobalt as the US builds its domestic battery supply chain.

The Global SCVI Scores highlight how cobalt and nickel are highly vulnerable at the global level in terms of reserves, mine production, and refining. Copper is less vulnerable.

At the national level, the US is significantly vulnerable in nickel, and slightly less so for copper. The vulnerabilities are down to major bottlenecks of supply that are dominated either by China directly (such as the refining of copper) or because of intense Chinese company investment in the metals' supply chains in Unaligned Countries, for example nickel in Indonesia.

Specific to nickel, not only is the largest extraction company Chinese and the second-largest Russian, but also the US heavily imports from China, and thus its supply chain is more vulnerable to disruption.

The picture for copper reserves and mine production is less serious, with Counter Aligned nations having limited control there. Copper refining, however, is mainly controlled by China.

At the global level, Chinese companies have taken significant positions in the world's main source of cobalt, the DRC. Although there are now efforts to reduce the involvement of Chinese firms (for example by the Mineral Security Partnership), it will take time to achieve this.

The US is relatively secure in cobalt for the moment. However, not only is the data opaque, but the score will likely change as cobalt demand increases and the US is forced to rely more on Chinese-dominated cobalt supply chains.

It is thus clear that the critical minerals examined are all notably susceptible to geopolitical disruption. The West is currently fundamentally reliant on China for its critical minerals, making it vulnerable to geopolitical pressure from Beijing. If, for example, China wanted to disrupt US manufacture of Electric Vehicles then it could.

Whilst there would be undoubted economic and political consequences for China restricting the flow of critical minerals to the West, any such action would almost certainly be part of a planned strategy where these consequences were anticipated (and thus would be able to be absorbed).

Why This Vulnerability is Important to Track

There are several reasons why it is important to reduce the geopolitical vulnerability of critical minerals supply chains.

The most obvious is being cut off from the commodities. China has shown its willingness to restrict exports, which it does not always do officially thus making it harder for Western politicians to react. The fact that China now has more theoretical export controls than any other country should give cause for concern for the buyers of these commodities. China's degree of structural influence over these supply chains also makes them inherently vulnerable to domestic events in China, and Chinese policies and initiatives which are not necessarily aimed at competition with the US and its allies.

How the US is Trying to Reduce This Vulnerability

The US is making attempts to reduce its critical minerals vulnerabilities. The Inflation Reduction Act (IRA) of 2022, for instance, set guidelines on raw materials that can be used in US-built electric vehicles to trigger tax credits for buyers. There is however a long way to go on this, with few believing that the US has the ability to reduce its vulnerabilities to the desired extent in the immediate term. One study suggests that only 8% of refined cobalt supply will be IRA-compliant in 2025, excluding European material.[61]

There are also US government funded initiatives to find substitutes for critical minerals and ways to boost recycling. There are though significant technical challenges in achieving both, meaning that they are unlikely to significantly reduce the US' vulnerabilities in the short term.

An alternative would be to build a significant stockpile of critical minerals. The US already has a National Defense Stockpile but this has been run down over the last few decades, with research showing that its value in 2022 was less than USD1 billion, 1/40th of its value in 1952.[62]

One way of reducing US vulnerabilities, and which is gaining more attention, is through ally-shoring.

Using the SCVI to Support Ally-Shoring and the Reduction of this Vulnerability

The SCVI provides a valuable tool for ally-shoring. By assessing vulnerabilities to disruption at the national and company level, as opposed to the traditional supply chain mapping focus on logistics chains, it provides a fuller picture of the geopolitical implications of supply chains. Import data alone does not necessarily provide a full picture of China's role in US critical minerals supply chains, for instance – as shown by the cases of Indonesian nickel refining and cobalt production in the DRC.

Moreover, ally-shoring by the US cannot solely rely on an understanding of the US' own supply chain vulnerabilities. This must be complemented by an understanding of allies and prospective partners' vulnerabilities in order to guard against re-routing dependencies on adversaries such as China via partners.

There is, however, a barrier to achieving this understanding, and that is the opacity of trade. Our research has revealed the complexity of commodity flows, which makes it difficult to fully map China's position on each supply chain. Challenges to the data include the failure to declare exports and unknown voting rights by Chinese companies over companies based in Unaligned Countries or US & Allies, both of which provide potential levers of manipulation over supply chains.

China's control of much of the supply chains of these three metals does not need to be permanent. Unilateral policies by Washington can have an effect, but they will likely be much more effective if done in cooperation with both allies and Unaligned Countries, something which will also mitigate risks to US allies from unilateral policies. In order to do so effectively, both US and allied supply chains need to be thoroughly mapped in order to understand the magnitude of the required reshoring initiatives and avoid forcing difficult choices on allies where their political alignment with the US is at odds with their economic ties to China.

Without concerted similar efforts and resources, the US and its allies are unlikely to be able to seriously counter China's dominance of critical mineral supply chains.

06.
Appendix – Full categorisation of geopolitical alignments

When calculating the US' vulnerability in these supply chains we use three categories of geopolitical alignment.

US & Allies

These are countries that are official treaty allies of the United States, including all NATO countries, plus nineteen Major Non-NATO Allies (MNNAs).[63] [64]

US NATO Allies

Albania
Belgium
Bulgaria
Canada
Croatia
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Italy
Latvia
Lithuania
Luxembourg
Montenegro
Netherlands
North Macedonia
Norway
Poland
Portugal
Romania
Slovakia
Slovenia
Spain
Sweden
Turkey
United Kingdom

US Major Non-NATO Allies

Argentina
Australia
Bahrain
Brazil
Colombia
Egypt
Israel
Japan
Jordan
Kenya
Kuwait
Morocco
New Zealand
Pakistan
The Philippines
Qatar
South Korea
Thailand
Tunisia

Counter Aligned Countries

This includes the six countries that are almost always described as adversaries to the United States, and which were also defined as "foreign adversaries" by the Trump Administration, a definition that has not been rescinded.[65]

These six countries are:

China
Cuba
Iran
North Korea
Russia
Venezuela

Unaligned Countries

All countries not included in the lists above are by default included in the Unaligned category.

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Disclaimer: The data in this report is correct as of 1 June 2024.

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