

THE WEAPONIZATION OF INTERDEPENDENCE: ENERGY SECURITY AND THE GEOPOLITICS OF THE GREEN TRANSITION

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Abstract. *The dominant narrative considers the green energy transition as a direction to energy autonomy and less geopolitical antagonism. This article questions that assumption. Based on US Geological Survey data on mineral production, trade flow statistics of the UN Comtrade database, and with the help of the International Energy Agency projections, this paper uses Herfindahl-Hirschman Index (HHI) analysis to measure the concentration of three key raw materials lithium, cobalt, and graphite. The comparative case study of EU and US legislative reactions, in particular, the Critical Raw Materials Act and the Inflation Reduction Act, charts the policy architecture of de-risking. Results indicate that the midstream processing segment of CRM supply chains is more concentrated than petroleum during the OPEC period with one jurisdiction dominating between 58 and 87 percent of all battery-grade material refining worldwide. The discussion puts these findings into the context of the interdependence theory of Keohane and Nye, that the transition is not a liquidation of energy-based power asymmetries but a reorganization into more inflexible, less replaceable choke points. The article concludes that strategic pluralism in response to supply chain weaponization in the emerging mineral-security order is the only possible option; that is, diversifying not only suppliers but also the underlying technologies.*

Keywords: critical raw materials, energy security, weaponization of the supply chain, strategic autonomy, green transition, interdependence theory, mercantilist realism.

1. INTRODUCTION

The Democratic Republic of the Congo contributed about 73 percent of mined cobalt in the world in 2023, but refined less than 1 percent of this production into battery-usable cobalt sulphate (USGS, 2024). The sum-total of the refining margin--and with it the leverage--moved to the plants in the provinces of Jiangsu and Zhejiang. This one fact is more accurate in defining the main contradiction of the green energy transition than any policy white paper: the resource-based power does not disappear when it is shifted to non-fossil fuels; rather, it is diverted.

The concept of energy security over the past hundred years was synonymous with petroleum security. The geography of hydrocarbons, namely, who extracted, who refined, who transported and who consumed crude oil and natural gas, played the key role in the architecture of post-1945 international order (Yergin, 2011). The OPEC embargo of 1973, the Iranian Revolution of 1979 and the more recent weaponization of Russian gas supplies to Europe in 2022 all served to demonstrate the effectiveness of carbon-based coercion. International political economists have devised strong analytical approaches to understand this dynamic, whether through the hegemonic stability theory to resource curse models, and the policy apparatus of the liberal international order, such as the International Energy Agency, strategic

petroleum reserves, maritime security doctrines, was made to address this very kind of vulnerability (Colgan, 2013).

The modern discussion of the green transition, however, has its own set of assumptions, which are entirely different. The transition to renewable energy and electric mobility has been positioned by policymakers in Brussels, Washington, and to a smaller extent Tokyo and Canberra, as a way to solve two related issues: climate change and reliance on authoritarian petrostate regimes (European Commission, 2023). It is simple logic that is alluring. When one of the countries produces energy using wind and sun, there would be no need to import Saudi crude or Qatari LNG. Should its fleet of vehicles be powered by lithium-ion batteries instead of internal combustion engines, it would be cushioned against the price spikes and supply shocks that have periodically rocked the economies of the world.

This argument, at the most, is partial. At worst it is fatally naive. Green transition does not cancel the resource dependency, it changes it. The concerned inputs are no longer hydrocarbons, which are geologically spread, and supplied by a well-developed, diversified, global trading system, but a subset of critical raw materials (CRMs), the extraction of which becomes centralized, and whose midstream processing is concentrated in much fewer jurisdictions. In the petroleum era, a multipolar supply environment (the Gulf states, Russia, the North Sea, West Africa, the Americas), the mineral-security era can be characterised by what could be called an oligopolistic processing regime, which is dominated by the People's Republic of China (IEA, 2023).

The literature on the green transition has been prolific in reporting the climate benefits of the green transition, its technological paths, and its macroeconomic outcomes (Sovacool et al., 2020; Bazilian et al., 2014). A less extensive yet expanding literature has explored the geopolitical aspects of CRM supply chains (Overland, 2019; Pitron, 2020). But there is still a glaring void. The supply chain risk is primarily analyzed as a logistical issue, an issue of investment, permitting and trade facilitation, and rarely as a structural feature of the new international order that brings its own security issues, escalation processes, and coercive possibilities. The difference is not semantic. Technological solutions to a logistic issue are admissible. A security dilemma can take only management and, in some cases, not even that.

The research question of this article is as follows: How does the tendency of centralizing raw material processing to certain jurisdiction, especially China, rethink the meaning of strategic autonomy to Western liberal democracies? The thesis presented here is that the green transition is not a shift toward energy autonomy but a restructuring of interdependence that establishes new, more inflexible choking points of supply chain nodes, at which a hegemon is able to enforce costs on dependent parties at the least cost to itself. The argument here is framed in the context of what Farrell and Newman (2019) have described as a process of weaponization of interdependence, but here between the world of financial networks and information infrastructure and the material substrate of the energy transition.

The article is organized in the following way. Section 2 presents the framework of methods, explaining the comparative case study method and the quantitative measures used. Section 3 provides the results of the market concentration of three representative CRMs, lithium, cobalt, and graphite and maps policy responses of the European Union and the United States. Section 4 interprets these findings in terms of the interdependence theory, explores the processes of weaponization of the supply chain and questions the paradox of a so-called clean energy transition that might require so-called dirty geopolitical methods. Section 5 ends with policy suggestions that are focused on what the author calls strategic pluralism.

2. METHODS

This analytical design is based on two mutually compatible methods: a quantitative evaluation of market concentration in the critical raw materials industry and comparative case study of the legislative response in the European Union and the United States. This combined method was chosen because it is able to capture both the structural aspects of supply chain vulnerability that are numerically measurable and the political-institutional aspects of policy reaction in which interpretative analysis of legal texts, parliamentary documents, and executive correspondence is necessary.

2.1. Quantitative Framework: Measuring Concentration

The main quantitative tool is the Herfindahl-Hirschman Index (HHI), a conventional measure of market domination that is extensively utilized in antitrust economics and, more and more often, in the resource security literature (Humphreys, 2019). The HHI is computed as the total market share squared of all the producers or processors in a certain market and the value is between 0 (perfect competition) and 10,000 (monopoly). Markets whose HHI exceeds 2,500 are considered highly concentrated by the US Department of Justice; the article uses the same but adds a second measure, the share of a single largest processor (SLP), to reflect the qualitative distinction between a three-actor oligopoly and a near-monopoly run by one.

The HHI was calculated based on three steps of the value chain, extraction (mining), midstream processing (refining to battery-grade material) and downstream manufacturing (cell and cathode production) of three representative CRMs, lithium, cobalt and graphite. These three minerals have been chosen based on two criteria. First, they are both essential to the existing lithium-ion battery chemistries, which comprise more than 95 percent of the global EV battery market (BloombergNEF, 2024). Second, each of them has a unique geographical distribution, which allows the comparison of them in various extraction-processing-consumption triad configurations.

2.2. Data Sources

The source of extraction data was the United States Geological Survey (USGS) Mineral Commodity Summaries of 2018-2023 with the support of the British Geological Survey dataset of World Mineral Production to confirm the data. Less systematically reported data have been processed and refined, which includes data on International Energy Agency (IEA) reports, specifically the Global EV Outlook series (2021, 2022, 2023) and the special report on The Role of Critical Minerals in Clean Energy Transitions (2021), as well as Benchmark Mineral Intelligence, a proprietary but widely-cited industry data provider. The UN Comtrade database was used to access trade flow data that would be used to triangulate the estimates of processing concentration, using HS codes 2825.20 (lithium oxide and hydroxide), 2822.00 (cobalt oxides and hydroxides), and 2504.10 (natural graphite).

It deserves a note on the quality of data. The statistics of CRM processing are not as transparent as petroleum production data. China, specifically, does not release disaggregated refining statistics as are released by OPEC member countries on crude production. As a result, there is an inter-source variation of Chinese processing shares by a range of 5-10 percentage points. In the event of discrepancy, this study took as a middle-range the IEA and Benchmark Mineral Intelligence estimates, which is conservative in nature and, in any case, will be underestimating the level of concentration (a summary of the data sources and coverage is presented in Table 1).

Table 1. Summary of Data Sources and Coverage

Data Domain	Source	Coverage	Notes
Mining / Extraction	USGS Mineral Commodity Summaries	2018-2023	Cross-validated with BGS World Mineral Production
Processing / Refining	IEA Global EV Outlook; Benchmark Mineral Intelligence	2020-2023	Midpoint adopted where estimates diverge ($\pm 5-10$ pp)
Trade Flows	UN Comtrade (HS 2825.20, 2822.00, 2504.10)	2018-2023	Used to triangulate processing concentration
Policy Documents	EU CRMA; US IRA; CRS reports; 14 policy briefs	2022-2024	Coded against mercantilist realism typology

2.3. Case Study Comparison: Eu And Us Policy Response.

A comparative case study between two key legislative responses to CRM dependency, the European Union Critical Raw Materials Act (CRMA), proposed in March 2023 and provisionally agreed upon in November 2023, and the Inflation Reduction Act (IRA) of the United States, which was signed into law in

August 2022, especially focusing on its Section 45X Advanced Manufacturing Production Credit and the battery component sourcing requirements of Section 30D.

The main approach of this component was document analysis that was applied to the legislative texts themselves and the impact assessments that accompany them, staff working documents of the European Commission, reports of the US Congressional Research Service, a purposive selection of 14 policy briefs and position papers of industry associations (European Battery Alliance, Li-Bridge), think tanks (Bruegel, Center for Strategic and International Studies, International Institute for Strategic Studies), and The analysis was done in a deductive manner by coding each policy instrument to a typology based on mercantilism realism: tariff instruments and local content policies, strategic stockpile policies, diplomatic diversification policies, and direct industrial subsidies. This was not intended to measure the effectiveness of individual instruments but to trace the general policy architecture of de-risking and to determine whether it is proportionate to the magnitude and nature of the vulnerability found in the quantitative analysis.

2.4. Limitations

There are a number of constraints that should be mentioned. Although informative, the HHI is a fixed point that fails to reflect the trend of the concentration; a market can be extremely concentrated and quickly becoming more diverse or the other way round. The comparative case study is also confined to two jurisdictions and leaves out key actors in terms of CRM strategies including Japan, South Korea, India and Australia whose CRM strategies are similar in relevant aspects. Lastly, proprietary information provided by Benchmark Mineral Intelligence, although generally considered the most of the granular information, cannot be reviewed by academic researchers on its own, which brings an aspect of trusting the industry to self-report, which is not completely satisfactory. These limitations are mentioned but, according to the judgment of the author, do not weaken the main results, which are strong in a variety of data.

3. RESULTS

3.1. Market Concentration: Extraction Versus Processing

The quantitative analysis reveals a consistent and striking pattern across all three CRMs: while the extraction stage exhibits moderate to high concentration, the midstream processing stage is dramatically more concentrated, and the disparity between the two stages constitutes the central empirical finding of this study. Table 2 presents the HHI values and single largest processor (SLP) shares for each CRM at each value chain stage.

Table 2. HHI and Single Largest Processor (SLP) Share by CRM and Value Chain Stage, 2023

CRM	Value Chain Stage	HHI	SLP (Country)	SLP Share (%)
Lithium	Extraction	2,840	Australia	47
	Processing	5,120	China	65
Cobalt	Extraction	5,480	DRC	73
	Processing	6,920	China	78
Graphite	Extraction	4,500	China	65
	Processing	7,700	China	87

For lithium, the extraction HHI stands at approximately 2,840, reflecting a market divided principally between Australia (47%), Chile (24%), and China (15%), with Argentina and emerging producers accounting for the remainder (USGS, 2024). This level of concentration, while above the DOJ threshold for

“highly concentrated,” is structurally comparable to the crude oil market in the 1990s—dominated by a few large producers but not monopolistic. The processing HHI, by contrast, reaches 5,120, with China accounting for an estimated 65% of global lithium hydroxide and lithium carbonate refining capacity (IEA, 2023; Benchmark Mineral Intelligence, 2024). Chile’s SQM and Albemarle’s operations in the Atacama, and Australia’s nascent hydroxide plants in Kwinana and Kemerton, represent the only significant non-Chinese processing nodes, and their combined output constitutes less than 20% of global supply.

The cobalt results are more extreme. Extraction is centred on the Democratic Republic of the Congo (73%), with Russia, Australia, the Philippines, and Cuba providing small supplementary volumes (USGS, 2024). The extraction HHI is approximately 5,480. But the processing HHI leaps to 6,920, as China refines an estimated 78% of global cobalt output into battery-grade cobalt sulphate, with Finland’s Umicore-operated Kokkola facility and Belgium’s processing plants constituting the principal Western alternatives (Benchmark Mineral Intelligence, 2024). The SLP share of 78% is, to place it in comparative context, higher than Saudi Arabia’s peak share of global crude oil production at any point in the post-war era.

Graphite presents the most concentrated profile of the three. Natural graphite mining is distributed across China (65%), Mozambique (13%), Brazil (8%), and Madagascar (6%), yielding an extraction HHI of approximately 4,500 (USGS, 2024). The processing stage, which involves purification to 99.95% battery-grade spherical graphite, is almost entirely Chinese: an estimated 87% of global anode-grade graphite processing occurs within China, producing an HHI of approximately 7,700 and an SLP share that, in all likelihood, understates the true figure due to incomplete reporting of small-scale Chinese processors (IEA, 2023). Figure 1 illustrates the divergence between extraction and processing HHI across all three minerals.

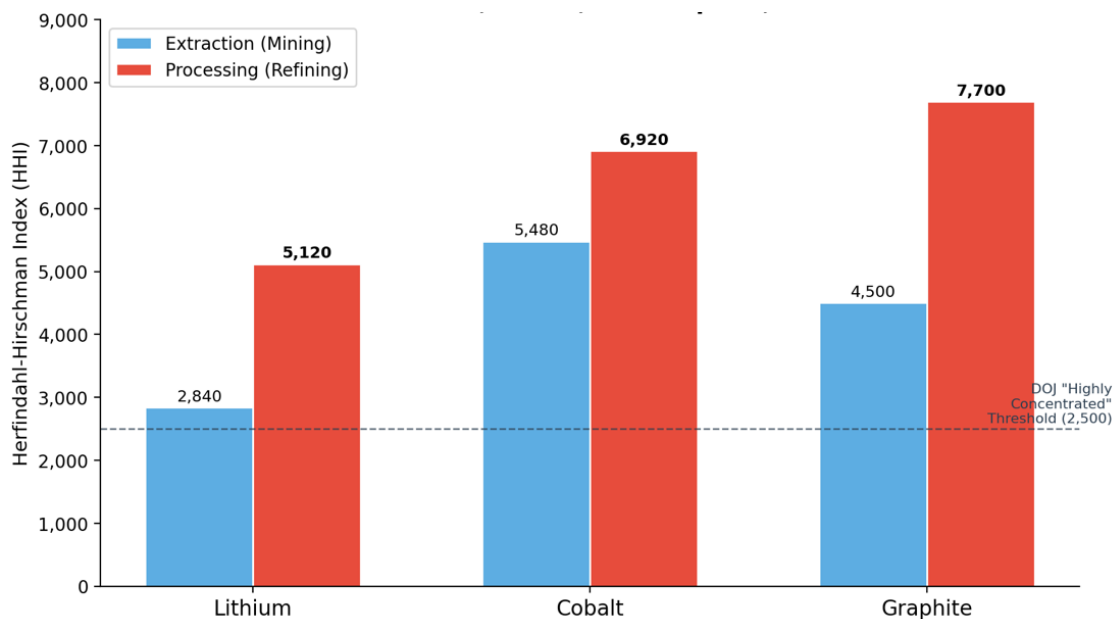


Figure 1. Extraction vs. Processing HHI for Lithium, Cobalt and Graphite, 2023

3.2. The Extraction–Processing Gap: A Structural Feature

This difference between extraction and processing concentration is not accidental; it is the result of twenty years of purposeful industrial policy. Starting in the early 2000s with Chinese state-owned and state-affiliated companies acquiring an interest in Congolese cobalt mines, and more recent (around 2015) long-term offtake agreements with Australian lithium miners, and heavy investment in local refining capacity through mechanisms such as subsidised electricity, preferential land allocation, and lax environmental standards (Pitron, 2020). It led to a bottleneck in the middle of the stream of a sort of which there is no exact parallel in the petroleum era: refining was decentralized throughout the Gulf, Europe, East Asia, and the Americas, with OPEC controlling the wellhead. The CRM industry is characterized by the dominance of one state over a large extraction volume and a preponderant refining share.

A corollary of this structural feature is critical: It is much harder to replace at the processing stage than at the extraction stage. It takes 7-12 years between the discovery of a new lithium mine in, say, Nevada or northern Portugal, and the production of the mineral (S&P Global, 2023). However, to build a lithium hydroxide refinery to produce battery-grade material to the specifications required by cathode manufacturers requires not only capital and time (usually 4-7 years) but also years of experience in process engineering, developed relationships with suppliers of chemical reagents, and environmental compliance, which in many jurisdictions of the West adds 2-4 years to the timeframe of permitting (European Commission, 2022). The skills gap is not insignificant: China refiners have 30 years of accumulated tacit knowledge in hydrometallurgical processing that cannot be replaced by capital investment.

3.3. Policy Response Mapping: EU and the US

The comparative study of EU and US legislative reactions shows two broadly parallel, yet instrumentally different, responses to what each jurisdiction terminates as, rhetorically, de-risking, not decoupling, a rhetorical difference with analytical consequences.

The Critical Raw Materials Act of the EU sets standards on domestic capacity: the EU must extract, process, and recycle at least 10 per cent of its yearly intake of strategic raw materials inside the EU by 2030 (European Commission, 2023). It also provides that the EU consumption of any strategic raw material should not exceed 65% of the total consumption by a particular third country- a clause that is obviously aimed at generating less dependency on China. The Act establishes a system of strategic projects that can receive expedited permitting and coordinates a European-scale stockpiling system. Importantly, though, the Act is a regulation, rather than a spending device; it does not apportion funds. The industrial subsidies needed to make domestic extraction and processing economic competition with Chinese operations are left to individual member states, with current state aid regulations.

The US Inflation Reduction Act uses a different rationale. It does not aim at establishing capacity goals but instead applies the tax code to reform supply chains by the use of incentive structures. The clean vehicle credit Section 30D provides eligibility criteria to consumers regarding the mineral content of their battery: starting in 2024, no less than 50 percent of the value of the critical minerals in the battery must be extracted or processed in the US or a free trade country, or recycled in North America (US Congress, 2022). Section 45X credit offers direct subsidies on production of battery components in the country. The net effect is to establish a pull mechanism which encourages the shifting of processing capacity to the US, allied countries, or FTA partners- a kind of what Aggarwal and Reddie (2021) have described as geoeconomic competition via industrial policy.

Table 3: Typological Classification of EU (CRMA) and US (IRA) CRM Policy Instruments

Instrument Type	EU (CRMA)	US (IRA)
Local Content Requirements	Benchmark: 10% domestic extraction, 40% domestic processing, 25% recycling by 2030	Sec. 30D: 50%→80% CRM value from US/FTA countries (2024→2027)
Supplier Concentration Cap	Max 65% of any CRM from a single third country	FEOC exclusion: no battery components from Chinese-controlled entities
Industrial Subsidies	Framework only; funding delegated to member states under state aid rules	Sec. 45X: direct production tax credits for domestic battery component mfg.
Strategic Stockpiling	European-level coordination mechanism (details TBD)	No formal CRM stockpiling provision in IRA; DoD programs separate
Permitting Reform	"Strategic projects" eligible for streamlined permitting	Not directly addressed in IRA; separate executive orders

3.4. Assessment: De-risking versus Physical Reality

The most important fact of the policy analysis is a time gap. The CRMA and the IRA have timelines of 5-10 years, and benchmark targets of 2027 and 2030, respectively. Physical infrastructure to achieve those targets, mines, refineries, recycling, works on a 7–15 year development timeline. With the most favourable assumptions about allowing reform and capital mobilisation, the Western lithium, cobalt, and graphite

processing capacity will hardly shrink to less than 50% of the Chinese market share by 2035 at the earliest (IEA, 2023; S&P Global, 2023). During the interim, or the timeframe that includes the fastest growth stage of projected EV adoption, the dependency is reinforced. Demand of lithium by the world is projected to grow by a factor of 13 between 2022 and 2040; of graphite by a factor of 8; of cobalt, by a factor of 3.4 (IEA, 2023). Should the rate of diversification in supply chain be below the rate of demand growth, the values of HHI reported above will not be decreasing, but rather increasing, in the medium term. This finding is represented graphically in Figure 2.

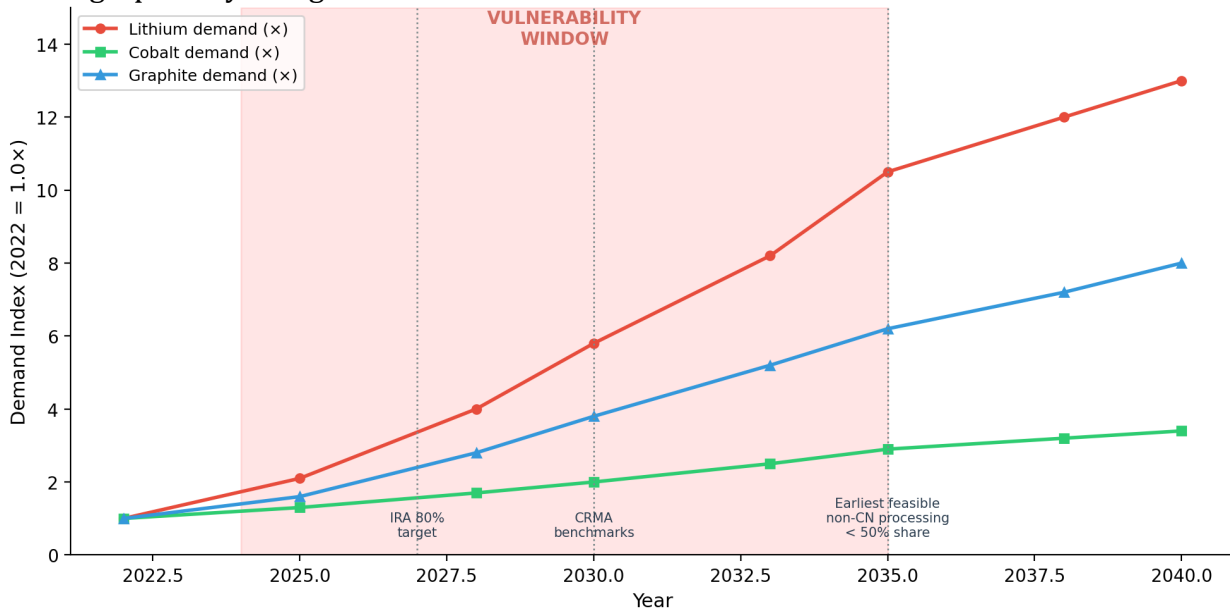


Figure 2: Projected Demand Growth vs. Diversification Timeline for Three CRMs, 2023–2040

4. DISCUSSION

4.1 Interdependence Revisited: Sensitivity to Vulnerability

The findings in Section 3 can only be given their proper weight when placed in the theoretical context of intricate interdependence as initially described by the Keohane and Nye (1977) and later perfected by Farrell and Newman (2019). Keohane and Nye made an initial distinction between interdependence of sensitivity and vulnerability. Sensitivity is used to describe how much costs are incurred by one country to alter the policies of another in advance of any alteration in policy being implemented; vulnerability is the costs left after the affected party has done as much adjustments as possible. The dimension of vulnerability is what is analytically determinative of the CRM question, since all the thrust of the Western de-risking policy, the CRMA, the IRA, bilateral mineral security alliances, is the type of adjustment feasible that the theory imagines. The rationale is whether these changes are adequate to bring the vulnerability to manageable levels in the time frame considered.

The facts herein indicate that they are not. All three CRMs have processing HHI values that are above the margin at which market power can be coercively exercised, and the estimated term of significant diversification is far in the future of the maximum demand growth. This generates what could be described as a vulnerability window - a window in which the dependent party has become aware of its exposure, has taken corrective action, but has not yet become diversified enough to de-leverage the power of the dominant actor. The theory is structurally parallel to the window of vulnerability in the theory of nuclear deterrence where a state believes that it is temporarily vulnerable to first strike during a period of transition in its modernisation of its forces (Wohlstetter, 1959). The comparison is flawed, the processes are economic and not kinetic, and the reasoning is strategic: not stasis but transition is the most dangerous.

The interdependence theory can be extended in this case by Farrell and Newman (2019). What they understand is that the globalised networks, be it financial, informational or, as this article posits, material,

harbor such effects as the panopticon and choke point, which can be leveraged by states that are at structurally privileged positions within such globalised networks. The panopticon effect gives the powerful state access to the flows -volumes of trade, counterparties, prices, etc. and thus gain informational benefits. The choke point effect enables it to constrain or condition such flows, subjecting parties that rely on it to costs. By the measures given above, the midstream processing component of the CRM supply chain is among the most concentrated choke points in the modern global economy, even more so than the SWIFT financial messaging system and the global semiconductor fabrication network (which, though dominated by TSMC, is spread across Taiwan, South Korea, and to a smaller extent the United States and Japan) in its level of single-actor concentration.

4.2. Mechanisms of Supply Chain Weaponization

In what ways, in what ways, can a dominant processor weaponize its position? The mechanisms are multi-faceted, ranging in intensity between low-level signalling, on one end, and coercive force, on the other, and it is convenient to place them on a scale of escalation.

On the bottom level, a powerful processor is able to control the pricing by building up and releasing stockpiles strategically. This ability has been evidenced by China in the rare earth elements (REE) market on numerous occasions, most notably in 2010 when it blocked rare earth exports to Japan in a maritime territorial conflict in the East China Sea (Mancheri et al., 2019). Although the rare earths studied here are not the same as the CRMs, the operational principles can be applied. A state that is a monopolist in 65-87 percent of the refining capacity of a major input has the natural market-making power to lower the prices to weaken the nascent competitors (a predatory pricing power at the state level) or raise the prices to take economic rents, depending on the strategic goals it pursues at any particular time.

In an escalatory situation, a powerful processor may place export quotas, licensing, or quality certification barricades that discriminatively limit supply to certain jurisdictions. China declared export restrictions on two minor metals, gallium and germanium, which have major uses in semiconductors, in July 2023, and exporters have to receive a licence from the Ministry of Commerce (Reuters, 2023). In December 2023, it also imposed the same on graphite, but in this case, high-purity, high-hardness, and high-strength artificial graphite anode materials in batteries were targeted (Benchmark Mineral Intelligence, 2024). These actions were largely seen as vindictive actions against US and Dutch restrictions on semiconductor exports of the latest lithography tools, and were a classic example of tit-for-tat escalation into the dynamic that defines geoeconomic competition. The graphite export regulations take a special concern in the given analysis: it shows that the above-described weaponization mechanism is not some hypothetical one but is already in effect in terms of the given mineral category this paper is going to analyze.

On the next level of escalation, which has not yet been achieved but is not impossible in the situation of, say, a crisis in the Taiwan Strait, a dominant processor may declare a total embargo on all CRM exports to enemy countries. The economic effects of such a measure would be asymmetric and harsh. China would lose the revenue of exports, but domestically produced EV and battery manufacturing would remain on the basis of home-cooked materials. The EU and the United States, in contrast, would experience instant and critical shortages of battery-grade lithium, cobalt, and graphite, and electric vehicle manufacturing, grid-scale energy storage implementation, and the defence-industrial base (which is increasingly relying on lithium-ion batteries to power submarines, soldier-portable power systems, and more) would all be affected in cascading impacts.

The possibility of the most extreme scenarios should not, however, be overstated. A total CRM embargo would be expensive to China too- both in terms of reputational harm, hastened Western diversification of its economy and possible countermeasures in areas where China relies on imports (especially agricultural goods, high-end semiconductors and civil aviation technology). It is more likely to follow this route, which Harrell et al. (2018) have proposed to call economic statecraft in its scaled-down version: discrete, deniable, and ambiguous enough to make a coordinated response difficult. Delays in licensing, quality checks, delays in customs, etc. - those are the weapons of asymmetric vulnerability

exploitation, and they are much more difficult to resist than an outright embargo because they are placed in the grey zone between the normal friction of bureaucracy and active coercion.

4.3. Security Dilemma of Mineral Geopolitics

Western reaction to dependency of CRM has created its own dynamic reaction which is subject to review using the security dilemma which is an international security concept imported (Jervis, 1978). The security dilemma is the event when the actions of one state to ensure that its security is increased are viewed by another state as a threat and counter-measures are taken that leave the two states less secure than they were initially. The dilemma works in the following way in the mineral-geopolitical context.

The EU and the US see their reliance on Chinese CRM processing as a strategic weakness and make moves to minimize it: the CRMA, the IRA, bilateral mineral relationships with Australia, Canada and several African nations, investment in recycling infrastructure, and the development of alternative battery chemistries (sodium-ion, solid-state) that require less cobalt and graphite. These are defensive responses (not decoupling) and are aimed at mitigating an asymmetric vulnerability in a Western viewpoint.

Beijing, though, interprets these same measures in another interpretive framework. In the Chinese view, Western de-risking policies are a tool of strategic decoupling, which is aimed at breaking down the competitive advantage that Chinese companies have developed over decades of investment, process innovation, and, of course, state subsidies. The provisions of the IRA that includes the term foreign entity of concern (FEOC), which does not apply to battery components produced by the entities that are owned, controlled, or headquartered in China (including Chinese companies that may operate in the third countries), are not seen as defensive diversification, but rather as offensive containment, an effort to keep Chinese industry out of the most profitable parts of the global clean energy market. Rhetorical difference between de-risking and decoupling, in this perspective, is a distinction without a difference.

This leads to escalation. China reacts to FEOC terms and to sourcing of graphite by imposing its export restrictions on graphite and broadening its restrictions on other CRMs. The US and EU react to Chinese export restrictions by hastening local processing investments and pursuing a friend-shore-sourcing strategy-strengthening the sense of Beijing of strategic encirclement. Every turn narrows the spiral. The dynamic of structure can be identified with the Cold War arms race but with industrial policy tools instead of nuclear warheads, and the lack of any sort of an arms control regime to geoeconomic rivalry, i.e. there is no SALT, START, or Chemical Weapons Convention on the sale of critical minerals, implies that there is no institutional way of checking the growth.

4.4. The Clean Energy Dirty Geopolitics Paradox

The green transition has an underlying, and in many ways unintrospected, paradox and it is time it was laid out. The normative argument of decarbonisation is based on a vision of international cooperation: climate change is a multilateral action problem, and its solution needs to be an international action, especially between the two biggest emitters, China and the United States. The Paris Agreement, the Glasgow Climate Pact, and the COP process in general are based on the premise that great powers have a sufficiently common community of interest in preventing disastrous warming to maintain cooperative structures even in the context of more general geopolitical rivalry.

The transition needs a material, however, which push in the very opposite direction. They bring about rivalry dynamics, around resources, around processing capacity, around technological standards, around market share, which erode the collaborative bases on which climate action relies. The local content requirements of the IRA are not optimal, climate-wise: they increase the price of EVs, pull down rates of adoption, and influence investment decisions away towards the most efficient places of production. Yet, in terms of national security, they are understandable, even natural, with the vulnerability rates being reported in this paper. The competition between the imperatives of climate optimality and security is not a problem that can be properly addressed in the current institutional framework.

This paradox has a historical background that has not been given due consideration in the debate. Cooperative interdependence was not the answer to petroleum dependence in the 1970s and 1980s; instead, mercantilist realism was the answer: strategic petroleum reserves (unilateral stockpiling), the

establishment of the IEA as a consumer cartel to counter the OPEC, huge investments in domestic production (the North Sea, the Alaskan North Slope), and, at the extreme, military interventions to secure supply routes (the Carter Doctrine, the Tanker War). The energy independence rhetoric was never quite as real as it was proclaimed to be as late as 2019, when America hit net petroleum independence, but the policy reaction was clearly unilateral and competitive rather than multilateral and cooperative.

Every sign is that mineral-security era is going to take up the same path. The CRMA and the IRA are, in their form and rationale, mercantilist tools: they aim to internalise value chains within national or block frontiers, they favour domestic industry over foreign rivals, and they use state resources (subsidies, tax credits, regulatory favour) to do what the market, left to its own devices, would not. The de-risking rhetoric must not mislead: they are protectionist actions in support of strategic autonomy, and they are expected to grow increasingly common as the CRM-supply competition accelerates.

The difference between the mineral-security era and the petroleum era, and what makes it possibly even more volatile, is the fact that it is more closely coupled with extraction, processing, and end-use. A disruption at the well head (an OPEC embargo, a civil war in Libya) would be partially offset by strategic reserves, demand reduction and the mobilization of spare production capacity in areas not affected. The system was redundant, according to engineers, that is, it had more than one way of taking the input to the output. The CRM system is much less redundant as it is currently set up. Cobalt does not have a strategic reserve. No additional lithium hydroxide processing capacity, which can be activated on short notice, is available outside of China. No OPEC-equivalent exists that can be pressured, coerced, and negotiated with since the bottleneck is not a cartel of sovereign producers but a complex of the industrial of a single state. In brief, the system is weaker, more centralized, and less responsive to the crisis-management processes that the petroleum-era international order had painstakingly established during the last half of the twentieth century.

4.5. Lithium-Ion Diplomacy and the Global South

One aspect of the CRM geopolitics that should be discussed further is the role of the resource-producing countries of the Global South, which are mostly the DRC, Chile, Argentina, Indonesia, and Mozambique, in the emerging mineral-security architecture. Such states are structurally comparable to the Gulf petrostate producers of the mid-twentieth century: they own the raw material, but they grab an unproportionately small portion of the value added along the supply chain. As an example, the DRC sells raw cobalt at a fraction of the price that Chinese refiners receive on battery-grade cobalt sulphate; the refining margin, and with it the economic and strategic power, goes to the refiner, not the miners.

This game of structure has produced what may be termed as lithium-ion diplomacy: attempts by resource-endowed states to alter the conditions of trade by limiting the export of raw materials, insisting on their internal processing conditions, or by carteling producers. The most notable example to date is the nickel ore export ban in Indonesia that aimed at forcing foreign investors to construct smelters in the country (Warburton, 2023). The 2023 Chilean announcement of a national lithium plan which would make the state a majority shareholder in all new lithium projects is another similar, but distinct strategy (Financial Times, 2023). The lithium-producing provinces in Argentina have discussed, but not yet introduced, an export tax or joint venture conditions.

These producer-state approaches put in place a third variable in the bipolar framing of US-China rivalry that prevails in the majority of policy analysis. Should resource-endowed states manage to seize a greater portion of the value chain, be it via Indonesia-type export embargo, Chile-type nationalisation, or in some hypothetical lithium-based OPEC, resource concentration of processing capacity can change, however it may not always change towards Western democracies. It can tilt towards a group of mid-income, politically heterogeneous states whose orientation to one side or the other of the Sino-American rivalry is contingent and transactional. This makes the strategic calculus rather more problematic and highlights the inefficiency of a de-risking approach that is solely about decreasing reliance on China and not about the larger structural dynamics of the global mineral economy.

An argument against the above analysis could be: the concentration risk as described above is only unique to the current lithium-ion battery chemistries and that technological innovation will make it a thing of the past by allowing alternative chemistries to be used based on more plentiful and widely distributed materials. An example is sodium-ion batteries, which utilize sodium, which is practically inexhaustible, in place of lithium, and does not need cobalt or nickel. Solid-state batteries are expected to have greater energy density, and can allow the use of alternative cathode and anode materials. Iron-air, flow, and other grid-scale storage technologies are an alternative to lithium-ion in stationary applications.

This is a valid objection but untimely. Sodium-ion technology is rapidly developing, but still in its initial commercial phase, and the energy densities of the cells are still about 30–40% lower than comparable lithium-ion cells (CATL, 2023). The manufacturing scalability issues facing solid-state batteries have forced commercial deployment schedules out into the distant future several times. In the most positive projections, lithium-ion chemistries are expected to control the EV battery market at least until 2035 and probably 2040 (BloombergNEF, 2024). The weakness that is defined in this paper therefore matches exactly to the time frame where other technologies are still in a commercial youthful stage. The technological diversification argument is appropriate as a long-term solution; it is inadequate as a short-to medium-term reaction to an imminent structural weakness.

Additionally, it is notable that other chemistries have their supply chain dependencies. Sodium-ion batteries need Prussian white or hard carbon anodes, to which China is also establishing predominant processing capacity. The germanium, lithium metal, or garnet-type electrolyte materials used in solid-state batteries have supply chains that are not any less concentrated than the typical lithium-ion inputs. The assumption that the concentration problem will be solved by technological innovation assumes that there can be a certain degree of material substitutability that is not supported by the chemistry. Battery technologies have their bill of materials and bill of materials have their geography of dependence.

5. CONCLUSION

This article has made a simple yet little recognized point: the green energy transition, as outlined, does not set Western liberal democracies free of resource-based geopolitical vulnerability but restructures this vulnerability in ways that are, by a number of measures, more pronounced and less manageable than the petroleum dependency that it aims to mitigate. The carbon-based hegemony has not been replaced by a mineral-based security, but it is not a liberation narrative but a substitution narrative, and that substitution, as current evidence indicates, is not a favourable one.

The empirical results are dramatic. The processing-stage HHI values of lithium, cobalt and graphite are between 5,120 and 7,700 -concentrations that are comparatively higher than any similar measure in the petroleum industry in the last five decades. Between 65 and 87 percent of the world refining capacity of these three materials is controlled by one state: China, which is structurally unprecedented in the modern history of energy commodities. The policies of both the EU and the US, though directionally correct, are out of phase with the physical schedules of supply chain diversification, and therefore present a vulnerability window that will remain throughout the timeframe of the greatest demand acceleration.

These findings have been placed in the theoretical context of interdependence theory and weaponization of interdependence and the middle processing part is argued to be a choke point of the first order which can be, and indeed is being to some degree, exploited geoeconomically. Competing de-risking strategies, the paradox of clean energy being sought through mercantilist methods, and the yet to be resolved situation of Global South resource producers make the situation even more complicated as a security dilemma.

The policy implication is that the only strategy which is commensurate with the magnitude of the challenge is strategic pluralism, a term which the author suggests applies to a diversification strategy that occurs at the supplier and processing node level and underpinning technologies level, simultaneously. The diversification of suppliers and being tied to one battery chemistry is not enough. Investing in other

chemistries without engaging the resource producing states diplomatically is not complete. It is not wise to construct domestic capacity of processing without paying attention to the security dilemma dynamics generated by the Western policies in Beijing. Successful strategy needs all three dimensions, which are sought simultaneously and in a conscious of their interactions.

One more point deserves a comment. Policymaking in some quarters tends to regard the green transition as a sector in itself, to consider CRM security as a technical challenge that can be isolated, independent of the overall dynamics of great power politics, the politics of alliances, and the future of the liberal international order. It is not. Whether based on carbon or on minerals, energy security is a zero-sum game on the margin. The data vary; the logic remains. The more quickly policymakers come to internalise this continuity, the more they are set to face a period of mineral-based geopolitics that will be at least as convulsed as the petroleum century it alleges to have replaced.

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