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Restructuring of Critical Mineral Supply Chain Faces "Trilemma"

— Economic risks to surge by pursuing de-risking from China and decarbonization* —

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〈Summary〉

◆ Developed countries and regions, mainly the US, EU and Japan, are attempting to implement a fundamental restructuring of their critical mineral supply chains. They have three goals: (1) de-risking (reducing dependence) from China, (2) decarbonization, and (3) economic stability. The first, de-risking from China, reflects the fact that critical minerals are essential inputs for high-tech equipment like semiconductors. As critical minerals also have an important role in military technology, the geopolitical risk posed by extreme dependence on Chinese supply — that has been weaponized in the past — raises serious concerns. The second, decarbonization, derives from the fact that critical minerals also play a vital role in the production of electric vehicles (EVs) and equipment related to renewable energies. Critical minerals are indispensable to the shift to clean energy, where rapid progress is required to avoid catastrophic climate change. The third, the importance of economic stability, has arisen from the reality that disruptions in critical mineral supply chains and failures in the energy transition pose significant economic risks. Fiscal sustainability is also at risk when pursuing decarbonization and de-risking from China through the use of government support. Reviewing the supply chain is imperative to mitigate and minimize risks, and to find strategies to avoid fiscal and other risks.

◆ China currently supplies clean energy-related equipment (such as batteries and other renewable energy-related instruments) and its components, including critical minerals, at low cost, thereby alleviating some of the economic burden of the global clean energy transition. Given that the world still relies on China as the primary source for the clean

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energy transition, it is unrealistic to expect that "de-risking from China", "decarbonization", and "economic stabilization" will proceed simultaneously.

◆ The restructuring of critical mineral supply chains faces this trilemma. In other words, the only possible combinations are (A) de-risking from China and decarbonization (sacrificing economic stability), (B) de-risking from China and economic stabilization (sacrificing decarbonization), or (C) decarbonization and economic stabilization (sacrificing de-risking from China), thus leaving no choice other than to abandon one of the three goals. Should developed countries, especially those that are fiscally constrained, attempt to forcefully restructure critical mineral supply chains based on the current priorities of de-risking from China and decarbonization, it would accelerate inflation and deteriorate fiscal conditions, destabilizing the economy.

◆ Both "de-risking from China" and "decarbonization" appear to be priorities in developed countries and might remain significant paths forward. If both directions are followed, a further move toward restructuring critical mineral supply chains must proceed, resulting in a greater risk of compromising price stability and fiscal sustainability.

● **This is an English version of "重要鉱物供給網再編のトリレンマ― 脱中国依存と脱炭素の追求が高める経済リスク ―" in JRI Viewpoint (The original version is available at https://www.jri.co.jp/MediaLibrary/file/report/viewpoint/pdf/14649.pdf)**

1. Preface

In recent years, the critical materials discussed in the context of economic security have ranged from inputs in industrial products such as semiconductors, batteries and robots, to energy resources such as Liquefied Natural Gas (LNG), and pharmaceuticals. Critical minerals are also included the critical materials, and as a result, developed governments are seeking to reorganize their supply chains. The priority for securing procurement of certain goods may vary from country to country, but many nations have placed critical minerals as their highest priority. Critical minerals are also receiving attention in Japan, second only to semiconductors.

The following section first examines why critical minerals have gained so much attention. The report then clarifies the relationship between "de-risking from China", "decarbonization", and "economic stabilization" and explores how achieving both "de-risking from China" and "decarbonization" simultaneously would affect the economy.

2. Why is it necessary to restructure the supply chain for critical minerals?

Recently, governments of developed countries have actively been restructuring their critical mineral supply chains. Their objectives include (1) de-risking from China, (2) decarbonization, and (3) economic stabilization, as described below.

(1) De-risking from China: China holds overwhelming market shares.

The definition of critical minerals may vary, including rare metals such as lithium and other minerals (for example, non-metallic minerals such as graphite and base metals such as copper). The priority for procurement of each mineral and the minerals listed as critical are not identical in each country. In Japan, the Ministry of Economy, Trade and Industry (METI) names 35 minerals as critical (経済産業省[2023]). The US lists 50 minerals (USGS [2022]), and the EU designates 34 critical minerals, of which 16 constitute "strategically important raw materials" (European Commission [2023]).

The EU has calculated the share of global supply for its 34 designated minerals, with China holding the highest share for 21 critical minerals (62% of the total) (Table 1). Critical minerals, like semiconductors, are indispensable inputs for high-tech equipment and also play an important role in military technology. The geopolitical risk posed by extreme dependence on China for supply has created substantial concern, driving a growing trend toward diversification of suppliers. Indeed, Japan considers critical minerals as materials attracting as much attention as semiconductors, and policy support for critical minerals and calls to attract companies to Japan are increasing (see the Appendix for comparisons with semiconductors).

That being said, as China does not necessarily have a concentration of mineral deposits, the country is not in a position to monopolize the extraction of many minerals and has a dependence on imports. Nevertheless, China is increasing its dominance in critical mineral markets by deploying its "Belt and Road Initiative" in mineral-rich countries and directing substantial funds to investments in resource development. For example, China is aggressively developing and building a procurement network for raw mineral materials by focusing on

developing cobalt mines in the Democratic Republic of the Congo. Additionally, it has intensified its investments in nickel refineries in Indonesia — a country known for harboring some of the world's largest nickel reserves. China also announced investments in a tungsten mine in Kazakhstan and a lithium salt lake project in Argentina at the Belt and Road Initiative Forum in October 2023.

Table 1. Analysis of Global Supply of Critical Minerals by the European Commission

	Material	Main global supplier	Share	Stage
1	aluminium	Australia	28%	E
2	antimony	China	56%	E
3	arsenic	China	44%	P
4	baryte	China	32%	E
5	beryllium	USA	67%	E
6	bismuth	China	70%	P
7	boron	Türkiye	48%	E
8	cobalt	DRC	63%	E
9	coking coal	China	53%	E
10	copper	Chile	28%	E
11	feldspar	Türkiye	32%	E
12	fluorspar	China	56%	E
13	gallium	China	94%	P
14	germanium	China	83%	P
15	hafnium	France	49%	P
16	helium	USA	56%	P
17	lithium	China	56%	P

	Material	Main global supplier	Share	Stage
18	magnesium	China	91%	P
19	manganese	S. Africa	29%	E
20	natural graphite	China	67%	E
21	niobium	Brazil	92%	P
22	nickel	China	33%	P
23	phosphate rock	China	48%	E
24	phosphorus	China	79%	P
25	scandium	China	67%	P
26	silicon metal	China	76%	P
27	strontium	Iran	37%	E
28	tantalum	DRC	35%	E
29	titanium metal	China	43%	P
30	tungsten	China	86%	P
31	vanadium	China	62%	E
32	HREEs	China	100%	P
33	LREEs	China	85%	P
34	PGMs	S.Africa	75%	P

Source: JRI based on European Commission [2023]
Note: E = Extraction stage P = Processing stage. PGMs(platinum-group metals) include iridium, platinum, rhodium, ruthenium.

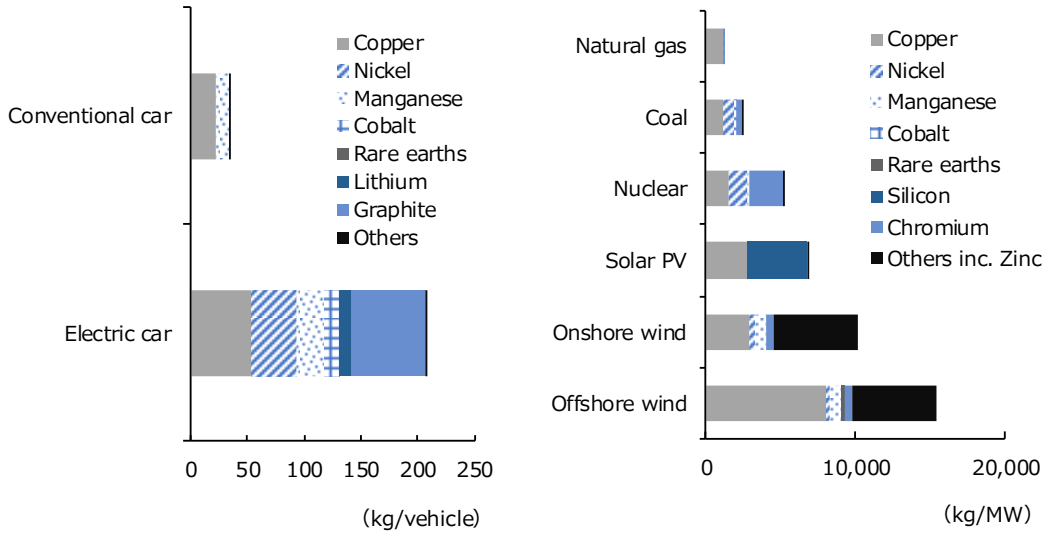
These investments and Chinese production of electric vehicles (EVs), solar panels and other renewable technologies reduce costs but pose challenges for developed countries as China's presence in renewable energy supply chains and its weaponized interdependence grow.

(2) Decarbonization: Essential for a clean energy transition

Critical minerals are also inputs in the equipment associated with EVs and renewable energy, such as batteries, high-performance motors and wind turbines. Therefore, they are essential for the transition to clean energy — an area expected to proliferate faster than ever (Hund et al. [2020]). In fact, among its 35 critical minerals, Japan has placed particular emphasis on the storage battery applications of materials such as rare earth elements, lithium, nickel, cobalt, graphite and manganese. (経済産業省[2023]).

The International Energy Agency's (IEA) data shows that the use of critical minerals in EVs (compared to conventional vehicles) and clean energy technologies (compared to the average use of coal and natural gas in

Figure 1. Critical Minerals used in Car and Clean Energy Generation



Source: JRI based on IEA[2021]

offshore, onshore and solar power generation) is more than six times greater than in conventional vehicles and energy (Figure 1). Some argue that critical minerals are less influential than oil and gas[1], but such arguments only take account of what has been the case to date. While coal currently is the second largest energy source after oil, with a market size of about $400 billion in 2020, critical minerals have a market size of only about $50 billion. However, the coal market will shrink in size by 2050, with the critical minerals market instead estimated to swell to more than $400 billion (Wood et al. [2023]). Assuming that EVs and clean energy will replace fossil fuels in the future, ensuring a stable supply of critical minerals is mandatory.

(3) Economic stabilization: Reduce economic risks such as supply disruptions and adverse effects of energy transition

When it comes to procuring critical minerals, the concentration of supply in China and supply chain disruptions are two sides of the same coin. Since August 2023, the Chinese government has introduced, but has not yet strictly deployed, export controls on gallium and germanium, which are critical minerals essential for manufacturing electronic components such as semiconductors. In addition, China tightened export controls on rare earth elements for motor magnets in October 2023, followed by graphite for batteries in December 2023. Amid the ongoing East-West confrontation represented by the US and China, the Chinese government may go beyond export controls and use critical minerals strategically, even by leveraging embargoes.

Furthermore, many countries, including Japan, have set a goal of achieving a decarbonized society by 2050. The challenge is to build an economic structure independent of fossil fuels such as oil, coal and natural gas. However, rapid structural change may cause energy shortages and other adverse effects in the process. Supply

[1] WSJ, Sept. 13, 2023, " As OPEC's Energy Influence Wanes, China's Minerals Clout Rises? - But geography and innovation mean cobalt, lithium and copper can never be weaponized as effectively as oil and gas."

chain restructuring now seems inevitable to mitigate the adverse economic effects of such a transition. Balancing energy security with an energy transition will be a challenge given geopolitical tensions and risks.

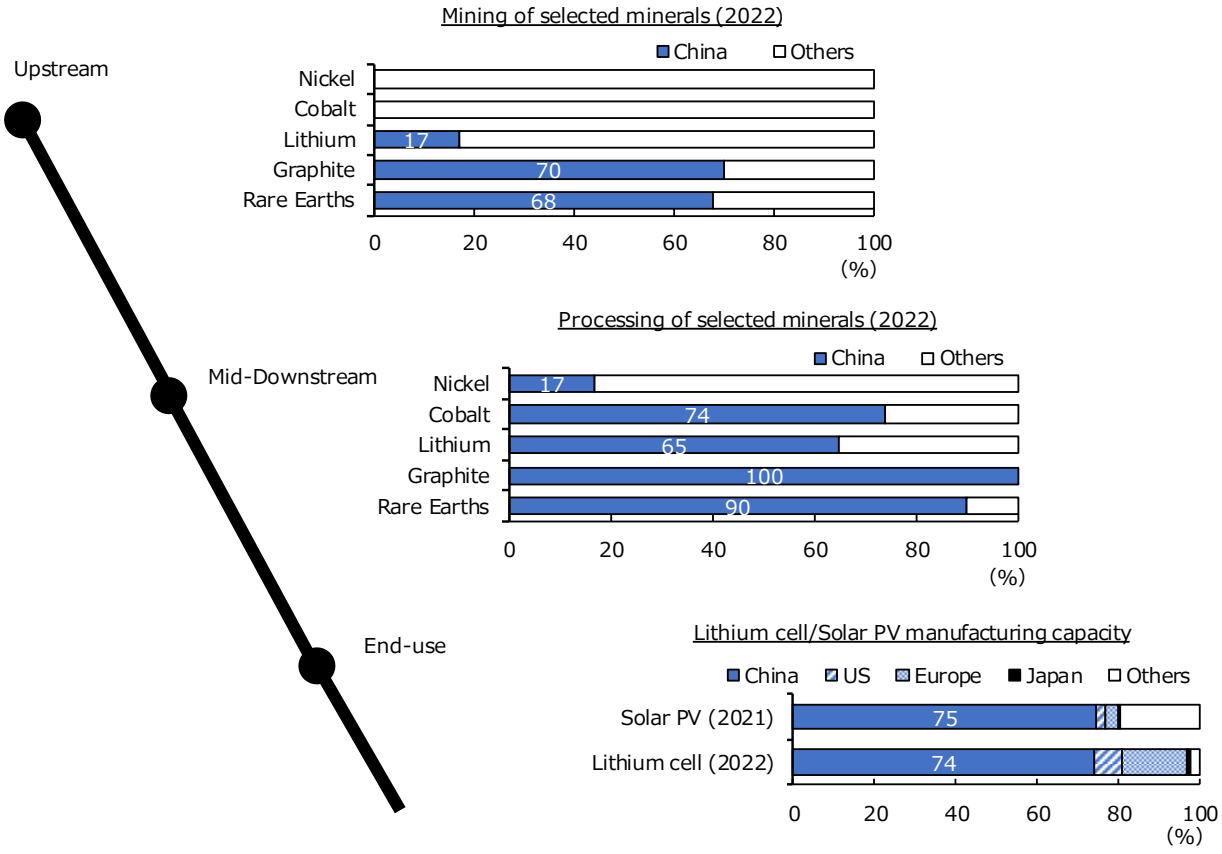
3. Simultaneously achieving de-risking from China, decarbonization, and economic stabilization not feasible

Achieving all three objectives of restructuring critical mineral supply chains — "de-risking from China", "decarbonization" and "economic stabilization" — appears to be virtually impossible. Herein lies the reality that the transition to clean energy for decarbonization is only possible with China. De-risking from China will have to mean mitigating, minimizing and managing risk, instead of avoiding risk completely by decoupling. Minimizing risk to zero is a corner solution that appears too costly to achieve.

(1) Manufacturing of equipment related to decarbonization is not feasible without China

China has an overwhelming share in not only critical minerals but also in clean energy-related equipment (batteries and renewable energy-related instruments) that uses critical minerals as inputs (Figure 2, 三浦

Figure 2. Critical Mineral Supply Chain: Up-Mid-Downstream and End-use



Source: JRI based on IEA[2023], BloombergNEF, Agency for Natural Resources and Energy in Japan

[2023]). Refining and processing critical minerals away from China but then ultimately exporting them to China would only add to the transportation costs. Creating clean energy equipment supply chains that are independent of China would be very costly if attempted at scale.

Moreover, with a cost advantage in the refining and processing processes for critical minerals, China is now reducing the economic burden of the clean energy transition worldwide by providing inexpensive materials. China's cost advantage derives from (1) large subsidies provided to Chinese companies, (2) labor costs remaining at a lower level than in developed countries, (3) mature companies in refining and processing operations for critical minerals, and (4) less stringent environmental regulations[2]. Regarding the lax environmental regulations, the Chinese government and companies have been increasing their attention to environmental measures in recent years, demonstrating that environmental efforts have not been entirely absent. Still, the extent to which stringent actions are being taken to process and treat critical minerals is unclear. Reports of pollution at Bayan Obo and many other mines (Nayar [2021]), along with news of lithium mining activities causing mass mortality of fish in rivers[3], suggest that allowing aggressive development and operations that cause environmental pollution has led to the low cost of lithium mining. While this is problematic from a humanitarian and global environmental perspective, it is also true that global decarbonization continues worldwide through the use of products that have undergone such processes.

(2) Restructuring Critical Minerals Supply Chain Facing a Trilemma

As described above, China plays a pivotal role in the global clean energy transition, and it is virtually impossible to restructure critical mineral supply chains in a way that simultaneously enables "de-risking from China", "decarbonization" and "economic stabilization." A "trilemma" arises where only one of the following options is available: (A) de-risking from China and decarbonization (sacrificing economic stabilization), (B) de-risking from China and economic stabilization (sacrificing decarbonization), or (C) decarbonization and economic stabilization (sacrificing de-risking from China) (Figure 3).

In the case of option (B), the suggested actions entail accepting a postponement of decarbonization efforts. This could facilitate the transition of sensitive technologies, particularly those related to high-tech equipment linked to military technology, into domestic production, a sector that deserves more emphasis. It has also been pointed out that excessive isolation of specific countries in economic interdependence or a return to self-reliance could heighten global economic risks. If a country forgoes the decarbonization measures that rely on China, it would also reduce the need to aggressively restructure its supply chain.

In case (C), economic cooperation with China would also come into consideration. The promotion of GX (Green Transformation)[4], which emphasizes both decarbonization and the economy, would not make sense if it were to place an excessive burden on the economy through factors such as increasing costs. It then ends up

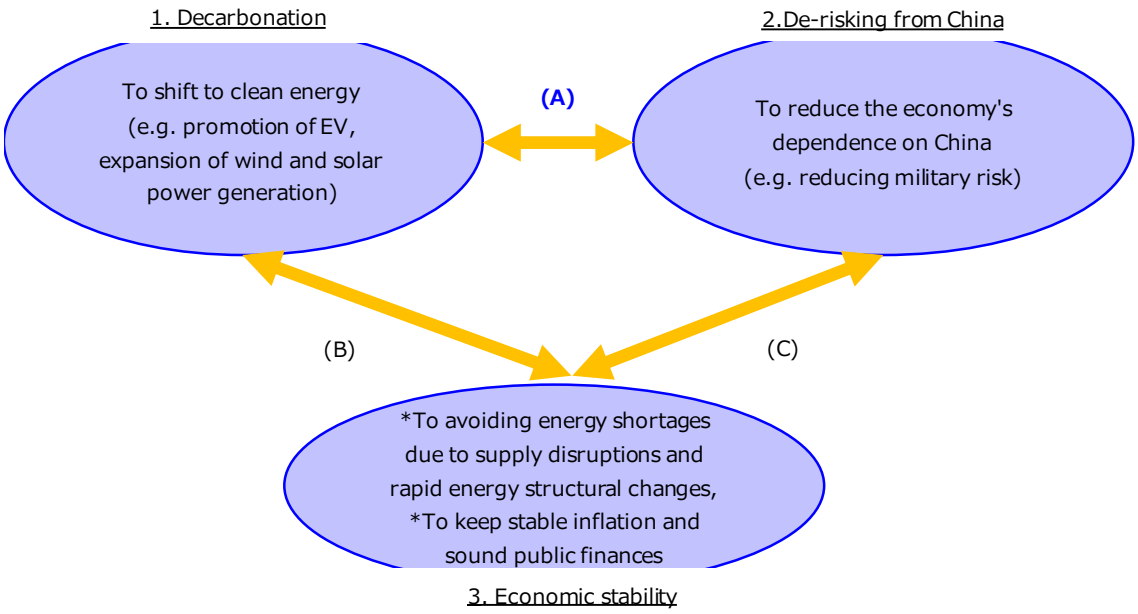
[2] The process of extracting impurities from ores could significantly strain the environment, leading to the generation of hazardous substances. In particular, many rare earth ores contain radioactive materials, generating radioactive waste in refining processes. Lynas, an Australian company, operates a rare earth processing plant in Malaysia, yet it receives intense criticism for its environmental problems in the country. (SCMP, Nov. 22, 2023, "Malaysia's rare earths ambition fuels Chinese displeasure fears, 'betrayal ' cries over radioactive waste.")

[3] AFP, Nov. 1, 2023, "China lithium boom harming fragile Tibetan plateau: report."

[4] METI describes GX as "an initiative to reduce carbon dioxide emissions by promoting solar, hydrogen, and other energy sources with minimal impact on the natural environment rather than relying on fossil fuels, and to transform the entire world to make these activities an opportunity for economic growth."

being more efficient to use the production of low-cost clean energy equipment available in China to accelerate toward a decarbonized society and to strengthen critical mineral supply chains that also involve China.

Figure 3. "Trilemma" of Critical Mineral Supply Chain Restructuring



Source: JRI

However, the US and other developed countries are currently pursuing option (A), which aims to simultaneously achieve both "de-risking from China" and "decarbonization." Advancing this approach would mean actively promoting a transition to clean energy independent of China. Such a shift would require substantial policy support, leading to concerns about escalating fiscal risks, especially in developed countries. Even if the reconfiguration of critical mineral supply chains progresses, the economy would have to accommodate higher-cost products, increasing its susceptibility to inflation. In such a scenario, "economic stabilization" would ultimately be deprioritized, setting the stage for the public and businesses to bear a growing economic burden.

The choices between substantial fiscal and economic risks, catastrophic climate change and growing interdependence with China are stark. Finding ways to manage the trilemma over time, and to reduce risks, are the key economic and strategic policy challenges.

4. Aggressive restructuring in pursuit of "de-risking from China" and "decarbonization" is likely to accelerate inflation

There is indeed a growing trend toward restructuring critical minerals supply chains in developed countries (Table 2). The US, the key player among these countries, has launched an extremely radical policy. Grants have been provided for investments in rare earth and graphite through the "Infrastructure Investment and Jobs Act", passed in November 2021, and through initiatives under the "Defense Production Act", launched in March 2022

(JOGMEC [2022]). Furthermore, in August 2022, the "Inflation Reduction Act (IRA)" came into law, containing the largest-ever climate change action package and allowing EV buyers to claim a tax credit if the critical mineral inputs originate in the US or from a country engaged in a free trade agreement (FTA) with the US. These policies aim to increase EV sales and battery production in the US, indicating that the nation is, through restructuring of its critical minerals supply chain, forcing towards "de-risking from China" and "decarbonization".

Table 2. Major Countries' Policies on Mineral Resources Supply Chain Restructuring

Critical mineral user countries	
US	*Inflation Reduction Act (IRA, August 2022): Tax credit for EV purchases (up to US$7,500, budget: USD12.5bn), which requirements mandate that EVs have a minimum percentage of critical minerals by value from North America or other free trade agreement partners. *Defense Production Act (DPA): Funding for critical minerals production projects *Infrastructure Investment and Jobs Act (IIJA, November 2021): Funding for critical minerals production projects (Rare earth, battery-related, etc)
Japan	*The government has allocated a budget totaling JPY 215.8 billion, which includes (1) investment projects by the Japan Organization for Metals and Energy Security (JOGMEC) and (2) subsidy programs related to mineral resources under the Economic Security Promotion Act.
EU	*European Critical Raw Materials Act (March 2023): EU aims to domestically process at least 40% of the annual consumption of critical minerals and mine 10% by 2030. To achieve this target, it simplified business permitting procedures.
Critical mineral supplier countries	
Australia	*2023 federal budget added AUD 57 million over four years to “foster international critical minerals partnerships” and a further AUD 23 million on critical minerals policy development. The prime minister has announced a AUD 2 billion expansion in critical minerals financing in October 2023.
Canada	*Canada’s Critical Minerals Strategy is released in December 2022, with up to CAD 3.8 billion in federal funding allocated in Budget 2022.

Source: JRI based on various media reports

However, supply chains with an almost exclusively US domestic manufacturing obligation have an inefficient cost structure. US policies centered on the IRA could fill the gap created by China's substantial market share in final goods and the large corporate subsidies that support its critical minerals industry. Nevertheless, these policies will not be able to compensate for China's strengths, such as its competitive advantage in low labor costs, high technology in critical minerals, and lax environmental regulations, thus failing to give the US a competitive advantage[5]. While the US subsidies for EVs will contribute to substantive price reductions, upward pressure on prices for clean energy-related equipment not covered by subsidies appears unavoidable[6].

Continuous subsidies for EVs and numerous other clean energy-related equipment are likely to be necessary to secure a stable market share in final goods relative to China. The US has set a goal of increasing the share of

[5] Considering the low-cost procurement (such as an inexpensive workforce) of critical minerals, emerging Asian countries could be an option for use. However, Indonesia, a country rich in nickel, is not included in the IRA due to concerns about the significant influence of Chinese companies in mining and refining. The emphasis is more on de-risking from China than on cost structure.

[6] Despite the name "Inflation Reduction Act", few believe that the law will be effective in controlling inflation (JETRO [2022]).

EVs in new vehicle sales to 50% by 2030. This means that the US aims to increase EV sales from the current value of around 800,000 units in 2022, to a staggering more than 7 million units (50% of the total 13.9 million vehicles sold in 2022). Given the ongoing sluggish state of EV sales in the US[7], a significant ramp-up in subsidies through fiscal expansion is necessary to realistically achieve this target. Yet if the current purchase subsidy ($12.5 billion), an already vast sum, expands further to continue over the long term, problems will likely arise from a fiscal sustainability perspective. Looking at the present situation, Japan and Europe will probably follow suit.

5. Conclusion

According to the Wall Street Journal, "Western governments once welcomed China's willingness to do this dirty work. It was the sort of interdependence globalization was supposed to foster[8]." The pursuit of "de-risking from China" and "decarbonization" have made such a situation a thing of the past, and the major focus is now on attracting industries for refining and processing processes that present high barriers to entry for developed countries in the global critical mineral supply chain.

There are, of course, some attempts to correct the overreaching argument that nations should de-risk from China entirely, or pursue an energy transition at an unrealistic pace. The US has not entirely excluded China from its policy framework for strengthening domestic manufacturing and has accepted investment from Chinese battery manufacturers[9]. While cooperating with the US in the critical minerals industry, Australia is not willing to exclude Chinese investment in this sector[10]. China is the largest market for Australia's critical minerals exports. The road to achieving a "decarbonized society by 2050" is a difficult one, and there are frequent discussions about allowing a delay in achieving the goal. Many have also pointed out the shortage of recharging infrastructure for EVs, raising skepticism about whether EVs can be the silver bullet for decarbonization.

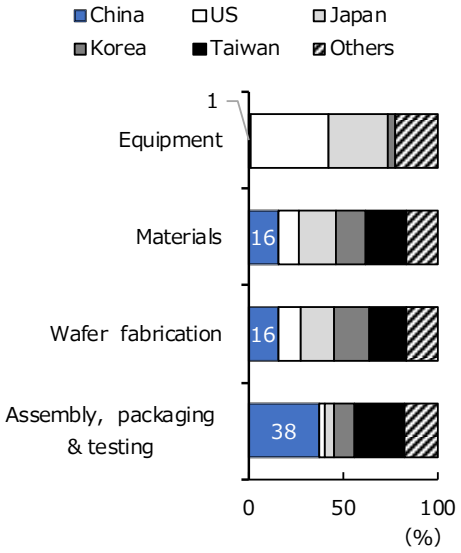
However, the aims of "de-risking from China" and "decarbonization" may be more easily embraced within developed countries and are likely to persist. Note that if these two discussions intensify, there will also be more aggressive moves to restructure critical mineral supply chains — exacerbating economic risks through accelerating inflation and heightened fiscal risks.

[7] WSJ, Nov. 17, 2023, " Are Americans Falling Out of Love With EVs? - Manufacturers need to cut costs as electric-vehicle inventories pile up, but this is easier said than done."
[8] WSJ, Sept. 13, 2023, " As OPEC's Energy Influence Wanes, China's Minerals Clout Rises? - But geography and innovation mean cobalt, lithium and copper can never be weaponized as effectively as oil and gas."
9 Nikkei Asia, Dec. 7, 2023, "CATL says Ford project on track despite new U.S. battery rules - Chinese EV battery maker confident its technology will be used at Michigan plant."
[10] The Australian Financial Review, Nov. 16, 2023 "Farrell welcomes Chinese investment in critical minerals."

Appendix: Differences from Movements in Semiconductor Supply Chain Restructuring

Critical minerals are not the sole industry experiencing a flurry of movement around supply chain restructuring. Semiconductors are a typical example of where support for the industry has intensified in recent years, particularly in the US. However, the situation is different for semiconductors, except for target (3), when it comes to the objectives of (1) de-risking from China, (2) decarbonization, and (3) economic stability, as outlined for critical minerals.

Figure 4. Semiconductor Industry Share by Activity and Region (2019)



Source: JRI based on SIA/BCG[2021]

The goal of the semiconductor industry, led by the US, was to prevent China from expanding its semiconductor manufacturing capacity, rather than to reduce its dependence on China. Compared to critical minerals, dependence on China in semiconductor manufacturing has not been as high (Figure 4). Furthermore, restructuring the semiconductor supply chain focuses primarily on protecting advanced technology rather than contributing to decarbonization. The advanced technologies involved are also narrowly limited through the strategy of "small yard, high fence." Initially, when the "CHIPS Plus Act" (with a budget of $52.7 billion) passed in the US in August 2022, the primary emphasis was on reshoring to the US. Japan and other countries also later developed aggressive support measures which accelerated moves to increase manufacturing capacity and centered mainly on the CHIP 4 alliance, comprising the US, Japan, Korea and Taiwan (Nogimori [2023]). The system does not necessarily concentrate on the US alone but involves regions with a competitive advantage in production, resulting in reinforcement rather than restructuring.

While supply chain restructuring is increasingly attracting attention in the debate on economic security, excessive separation of a particular country or focus on reshoring, in turn, would increase risks for the global economy. With the world relying on China as the source of the clean energy transition, restructuring critical mineral supply chains poses a more significant challenge than for semiconductors, necessitating an understanding that it could lead to economic irrationality and pose a greater risk to the global economy.

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