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CRITICAL MATERIALS' SUPPLY CHAINS AND US NATIONAL SECURITY

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Abstract. The COVID-19 crisis and the Special Military Operation in Ukraine have showed how quickly and deeply global supply chains can be disrupted. This is especially true for critical and strategic materials. Many of these raw materials are critical to the European and US economies. They form a strong industrial base, participating in the production of a wide range of goods used in everyday life and modern technologies. Reliable and unfettered access to certain raw materials is a growing concern in the United States and around the world. Success in transforming and modernizing economies depends on the sustainable supply of primary and secondary raw materials needed to scale up clean and digital technologies in all industrial ecosystems. One of the lessons of the COVID-19 crisis is the need to reduce dependency and strengthen the diversity and security of supply of critical raw materials. The expansion of strategic self-sufficiency is a priority of the long-term policy of the US and the EU. This article highlights the challenges and priorities for the United States to strengthen its strategic approach to building more sustainable commodity value chains. Strategic self-sufficiency, therefore, should, in the opinion of American and European experts, be based on diversified access to world commodity markets. At the same time, in order to reduce external dependence, the problem of rapidly growing global demand for resources is proposed to be solved by reducing and reusing materials. Achieving resource security requires action to diversify supply from primary and secondary sources, reduce dependency, and improve resource efficiency. This applies to all types of raw materials, including base metals, industrial minerals, and biotic materials.

Keywords: critical material, supply chains, risk of disruption, US national security.

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ЦЕПОЧКИ ПОСТАВОК КРИТИЧЕСКИ ВАЖНЫХ МАТЕРИАЛОВ И НАЦИОНАЛЬНАЯ БЕЗОПАСНОСТЬ США

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Аннотация. Стратегические материалы критически важны для экономики и национальной обороны. В последнее время глобальные цепочки их поставок оказываются подверженными серьезным рискам сбоев вследствие геополитических конфликтов, форс-мажорных обстоятельств и других факторов, что заставляет США вырабатывать новые стратегии устойчивости и самообеспеченности.

Ключевые слова: критически важные материалы, цепочки поставок, национальная безопасность, США.

The United States is increasingly complaining about the excessive dependence on external supplies of many types of products, especially strategically important materials [source 1]. The spurt of globalization that has taken place in recent decades has been accompanied by a boom in offshore production. As a result, the US has largely "demobilized" its manufacturing facilities. Deficits associated with the COVID-19 pandemic in 2020–2021 highlighted the shortcomings of such a system, and unprecedented sanctions against Russia and heightened tensions with China in 2022 made the US authorities seriously think about the dangers of economic tying to a limited number of foreign states.

SUSTAINABILITY CHALLENGES IN GLOBAL SUPPLY CHAINS AND VALUE CHAINS

The COVID-19 pandemic has exposed longstanding vulnerabilities in US supply chains. The transition to work and learning from home has created a global shortage of semiconductor chips that has affected the automotive, industrial, and telecommunications sectors. Extreme weather events exacerbated by climate change have further exacerbated the deficits.

Both Republican and Democratic administrations have expressed concern about the dependence of the American defense sector on a limited number of domestic suppliers [source 2]. The innovation it needs often requires ecosystems, skills, and manufacturing facilities that the US does not have.

Economic security – stable employment and a smooth operation of critical sectors – also requires sustainable supply chains. More than 10 years ago, the Department of Defense discovered that major civilian sectors could be severely damaged by the disruption of strategic supplies of critical materials. It was noted that today, China processes 60% of the world's lithium and also 80% of cobalt, the main raw material for high-capacity batteries, which are critical for the US automotive sector [source 2].

Finally, the country's domestic innovation potential depends on a robust and diversified industrial base. When manufacturing moves offshore, innovation tends to follow. The US Department of Commerce notes that large-scale government investment in semiconductor manufacturing has allowed Korean and Taiwanese firms to outpace American firms in this area [source 3].

The stability of the supply chain is determined by its ability to quickly recover from any shocks. The traditional private sector and public policy approach to domestic manufacturing, which for many years prioritized efficiency and low costs over safety and sustainability, has led to increased risks in the supply chains of critical products, and, according to American experts, undermined worker standards of living and the ability to manage natural resources domestically and globally.

The Biden administration has set a course to revitalize the national manufacturing facilities and ensure the security of global supply chains, restoring sustainability at the national level. Particular attention is paid to the supply chains of strategic materials, in particular rare earth metals. Demand for them is projected to rise sharply over the next decades, especially as the world moves to eliminate carbon emissions. For example, global demand for lithium and graphite by 2040 will grow by 4,000 and 2,500%, respectively [source 4]. China in 2020 controlled 55% of the world's capacities for the extraction of rare earth elements and 85% of their processing [1].

The Department of Defense notes four fundamental risks to global value chains:

1) threats in the event of a serious armed conflict;

2) consolidation (concentration) of supply chains in terms of ownership, geography, and market access;

3) lack of objective information on the sources of materials supplies;

4) lack of sustainability in supply chains [source 5].

Table 1. Exposure to shocks in major global value chains (1 is the highest vulnerability rank)

Sectoral value chain	Shock vulnerability rank
Communication equipment	1
Manufacture of wearing apparel	2
Petrochemistry	3
Transport equipment	4
Mining	5
Computers and electronics	6
Textile industry	7
Aerospace	8
Semiconductors	9
Construction materials	10
Chemistry	11
Metallurgy	12
Furniture manufacture	13
Automotive	14
Rubber	15
Electrical equipment	16
Agriculture	17
Mechanical engineering	18
Pharmaceuticals	19

Source: [source 6].

The five global chains most exposed to external shocks account for USD4.4 trillion of annual world exports or ¼ of global merchandise trade. Mining, oil and gas, and petrochemical sectors are among the most vulnerable and risk-prone industries (Table 1).

SUPPLY CHAIN VULNERABILITY FACTORS

For various sectoral value chains, American experts assessed a wide range of supply risks – from the search for raw material stock to the manufacture and distribution of finished products. The following risk factors have been identified.

1. Insufficiency of manufacturing capacities in the US manufacturing industry, which have been declining for several decades. In the period from 2000 to 2010, more than 1/3 of production jobs were lost there [source 6]. This can be partly explained by competition from low-wage countries. It has been estimated that about 25% of US job losses can be attributed to China's economic recovery, especially after WTO accession [2]. In the United States, there was also stagnation in productivity growth (compared, for example, with Germany) and innovation potential [3].

2. Short-term effect of market incentives. Research shows that current US market structures do not adequately reward firms for investing in quality, sustainability, and long-term productivity. The emphasis on maximizing short-term returns on capital has led to underinvestment by the private sector in long-term projects. For example, between 2009 and 2018, *S&P 500* firms diverted 91% of their net income to shareholders either in share buybacks or as dividends, which meant a reduction in the share of corporate income devoted to research and development, new facilities, or sustainable manufacturing processes [4].

3. The nature of industrial policy. While US investment in domestic manufacturing facilities was declining, competing countries were adopting strategic programs to increase national competitiveness. For example, in Europe, policies have been developed to support demand, investment incentives, and regulatory instruments – both in the EU as a whole and at the level of member states –

to stimulate the national production of electric vehicles and lithium-ion batteries, which have been designated as having "strategic interest", and a USD3.5 billion R&D fund was announced to improve the competitiveness of the industry. Taiwan, a global leader in the production of state-of-the-art semiconductor chips, provides subsidies for the establishment of manufacturing facilities in the sector, including covering 50% of the cost of acquiring land and 45% of the cost of construction and equipment in addition to investments in R&D [4].

4. Geographic concentration of global supply chains. The search for cheap manufacturing, coupled with effective industrial policies in key countries, has led to the geographic concentration of major supply chains in a few countries, increasing the vulnerability of the US and other global manufacturers to disruption, whether it be some kind of natural disaster, geopolitical event, or pandemic. Thus, the world depends on Taiwanese firms that produce 92% of advanced semiconductor products. China accounts for more than 75% of the world's capacity for making cells for modern batteries. India competes with the United States for market share in many drugs, but at the same time, imports almost 70% of its active pharmaceutical ingredients from China [4].

SUPPLY CHAINS FOR STRATEGIC MATERIALS

The materials sector includes all the elements of Mendeleev's periodic table in their natural and synthetic forms. Strategic and critical materials and their supply chains are the backbone of value-added in the manufacturing sector, as well as the provision of a variety of services in telecommunications, agribusiness, finance, healthcare, education, transportation, and public safety.

In the civilian sectors of the US economy, such materials are essential to the manufacture of a wide range of industrial products, ranging from personal electronics and consumer goods, fuels, food, and medical supplies to building homes and maintaining the national critical infrastructure. In the defense industry, they guarantee the expansion of manufacture and development of military equipment, ensuring its high tech status.

Although the domestic manufacture of strategic and critical materials represents only a small portion of the total US output, employment, and GDP, it provides broad support for downstream segments of the manufacturing and service chains. For example, the annual production of minerals in the country is estimated at less than USD100 billion, but it provides the manufacture of more than USD3 trillion of value added, out of the country's USD20 trillion GDP [5]. Non-fuel minerals (or mineral materials) perform an important function in the manufacture of commodities. Their absence would have significant consequences for national security [source 7].

A material flow analysis is an important tool in studying the demand for strategic and critical materials coming from the mining sector and the process of their recycling [source 8]. Such an analysis is also important for identifying excessive dependence on foreign sources of raw stock and the degree of vertical integration in supply chains. So, in the supply chain of neodymium-iron-boron ($Nd - Fe - B$) magnets, only China is able to be present in all its segments [source 3].

Recycling and secondary consumption of critical materials are of great importance. Recycling rates for base metals are often very high; so, for steel they usually exceed 80%, satisfying a significant part of its annual consumption. A number of strategic materials (such as certain gases and refrigerants) are obtained exclusively from recycling processes after primary consumption.

Establishing the manufacture of strategic and critical materials is an extremely lengthy process. Without taking into account the time of obtaining permission to conduct such operations, an approximate industry benchmark for the development of a project on strategic and critical materials on a mineral basis is at least ten years. Moreover, most companies quite often fail to complete this process due to long project development times, cost recovery, and technical problems associated with financing large and comprehensive production materials projects. For example, at the peak of industrial and market interest in the rare earths sector in the early 2000s, *Technology Metals Research* surveyed approximately 275 rare earth projects being developed by 180 public companies in 30 countries, excluding projects in China, Russia, and India. As of April 2021, only two projects have been fully launched, while the other two remain at the stage of pilot production, that is, the cumulative success rate over the past decade was 1.5% [6].

The US always, even in wartime, relied on imports of strategic and critical materials to meet the needs of the public and private sectors. Over the past 60 years, the country's net dependence on imports of a number of such materials has increased dramatically [7]. It is defined as the amount of a material imported (including changes in existing stocks) less exports as a percentage of domestic consumption. The number of non-fuel minerals, the imports of which in the United States are at least 25%, has grown from 21 in 1954 to 58 at present (Table 2). In the supply of critical materials, the United States seeks to maintain relations primarily with its allies.

Canada has become the second largest source of imports of those strategic and critical materials for which the US has a net import dependence of more than 50%. Canadian companies export various strategic and critical materials to the US, including high-purity aluminum and gallium. Gallium is becoming increasingly important in the production of integrated circuits, laser and light-emitting diodes, solar cells, radar, and infrared equipment. The volume of trade in strategic and critical materials between the US and Canada exceeds USD80 billion a year. Canada is also a global center for financing mining projects, including financing risks and supporting exploration companies looking for new deposits of crit-

Table 2. US dependence on imports of critical materials, %

Material	Dependence on imports	Key imports supplier
Arsenic	100	China, Morocco, Belgium
Asbestos	100	Brazil, Russia
Fluorspar	100	Mexico, Vietnam, China, South Africa
Natural graphite	100	China, Mexico, Canada, India
Manganese	100	Gabon, South Africa, Australia, Georgia
Niobium	100	Brazil, Canada, Germany, Russia
Rare earth elements	100	China, Estonia, Japan, Malaysia
Scandium	100	China, Japan, Russia
Tantalum	100	China, Germany, Australia, Indonesia
Yttrium	100	China, South Korea, Japan
Vanadium	96	Brazil, South Africa, Austria, Canada
Bismuth	94	China, South Korea, Mexico, Belgium
Potash	94	Canada, Belarus, Russia
Zinc	83	Canada, Mexico, Peru, Spain
Platinum	79	South Africa, Germany, Italy, Switzerland
Cobalt	76	Norway, Canada, Japan, Finland
Bauxites	75	Jamaica, Guyana, Australia, Brazil
Chromium	75	South Africa, Kazakhstan, Mexico, Russia
Tin	75	Indonesia, Malaysia, Peru, Bolivia
Lithium	50	Argentina, Chile, China, Russia
Nickel	50	Canada, Norway, Finland, Russia
Palladium	40	Russia, South Africa, Germany, UK
Copper	38	Chile, Canada, Mexico
Lead	24	Canada, South Korea, Mexico, India

Source: [source 9].

ical materials. The country can meet US needs for cobalt, tantalum, antimony, and 20 other strategic materials.

Australia. Australian companies have established important partnerships with several US companies to participate in projects on the extraction of strategic and critical materials. Key examples of this work are joint ventures associated with the processing of light and heavy oxides of rare earth elements [source 10]. Australia competes with Canada approximately on an equal footing in financing mining (USD1.5 billion and 1.3 billion in 2019, respectively [source 11]), since it owns their vast deposits, including 21 from the list critical for the USA [source 12].

Japan. Japan is one of the founders of trilateral cooperation in critical materials, together with the US and the European Union (EU). It is an active player in the supply chains of strategic and critical materials as an importer of raw stock, a source of project finance, downstream manufacturing in global supply chains, and an R&D center for materials. After 2010, in response to a territorial dispute with China that led to a de facto Chinese embargo on the exports of rare earth elements, Japan adopted a coordinated national program to diversify its rare earths supply chains by combining research and development related to waste processing, stockpiling, replacement, and development of new products, as well as facilitating project financing for foreign mining projects.

The European Union. The main mechanism by which the United States interacts with the EU on strategic and critical materials is the aforementioned EU-US-Japan Tripartite Agreement. The European Commission released, in 2020, the Action Plan on Critical Raw Materials, which sets out the goal of reducing dependence on foreign sources along the entire value chain of critical materials, see [source 13]. Active joint work is carried out through the European Rare Earths Competency Network (*ERECON*); part of it is taken over by the emerging European Raw Materials Alliance [source 14].

ERECON's recommendations include the following:

– support for promising technologies by financing pilot plants for the manufacturing and processing of heavy rare earth elements;

– creating a level playing field for the exploration of heavy rare earth elements in Europe through co-financing of preliminary and bank feasibility studies;

– improving the efficiency of rare earths waste management through eco-design, incentive schemes for the collection of priority waste, as well as rationalization of the regulatory policy in this area [source 14].

As the world's largest economies, the United States and China are the main consumers of strategic and critical materials. The unprecedented growth of the Chinese economy has led to a reorientation of many of their supply chains. China now dominates the processing of such materials, effectively maintaining control over supply chains.

Despite the growth in domestic production and mining in China, they have not kept pace with the rapid growth of the country's economy, whose nominal GDP rose from USD426 billion in 1992 to USD14.2 trillion in 2019. This significant growth has led to an equally significant increase in China's net dependence on imports of strategic and critical materials. As China's demand for cobalt, copper, lithium, platinum group metals, and other materials has increased, the country has intensified its efforts to cover the entire value chain in a variety of modern technology segments such as permanent magnets, batteries, and semiconductors. There have been significant flows of Chinese foreign direct investment in the supply chains of materials related to lithium-ion batteries [source 15].

For example, China's nominal net dependence on imports of cobalt ores and concentrates is approximately 97%. At the same time, this figure hides the fact that Chinese companies were actively investing in shares or even direct ownership of cobalt assets in the Democratic Republic of the Congo, Papua New Guinea, and Zambia. With these activities, China's net dependence on cobalt imports reduced from 97% to 68%. China dominates in the field of cobalt processing, effectively controlling global material flows in this segment of the chains [source 15].

It should be noted that the US net dependence on imports of cobalt ores and concentrates is zero. At the same time, the absence of such dependence does not necessarily indicate the absence of risks. In this case, the US does not import cobalt ores and concentrates because it does not have the appropriate processing capacity. Therefore, the US is highly dependent on net imports of high-value-added cobalt and cobalt in finished products (such as batteries).

RISKS OF THE SUPPLY OF STRATEGIC MATERIALS

Over the past decade, peacetime supply chain disruptions have become more frequent and intense. The main reasons are as follows:

- territorial and country concentration of supply and sources of supply;
- availability of only one source of supplies;
- price shocks;
- lack of human capital;
- foreign trade practices;
- geopolitical risks.

When the share of a particular country exceeds half of the world output for a particular strategic and critical material, it is considered to be dominant in the foreign market. The US Department of Defense has compiled a list of 37 scarce strategic materials with a dominant supplier [source 9].

Supply from a mono source. In some cases, supply concentration can be extreme, with the global or national production of a commodity concentrated in one place. According to the Department of Defense, out of 53 critical materials, 29 are supplied to the market from a single domestic source, and 18 materials are not domestically produced at all.

Gaps in skills and human capital development. The 2020 Industrial Capabilities Report to Congress of the Department of Defense highlights the danger of a reduction in the workforce in advanced manufacturing sectors [source 5]. A discrepancy between the needs for the qualification of the labor force and the curricula has been discovered. The entire US supply chain for critical minerals is facing workforce challenges, including the aging and retirement of staff. For more than 35 years, the number of colleges and universities with mining and metallurgical programs has been steadily declining [8].

Market shocks and price shocks. Markets for strategic and critical materials are often very small because efforts to increase the output require comprehensive project financing and supply is relatively inelastic in the short term. Meantime, there is significant short-term price volatility for many strategic and critical materials. So, in 2010–2011, changes in China's rare earths export policy and the territorial dispute between China and Japan in the East China Sea have led to an exponential increase in the price of rare earths. Their prices returned to "normal" values only after 2014.

Foreign trade practices. Another type of risk for critical materials supply chains is related to unfair foreign trade practices that distort world prices and affect competitiveness. These include, but are not limited to, exports restrictions that encourage domestic manufacturing and processing, intellectual property theft, especially related to materials processing technology, and export subsidies.

Thus, the US has filed 23 cases against China since its entry into the WTO. Of these, 11 cases were resolved in favor of the United States, 9 were settled in good faith, and the rest were "stuck". In particular, for a number of goods, Beijing canceled the preferences for the national industry. As of April 2021, the United States had more anti-dumping and countervailing duties against China than any other country – 215 out of 576 [source 16]. Almost 60% of duties concerned chemicals, steel products, metals, and other minerals.

The Department of Defense notes that out of the 283 materials it has reviewed and evaluated, 53 are in short supply in the United States [source 5], and in an emergency situation, the country may face a lack of access to foreign sources (Table 3). Among them are 84 countries, each making at least one material that is scarce for the United States:

- 27 countries produce 1 scarce material;
- 20 countries – 2 materials;
- 16 countries – from 3 to 5;

Table 3. List of scarce materials and their main areas of application in the US economy

Material	Areas of application
Aluminum	Commercial aircraft, combat vehicles and vehicles
Alloys of aluminum and lithium	Commercial aircraft
Antimony	Pressure blasting technology, plastics, batteries, synthetic rubber
Arsenic	Semiconductors and other electronic components
Beryllium	Search-detecting and navigation equipment
Bismuth	Medicinal chemicals and herbal products, pharmaceuticals
Bor-10	Nuclear power
Carbon	Defense industry
Cerium	Auto parts, oil refining, glass and glass products, equipment and media communications
Energy materials	Primers and tracers of ammunition, explosives
Erbium	Laser technology, optical fibers
Europium	Other manufacturing
Fluorspar acidic	Fluorocarbon air conditioners
Gadolinium	Pharmaceuticals and medicines, transport equipment
Graphite	Semiconductor equipment, industrial molds
Lanthanum	Oil refining, auto parts
Lithium	Alloys, batteries, pharmaceuticals
Magnesium	Metal containers, packaging, packaging materials, building materials, auto parts, electronic and communication equipment
Ferromanganese	Building materials, auto parts, oil and gas production
Neodymium	Computers, non-metallic mineral products, transport equipment, electronic components, motors and generators
Niobium	Oil and gas production, auto parts, aerospace
Praseodymium	Synthetic dyes and pigments, non-metallic mineral products, computers, auto parts
Permanent magnets (Nd-Fe-B)	Industrial engines, auto parts, magnetic resonance imaging
Rare earth permanent magnets, samarium-cobalt (Sm-Co)	Industrial motors, medical devices, consumer electronics
Natural rubber	Tire production
Samarium	Electromedical and electrotherapeutic devices
Scandium	Fuel cells
Tantalum	Electronic capacitors, explosive projectiles, warheads
Tin	Solders for electronic components
Titanium sponge	Aerospace
Tungsten	Metalworking equipment, electric lighting equipment
Yttrium	Flasks for electric lamps, aircraft engines and parts for them, semiconductors, and other electronic components

Source: [source 2].

- 11 countries – from 6 to 10;
- 7 countries – from 11 to 20;
- 3 countries – more than 20.

The Russian-Ukrainian conflict has had a huge impact on the restructuring of global supply chains for critical materials. It is the first major interstate conflict since the decade-long US policy focused on critical minerals began with the 2010 Chinese embargo on exports of rare earths to Japan, sparked by territorial disputes in the East China Sea [source 17]. The US Geological Survey modeled the consequences of a potential cessation of Russian metal exports in 2017 after a series of sanctions imposed against the Russian Federation after the takeover of Crimea in 2014. It was noted that the volume of supplies is not the only factor that forms the consequences of the cessation of supplies of Russian metals, much depends on the market dynamics, for example, the availability of alternative sources of supply and substitutes [9].

Russia provides 37% of the world's output of palladium, 18% of potassium, 14% of coal, 10% of platinum, and many other important metals. Russia controls about 10% of the world's copper reserves and 20% of titanium ore [source 7]. Ukraine has 5% of the world's natural resources. About 7% of the world's iron ore reserves are concentrated in the Krivoy Rog basin, Dnepropetrovsk, Kremenchug, and Poltava regions – in all regions located along or in close proximity to the Russian border and the line of hostilities. The country also has Europe's largest deposits of uranium and graphite (1.8% and 20% of known world reserves, respectively). Ukraine is one of the few countries with a full cycle of the titanium sector: from the extraction and processing of ores to the making of finished products.

The US chip industry is heavily dependent on Ukrainian-made neon, and Russia exports a number of elements critical to semiconductors, jet engines, automobiles, and medicine. Russia and Ukraine also lead the world in making such metals as nickel, copper, and iron ore. The aerospace industry of the USA, Europe, and the UK also depends on the supply of titanium from Russia [source 18].

They also export significant amounts of palladium and platinum. Palladium is used in almost everything, from car exhaust systems and mobile phones to dental fillings. Russia provides almost 37% of the world's palladium [source 7]. Russian palladium illustrates one of the key geopolitical features of critical minerals: alternative sources are often found in equally difficult markets. The second largest producer of palladium is South Africa, where in the last decade, the mining sector has been destroyed by numerous strikes [10].

Closed from Western markets, the Russian Federation may well begin to look for new opportunities for cooperation with China in the field of critical minerals. Countries have vast resource reserves, processing and manufacturing capacities, and strong geopolitical reasons for cooperating.

Restructuring of the global supply chain, with Russia and China controlling most of the world's critical minerals, is having a direct impact on strategic US industries, including aerospace and the green energy transition. The US and its allies have all the necessary resources but lack the appropriate manufacturing and processing facilities to meet their needs. It takes time to launch such facilities. Therefore, the US seeks to prepare for supply chain disruptions through strategic long-term investments in domestic and adjacent mineral supply chains [11].

In February 2021, the Biden administration launched a 100-day review of the supply chains of four key products in the US economy. The review included both rare earths and minerals and components for the production of batteries, in particular lithium, cobalt, nickel, and graphite [source 19]. In March 2022, the Biden administration committed to using the Defense Production Act to increase the supply of critical minerals by providing government financing for feasibility studies of new mining projects along with supporting innovation in the extraction of minerals from mining waste [source 20].

Apparently, in the future, Russian-Chinese cooperation in the field of critical minerals will accelerate due to the conflict in Ukraine and the resulting isolation of Russia from Western economies. In addition, a prolonged disruption in the supply of critical minerals from Russia will stimulate their extraction, where possible elsewhere, as the cost of resources rises, which will further increase the strategic importance of, for example, Indonesian nickel, South African palladium, and Chinese aluminum.

Switching supplies is associated with long multi-year cycles of project development and issuance of permits for new supplies and the concentration of many existing alternative sources in regions where political instability and labor conflicts are observed [12]. The reduction in the supply of critical minerals is especially painful for the EU as it seeks to accelerate the development of mineral-intensive renewable energy sources such as wind, solar energy, and batteries as an alternative to Russian gas and coal [13]. Regardless of the outcome, the Russian-Ukrainian crisis will make it even more urgent to assess the supply chains of critical minerals based on national security considerations [source 21].

RESULTS AND CONCLUSIONS

Today, much of the discussion about the sustainability of supply chains in the face of dramatic geopolitical and economic upheavals in advanced economies revolves around the idea of a return to domestic production. However, there are some other opportunities as well. *McKinsey* conducted a survey of the CEOs of the world’s leading companies in major global value chains. To increase the sustainability of supply, 53% of respondents plan to diversify their supply network, 47% plan to increase stocks of critical goods, 40% plan to move their supply sites closer to their production facilities, and 38% plan to regionalize their supply network [source 6]. In fact, the question is raised on the opportunities of mobilizing the economy and replacing the policy of short-term profits with a strategy of long-term national defense.

REFERENCES

1. Williams C. *China Continues Dominance of Rare Earths Markets to 2030, says Roskill*. Mining.Com, 26.02.2021. Available at: https://www.mining.com/china-continues-dominance-of-rare-earths-markets-to-2030-says-roskill (accessed 13.10.2022).
2. Autor D., Dorn D., Hanson G. The China Syndrome: Local Labor Market Effects of Import Competition in the United States. *American Economic Review*, January 2013, vol. 103, no. 6, pp. 2120–2168. DOI: 10.1257/aer.103.6.2121
3. Kochan T., Appelbaum E., Gittell J., Carrie R. Leana. *The Human Capital Dimensions of Sustainable Investment: What Investment Analysts Need to Know*. SSRN, 23.02.2013. 18 p. Available at: https://dx.doi.org/10.2139/ssrn.2222657
4. Pisano G., Shih W. *Producing Prosperity: Why America Needs a Manufacturing Renaissance*. Boston, Harvard Business Press, 2012. 192 p.
5. Lazonick W., Sakinc M., Hopkins M. Why Stock Buybacks are Dangerous for the Economy. *Harvard Business Review*, 07.01.2020. Available at https://hbr.org/2020/01/why-stock-buybacks-are-dangerous-for-the-economy (accessed 13.10.2022).
6. Nassar N. Shifts and Trends in Global Anthropogenic Stocks and Flow of Tantalum. *Resources, Conservation and Recycling*, 2017, vol. 124, pp. 233-250.
7. Hatch G. *Introducing the TMR Advanced Rare-Earth Projects Index*. Seeking Alpha, 07.01.2011. Available at: https://seekingalpha.com/instablog/466501-gareth-hatch/126343-introducing-the-tmr-advanced-rare-earth-projectsindex (accessed 13.10.2022).
8. Daniel J. The Circumstances, Events and Politics Leading the Closure of the U.S. Bureau of Mines: Was It the Correct Decision? *Mining Engineering*, 2010, vol. 62, no. 4, p. 20.
9. Safirova E. et al. *Estimates of Immediate Effects on World Markets of a Hypothetical Disruption to Russia’s Supply of Six Mineral Commodities*. U.S. Geological Survey Open-File Report 2017-1023. 22 p. Available at: https://doi.org/10.3133/ofr20171023
10. Basov V. Sibanye-Stillwater Receives Strike Notice from Two South African Unions. *Kitco*, 08.03.2022. Available at: https://www.kitco.com/news/2022-03-08/PGM-producer-Sibanye-Stillwater-receives-strike-notice-from-two-South-African-unions.html (accessed 13.10.2022).
11. King E. Mining Goes Critical: Russia, Ukraine and US Mineral Supply Chains. *Prospector*, 21.03.2022. Available at: https://thenugget.prospectorportal.com/mining-goes-critical-russia-ukraine-and-us-supply-chains (accessed 13.10.2022).
12. Farchy J., Burton M., Attwood J. Metals World Agonizes Over War but Keeps Buying from Russia. *Bloomberg*, 04.04.2022. Available at: https://www.bloomberg.com/news/articles/2022-04-04/metals-world-agonizes-over-warbut-keeps-buying-from-russia (accessed 13.10.2022).
13. Abnett K. EU Unveils 210 bln Euro Plan to Ditch Russian Fossil Fuels. *Reuters*, 18.05.2022. Available at: https://www.reuters.com/business/sustainable-business/eu-unveils-escape-route-russian-fossil-fuels-by-2027-2022-05-18/ (accessed 13.10.2022).

SOURCES

1. -The War in Ukraine Has Exposed a Critical American Vulnerability. *The Atlantic*, 14.06.2022. Available at: https://www.theatlantic.com/ideas/archive/2022/06/us-supply-chain-semiconductor-production-economic-warfare/661267/ (accessed 13.10.2022).
2. -*Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States*. Department of Defense, September 2018. 146 p. Available at: https://media.defense.gov/2018/Oct/05/2002048904/-1/-1/1/AssessingAndstrengthening-The-Manufacturing-And-Defense-Industrial-Base-And-Supply-Chainresiliency.Pdf (accessed 13.10.2022).
3. *Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth*. June 2021. 250 p. Available at: https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-reviewreport.pdf (accessed 13.10.2022).
4. *The Role of Critical Minerals in Clean Energy Transitions*. International Energy Agency, May 2021. 287 p. Available at: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf (accessed 13.10.2022).
5. *Industrial Capabilities Report to Congress. 2020 Annual Report*. Washington, Department of Defense, January 2021. 184 p. Available at: https://media.defense.gov/2021/Jan/14/2002565311/-1/-1/0/fy20-industrial-capabilities-report.pdf (accessed 13.10.2022).
6. *Risk, Resilience, and Rebalancing in Global Value Chains*. McKinsey Global Institute, August 2020. 112 p. Available at: https://www.mckinsey.com/capabilities/operations/our-insights/risk-resilience-and-rebalancing-in-global-valuechains (accessed 13.10.2022).
7. *U.S. Geological Survey, Mineral Commodity Summaries 2022.* 31.01.2022. 206 p. Available at: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf (accessed 13.10.2022).
8. 8. A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals. *Federal Register*, 26.12.2017, vol. 82, no. 246, pp. 60835–60837. Available at: https://www.govinfo.gov/content/pkg/FR-2017-12-26/pdf/2017-27899.pdf (accessed 13.10.2022).
9. *United States Geological Survey, Comparison of U.S. Net Import Reliance for Non-Fuel Mineral Commodities — A 60-Year Retrospective (1954–1984–2014)*. DOI: 10.3133/fs20153082
10. *Why Australia: Benchmark Report 2022.* Available at: https://www.austrade.gov.au/benchmark-report/home (accessed 13.06.2022).
11. *Mineral Finance 2020: Canada Holding Ground.* Prospectors & Developers Association of Canada (PDAC), 2020. 32 p. Available at: https://pdac.ca/docs/default-source/priorities/access-to-capital/state-of-mineral-finance-reports/pdac-mineral-finance-2020_revised_june-18–2020.pdf?sfvrsn=c9ec9b98_2 (accessed 13.10.2022).
12. *Australian Critical Minerals Prospectus 2020. Australian Goverment. October 2020.* 172 p. Available at: https://www.australianvanadium.com.au/wp-content/uploads/2020/10/Australian_Critical_Minerals_Prospectus.pdf (accessed 13.10.2022).
13. *Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability.* Communication from the Commission to the European Parlament, the Council, the European Economic and Social Committee and the Committee of the Regions. EU. Brussels, 3.9.2020. COM (2020) 474 final. 24 p. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474 (accessed 13.10.2022).
14. *Strengthening of the European Rare Earths Supply-Chain. Challenges and policy options.* A Report by the European Rare Earths Competency Network (ERECON). 2015. 104 p. Available at: https://reinhardbuetikofer.eu/wp-content/uploads/2015/03/ERECON_Report_v05.pdf (accessed 13.10.2022).
15. *Going Out: An Overview of China's Outward Foreign Direct Investment.* Available at: https://www.uscc.gov/sites/default/files/Research/GoingOut.pdf (accessed 13.10.2022).
16. Antidumping and Countervailing Duties. *International Trade Administration*. Available at: https://www.trade.gov/us-antidumping-and-countervailing-duties (accessed 13.10.2022).
17. China Cuts Rare Earth Export Quotas, U.S. concerned. *Reuters*, 28.12.2010. Available at: https://www.reuters.com/article/us-china-rareearth-idUSTRE6BR0KX20101228 (accessed 13.10.2022).
18. *How a Russian Invasion of Ukraine, the "Breadbasket of Europe" Could Hit Supply Chains.* CNBC, 24.02.2022. Available at: https://www.cnbc.com/2022/02/23/impact-of-russia-ukraine-on-supply-chains-food-metals-commodities.html (accessed 13.10.2022).
19. *Fact Sheet: Biden-Harris Administration 100-Day Battery Supply Chain Review.* 08.06.2021. Available at: https://www.energy.gov/articles/fact-sheet-biden-harris-administration-100-day-battery-supply-chain-review (accessed 13.10.2022).

20. Biden to Use Defense Production Act for U.S. Critical-Minerals Supply. *The Washington Post*, 31.03.2022. Available at: https://www.washingtonpost.com/climate-environment/2022/03/30/critical-minerals-defense-production-act/ (accessed 13.10.2022).

21. *Supply of Critical Minerals amid the Russia—Ukraine War and Possible Sanctions*. 19.04.2022. Available at: https://www.energypolicy.columbia.edu/research/commentary/supply-critical-minerals-amid-russia-ukraine-war-andpossible-sanctions (accessed 13.10.2022).