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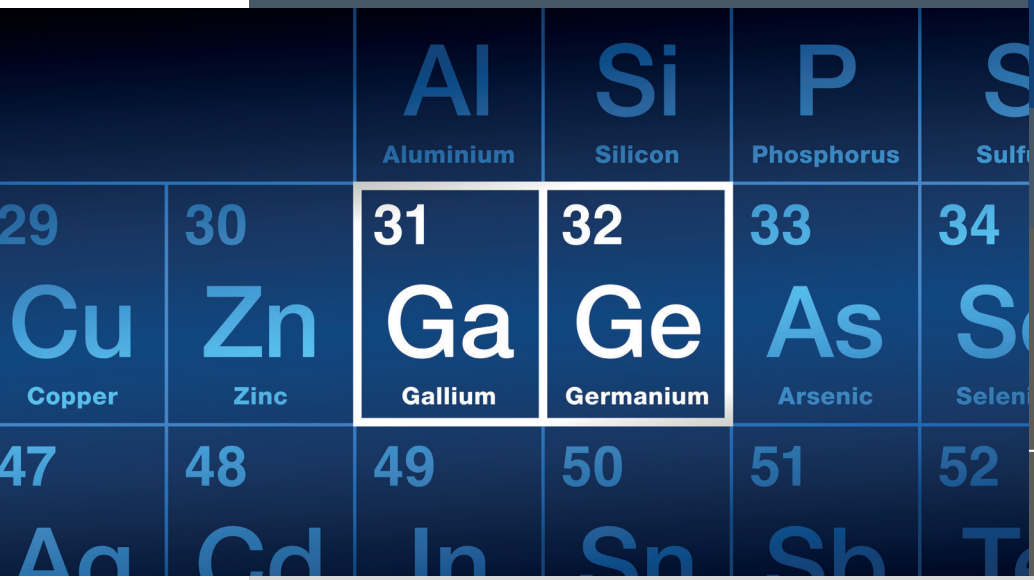

China's Weaponization of Gallium and Germanium

The Pitfalls of Leveraging Chokepoints

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Key Takeaways

- China announced that from August it would apply export controls on gallium and germanium, critical raw materials notably for the energy and digital transitions.
- The move sends a strong signal that Beijing is willing to enter into a game of reciprocal escalation on trade and technology restrictions with Washington.
- Yet, this case highlights the pitfalls of weaponizing dependencies in a complex, interdependent global economy – not all chokepoints are created equal.
- While China dominates global production of these two metals today, its advantage is more a result of economic policy than geology. Export restrictions are likely to weaken China's position as consumers move to diversify, though this will take years, if not a decade or more.
- Meanwhile, China is critically dependent on downstream technology. In the field of power semiconductors, where gallium is an essential ingredient to make chips for electric vehicles, 5G equipment, solar PV and more, Chinese firms are absent and may need 5-10 years to catch up.

China responds to US export controls

China's recent announcement of raw material export controls highlights important pitfalls of weaponized interdependence and demonstrates that not all chokepoints are created equal.

On July 3, China's Ministry of Commerce announced that from August it would restrict exports of raw gallium and germanium as well as products derived from these two metals.[1] China dominates global supply of both elements, which are important notably in the production of semiconductors for electric vehicles, 5G telecommunications infrastructure, renewable energy technologies, as well as in other important uses such as LED lighting, fiberoptic cables or various space and military applications. They are, as of today, critical raw materials for enabling the twin transitions toward a digital, carbon-neutral future.

The measures will come nine months after the United States (US), in a major shift of strategy to stymie China's technological development in dual-use fields, unveiled stinging export controls on the most advanced range of semiconductors, as well as the tools and knowhow needed to produce them. China's direct response to this scaling up of American pressure in high-tech domains has been slow to emerge, and its decision to signal a willingness to leverage its raw material advantage is a significant step with potentially far-reaching implications.

But Beijing's yet-to-be-defined measures highlight two important features of leveraging dependencies in a context of complex economic interdependence. First, from the moment an economy declares its willingness to weaponize its advantage, the strength of its position begins to erode as others seek to reduce their vulnerabilities over time. Second, mutual vulnerability is a central feature of today's global, networked economy. Indeed, a broad weaponization of gallium and germanium won't only harm those it sets out to target and press them to develop alternative supplies, but would significantly, and perhaps even disproportionately, undermine China's own industrial interests as well.

China's constructed resource advantage and the race for diversification

China currently supplies more than 95% of the world's raw gallium and 60% of refined germanium,[2] putting it in a strong position to disrupt downstream supply chains. Still, the

1. "Announcement No. 23 of 2023 on the Implementation of Export Control on Gallium and Germanium Related Items" (in Chinese), Ministry of Commerce, July 3, 2023, available at: www.mofcom.gov.cn.

2. "Mineral Commodity Summaries 2023 for gallium", United States Geological Survey (USGS), 2023, available at: www.usgs.gov; "Mineral Commodity Summaries 2023 for gallium germanium", USGS, 2023, available at: www.usgs.gov. The European Commission estimates that China

geological concentration of these metals does not lend itself to a natural monopoly in China's favor. These two elements, which each occur in low concentrations in nature, can only realistically be produced either in conjunction with associated base metals and minerals, such as zinc, bauxite or coal. These base resources are rather widely distributed across the globe. Recycling is also an important factor, particularly in the case of germanium. China's resource advantage in this as in many cases, meanwhile, is more the result of broader market dynamics and policy initiatives that have seen the hollowing out in recent decades of mining and heavy industry in post-industrial economies such as the United States and Europe and their localization in China.[3]

As such, the high concentration in China of critical raw material extraction and processing has not always been the case, nor is the country's position immovable. Germany, for instance, produced raw gallium until 2016 as a byproduct of aluminum production in Lower Saxony. Hungary also produced raw gallium until 2013. Until 2018, the extracted raw material could be shipped to the UK for high-quality purification. While these processes have since been moth-balled, Germany's historic producer, Aluminium Oxid Stade, indicated its intention in 2021 to re-start gallium production,[4] while France is investing in the capability to process gallium and create gallium nitride (GaN), a key chemical component of many semiconductors.[5] The VALORE project in Greece also began the process of extracting gallium (as well as vanadium) from the Mytilineos Group's aluminum processing operations in 2022.[6]

China's dominant position is not immovable.

In the case of germanium, while China is the world's dominant producer, global production statistics are obscured by the fact that the United States, while having important germanium extraction activities in Alaska, Tennessee and Washington, withholds its production figures. Indeed, the US maintains strategic stockpiles of some 88,000 kg of germanium in the form of metal, scrap and wafers (global refinery

currently accounts for 83% of the world's extraction of raw germanium. "Internal Market, Industry, Entrepreneurship and SMEs", European Commission, 2023, available at: https://single-market-economy.ec.europa.eu.

3. D. Humphreys, *The Remaking of the Mining Industry*, London, Palgrave Macmillan, 2015.

4. "AOS Stade to Resume Gallium Metal Production", *Asian Metal*, February 3, 2021, available at: www.asianmetal.com.

5. The project NIGAMIL (NItrure de Gallium pour applications MILlimétriques) began in 2015 via the *Direction générale de l'armement* of French Ministry of Armed Forces and has been conferred to United Monolithic Semiconductors (UMS), https://www.defense.gouv.fr, while GREAT (hiGh fREquency GAn elecTronics) began in 2020 as a cooperative project between the French Ministry of Armed Forces and the French CNRS, https://www.defense.gouv.fr.

6. Selective Vanadium recovery from ALuminia Refinery (VALORE) is a co-funded project of €2.2 million with the EIT Raw Materials that will run through 2024, https://kic-valore.eu/en.

production of germanium in 2022 was estimated at 140,000 kg).[7] Meanwhile, Canada has proven to be an important processor of germanium today,[8] with Finland also having significant operations until 2015.[9] Recycling also plays an important part in the supply chain, accounting for an estimated 30% of global supply, according to the United States Geological Survey (USGS). Umicore in Belgium, for instance, is an important supplier today through recycled e-waste.[10] Finally, the metal's minuscule market size has led to limited amounts of prospecting for potential sources, for instance from coal ash produced from certain types of coal-fired power generation and heavy industry, which could further be explored. All of this suggests that China's position is not immovable.

Broader policy frameworks such as the EU's Critical Raw Materials Act published in March,[11] or France's industrial strategy for 2030, which includes a critical raw materials investment fund of up to €2 billion,[12] aim to boost production in Europe while engaging with a more diverse range of partners abroad. But diversifying supplies away from China will undoubtedly take time, as identifying mineral resources, securing financing, dusting off shuttered infrastructure, mobilizing appropriate expertise and human capital, securing production permits and ensuring a downstream market is not as easy as flipping a switch. Some industry experts estimate that if all goes smoothly, it could still take up to 5 or even 10 years or more to re-start production in the EU.

Ultimately, these efforts will require more than just a targeted focus on producing a few obscure metals, but will have to focus on building and maintaining industrial competence in larger base industries, such as aluminum and zinc, and nourishing downstream industrial ecosystems to ensure demand and strengthen resilience elsewhere along the supply chain. Negative externalities such as excessive redundancies, over-production and resource waste are also an important consideration, particularly in times when growing resource demand for the twin transitions already risks over-taxing the planet's natural resources.

7. "Mineral Commodity Summaries, Germanium", USGS, 2023, available at: www.usgs.gov.
8. S. Lasley, "The Quantum Realm of Alaska Germanium", *North of 60 Mining News*, October 29, 2020, available at: www.miningnewsnorth.com.
9. P. Eilu, *et al.*, "The Nordic Supply Potential of Critical Metals and Minerals for a Green Energy Transition", *Nordic Innovation Report*, Nordic Innovation, 2021, available at: www.nordicinnovation.org.
10. Germanium Services, Umicore Electro-Optic Materials, available at: https://eom.umicore.com.
11. "Critical Raw Materials Act", European Commission, March 2023, available at: https://single-market-economy.ec.europa.eu/.
12. "France 2030 : le gouvernement annonce le lancement d'un fonds d'investissement dédié aux minerais et métaux critiques", Ministry of Economy, Finance and Industrial and Digital Sovereignty, May 11, 2023, available at: https://presse.economie.gouv.fr.

Raw material chokepoints: China's lose-lose proposition

While generating more resilient and sustainable supply chains will take years at best, a more immediate hurdle is nevertheless likely to lessen the scope of Beijing's prospective measures: China's acute dependence on foreign suppliers of critical downstream technologies. Here, the example of power semiconductors is poignant.

Power semiconductors are essential components in a range of products from power generation technologies (including solar PV and wind turbines), telecommunications infrastructure, plug-in hybrid and full-electric vehicles, as well as other military, aerospace and industrial uses. Gallium, when combined with arsenic to produce gallium arsenide (GaS) or particularly with nitrogen to make gallium nitride (GaN), is a key additive that enables greater energy efficiency, better heat management, and reduced product size.

While Chinese producers dominate the global supply of gallium, Chinese firms cannot competitively produce power semiconductors today. Indeed, a handful of American and European firms such as Infineon, Texas Instruments, STM, NXP and ON Semiconductor dominate roughly 70% of this specific sector, with Japanese producers such as Mitsubishi and Rohm also having significant capacity in a market worth $41 billion.[13]

> Chinese firms are unable to make power semiconductors today.

Notably, power semiconductors are not impacted by the paradigm-shifting export controls imposed by the United States on October 7, 2022, which target advanced logic and memory chips destined for supercomputing and Artificial Intelligence applications. This means Chinese firms are still able to access them on the global market, but also partner with foreign firms to build production capacity in China. Ultimately, power semiconductors present less of a technical barrier to entry than logic or memory chips in that reduced size is not a major factor in performance and utility.

For China, this means that overcoming its dependence on foreign suppliers is possible. Some Chinese firms, such as Sanan Optoelectronics, SICC and TankeBlue Semiconductor have already inked joint-venture agreements with leading firms such as STM and Infineon,[14] while Chinese automakers are also seeking to produce their own

13. J.P. Kleinhans, R. Goujon, J. Hess and L. Dudley, "Running on Ice: China's Chipmakers in a Post-October 7 World", *China Corporate Advisory*, Rhodium Group, March 31, 2023, available at:https://rhg.com; "Power Semiconductor Market Size & Share Analysis – Growth Trends & Forecasts (2023-2028)", Mordor Intelligence, 2023, available at: www.mordorintelligence.com.
14. N.Y. Huang and P. Chen, "Why Prominent Power Semiconductor Manufacturers Race to Gain a Presence in China", *DigiTimesAsia*, June 9, 2023, available at: www.digitimes.com.

chips.[15] Still, building capacity in China and competitiveness among Chinese firms will take time. Industry experts estimate that it may be another 5-10 years before Chinese companies are able to break into the power semiconductor market to a significant degree.[16]

This complex interdependence ultimately leaves China acutely vulnerable to supply disruptions, particularly those of its own making. Electric vehicles (EVs) is one area where China may stand to lose the most. Indeed, Chinese automakers are on the verge of making a major break-out in the global EV market and, at the crucial moment when they seek to demonstrate superior technology and build brand names on the world stage, a major supply chain disruption would handicap their production and undermine consumer trust in Chinese manufacturers. Solar PV, wind energy and 5G telecommunications are also sectors where Chinese firms are strong, but would be adversely impacted by a broad-based disruption of global supply chains linked to gallium. As such, any Chinese measures are likely to be highly targeted, focusing for instance on specific firms in the defense sector or those with symbolic value.

A game of signaling – toward a broader leveraging of critical raw materials?

Given China's own vulnerabilities, why would Beijing choose to activate this chokepoint in particular? The export controls announced for August 1 are likely meant more as a political signal than a functional leveraging of strategic resources – though Beijing may still choose to overplay its hand. Herein, the timing of China's announcement on July 3 is important. Coming on the heels of the Netherlands' announcement on export controls for semiconductor equipment, which will enter into force in September,[17] Europe is certainly one target audience. But the message is more likely aimed at the other side of the Atlantic. Beijing's announcement was made on the eve of a high-profile visit of US Treasury Secretary Janet Yellen and amidst a broader push by Washington to re-engage with China diplomatically. In parallel, the US administration is also considering further measures to limit China's access to technology, for instance by barring access to US cloud servers and screening outbound American investments into China's high-tech sectors, such as quantum technologies.

15. W. Zhou and J. Shen, "Chinese EV Makers Nio, Xpeng, and Li Auto Expand Bets on Self-Produced Chips: Report", *TechNode*, October 10, 2022, available at: https://technode.com; S. Tabeta, "Chinese Auto Chips Only: Inside Xi's Self-Sufficiency Campaign", Nikkei Asia, March 15, 2023, available at: https://asia.nikkei.com.
16. K. Yuan, "KIEP: China is Likely to Emerge as Leader of Next-Gen Power Chip Field in Next 5-10 Years", *JW Insights*, June 29, 2023, available at: https://jw.ijiwei.com.
17. "Government Publishes Additional Export Measures for Advanced Semiconductor Manufacturing Equipment", Government of the Netherlands, June 30, 2023, available at: www.government.nl.

Announcing measures on gallium and germanium is a shot across Washington's bow and an invitation to consider the spiraling effect of further limiting exchanges in high-tech fields. More than the impact of the measures themselves, which would be counterproductive, the announcement is likely meant to signal that Beijing is willing to play the game of escalation and weaponize in turn its own asymmetric advantages, starting with critical raw materials.

Gallium and germanium ultimately sit at a very weak chokepoint for China in the semiconductor supply chain, but China has stronger cards to play in a game of escalation – for instance rare earth elements and NdFeB permanent magnets, or battery materials and supply chains, where Chinese firms master much larger swaths of the supply chain.

A hasty conclusion to the analysis above would be that China's announcement should be seen as self-defeating and can thus be ignored. Rather, it should be seen as an invitation to the United States, Europe and others to clarify the goals and contours of a de-risking strategy that the G7 has now endorsed as a guiding principle, and which many in Beijing interpret as a veiled attempt to press forward with a broader containment strategy.

We now appear to be on the verge of entering into a dangerous spiral of escalation in tensions with China. As Beijing and Washington work to strengthen their resilience, the less they have to lose in weaponizing their advantages. There may be little Europe can do to arrest this trend.

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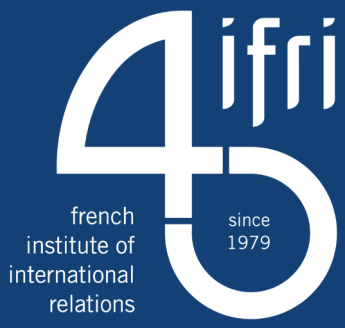

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