China's graphite export controls

Political theater and economic drama

December 1st, 2023

Today, the Chinese government will begin to enforce new export controls for nine types of graphite products. These controls are the latest shot fired in the China-US trade war and, as with any other conflict, there is a risk of collateral damage.

TMP is concerned that one victim will be the broader effort to fight climate change, insofar as these graphite products are crucial for the battery anodes[1] of electric vehicles (EV) and many energy storage systems (ESS) while China is the world's dominant supplier.

The following provides the most up-to-date information available about these controls and analyzes their implications for battery supply chains and decarbonization efforts more broadly.

1. Anodes are the negative electrodes in a battery. During discharge, they release electrons that are taken up by the battery cathode (the positive electrode), producing electricity in the process.

China's new graphite controls: three things you need to know

On October 20th, China's Ministry of Commerce (MOFCOM) and General Administration of Customs (GAC)[2] announced that three synthetic and six natural graphite derivatives[3] will require dual-use item export licenses due to "national security concerns".[4] This latest move comes on the heels of US controls on high-tech chips and an EU probe into China's EV exports, as well as similar controls from China over chip materials gallium and germanium, heightening tensions in the ongoing trade war between China, the US and its allies.

The nine affected graphite derivatives comprise the bulk of available high-end synthetic and spherical (natural) graphite,[5] which are essential for LIB anodes and in ever-higher demand globally. What's more, China dominates every phase of the global graphite anode supply chain,[6] and its sway over parts of other transition mineral supply chains (e.g., manganese, rare earths, lithium) raises prospects for extending these measures, should it feel the need to rein in control.

The new graphite permits started December 1st and there is significant concern about their impact on battery manufacturers, automotive supply chains and broader decarbonization efforts. This is because EVs rely almost exclusively on LIBs, which also make up the lion's share of battery energy storage systems (BESS).

As part of our broader work on transition minerals, TMP has examined evidence from China as well as Western sources and reached the following conclusions:

01 The export controls are more smoke than fire.

The export controls are far more likely to be a political shot across the bow of the US than an attempt to cause economic damage. If the US does not escalate its efforts to contain China, the controls are unlikely to be strict. Instead, Beijing is likely creating a bargaining chip to keep in hand for future negotiations while strengthening its lead in the battery industry. It will also be seeking to help domestic graphite producers and its EV industry at a time when the country's economy is slowing, and prices for the commodity have been especially low.

2. http://www.mofcom.gov.cn/article/zwgk/gkzcfb/202310/20231003447368.shtml; https://www.mfa.gov.cn/web/wjb_673085/zzjg_673183/jks_674633/fg_674663/200802/t20080218_7668996.shtml; https://english.news.cn/20231020/b218269f9f9e4c708aae37c0ad3d4fe1/c.html
3. https://www.fastmarkets.com/insights/china-to-impose-export-controls-on-graphite-related-items/
4. " 为维护国家安全和利益 "
5. Chinese companies use lower-grade graphite which is not affected by these rules and expect minimal impact. For details, see https://www.reuters.com/markets/commodities/global-ev-battery-supply-chain-puzzles-over-china-graphite-curbs-2023-10-27/
6. https://source.benchmarkminerals.com/article/infographic-china-controls-three-quarters-of-graphite-anode-supply-chain

02 And yet, that smoke may be noxious...

Good politics is not always good economics, and the very mention of these export controls has begun to impede the broader Western push for EVs and BESS. The most immediate issue is upwards price pressure: uncertainty about graphite supplies may lift global prices off their multi-year lows. This would be an unwelcome development in a relatively inflexible EV battery market already struggling with high costs. On the flip side, it may encourage greater investment in the development of alternative battery chemistries for EVs and ESS grid rollout.

03 ...and potentially even toxic.

The greater risk is the psychological impact of these export controls, which have made clear just how dependent Western EVs are on Chinese policies. Evidence suggests that battery manufacturers and automakers have already begun to aggressively seek other sources of graphite as well as alternative technologies that do not require graphite. This duplication of supply chains is highly inefficient and could jeopardize global efforts to achieve pressing climate targets. But we also believe that Western governments and companies will be surprised at just how long new supply chains and technologies will require to achieve scale, prompting the realization that their future EV rollout plans are in fact dependent on good US-China relations. If relations continue to deteriorate, some decision-makers will begin to question whether the EV transition is worth investing in at all.

While the impact of this beyond 2030 is likely to be an increasing independence of Western EV and BESS production from Chinese inputs, this will not happen quickly.

The following explains the proposed export controls and these conclusions in detail. TMP has additional information which may be helpful in analyzing the specific impact of the controls for different companies and actors, please contact a TMP representative to find out more:

China	Orlando Bowie
Japan	Nobuyuki Egawa
Europe	Ivana Ema Pavkova
Latin America	Gonzalo Silva-Ayarza
The rest of the world	Justin Muhl

Trade war turns to Lithium-ion batteries

Analysts agree that the new dual-use item export licenses are a response to American efforts to restrict Chinese access to semiconductors and similar inputs for artificial intelligence. The Chinese government has denounced these as "improper controls [that] have seriously hindered normal economic and trade exchanges"[7] and promised retaliatory actions in various forms. These have received major attention in the Western media.

At the same time, both MOFCOM and GAC have been strategically vague about what will happen come the deadline and details of the permit requirements have not yet been released. In our view, this is because China is facing a genuine economic crisis caused by a collapse of property values similar to the 2008 financial crisis, which largely affected Western economies. It therefore has little incentive to enter a full-blown trade war with its global customer base.

This impression has been reinforced by Beijing's recent and highly cordial efforts to engage Washington, including the *Sunnylands Statement on Enhancing Cooperation to Address the Climate Crisis*[8] and Biden's long-awaited meeting with Xi in California. This comes at a time when US-China relations are widely considered the worst they've been in decades.

With cooperation on climate change long seen as a rare bright spot in bilateral dialogue, reception of these developments has been cautiously optimistic. Li Shuo, director of China Climate Hub at the Asia Society Policy Institute described the statement as a "timely effort of aligning the US and China" ahead of COP28. But he noted the frosty relationship meant the agreement should be seen as "floor setting" rather than "tone setting", and COP28 remains a key indicator of progress between the two sides.[9]

Zou Ji, CEO and President of Energy Foundation China, meanwhile emphasized the opportunities for co-operation given China's strength in manufacturing renewable energy equipment coupled with the US's prowess in advanced technologies and R&D.[10] While we do not think this detente has eliminated the possibility of further policy maneuvers on either side, future measures are likely to be less aggressive as a result.

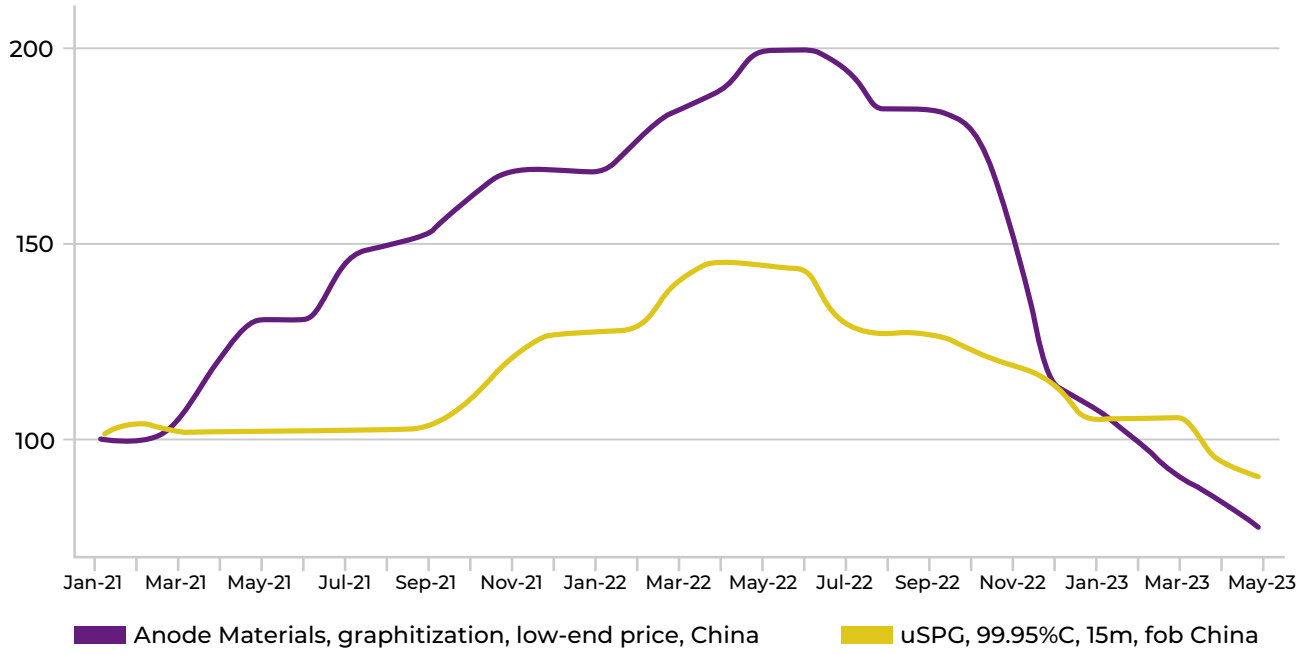
Graphite remains essential anode ingredient

Despite this, the reality is that these nine derivatives make up the bulk of high-end synthetic and spherical graphite available. There is therefore significant and legitimate concern about their impact on battery manufacturers, automotive supply chains and broader decarbonization efforts.

7. "美方不当管制严重阻碍各国 ... 正常经贸往来 ": http://www.mofcom.gov.cn/article/syxwfb/202310/20231003446671.shtml
8. https://www.state.gov/sunnylands-statement-on-enhancing-cooperation-to-address-the-climate-crisis/
9. https://edition.cnn.com/2023/11/15/world/us-china-climate-announcement-summit-intl-hnk/index.html
10. https://www.cenews.com.cn/news.html?aid=1096144

The graphite materials covered by these new export controls are key ingredients in LIB anodes, which are by extent directly relevant for the rollout of EVs and BESS. Despite increasing demand for LIB inputs among foreign battery makers, they had been benefiting from relatively low graphite prices over the past year.

Chinese graphitization costs vs. uSPG prices January 2021 - May 2023



Source: Fastmarkets, BAIINFO • Jan 2021 = 100 [11]

Gallium, Germanium exports indicate what's to come

China's restrictions on gallium and germanium exports which came into effect on August 1st offer some indication of how the graphite permitting process may play out. Exports of both commodities ramped up in July after the regulations were announced, before drying up entirely in August and remaining negligible in September.[12]

Some exporters reportedly started obtaining permits for gallium towards the end of September, almost two months after the regulations took effect.[13] Customs data shows exports of both commodities started to trickle through in October but remained anemic: germanium shipments for the month were down about 93% from July, and just 1.5% of the total volume exported in 2022. Gallium exports were similarly down 97% from July, and a mere 0.27% of their total 2022 volume.[14]

11. https://www.fastmarkets.com/insights/spherical-natural-graphite-prices-plunge-11-year-lows/
12. https://www.reuters.com/world/china/china-export-curbs-choke-off-shipments-gallium-germanium-second-month-2023-10-20/
13. https://www.fastmarkets.com/insights/china-gallium-germanium-indium-prices-lme-week/
14. https://www.miningweekly.com/article/china-allows-a-trickle-of-critical-minerals-exports-ahead-of-graphite-curbs-2023-11-22

Friend-shoring allies exposed

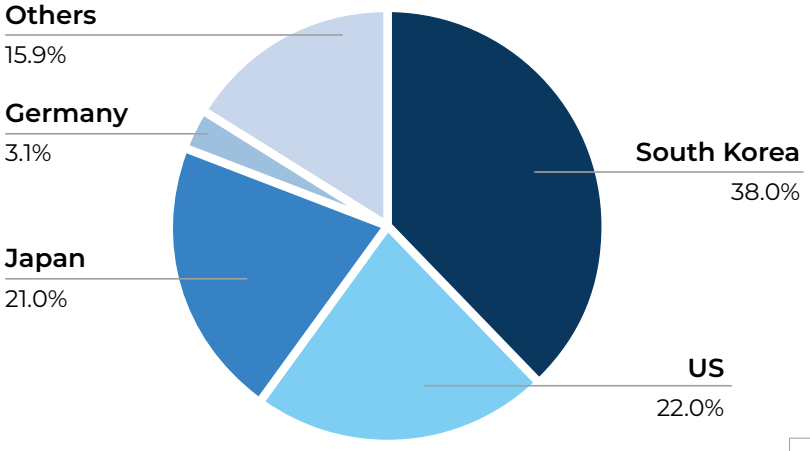
China's choice of graphite seems to up the ante in its tit-for-tat trade war with the US, EU and their friend-shoring allies, extending the battlefield from chips to the LIB supply chain. Like graphite, gallium and germanium prices were boosted by the restrictions.[15] Germanium production is more diversified than gallium, so buyers have been less concerned with the restrictions and prices were impacted less by the rules.

South Korea and Japan are among the countries most exposed to the restrictions given their large battery industries - South Korea imports 93% of its high-end graphite from China.[16] The importance of both countries to America's friend-shoring strategy also increases their exposure against the backdrop of geopolitical tensions between the US and China.

South Korea has said it is ready to look for new sources of graphite if supplies prove to be severely affected. It is hoping to mitigate shortages with a supply chain coordination agreement signed earlier this year among members of the US-led Indo-Pacific Economic Framework for Prosperity (IPEF). The 14 members of the group inked a further agreement to enhance supply chain coordination mid-November in Malaysia.[17]

The US is likewise in the firing line as one of the biggest buyers of graphite from China and as the trade war between the two countries ramps up.[18] The new regulations were announced days after the US further tightened controls on chip exports to China, while China might be seeking to gain leverage over its rival as the US decides on requirements for funding under the Inflation Reduction Act (IRA), some of the finer details of which have yet to be hashed out.

Share of China's natural graphite exports, by value (2022)



Source: TrendEconomy [19]

15. https://www.theregister.com/2023/07/27/prices_of_gallium_and_germanium_rise/
16. https://www.huxiu.com/article/2212246.html
17. https://www.bloomberg.com/news/articles/2023-10-20/south-korea-to-seek-alternative-graphite-source-if-shortage-hits#xj4y7vzkg; https://www.americanprogress.org/article/the-ipef-supply-chain-agreement-is-a-win-for-u-s-industrial-policy/
18. https://trendeconomy.com/data/h2/China/2504
19. https://trendeconomy.com/data/h2/China/2504

While Chinese state-owned companies fall into the IRA's category of "foreign entities of concern",[20] requirements for private Chinese involvement might be decided quantitatively based on ownership share.[21] How strict the US decides to be may well affect the stringency of China's restrictions - if the US tries to exclude Chinese companies from IRA funding entirely (e.g., by not allowing them minority stakes in JVs), then China is likely to flex its muscles with graphite export permits.

The EU meanwhile in early October launched a probe into Chinese EV exports.[22] The block currently imposes a lower tariff on these than the US (10% and 27.5%, respectively).[23] China could be looking to influence the outcome, leveraging graphite as a new bargaining chip. The new restrictions also serve to protect China's domestic graphite and battery producers by increasing its control over pricing amid faltering growth in its wider economy.

Graphite prices set to rebound on supply disruptions

While industry watchers do not expect the new regulations to choke off supplies in the long-term, they are likely to result in temporary delays while companies work through the licensing process - similar permits have reportedly taken between two weeks to two months to obtain.[24] This suggests the restrictions are "a geopolitical signaling device rather than a rote retaliation tool", as the Center for Strategic International Studies put it.[25] Meanwhile, these disruptions to supply are likely to continue buoying prices into 2024 and beyond.

In some ways this is a two-sided coin: the new rules will encourage other countries to hasten the buildup of their own supply chains, while higher graphite prices should make it easier to attract funding. Shares in overseas producers such as ASX-listed Syrah Resources Ltd, the largest graphite producer outside China, surged following the announcement.[26]

However, building out new capacity and ensuring high enough quality for end-users in the battery industry will take a substantial amount of time, and will not allow for a quick pivot away from Chinese supplies.[27] Meanwhile, supply disruptions are also likely to increase R&D investment in more efficient production processes, alternative battery chemistries and the circular economy.

20. https://www.law.cornell.edu/definitions/uscode.php?width=840&height=800&iframe=true&def_id=42-USC-50049688-660030421&term_occur=999&term_src=title:42:chapter:162:subchapter:II:section:18741
21. https://www.csis.org/analysis/us-china-ev-race-heats-forthcoming-guidance-foreign-entity-concern-rules
22. https://www.politico.eu/article/brussels-officially-starts-probe-into-chinese-electric-vehicles/
23. https://www.bloomberg.com/news/newsletters/2023-09-28/eu-needs-more-than-just-tariffs-to-counter-china-s-electric-cars#xj4y7vzkg
24. https://source.benchmarkminerals.com/video/watch/analyst-insights-what-do-chinas-graphite-export-restrictions-mean-for-lithium-ion;
25. https://www.csis.org/analysis/chinas-new-graphite-restrictions
26. https://www.afr.com/companies/mining/graphite-stocks-surge-as-beijing-opens-new-frontier-in-trade-war-20231023-p5eebo
27. https://source.benchmarkminerals.com/video/watch/analyst-insights-what-do-chinas-graphite-export-restrictions-mean-for-lithium-ion

Previous graphite restrictions less targeted

China implemented restrictions on graphite exports in 2016, though these were more broadly targeted, with export duties and other measures allegedly imposed on a basket of raw materials (also including antimony, chromium, cobalt, copper, indium, lead, magnesia, talc, tantalum and tin). While these restrictions did not appear to have a significant impact on the graphite market, the EU led other countries in launching a dispute with the World Trade Organization (WTO)[28] and China dropped the rules the following year.

Additionally, China has informally restricted exports to Swedish buyers since 2020, in part to curtail the development of Sweden's battery industry at a point when it was just getting off the ground. It also followed a number of minor diplomatic spats between the two countries, most notably in 2019 when free-speech advocacy group Swedish PEN gave an award to publisher and dissident Gui Minhai, a Swedish citizen who is imprisoned in China.[29]

Japan is reportedly assessing whether the latest set of export restrictions violates WTO rules[30] and it is hard to see how China would argue the case for national security concerns when it comes to graphite supplies. However, whether or not a complaint is lodged with the WTO, the body would likely take some time to achieve a resolution and has little heft anyway.

Chinese officials downplay move, nationalistic commentators gleeful

There have been a range of reactions from commentators in China. Some officials such as Sun Qing, Honorary President of the China Carbon Industry Association, have downplayed the importance of the move, saying that the rules do not have any particular targets and will simply create more paperwork for exporters.[31]

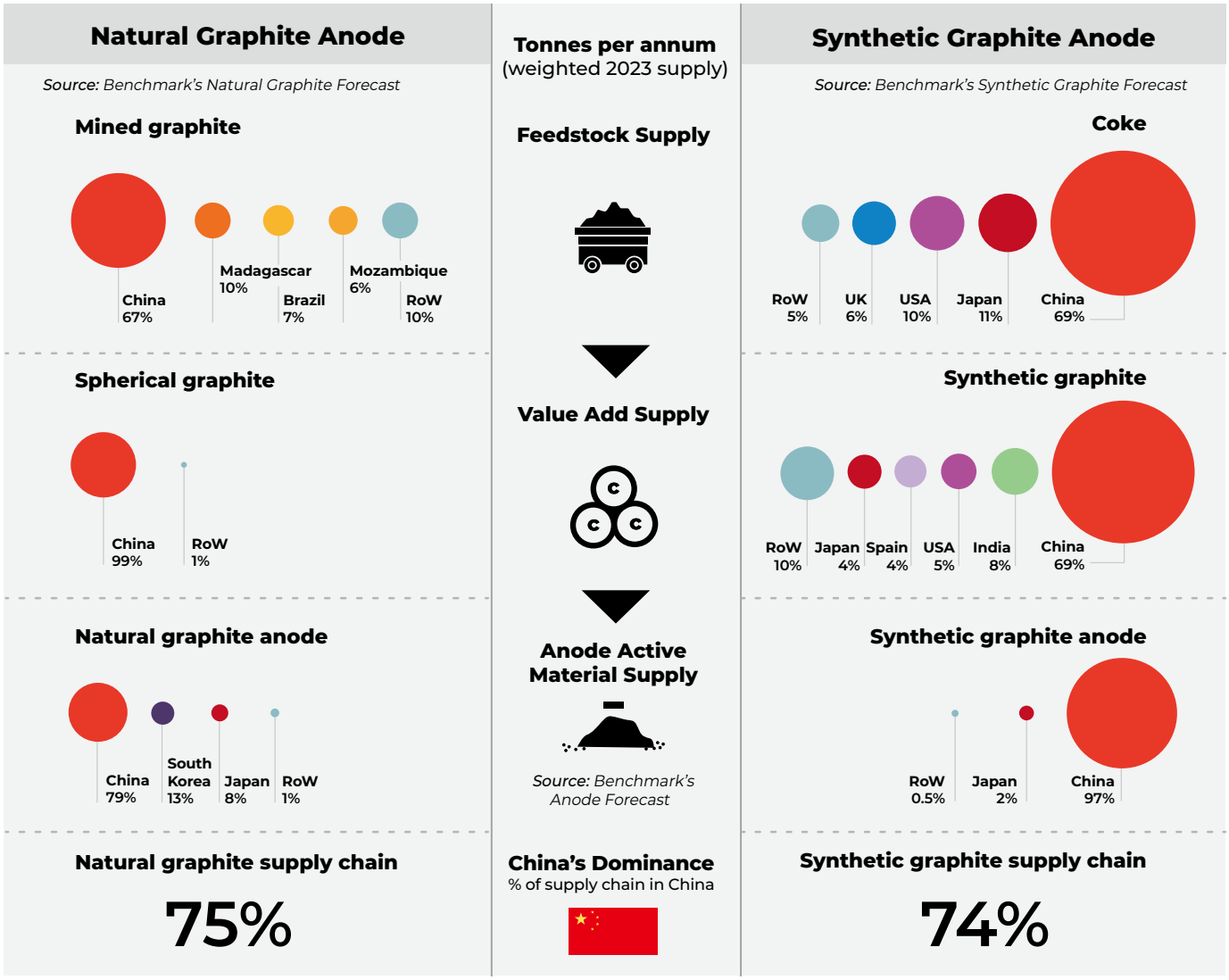
Other media commentators, who are likely to speak more candidly but are very nationalistic in their outlook, believe the move will make it more difficult for the US to build its own supply chains,[32] and China could choke off supplies severely.[33] Some suggested the restrictions would give China leverage over South Korea to prevent further adoption of the US's THAAD missile defense system – long a bone of contention between the two countries – or reduce Korea's role in the US's friend-shoring and chip-making strategies.[34]

28. https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds509_e.htm
29. https://www.economist.com/business/2023/06/22/why-is-china-blocking-graphite-exports-to-sweden
30. https://exportcompliancedaily.com/news/2023/10/24/Japan-Assessing-Whether-Chinas-Graphite-Export-Controls-Violate-WTO-Rules-2310230050
31. https://baijiahao.baidu.com/s?id=1780275953372977888&wfr=spider&for=pc
32. https://baijiahao.baidu.com/s?id=1780260742052550417&wfr=spider&for=pc
33. https://www.huxiu.com/article/2212246.html
34. https://new.qq.com/rain/a/20231101A05RH600 In June 2023, South Korea completed an environmental study of the plan to build THAAD, taking it closer to completing the roll out.

China dominates battery anode supply chains

LIB anodes need pure graphite, which means spherical graphite (derived from natural graphite), synthetic graphite, or some combination. Supply of both forms of graphite, as well as the assembly of battery anodes themselves, are heavily concentrated in China (see below).

Comparison of Synthetic and Natural Graphite properties



Source: Benchmark Mineral Intelligence [35]

35. https://source.benchmarkminerals.com/article/infographic-china-controls-three-quarters-of-graphite-anode-supply-chain

Natural graphite supply chains need a decade to diversify

China will remain the largest producer of graphite for the remainder of the 2020s, but Mozambique, Madagascar and Tanzania are expected to grow their shares of the global natural graphite market significantly over the next decade.[36] These three countries could collectively account for as much as 43% of global natural graphite production by 2033, with China's share falling to 30% from 67% today.[37]

Processing of natural graphite may not keep pace with the diversification of mining, as we have seen before in the rare earth industry.[38] Indeed, Sweden is currently the only EU country projected to have any processing capacity by 2030.[39] There are some North American projects in the pipeline, including Nouveau Monde's[40] and Northern Graphite's[41] facilities, but neither are expected to come online before 2026, at the earliest.

In the next year or two, new sources of natural graphite (e.g., Molo mine in Madagascar[42], Santa Cruz mine in Brazil[43]) and processed battery anode materials (e.g., Vidalia facility in the US[44]) that are already close to operation should provide LIB manufacturers some diversification outside of China. But these new facilities will not have enough capacity to replace Chinese graphite supply entirely.

Syrah Resources' Vidalia battery anode plant in the US is anticipated to be the largest ex-China[45] producer of spherical graphite by the end of this year, with an expected capacity of 11,250 tons per annum.[46] By comparison, this only makes up about a quarter of what China exported between January-September 2022 alone.[47] This suggests that at least some battery manufacturers and EV partners will still be heavily reliant on Chinese exports for some time.

36. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/051022-infographic-africa-boom-graphite-mining-projects-ev-battery-demand-surges
37. https://www.fastmarkets.com/insights/china-to-impose-export-controls-on-graphite-related-item
38. Rare earth mining was concentrated in China until it began to diversify in 2010 following a set of export restrictions. However, processing capacity remains largely concentrated in China today: https://elements.visualcapitalist.com/rare-earth-metals-production-not-monopolized-china/ ;https://www.oxfordenergy.org/wpcms/wp-content/uploads/2023/06/CE7-Chinas-rare-earths-dominance-and-policy-responses.pdf
39. https://source.benchmarkminerals.com/article/sweden-is-only-eu-member-set-to-produce-spherical-graphite-by-2030
40. https://finance.yahoo.com/news/nouveau-monde-graphite-laying-groundwork-150914790.html
41. https://www.northerngraphite.com/media/news-releases/display/northern-graphite-signs-land-agreement-for-baie-comeau-battery-anode-material-plant-advances-mine-to-market-strategy
42. https://www.fastmarkets.com/insights/nextsource-targets-2024-graphite-project/
43. https://www.reuters.com/article/china-graphite-brazil-idCAL1N3BQ319
44. https://www.syrahresources.com.au/our-business/vidalia-active-anode-material-facility
45. "Ex-China" refers to all countries or regions outside of China.
46. https://www.syrahresources.com.au/our-business/vidalia-active-anode-material-facility ; https://source.benchmarkminerals.com/article/esg-of-graphite-how-do-synthetic-graphite-and-natural-graphite-compare
47. https://www.fastmarkets.com/insights/china-to-impose-export-controls-on-graphite-related-items

Synthetic graphite is a quicker alternative, but no silver bullet

Synthetic graphite[48] is an important alternative because new facilities are generally much quicker and easier to develop than natural graphite mines, which can take anywhere between 6-17 years to reach full capacity.[49] Synthetic graphite facilities do not need to be sited at graphite deposits, nor do they need to go through the usual rigorous geological and technical assessment processes associated with new mines.

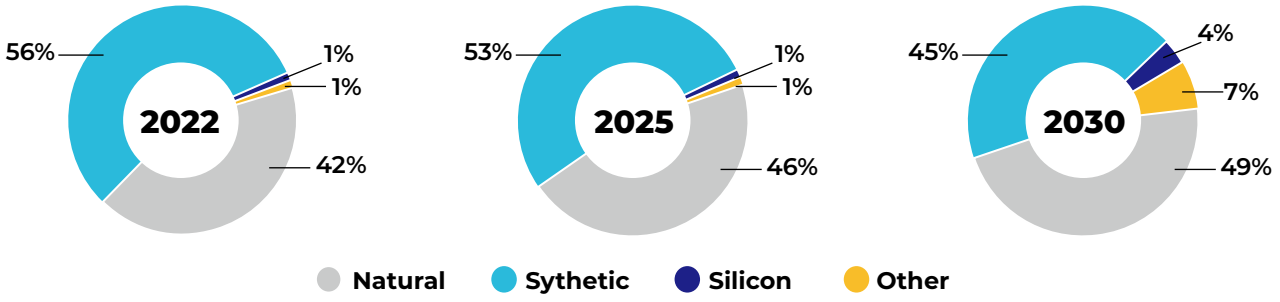
New ex-China synthetic graphite players will need to contend with an already established and mature Chinese market.[50] Graphite prices in China have recently fallen considerably in response to new Chinese synthetic graphite capacity, alongside lower input costs, and lower than expected demand from China's EV sector.[51] Indeed, some ex-China companies assert that China will remain the dominant synthetic graphite producer for the next decade or two.[52]

Competition aside, there is evidence of new synthetic graphite capacity being rapidly developed outside of China. Just 11 days after China's export controls were announced, the US DOE approved $100 million in grant funding to support the development of NOVONIX's synthetic graphite facility, which is expected to begin production in late 2024.[53] Similarly, Anovion received support from the US DOE earlier this year to develop a new facility by late 2025.[54]

Synthetic graphite is not all positive though. It is generally more expensive[55] and energy-intensive than natural graphite and the production process relies on hydrocarbons for feedstock, which raises its carbon emissions profile.[56] The average natural graphite anode produced in China can be up to 55% less carbon intensive than anodes using synthetic graphite materials.[57] Coupled with the introduction of new battery chemistries, this helps explain the expected increase in natural graphite market share amongst LIB manufacturers in the coming decade (see below).

Flake Graphite Forecast Q4 2022

Expected shift toward natural graphite driven by superior ESG profile, lower cost and improving performance



Source: Benchmark Mineral Intelligence Flake Graphite Forecast Q4 2022" [58]

48. Synthetic graphite is produced by heating hydrocarbon feedstocks (e.g., petroleum or coal-based coke) at extremely high temperatures to convert the feedstock into graphite through a process known as graphitization.
49. https://www.linkedin.com/pulse/comparing-timelines-natural-vs-synthetic-graphite-libs-jacob-robin/
50. https://www.reuters.com/world/china/synthetic-graphite-ev-batteries-can-west-crack-chinas-code-2023-09-12/
51. https://www.fastmarkets.com/insights/spherical-natural-graphite-prices-plunge-11-year-lows
52. https://www.reuters.com/world/china/synthetic-graphite-ev-batteries-can-west-crack-chinas-code-2023-09-12/

Graphite is neither quick or easy to replace

Despite materials like lithium frequently grabbing headlines in the EV space, there is in fact more graphite in LIBs than any other material.[59] Graphite has been the predominant anode material in LIBs since commercialization.[60] This can be explained by its relatively low cost, wider abundance, high energy and power density, and long cycle life.[61]

Graphite makes up at least 95% of the LIB anode across common chemistries.[62] EV battery manufacturers usually use a roughly equal blend of (natural) spherical and synthetic graphite[63] because of their complementary properties (see graphic below), alongside a very small proportion of silicon and/or other materials.[64]

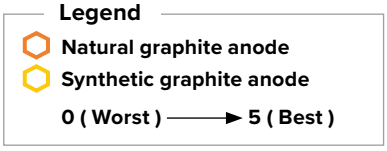
Comparison of Synthetic and Natural Graphite properties

Comparing synthetic and natural graphite anode supply chains

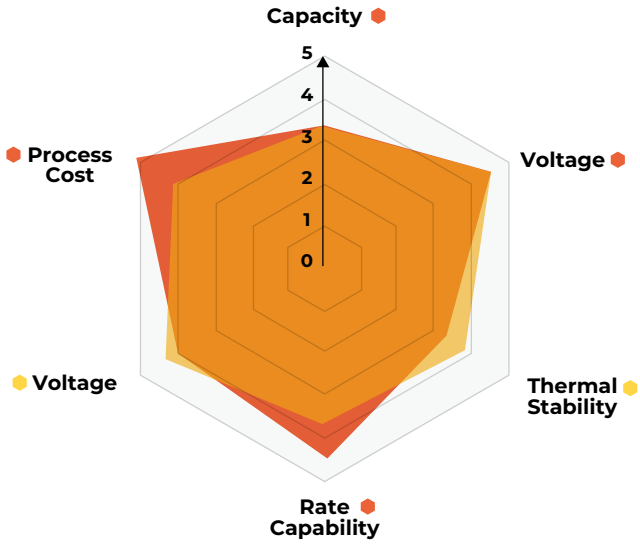
China controls three-quarters of the global graphite anode supply chain

Synthetic graphite anodes generally have **better cycle life capabilities** as the greater number of exposed edges allows faster movement of lithium ions in and out of the graphite layers.

Natural graphite anodes, however, can achieve **higher capacities** due to the more ordered crystalline domains of the graphite.



***Source**: Benchmark's Anode Forecast*



Source: Benchmark Mineral Intelligence [65]

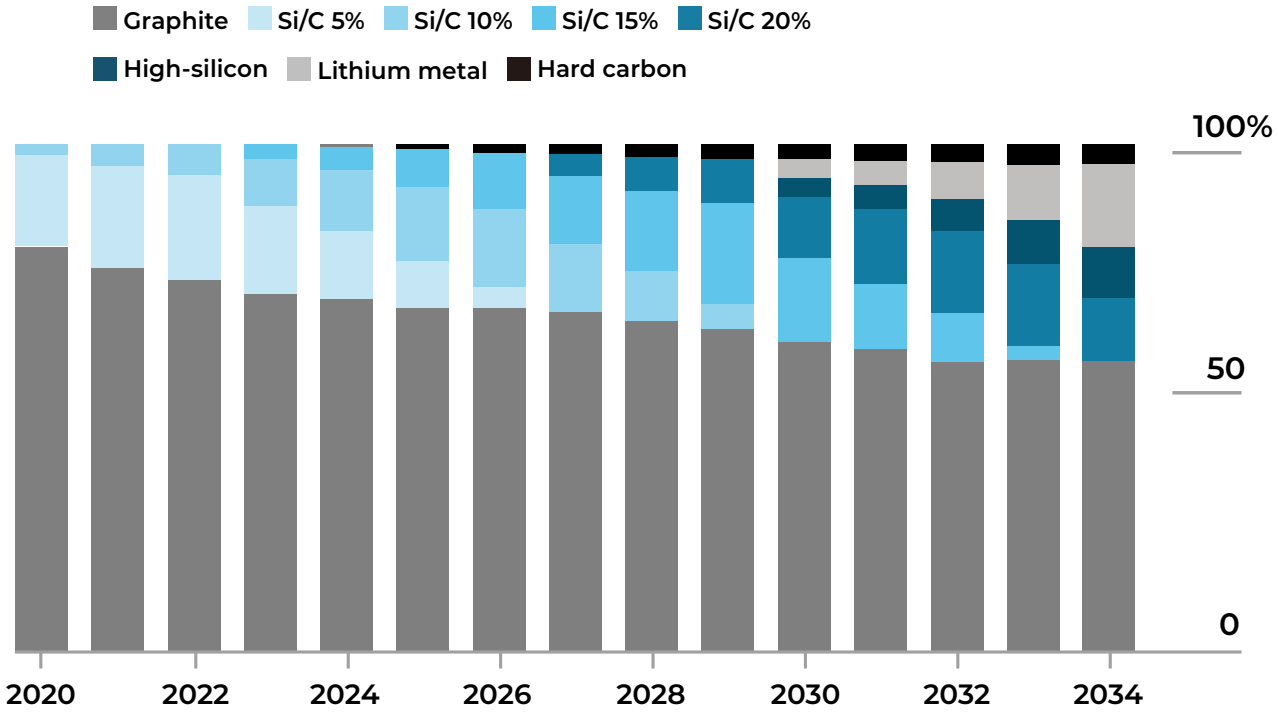
53. https://www.novonixgroup.com/novonix-finalizes-us100-million-grant-award-from-u-s-department-of-energy/
54. https://www.anoviontech.com/news/anovion-technologies-announces-plans-for-800-million-initial-investment-in-new-manufacturing-facility-in-southwest-georgia/ ; https://gov.georgia.gov/press-releases/2023-05-15/gov-kemp-anovion-technologies-create-over-400-jobs-bainbridge-invest-800m
55. Synthetic graphite prices have become increasingly competitive in the past year, which has improved its use case in battery anodes: https://www.fastmarkets.com/insights/spherical-natural-graphite-prices-plunge-11-year-lows/
56. https://hcss.nl/wp-content/uploads/2022/03/Graphite-Challenges-and-Recommendations-HCSS-2022.pdf
57. https://source.benchmarkminerals.com/article/esg-of-graphite-how-do-synthetic-graphite-and-natural-graphite-compare
58. https://nmg.com/wp-content/uploads/2023/06/NMG-Graphite-101.pdf
59. https://www.iea.org/data-and-statistics/charts/minerals-used-in-electric-cars-compared-to-conventional-cars
60. https://www.sciencedirect.com/science/article/abs/pii/S2352152X21009282
61. https://www.sciencedirect.com/science/article/abs/pii/S2405829720304906
62. https://ecga.net/wp-content/uploads/2023/02/Graphite-in-batteries_Infosheet_final.pdf
63. Synthetic graphite is the leading material for batteries in general, but there is a more equal split for LIBs: https://www.fastmarkets.com/industrial-minerals/graphite/
64. https://chargedevs.com/features/a-closer-look-at-graphite-its-forms-functions-and-future-in-ev-batteries/ ; https://source.benchmarkminerals.com/article/infographic-china-controls-three-quarters-of-graphite-anode-supply-chain
65. https://source.benchmarkminerals.com/article/infographic-china-controls-three-quarters-of-graphite-anode-supply-chain

While natural graphite is generally cheaper to source, enables higher capacities and consumes less energy, synthetic graphite offers faster charging and a longer battery life.[66] Battery and EV manufacturers are now investing in new anode materials that can at least complement these material properties, and may even replace graphite anodes entirely.

Silicon-based anodes could commercialize by 2030

Silicon is already used in small quantities (around 5%) in about 30% of battery anodes today because it is lighter than graphite and so enables improvements in energy density.[67] High-silicon batteries (i.e., with proportions of >50%) are only projected to make a material impact on the commercial market towards the turn of the decade.[68]

Battery Anode Chemistry Mix for Electric Vehicles



Note: Si/C refers to silicon-graphite composite anodes, with the silicon percentage expressed alongside. High silicon refers to anodes using more than 50% silicon.

Source: BloombergNEF [69]

66. https://www.fastmarkets.com/insights/synthetic-versus-natural-graphite-debate/
67. https://www.bloomberg.com/news/newsletters/2023-07-07/new-ev-battery-materials-will-beget-new-dilemmas ; https://www.iea.org/reports/global-ev-outlook-2023/trends-in-batteries
68. https://www.bloomberg.com/news/newsletters/2023-07-07/new-ev-battery-materials-will-beget-new-dilemmas
69. https://www.bloomberg.com/news/newsletters/2023-07-07/new-ev-battery-materials-will-beget-new-dilemmas

A complete replacement of graphite with silicon could, in theory, increase battery energy densities ten-fold,[70] which is certainly worth striving for. In practice, silicon can swell to triple its size while charging[71] which has limited its use in EV batteries that are necessarily compact.

While the EV industry is investing to address these challenges, purely silicon-based anodes are unlikely to reach the market before the mid-2020s at the earliest, and these early arrivals will be limited to luxury EVs until they can compete with graphite options.[72] There is however significant disagreement amongst analysts about the actual commercialization date of pure silicon-based anodes, as reflected in BNEF's forecast above.

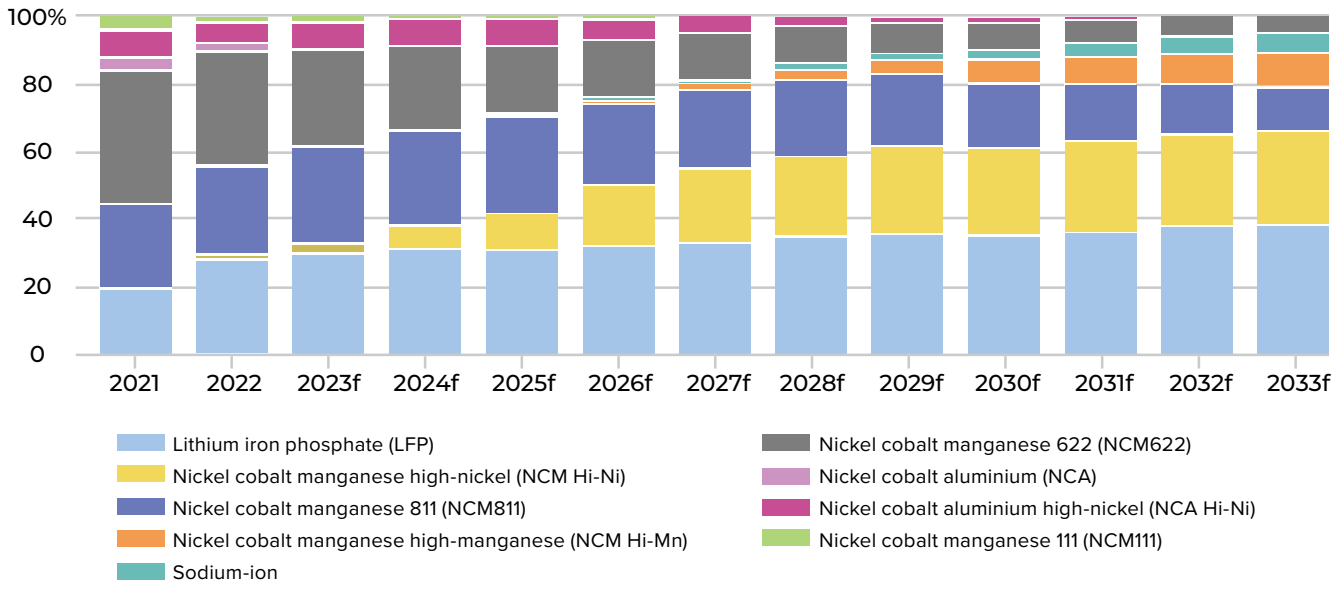
Crucially, substituting graphite with silicon is not an effective way of diversifying away from China, which accounts for 68% of global silicon production, far ahead of Russia at 7% and Brazil at around 5%.[73] Western companies are starting to catch on to this fact but, again, these processes take time. *Canadian company, NEO Battery Materials*, plans to develop its first commercial silicon anode plant in South Korea by early 2024[74] but is not expected to reach full capacity for another 3-4 years after that.[75]

Sodium-ion batteries enable replacement, but are largely a China story

Sodium-ion batteries are a nascent technology that replace the need for graphite anodes with hard carbon, a material that can be derived from synthetic polymeric feedstocks or biomass (preferably waste).[76] R&D is underway to remove the anode in sodium-ion batteries entirely.[77] The first sodium-ion powered EVs have only recently been announced[78] and are forecast to make up just 6% of the global passenger EV market[79] and 9% of the ESS market by 2033.[80]

70. https://www.eetasia.com/silicon-anodes-improve-li-ion-batteries/
71. https://www.sciencedaily.com/releases/2019/02/190221130302.htm
72. https://www.bloomberg.com/news/articles/2023-04-04/a-new-class-of-long-range-ev-batteries-heads-to-production
73. https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-silicon.pdf
74. https://neobatterymaterials.com/nbmside-commercial-plant/
75. https://www.fastmarkets.com/insights/ex-china-silicon-producers-increase-output-burgeoning-battery-anode-consumption/
76. https://iopscience.iop.org/article/10.1088/2515-7655/ac8dc1/pdf
77. https://www.pv-magazine.com/2021/05/05/a-stable-sodium-battery-without-the-anode/ ; https://carnewschina.com/2022/01/13/catl-new-patent-allows-anode-free-sodium-ion-battery-density-to-go-above-200wh-kg/
78. https://jacmotors.co.za/jac-motors-unveils-worlds-first-sodium-ion-battery-vehicle/ ; https://www.catl.com/en/news/6013.html
79. https://www.fastmarkets.com/insights/solid-state-sodium-ion-batteries-lithium-supply-crunch/
80. https://www.fastmarkets.com/insights/northvolt-first-company-outside-china-to-develop-sodium-ion-battery-with-160-wh-kg-energy-density/

Global chemistry outlook for the passenger EV segment 2021 - 2033



Source: FastMarkets [81]

While sodium-ion batteries do offer some prospect of alleviating the LIB sector's graphite demand over the coming decade, they will do little for ex-China EV companies in the way of diversification in the short- to medium-term. This is because there is not yet an established sodium-ion battery supply chain for EVs outside China.[82]

Indeed, most of the early investors in sodium-ion batteries are Chinese companies, including battery makers CATL, BYD and HiNa, as well as auto manufacturers JAC and Chery.[83] There are some exceptions, including Northvolt[84] and Faradion,[85] but they appear more focused on ESS applications.

Northvolt's recent announcement[86] suggests that there is certainly opportunity for these newer entries to scale and China's graphite restrictions could improve the pricing prospects and eventual penetration of sodium-ion batteries in EV and ESS markets. The fact remains, however, that entirely new supply chains for these technologies will take a few years to reach any considerable scale, and in the meantime, EV and BESS rollout will be largely dependent on China.

81. https://www.fastmarkets.com/insights/solid-state-sodium-ion-batteries-lithium-supply-crunch/
82. https://www.fastmarkets.com/insights/five-things-we-learned-at-the-european-battery-raw-materials-conference-2023/
83. https://energypost.eu/sodium-ion-batteries-ready-for-commercialisation-for-grids-homes-even-compact-evs/
84. https://www.theguardian.com/business/2023/nov/21/breakthrough-battery-from-sweden-may-cut-dependency-on-china
85. https://faradion.co.uk/first-faradion-battery-installed-in-australia/
86. https://northvolt.com/articles/northvolt-sodium-ion/