Energy Security Fellows Program

Graphite, the Forgotten Critical Mineral

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The electrification of the United States' (U.S.) automotive fleet is an effective strategy for curtailing American dependency on foreign oil. The U.S. department of Energy anticipates that widespread electric vehicle (EV) adoption across the U.S. will only occur once EVs (1) have enough capacity to fulfill a 310-mile trip and (2) battery pack costs will drop to or below 125 US$/kWh.[1] While current EVs on the market possess the appropriate capacity/range, battery pack costs are still high at 132 US$/kWh and are expected to rise in the coming years as demand increases for battery raw materials.[2,3] A typical EV battery consists of a cathode and an anode, both of which are made from minerals designated critical by the U.S. Geological Survey.[4] Much attention is focused on the mining and procurement of cathode materials – lithium, nickel, and cobalt – resulting in a push to re-shore their supply chains, as well as the search for alternative cathode formulations that minimize or eliminate them altogether. Anode materials like graphite (~28% of a battery's composition) have not received the same attention, likely due to the fact that battery performance is currently limited by the chemistry of the cathode.

While modern EVs use a variety of cathode materials, graphite is utilized across most makes and models (85% market share).[5] China is currently the world's top producer of graphite, with 820,000 metric tons produced in 2021, accounting for the bulk of global production and exports. The next largest graphite producer, Brazil, was responsible for only 68,000 metric tons in 2021.[4] Graphite can be segmented into two varieties: natural and synthetic. While natural graphite is mined directly from graphite ore, synthetic graphite is manufactured from petroleum coke (a carbon rich solid derived from oil refining) in a process called 'graphitization', which utilizes heavy equipment, harsh chemicals, and elevated temperatures over days to weeks (longer durations result in higher quality material at lower recovery rates).[6] Synthetic graphite's higher quality makes it favorable for battery performance at the expense of its cost (US$ 20/kg for synthetic vs. US$ 6-10/kg for natural graphite).[7] Manufacturers use a mixture of natural and synthetic graphite to balance the cost and performance of the resultant anodes, a trend which will continue until the economics of synthetic graphite drastically improve.[8-9] Demand for graphite is expected to increase tenfold in the next decade, outpacing the supply of natural graphite, necessitating further investment into synthetic graphite manufacturing in order to secure its domestic supply.[10]

In 2022, President Biden invoked the Defense Production Act to secure the domestic supply of EV critical minerals. The U.S. has the opportunity to become a leader in graphite production – which encompasses mining, refinement, and recycling – by incentivizing American companies to enter the market, create jobs, and boost local economies. New and developing businesses will benefit from subsidies and tax cuts, encouraging capital investment into mining, supply chain, and manufacturing operations that will bolster the national supply of graphite. High prices in the immediate term could be mitigated by tax breaks for manufacturers and incentives for consumers who buy U.S. produced graphite or graphite products. Similar provisions already exist in the Inflation Reduction Act of 2022[a], lowering the $7,500 credit for the purchase of a new EV if a certain percentage of the critical minerals in its battery is not mined, refined, or recycled in a Free Trade Agreement country.[11] Larger incentives for purchasing U.S. produced materials will be critical in cultivating a domestic graphite production, leading to long-term gains in supply chain sovereignty and domestic job creation.

The U.S must also look into graphite alternatives to ensure its independence and leadership in the field. While graphite is adequate for current battery applications, future use cases are expected to be more technically demanding. Silicon materials are logical alternatives to graphite due to the relationship the two elements share on the periodic table. Silicone anodes possess better electrochemical properties than their graphite counterparts and silicon is the second most abundant element on the planet.[12] Despite this promise, silicon undergoes a volumetric expansion of up to 400% upon lithium intercalation, leading to the rapid deterioration of the material over time, rendering it useless for energy storage.[13] The utilization of silicon nanoparticles, which bear unique structural motifs compared to bulk silicon is one way to overcome the expansion problem, but the preparation of these materials is not commercially feasible.[14-15] Other approaches involve the doping of silicon or silicon oxide into graphite to enhance its performance, a strategy already employed commercially.[15-17] More research and development should be done to find suitable and more abundant alternatives to graphite.

Like nickel, cobalt, and lithium, graphite is a critical mineral that represents a weak point in battery fabrication and EV manufacturing. Abundant access to graphite will safeguard U.S. industries from shortages and help wean the U.S from foreign oil and external influence.

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The contents of this article express the views of the author alone. They do not reflect those of his employer.

[a]The Inflation Reduction Act of 2022 passed on August 7th, 2022

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