CLIMATE IMPACT OF GRAPHITE PRODUCTION

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LOOKING DEEPER

Producing anode grade graphite for lithium-ion batteries is energy intensive. Existing graphite supply chains often situate energy-demanding process stages in regions with low-cost energy, such as Inner Mongolia where the grid is dominated by coal and therefore has a high climate change impact per kWh.

Life Cycle Assessment (LCA) is a scientific and robust approach to quantifying environmental impacts of a product or service, to show the quantifiable impact of producing critical metals and minerals. It can also be used to identify impact mitigation opportunities for production chains, making it a critical step when developing projects.

Published LCA studies for graphite production do not sufficiently represent the sizable contribution of different electricity scenarios to the overall impact of operations. As the global demand for battery grade material rises, this merits careful reconsideration. This LCA study suggests that the true climate change impact of producing battery-grade graphite can be as much as ten times higher than published values, depending on the energy and material inputs.

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The Forgotten Material of the Battery Revolution

The demand for electric vehicles (EVs) is growing exponentially worldwide, with global sales rising to 3.2 million new units in 2020, an increase of 43% on the previous year [1,2]. Consumers contributed USD $120 billion to electric car purchases in 2020, a 50% increase from 2019 [3]. The British and French governments recently announced plans to remove combustion engine vehicles from roads by 2040 [4], to be replaced primarily by EVs. The demand growth for EVs is accompanied by demand for the lithium-ion batteries (LIBs) used to power them. Constituent materials in LIBs have significantly different environmental impacts depending on the resource type that they are sourced from, the technology used in the production route, energy and material inputs including water consumption, electricity grid mix, as well as the reagents and chemicals used in production.

Around 96% of all anodes in LIBs contain natural and/or synthetic graphite as their primary material [5] with each LIB requiring 10-15 times more graphite than lithium, which is the second most common component in most battery chemistries. Around 75,000 tonnes of graphite is required to create 1 million EVs [6] meaning that 900,000 tonnes will be required to meet the 12 million EVs that will be produced by 2025 [7].

Natural vs. Synthetic Graphite

Anode materials in LIBs are selected based on their charge collection capability. Graphite is the primary choice for anode material due to it meeting the voltage requirements of most common Li-ion cathodes, its relative affordability, and extremely light, porous and durable physical properties [8]. Battery grade graphite is produced from either natural graphite ore extracted from the Earth's crust or synthetic graphite created by the treatment of a coke-based precursor [5]. China is the world's largest producer of graphite for all purposes, including anode production, with an output of 650,000 tonnes of natural graphite ore in 2020 [9] [10], and 697,000 tonnes of synthetic graphite products in 2016 [11]. The IEA believes that for LIB anodes, natural graphite will continue to account for the majority of market share, despite the superior charge performance and cycle life of synthetic graphite compared to natural graphite [12].

Natural and synthetic graphite concentrates are fed through a range of separate multi-stage processing routes to create the final high-quality anode grade graphite product. Two specific routes are summarized in Figure 1a-b. It is important to note that there are different routes to get to a final artificial graphite for use in batteries, but that all these processes at least require the high temperature (>3000°C) graphitisation step where a majority of the energy is consumed.

Like with all battery materials, the production of natural and synthetic graphite can have a wide range of environmental impacts depending on the source of the raw material, the technology used for processing and purification, energy grid mix in the operating region(s), and production route. Natural graphite mining can cause dust emissions, and the purification of battery-grade anode products requires high quantities of reagents such as sodium hydroxide and hydrofluoric acid, which may be harmful to both human health and the environment. The synthetic graphite production route is more energy-intensive than the natural graphite route. The high energy demand of synthetic graphite production has leads operators to seek the cheapest power sources that tend to be coal dominant, generating a higher overall carbon footprint [13].

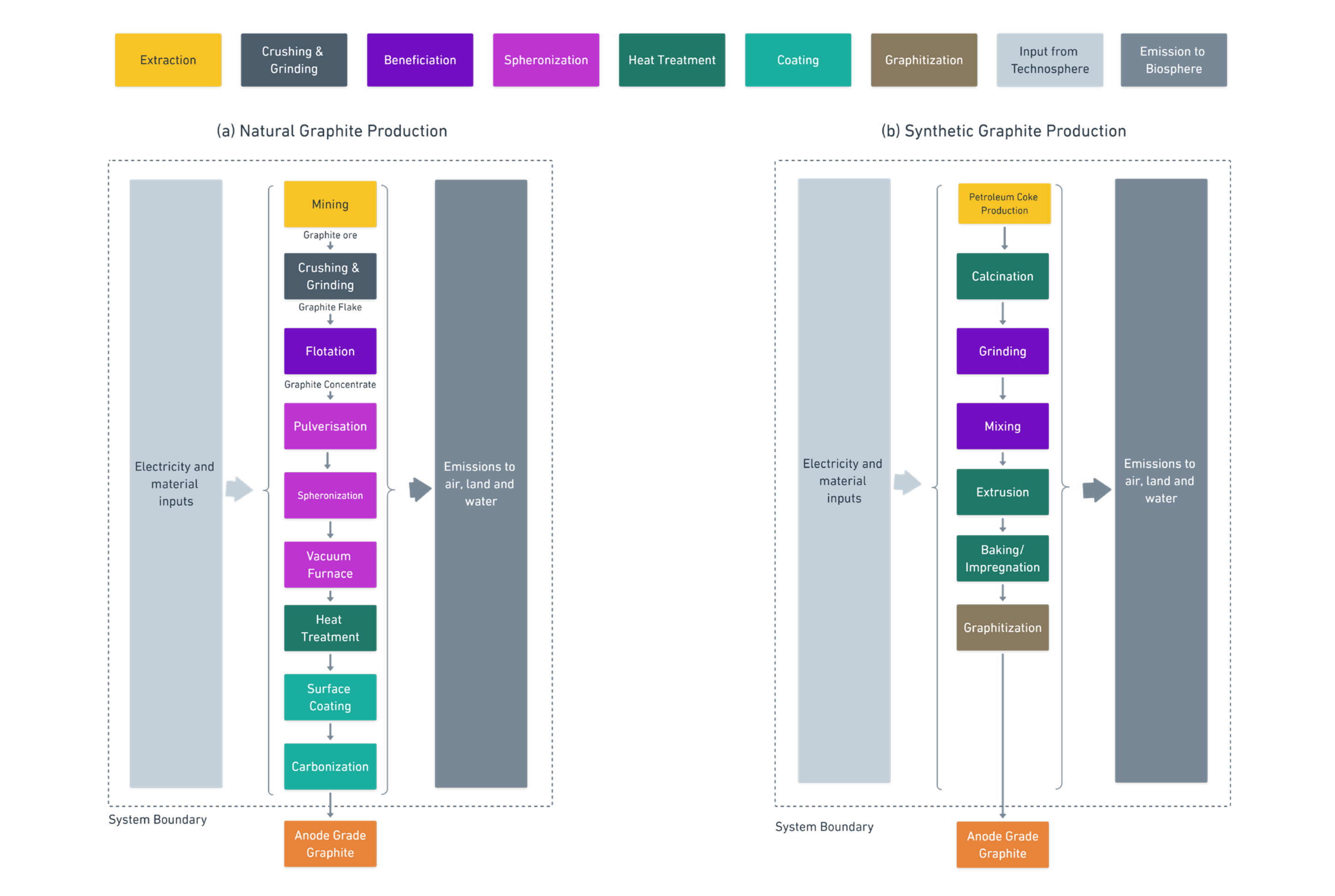

Figure 1. System boundary of: (a) Production route for natural graphite including extraction, beneficiation, processing, spheronization and coating stages to produce battery-grade anode material and three intermediate sellable graphite products. (b) Production route for synthetic graphite including beneficiation, roasting and graphitization stages to produce battery-grade anode material.

Climate Change Impacts of Graphite Anode Precursors

Environmental impact classification factors for many graphite products and projects are significantly underestimated in previous LCA databases due to poor data quality, conservative energy contributions or omitting upstream scope 3 emissions (i.e., embodied impact of consumables).

The rapid rise in demand for graphite anode for LIB has provided impetus for re-calculation of impacts using more recent, higher quality data. By modelling the direct and embodied impacts contained within the production of natural and synthetic graphite anode, Minviro has more accurately identified the environmental costs associated with this key economic sector.

New life cycle impact assessments were conducted on data from natural and synthetic graphite anode producers in high-impact coal-based grid mix regions from existing supply chains (i.e., fossil fuel dominant, low cost). The production route for each was based on those in Figure 1. These new results were compared to representative academic natural and synthetic graphite values and the current best-fit data entry from a commercial LCA database for mixed natural/synthetic battery-grade graphite products. Results for Global Warming Potential (GWP), a common environmental impact indicator, are given in Figure 2. The LCA was a cradle-to-gate study with the functional unit of 1kg of anode grade graphite, with the system boundary as presented in Figure 1.

The calculated GWP values for producing 1 kilogram of anode grade graphite in coal-based grid mixes, like Inner Mongolia, are ~800% and ~1,000% higher than the commercial database value for natural and synthetic routes, respectively. Environmental impacts associated with anode grade graphite from natural mined material are predominantly the result of energy consumed

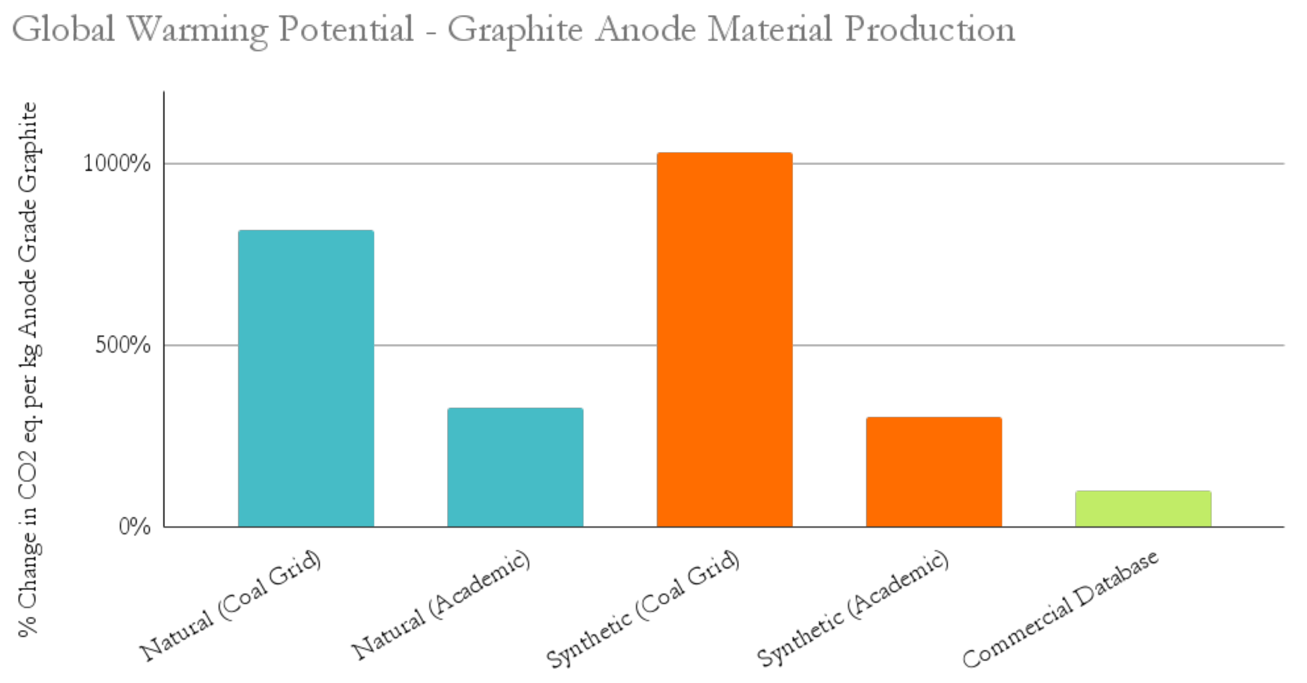

Figure 2. Percentage change in Global Warming Potential (GWP) for various battery-grade graphite LCA data points, normalised to a database value. Includes the two new calculations conducted for this study (natural and synthetic routes for coal-based grid mixes), natural academic data, synthetic academic data and a battery-grade graphite entry in a commercial LCA database.

in the purification process; mining contributes less CO_2 impact per kg of battery grade graphite product compared to subsequent production stages. This is due to the relatively low energy consumption in open pit operations per kg product, particularly for high grade ore. The majority of impacts for synthetic graphite manufacturing routes are the result of the vast energy consumption during graphitization and roasting processes, in addition to embodied impacts associated with calcined petroleum coke production which is the synthetic graphite feedstock. The reliance on electricity input for all aspects of synthetic production means that the CO_2 impact of these products significantly vary depending on the grid mix, whereas a larger proportion of natural impacts can come from reagent and fuel use, for example.

This study clearly highlights that the values for GWP in the specified production routes for the existing graphite anode supply chain are much higher than previously published and assumed values from LCA databases and academic studies, underscoring the importance of accurate grid mix definition in final impact assessments. Both natural and synthetic graphite anode routes have huge energy considerations for different aspects of the production chain. With all other inputs identical, the localized environmental impact of electricity generation can cause significant variation between individual operations as a result.

This creates a challenging economic-environmental trade-off. Battery grade graphite produced in low cost, fossil-dominated energy regions will inevitably generate the highest environmental impacts which may not be acceptable for LIBs or EV customers. The majority of the global supply of graphite is currently produced in high-impact grid mix regions, and the prior misrepresentation of environmental impacts in the production chain requires disclosure and rectification. Switching production to regions with dominant renewable energy sources will reduce GWP related to electricity use, particularly for synthetic graphite. For more information regarding the environmental impact of different impact categories producing battery grade graphite via natural and synthetic graphite routes, please contact Minviro directly.

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Future work

With graphite demand increasing, new projects and production routes will be developed for both natural and synthetic anode grade graphite. It is critical that life cycle assessment is applied at the development stage of these projects to ensure that all impact mitigation opportunities are explored. There are significant opportunities to reduce the environmental impact of anode production by utilizing low carbon or renewable energy sources, exploring new production routes, minimising waste products or identifying new material or reagent suppliers. Whilst companies strive for the cheapest production route, environmental standards especially relating to climate change will place value on low impact materials and have tangible economic impacts in the coming years.

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