

Refining the Strategy: The Economics of Lithium Value Addition in Ghana

THOMAS SCURFIELD AND DAVID SEFA ADJEI

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Natural Resource Governance Institute

Contents

Key messages 3

Summary 4

Introduction 7

The state of play in global lithium refining 8

The potential viability and benefits of a Ghanaian refinery 20

A mine-and-monitor approach 30

Adhering to the principle of doing no harm 32

Transparency and trust 33

Conclusion 34

Appendix 35

Endnotes 38

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Key messages

- Ghana's plan to refine its lithium domestically should be based on economic feasibility, market outlook and a rigorous cost-benefit analysis.
- A Ghanaian refinery would currently face limited access to feedstock and high costs compared to global competitors, particularly in China. Excess refining capacity in China and uncertainty about the growth of lithium chemical demand outside China further compound these challenges.
- A refinery built in the next few years is unlikely to generate much benefit for Ghanaians. NRGI modeling suggests it could cost the government at least USD 500 million in lost revenue, as the refinery would need to purchase Ghana's concentrate at below-market prices just to break even. It is also unlikely to create more than 200 direct jobs once operational, and the stimulus for other sectors is uncertain. In contrast, the opportunity costs as well as environmental and social harms could be considerable.
- The government would benefit from a mine-and-monitor approach instead: ensuring that the Ewoyaa mine starts as soon as possible while supporting further lithium exploration, monitoring the evolution of global conditions for lithium refining, and taking domestic steps to improve future refining prospects—such as developing a strategy for byproduct use.
- Transparency and citizen engagement in the decision-making process are essential to building trust, managing expectations, and fostering a strong investment climate for future lithium refining.

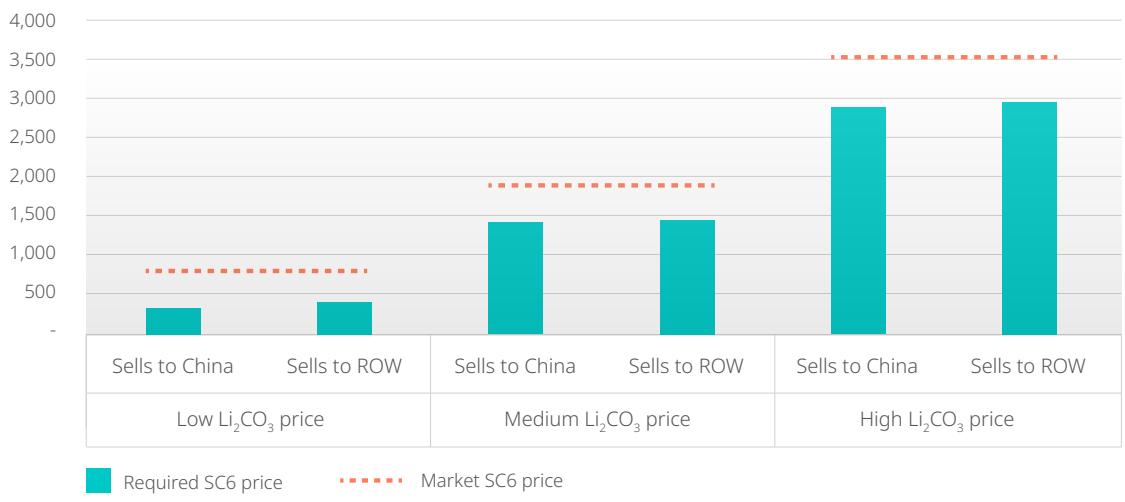
Summary

Ghana is on the brink of becoming a lithium producer. Barari DV Ghana Ltd, a subsidiary of Atlantic Lithium, plans to begin producing lithium spodumene concentrate from its Ewoyaa mine within two years, pending parliamentary approval of its mining lease agreement. Half of Ewoyaa's production is already committed for export. The government, civil society and broader public want a refinery built in Ghana to process the remaining lithium. Ghana's ambition to advance along the lithium value chain is understandable. However, access and proximity to mineral deposits play only a minor role in determining the viability and benefits of such a move. As it pursues its lithium refining ambitions, the government must ground its strategy in economic feasibility, market outlook and a rigorous cost-benefit analysis.

Ghana's ambitions to refine its lithium domestically are unfolding in a challenging global context. While many governments and companies have pursued lithium refining in recent years, few have been successful. China's technical expertise and cost advantages mean it currently hosts all but three of the world's refineries for converting spodumene concentrate into lithium chemicals, and two of the refineries outside China have recently canceled expansion plans. Excess refining capacity in China, along with uncertainty about the growth of demand for and pricing of lithium chemicals in the rest of the world, is further compounding the challenging economics for refineries outside China.

A Ghanaian refinery would face additional challenges. First and foremost, it would have limited access to feedstock unless more lithium discoveries are made in the country or the refinery identifies other sources. We modeled a potential Ghanaian lithium carbonate refinery that would begin operations in the next few years to assess its viability and benefits for the country in this context. Our modeling suggests that such a refinery—whether built by private investors, as currently envisioned, or by the state—is unlikely to generate much benefit for Ghanaians. If the modeled refinery pays the market price for spodumene concentrate, it incurs a loss on every metric ton of lithium carbonate it produces. It only breaks even if it purchases Ghana's mined concentrate at below-market prices. This holds true whether it has access only to Ewoyaa's current reserves (as shown in the figure below) or secures enough feedstock for a typical 20-year operation; sells to China or the "rest of the world" (ROW); or faces low, medium or high lithium carbonate prices.

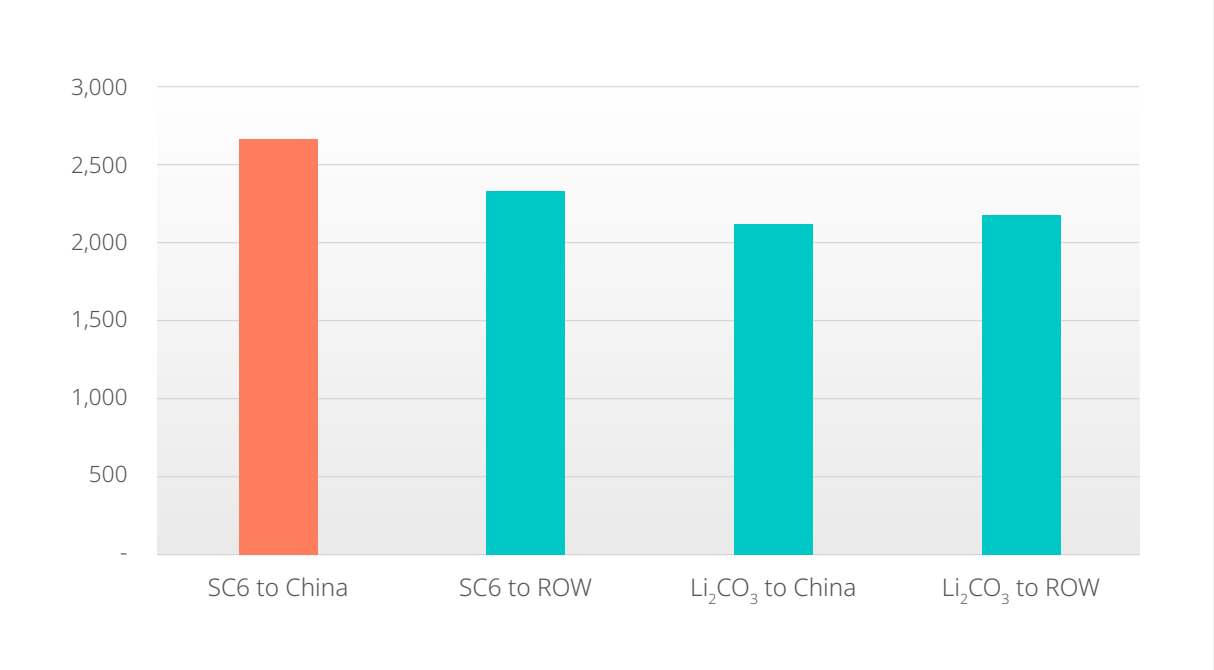
Spodumene concentrate (SC6) prices needed for a Ghanaian refinery to break even vs. the modeled market price, at different lithium carbonate (Li_2CO_3) prices (USD per metric ton)[1]



The lower price that the refinery would pay for Ewoyaa's production would reduce government revenue from royalties, taxes and dividends paid by Barari. In our medium-price scenario, the government earns $500 million less from the country's current lithium reserves by having a refinery instead of exporting unrefined output (as shown in the figure below).

Even if the refinery secures enough feedstock to operate for 20 years, the government still loses more than $300 million in revenue. However, the government would struggle to attract investors in an unprofitable refinery, and providing direct financial support or building and owning the refinery itself would also negatively impact the public finances.

Government revenue from Ewoyaa mine from exporting spodumene concentrate (SC6) vs. lithium carbonate (Li_2CO_3) in medium-price scenario (USD millions)[2]



The government will need to account for the opportunity costs of lower revenues or the use of public funds. For example, $500 million is considerably more than the amount budgeted for kindergarten, primary and junior secondary education in 2024.[3] The government will also need to consider the potential trade-offs between pursuing lithium refining and other ways Ghanaians can benefit from their mineral wealth, such as supporting local companies that supply goods and services to mining operations or developing other, potentially more beneficial, mineral value chains.

These opportunity costs could be justified if the refinery also generates other significant benefits. Further analysis is required to quantify these benefits, but their potential appears uncertain. The refinery will likely create at most 200 direct jobs once operational—albeit relatively high-paying and skilled ones—and the stimulus for other sectors is unclear. In contrast, the environmental and social harms could be considerable. For example, the refinery could consume as much water in a year as 90,000 Ghanaians.[4]

The government would benefit from adopting a mine-and-monitor approach instead. This approach would involve ensuring the Ewoyaa mine begins operations as soon as possible while supporting further lithium exploration and development, as well as monitoring how conditions for lithium refining evolve—paying close attention to certain market signals and thresholds.

Our model shows that, currently, Ghana would generate the largest benefit from selling unrefined output to the leading buyer: Chinese refineries. However, the market, technological and geopolitical landscape is highly dynamic, and the economics of lithium refining could change significantly in the coming years. If battery cathode manufacturing outside of China ramps up, and a sufficiently large premium (at least $3,000 per metric ton of lithium carbonate, according to our modeling) is placed on non-Chinese supply, Ghana would benefit from having a refinery. The government should also monitor the evolution of new lithium products, such as lithium phosphate. Depending on the economics and market conditions, being an early entrant in new products could provide a premium that makes refining a more feasible and beneficial prospect for Ghana.

As part of this approach, the government will need to manage the risk of Ghana's lithium being tied up in long-term offtake agreements by the time the country is in a position to benefit from a refinery. It will need to continuously engage with Barari and any other companies that develop lithium mines on their export plans, and coordinate its approval of offtake agreements with any changes to its refining strategy.

If the government decides to continue pursuing lithium refining in the next few years, it should work with potential investors to avoid the biggest pitfalls and increase the chances of success. As part of this, it should: ensure the refinery replicates proven designs from China; assess the feasibility and benefits of developing capacity to produce key reagents (the main input in the refining process and a significant determinant of costs); and develop a strategy to use the refinery byproducts to reduce waste-management costs and provide useful inputs for other sectors, such as Ghana's cement industry.

In any case, the government should be transparent in its decision-making and involve citizens at every step. Trust is essential for managing public expectations and fostering an understanding of the trade-offs involved. By building trust, the government will improve the investment environment and therefore the prospects for lithium refining in the longer term.



Photo by Jasonbennee for iStock

Introduction

Amid increasing global demand for minerals essential to the energy transition, Ghana is on the brink of becoming a lithium producer. In 2024, the government presented a mining lease agreement for the country's first lithium mine, Ewoyaa, to parliament for review.[5] Following the election of a new government in December 2024, the agreement is still awaiting approval at the time of writing. If approved, Barari DV Ghana Ltd, a subsidiary of Atlantic Lithium, expects to begin production within two years.[6] Like other African countries, Ghana has hard rock deposits of lithium (in contrast to the brine deposits in the Latin American "Lithium Triangle" of Argentina, Bolivia and Chile).[7] As a result, Barari will produce lithium spodumene concentrate.[8] Ongoing exploration of the Ewoyaa lease area suggests expansion potential beyond the initial planned mine.[9] Companies, such as CAA Mining, are also exploring other areas of the country for lithium.[10]

After the parliamentary process for Barari's mining lease, a significant decision for the government will be whether to pursue construction of a refinery to process at least some of the country's spodumene concentrate into lithium chemicals. Half of Ewoyaa's production is currently committed to Piedmont Lithium, which intended to use it as feedstock for its own planned refinery in the U.S. (though this refinery has since been canceled).[11] The previous government wanted a domestic refinery to process the remainder. The new government also set out this ambition in its manifesto.[12] Ghanaian civil society, among others, have also supported domestic lithium refining as a priority.

The lease agreement with Barari requires the company to conduct a scoping study to evaluate the viability of a refinery. The company submitted this study to the government around May 2024, but the contents have not been published. Separately, the previous government had been in discussions with CAA Mining and Livista Energy about construction of a refinery.[13]

Ghana's ambition to move along the lithium value chain is understandable. Like many low- and middle-income countries, Ghana has historically seen mining companies extract and export minerals with little processing. This has typically limited the benefits that the mining sector could generate for Ghanaians. However, the viability and benefits of advancing along a mineral value chain depend on multiple factors, including the mineral itself, the stage of the value chain targeted and the country context.[14] Ghana's lithium refining ambitions must therefore be based on a rigorous assessment of economic feasibility, market outlook and cost-benefit analysis. This clarity is essential for guiding government decision-making on the amount of political capital, time and money to invest, what trade-offs to accept, and which risks to take in attempting to progressively move along the value chain.

In this report, we assess the viability and benefits of establishing a lithium refinery in Ghana to inform public understanding and government decision-making. This assessment is based on, and limited by, the available public information on these plans and builds on our earlier work on Ghana's lithium sector.[15] The economic model and data used for this analysis are available on the Natural Resource Governance Institute's website.

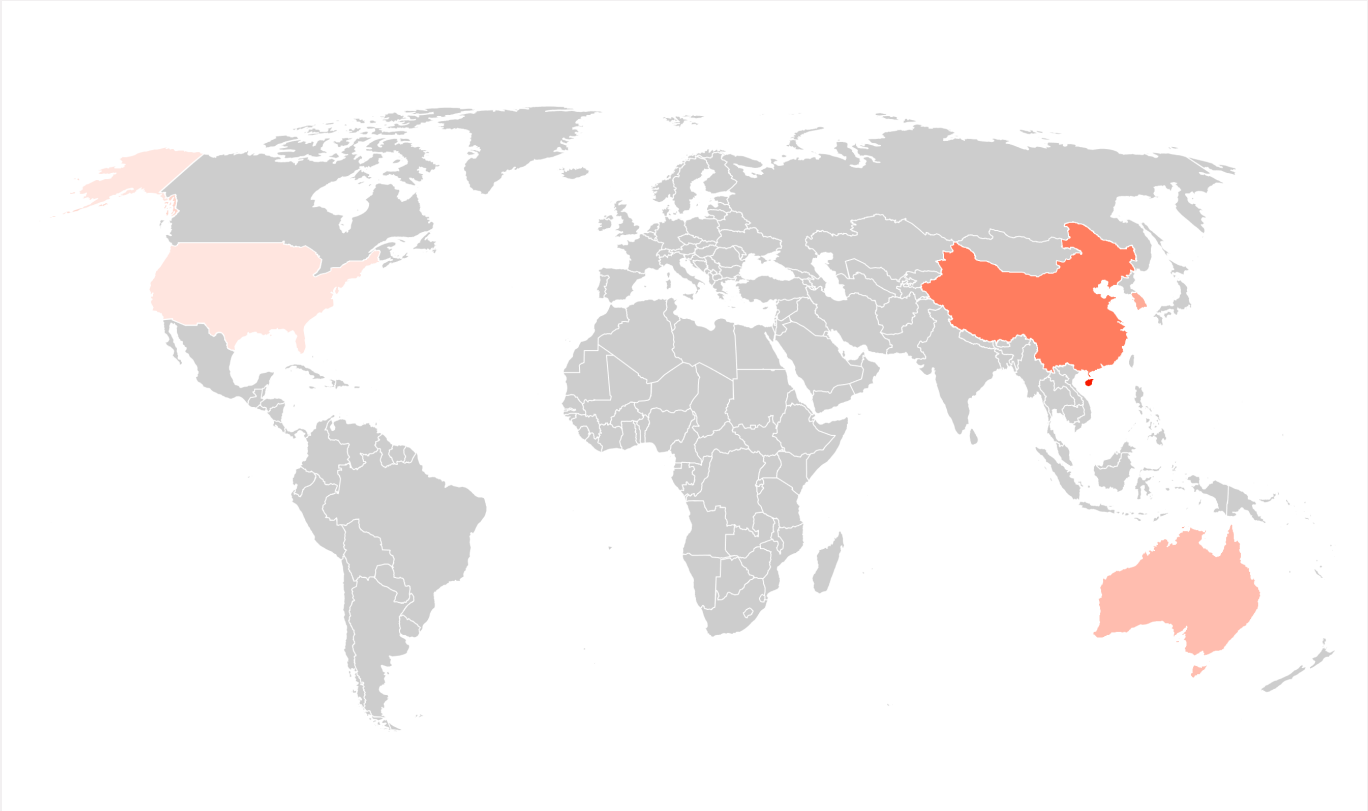
The state of play in global lithium refining

Many governments and companies have pursued lithium refining in recent years—in both lithium-producing and lithium-consuming countries. However, challenging economics have hindered these ambitions in most cases.

While companies in the Latin American lithium triangle can typically produce lithium chemicals from brine deposits on-site, the process is more challenging for hard rock lithium.[16] China hosts all but three of the world's refineries for converting spodumene concentrate to lithium chemicals, amounting to approximately 93–94 percent of global refining capacity.[17]

Australia hosts two of the refineries outside of China. However, after a few years of struggling with technical and economic challenges, the companies involved have canceled expansion plans and intend to expand their refining capacity in China instead.[18] South Korea hosts the other refinery outside China and appears to be performing better than the Australian refineries, though information in the public domain is limited at this point.[19] The U.S.'s first refinery, owned by Tesla, started operations at the end of 2024 but is yet to produce chemicals.[20] Several other refineries are planned in Europe and North America but are yet to start operation.[21] Many have been canceled, are on hold or are delayed.[22]

Figure 1. Spodumene refining capacity across the world[23]



Below, we set out the global landscape of spodumene refining capacity in more detail, then turn to the implications for a Ghanaian refinery in the following section.

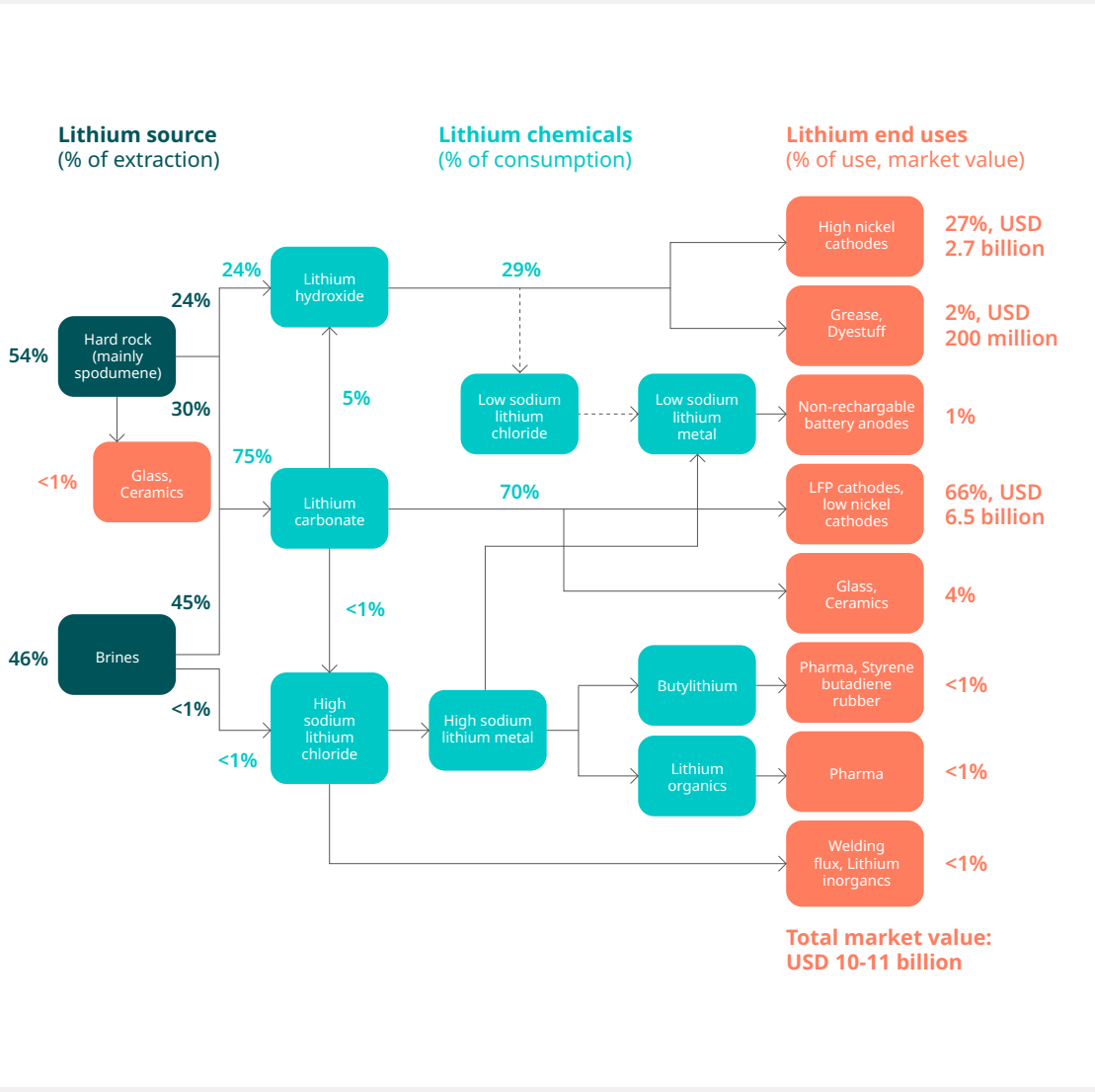
Uses of lithium

Currently, lithium is primarily refined into lithium carbonate and lithium hydroxide monohydrate.[24] In 2024, manufacturers used around one million metric tons (t) of these chemicals, measured in lithium carbonate equivalent (LCE).

China accounted for around 80 percent of this consumption, with Japan and South Korea consuming most of the remainder. Europe and the U.S. also consumed smaller amounts.[25]

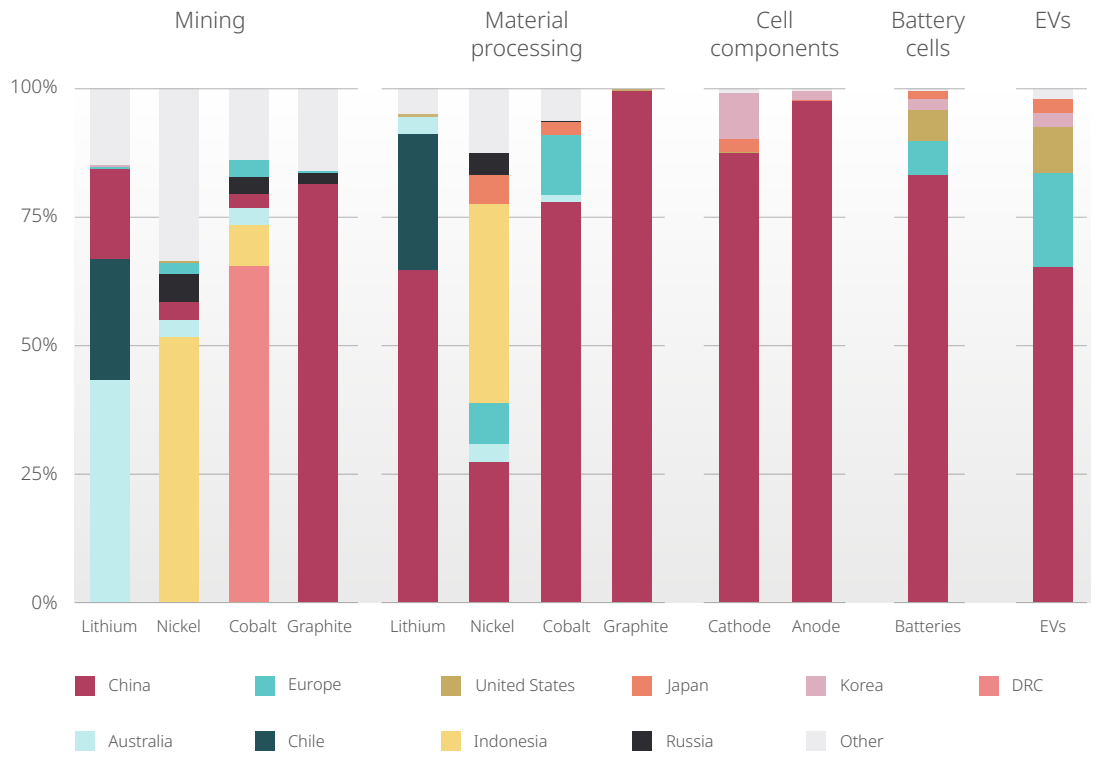
Battery cathode manufacturers use around 90 percent of these chemicals (see Figure 2).[26] These manufacturers mainly use hydroxide to make nickel manganese cobalt (NMC) cathode material for battery cells for electric vehicles (EVs). They primarily use carbonate to make lithium iron phosphate (LFP) and low-nickel NMC cathode material for EVs and energy storage systems (ESS).

Figure 2. Products currently produced from lithium (2024 estimates)[27]



Cathode manufacturing, of which China currently hosts nearly 90 percent, is even more concentrated there than the overall production of lithium chemicals. The only other countries with significant shares of cathode-manufacturing capacity are South Korea and, to a lesser extent, Japan. Given the prevalence of LFP batteries in the Chinese EV market, China is home to almost 100 percent of LFP cathode manufacturing. The LFP market is growing outside of China because of the greater affordability of LFP EVs and increased use of ESS. However, NMC batteries are currently more common in Europe and the U.S., which are the second and third-largest EV markets after China. As a result, cathode manufacturing outside of China has focused on NMCs.[28]

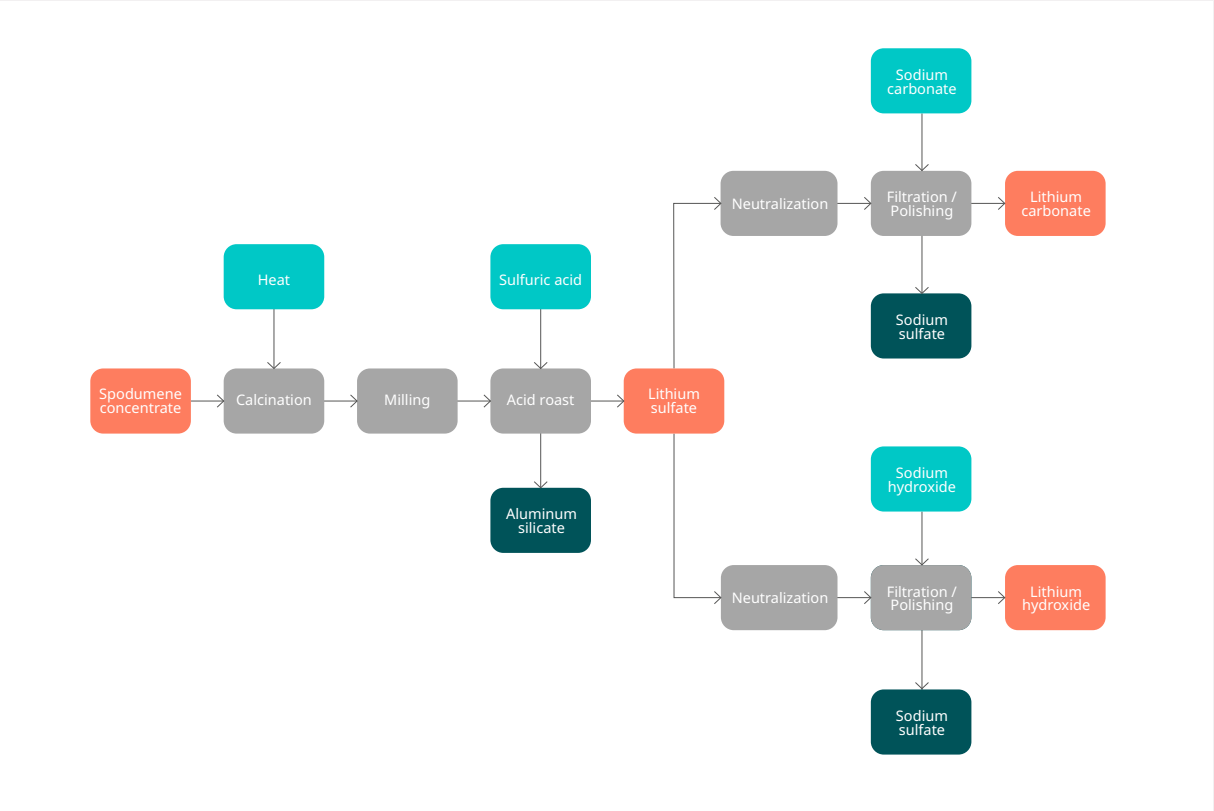
Figure 3. Geographical distribution of the global electric vehicle battery supply chain in 2023[29]



If lithium is refined to a slightly lower purity, called "technical grade," it is mainly used in products like grease, dyestuff and specialist glass.[30] However, these markets are relatively small, and their growth tends to be correlated with the global economy.

Current refining process

Figure 4. The process for converting spodumene concentrate to lithium carbonate and hydroxide[31]



China has both lithium carbonate and lithium hydroxide refineries. Given the current dominance of NMC EVs outside of China, most operating and planned refinery projects beyond China are for hydroxide. The refining processes for carbonate and hydroxide production are set out in Figure 4.

Refineries currently use sulfuric acid leaching to produce lithium sulfate. They then use either sodium carbonate to convert the sulfate to lithium carbonate, or sodium hydroxide (alongside several other reagents) to convert the sulfate to lithium hydroxide. These processes also require significant energy in the forms of both electricity and heat as well as large volumes of water.[32]

Sulfuric acid leaching generates large volumes of byproducts. Refineries typically produce 10–12t of aluminum silicate and 2t of sodium sulfate for every 1t of lithium carbonate or lithium hydroxide. These byproducts can be put to use in various ways. For instance, aluminum silicate can be mixed with cement for construction.

Several industries, including paper pulp, detergent powder, textiles and glass manufacturing, currently use sodium sulfate, and some companies are exploring other uses, such as fertilizer production.[33] However, limits on such use—including technical limits on aluminum silicate in cement and a global surplus of sodium sulfate supply—pose a challenge. In such cases, refineries must dispose of these byproducts as waste. Particular caution is required in the disposal of sodium sulfate. While sodium sulfate is found naturally in the ocean, uncontrolled discharge into seawater and any discharge into freshwater can severely impact these ecosystems, killing organisms, including fish.[34] High levels of sodium sulfate can also make freshwater unsafe to drink.

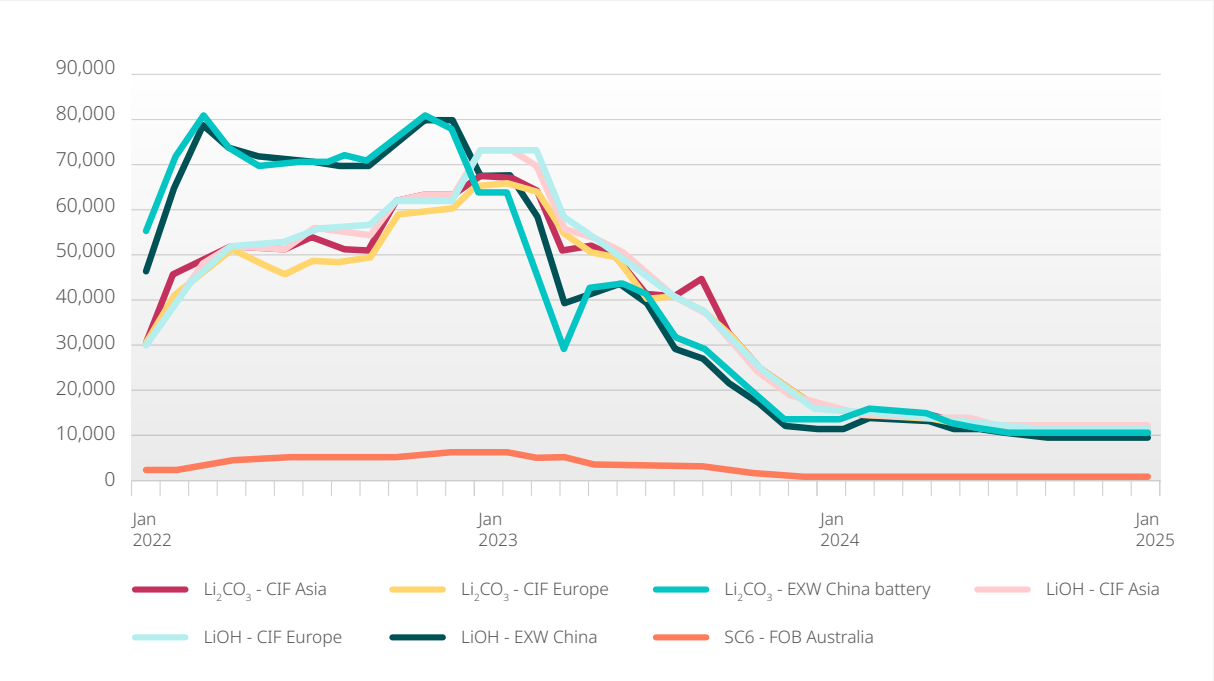
Sulfuric acid leaching also releases several pollutants, including nitric oxide, sulfur dioxide and sulfuric acid mist. Exposure to these pollutants can cause severe health issues, including respiratory problems and cancer, as well as environmental problems, such as acid rain.

Economics of lithium refining: a challenging landscape outside of China

Most lithium refineries—whether they produce hydroxide or carbonate, at battery-grade or technical-grade—have generated limited profit in recent years, considerably less than a mine producing spodumene concentrate.[35]

Refineries have been particularly struggling recently because of low prices.[36] As Figure 5 shows, prices for carbonate and hydroxide have fallen significantly in the past two years.[37]

Figure 5. Prices for spodumene concentrate (SC6), lithium carbonate (Li_2CO_3) and lithium hydroxide (LiOH) (USD per metric ton)[38]

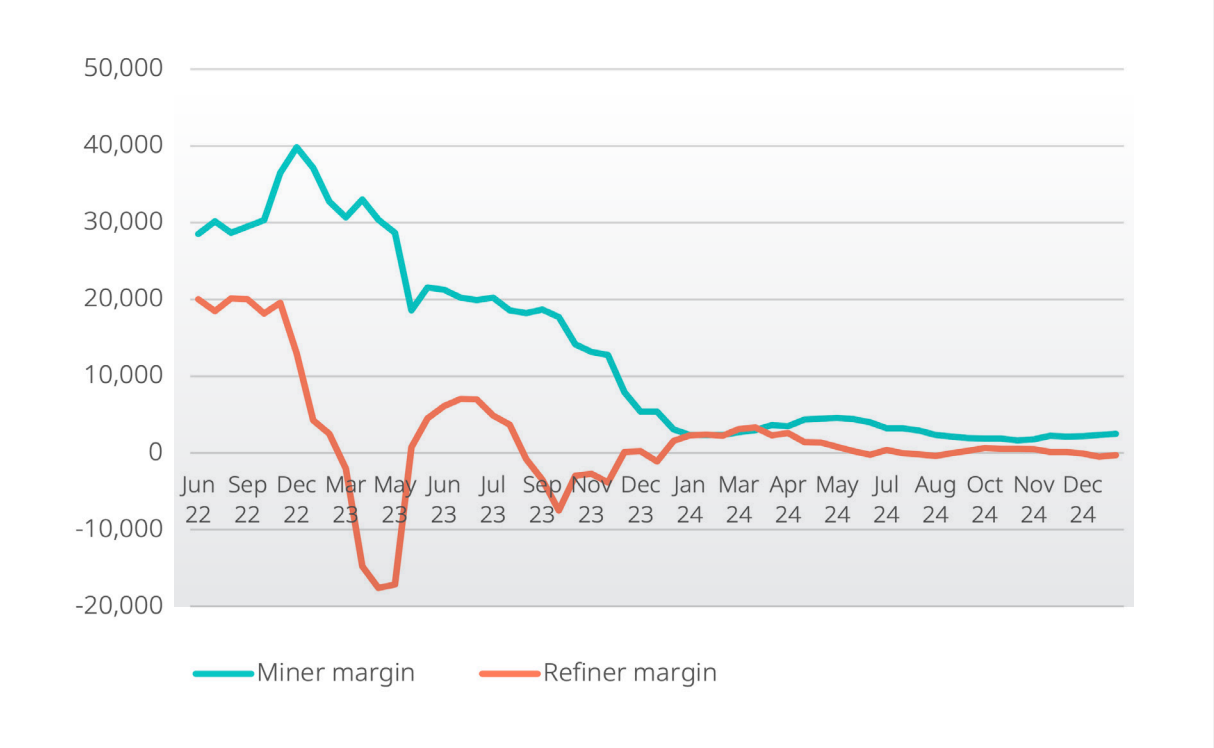


These low prices result from substantial overcapacity in China. As with other parts of the battery value chain, companies have constructed considerable new refining capacity in the country over the past decade. Refinery construction particularly increased as prices rose in 2021–22. Chinese refineries are currently only using 50–60 percent of their capacity.[39]

Demand for lithium chemicals has also risen significantly during this period, but at an insufficient rate to use this large amount of refining capacity. While global EV sales hit another record high in 2024, sales growth has slowed from 66 percent in 2022 to 33 percent in 2023, and around 25 percent in 2024. In 2024, sales particularly slowed in North America and shrank in Europe.[40] Despite significant growth in China, a larger proportion of sales were of plug-in hybrids, which require smaller batteries and therefore fewer lithium chemicals.

Chinese refining companies started reporting significant stockpiling of lithium chemicals in 2023. These inventories are estimated to have doubled in 2024.[41] However, modeling by iLiMarkets (a lithium-specialist consulting firm) suggests that even if the average Chinese refinery had been able to sell all its product at prevailing prices, it would likely have managed to generate only enough revenue to cover its variable operating costs in the past year (see Figure 6 on the next page). Indeed, several Chinese refineries were operating at a loss in 2024.[42]

Figure 6. Modeled operating margin of Australian lithium spodumene mine vs. Chinese lithium carbonate refinery (USD per metric ton of lithium carbonate equivalent)[43]



With increased capacity now online and in the pipeline, prices are not expected to return to previous highs in the foreseeable future. However, they are expected to rise again over time as lithium demand continues to increase. Wood Mackenzie, for example, expects an overall surplus of lithium chemical supply for the rest of this decade, but for the battery-grade market to shift back into deficit in the longer term.[44] The iLiMarkets base case is for prices to average $18,000/t LCE. Its high price scenario is $30,000/t LCE in the longer term.[45]

However, even as prices recover, the economics may continue to be challenging for refineries outside of China. Below, we outline some of these challenges in more detail.

Technical know-how

The technical know-how for lithium refining is concentrated in China.[46] The Australian refineries appear to be struggling partly because of mistakes in their design and equipment choice, having moved away from the design used by Chinese refineries and opted to use Australian rather than Chinese engineering.[47] As a result, they have a lower rate of lithium recovery than Chinese refiners (80 percent instead of 85 percent). They have also struggled to achieve the required quality for cathode manufacturers, leading them to sell at lower prices to other users.[48]

Several European and North American refineries are trying a new refining process altogether—alkaline pressure leaching (also known as the Metso process). This process could reduce the environmental impact of lithium refining by avoiding the production of sodium sulfate and emitting fewer pollutants than sulfuric acid leaching.[49] However, it has not yet proven to be viable on an industrial scale. Even if everything goes to plan, based on the feasibility studies of these refineries, the economics may be worse on average than sulfuric acid leaching. It could mean a lower lithium recovery rate, higher costs and greater energy and water requirements.[50]

Tesla's recently established refinery uses alkaline pressure leaching and will provide a useful indication of how the two processes compare in practice.

Going forward, it is unclear whether refineries intending to use Chinese technical know-how will be able to do so. The Chinese government is currently considering imposing export controls on lithium refining (and cathode) technologies.[51] The government has also recently made it more difficult for Chinese engineers and equipment to leave the country.[52]

Costs

Chinese refineries benefit from significantly lower costs than elsewhere. Public information on the cost of many Chinese refineries is limited. However, based on available information, iLiMarkets estimates that the costs of Chinese refineries could be $2,500–3,500/t LCE lower than existing and planned refineries elsewhere in the world. This advantage arises from lower capital and operating costs.

Capital costs

Chinese refineries have capital costs of around $6,000–10,000 per metric ton of capacity based on available information.[53] As Table 1 shows, for the Australian and South Korean refineries, the companies were expecting the capital cost to be at least double Chinese costs—even if everything went to plan. In practice, the Australian refineries have faced even higher capital costs. The feasibility studies of refineries that are under construction or planned in Europe and North America suggest a similar capital intensity. It remains to be seen whether they will also be overoptimistic.

Table 1. Capital costs of various existing and planned lithium refineries[54]

Company	Albemarle		Tianqi-IGO		SQM-Westfarmers	POSCO-Pilbara	Avalon	Piedmont	Tesla	European Lithium	Sibanye - Stillwater	Various
Project	Kemerton		Kwinana		Mt Holland	POSCO Pilbara Lithium Solution	Becancour	Carolina Lithium	Robstown	Wolsfberg	Keliber	Various
Country	Australia		Australia		Australia	South Korea	Canada	US	US	Austria	Finland	China
Info source	DFS	Actual	DFS	Actual	Estimated	Estimated	DFS	DFS	DFS	DFS	DFS	Various
End product	LiOH	LiOH	LiOH	LiOH	LiOH	LiOH	Li_2CO_3	LiOH	LiOH	LiOH	LiOH	Li_2CO_3 / LiOH
Capex (USD millions)	1,400	1,400	2,100	1,850	1,000	750	494	408	1,000	321	300	Various
Capacity (thousand t)	48	24	100	40	50	40	20	30	50	10	15	Various
Capex intensity (USD / kg)	29	58	21	46	20	19	25	14	20	32	20	6-10

The difference in the capital intensity of refineries in China and elsewhere results from a combination of cheaper equipment and the technical know-how discussed above, which enables more efficient design and operations. To compound this cost difference, Chinese refineries are also likely to benefit from a low cost of capital. The Chinese government is involved in many of the country's refineries and has often provided substantial support. For example, between 2009 and 2019, the Chinese government reportedly provided $100 billion in subsidies, rebates and tax exemptions to Chinese companies and consumers to support the lithium-refining industry.[55]

Operating costs

China also has an advantage in operating costs. First, Chinese refineries can recover a greater proportion of lithium from spodumene concentrate due to the more efficient design and equipment that they use. As a result, Chinese refineries require less spodumene to produce the same amount of carbonate or hydroxide.

Chinese refineries can also access most reagents at a lower cost than other countries.[56] This is at least partly because the country produces many of them in large quantities. For example, China is the world's largest producer of the key reagents of sulfuric acid, sodium carbonate and sodium hydroxide. The North American refineries could also benefit from lower costs for some of these reagents because of large domestic production. In contrast, for example, Australia imports reagents from China.[57]

Finally, Chinese refineries have had a significant cost advantage in waste disposal. China uses at least some of the byproducts from its refineries in other industries, such as aluminum silicate in road construction. However, Australian refineries have struggled to find customers for their byproducts and, therefore, have the additional cost of disposing of them. Many of the feasibility studies of planned European and North American refineries reference plans to sell their byproducts, but it remains to be seen whether they will be able to do so.

Table 2. Range of operating costs for existing and planned lithium carbonate (Li_2CO_3) refineries[58]

	Unit	USD per unit		Consumption factor		USD/t Li_2CO_3	
		Min	Max	Min	Max	Min	Max
Lithium recovery						85%	80%
Spodumene concentrate	t	0	0	7.5	8.5	0	0
Sulfuric acid	t	140	200	2.1	2.4	293	480
Sodium carbonate	t	250	500	1.9	2.2	475	1,100
Energy	MWh	75	150	7.5	9.0	563	1,350
Waste Disposal	t	0	100	10.8	11.9	0	1,190
Labor						150	300
Other Reagents						250	350
Maintenance						150	250
Total						**1,880**	**5,020**

Table 3. Range of operating costs for existing and planned lithium hydroxide (LiOH) refineries[59]

	Unit	USD per unit		Consumption factor		USD/t LiOH	
		Min	Max	Min	Max	Min	Max
Lithium recovery						85%	80%
Spodumene concentrate	t	0	0	7.0	7.5	0	0
Sulfuric acid	t	140	200	2.1	2.3	294	460
Sodium hydroxide	t	350	450	2.0	2.5	700	1,125
Calcium carbonate	t	200	200	0.3	0.3	52	52
Hydrogen peroxide	t	200	200	0.1	0.1	26	26
Sodium carbonate	t	250	500	0.1	0.1	18	35
Hydrochloric acid	t	250	250	0.1	0.1	15	15
Energy	MWh	75	150	7.5	7.5	563	1,125
Waste Disposal	t	0	100	10.2	11.3	0	1,130
Labor						150	300
Other Reagents						250	350
Maintenance						150	250
Total						**2,217**	**4,868**

Market dynamics

The higher cost of refineries outside of China does not rule out investment in them, however. The Australian, South Korean and U.S. refineries expected to have significantly higher capital intensity than the Chinese refineries and, even so, they were still constructed. Most of the other refineries in Table 1 also expect similarly high costs.

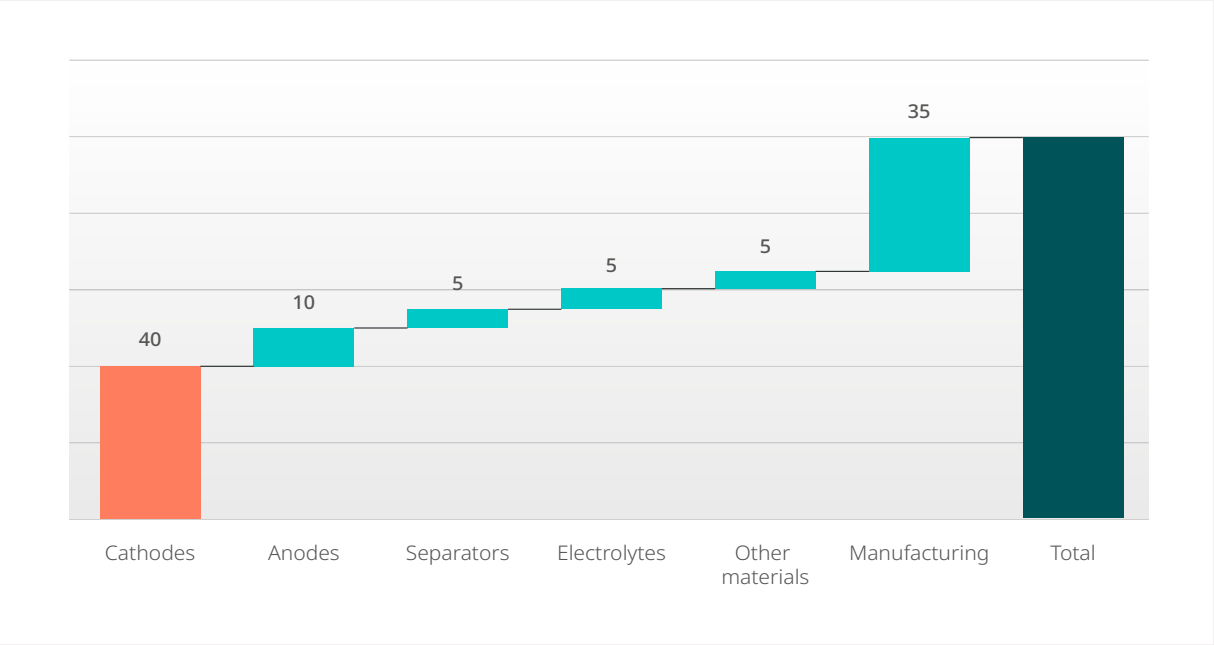
Geopolitical tensions and the resulting push to establish value chains beyond China have led investors to anticipate that cathode manufacturers outside of the country will be willing to pay a price premium for non-Chinese lithium chemicals. Investors have expected this premium to be sufficiently high to largely mitigate the cost differential and enable the refineries to make a profit.

Yet lithium chemical demand outside of China is not increasing as quickly as anticipated. Although demand growth in China has been lower than expected, it has been particularly below expectations outside of China. This is due to challenges with establishing more cathode and battery-cell manufacturing in the face of Chinese competition, challenges that have now been compounded by slowing EV sales. Like Chinese refineries, Chinese cathode and cell manufacturers have significant cost advantages. For example, in Europe, cathode manufacturing plants cost around 27 percent more to construct and around 13 percent more to operate than in China.[60] Chinese manufacturers also have significant spare capacity, resulting in a willingness to sell at even lower prices. In 2023, for example, China's cathode manufacturing capacity was almost four times greater than global demand, and its cell manufacturing had over 60 percent spare capacity.[61]

Cell manufacturing outside of China has been increasing, and this trend is expected to continue. For example, S&P Global expects Europe's share of manufacturing capacity to rise from 13 percent in 2023 to 17 percent by 2030, and the U.S.'s share to increase from 4 to 16 percent during this period.[62] However, companies canceled multiple planned projects in 2024.[63] CRU Group estimates that around half of the announced capacity in Europe and a quarter of the announced capacity in the U.S. is at high risk of being underused or not built at all by 2030.[64]

Cathode manufacturing is taking longer to increase in Europe and the U.S. Cathode manufacturers need cell manufacturing to be fully established to give them sufficient confidence to invest. Moreover, cathodes typically account for the largest cost for battery cells, ranging from approximately 40 to 55 percent, depending on the estimate. Cell manufacturers are therefore particularly sensitive to differences in cathode costs.[65] For example, only three cathode manufacturers currently operate in Europe, and they produce limited volumes. This is despite a reasonable amount of cell manufacturing capacity in the region and large incentives.[66]

Figure 7. Illustrative cost breakdown of typical lithium-ion battery cell[67]



The evolution of cathode manufacturing outside of China is difficult to predict, and the economics are complicated by increasingly fluid industrial and trade policies as geopolitical tensions rise. Plans for considerable cathode manufacturing by both domestic and overseas companies exist. For example, companies are planning projects in Europe that could increase manufacturing capacity by more than tenfold by 2030.[68] Cathode manufacturing capacity planned in the U.S. by 2030 has increased sixfold since the previous government passed the Infrastructure Investment and Jobs Act in 2021 and Inflation Reduction Act (IRA) in 2022.[69] Cathode manufacturers have also announced projects in countries with free trade agreements with the U.S., such as Morocco and South Korea, in anticipation of benefiting from the IRA.

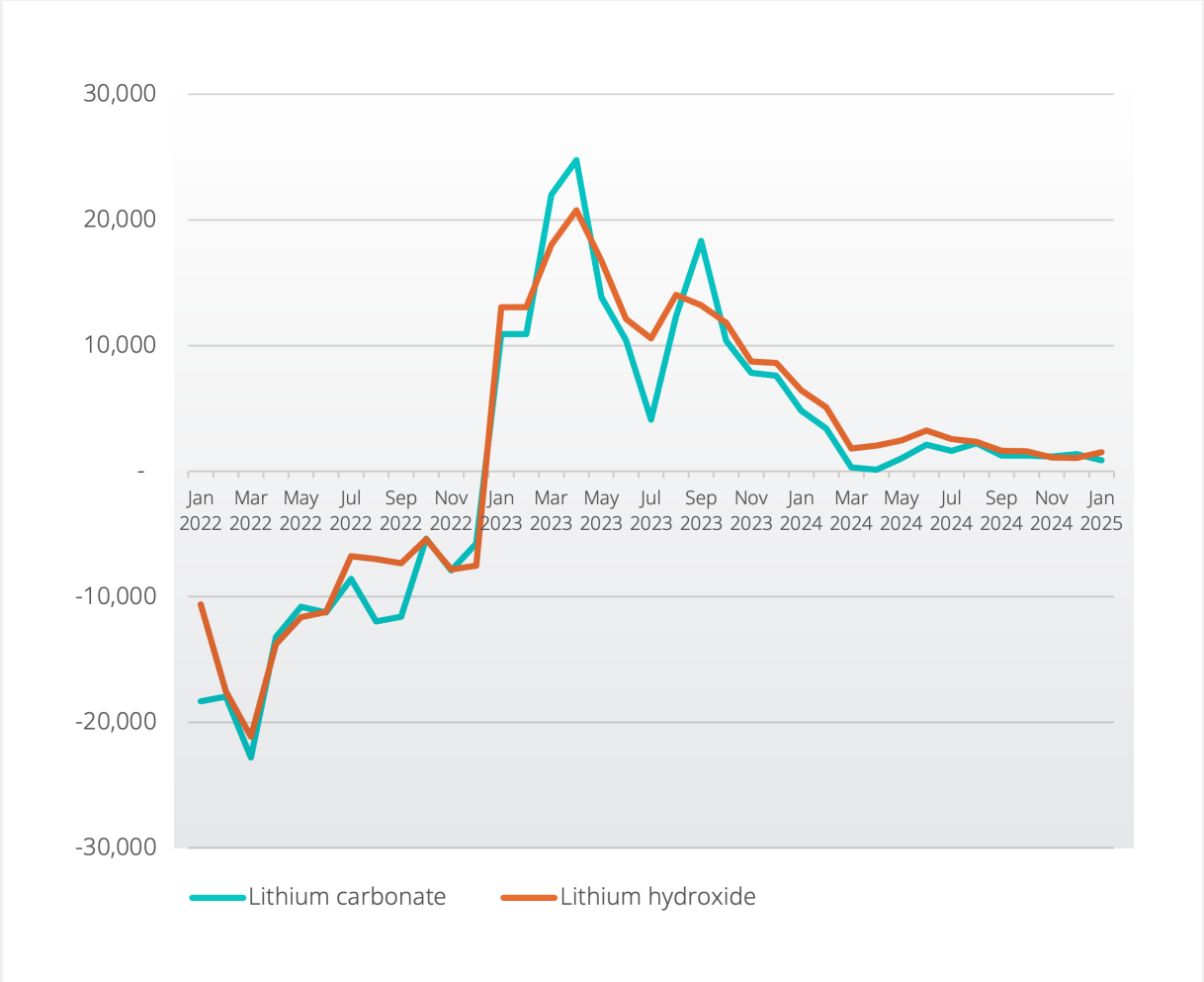
The proportion of these projects that will ultimately be developed in the medium term is uncertain. For example, industry analysts viewed 51 percent of Europe's planned capacity as "less certain" even before the cancelation of some

cell manufacturing capacity in 2024.[70] In the U.S., the recent suspension of the Infrastructure Investment and Jobs Act disbursements and opposition to the IRA, as well as increased tariffs on Chinese imports, compound the uncertainty surrounding the economics. Similarly, China's consideration of export controls on LFP cathode production technology, if implemented, would hinder the establishment of advanced LFP cathode manufacturing outside the country. Given that EVs powered by LFP batteries are a key component of rising sales outside of China, it is difficult to predict whether this would lead to continued reliance on LFP cathode imports from China or a boost for NMC batteries and cathode manufacturing. However, given these various dynamics, it is possible that cathode manufacturing outside of China will continue to grow slowly.

If so, refineries outside China will likely need to sell some of their chemicals to the highly competitive Chinese market, at least in the medium term.

The extent to which cathode manufacturers outside of China will be willing to pay a premium for non-Chinese chemicals is also uncertain. Non-Chinese cathode manufacturers are currently paying more for lithium chemicals. However, this mainly reflects their higher-quality standards than the average Chinese cathode manufacturer, which limits their supply options. The price differential has fluctuated significantly over the last few years rather than been systematically higher. Prices outside of China have averaged around $700/t and $1,700/t higher for carbonate and hydroxide respectively. This differential has been insufficient to overcome the cost disadvantages that refineries outside of China face of around $2,500–3,500/t.

Figure 8. Lithium chemical price in Northeast Asia minus lithium chemical price in China (USD per metric ton)[71]



It remains to be seen how any new cathode manufacturers in Europe and the U.S. will approach procuring chemicals. A premium could be placed on non-Chinese supply due to the risk of losing IRA subsidies (if they remain available) in the U.S., increasing concerns among European companies about their dependence on China, and tariffs being placed on Chinese EVs.[72] However—particularly given that tariffs on lithium imports remain unlikely—the reliability and cost advantages of Chinese supply may still prove decisive. Non-Chinese cathode, cell and EV manufacturers will continue striving to keep costs down in order to stimulate demand and remain competitive.[73] If so, any increase in cathode manufacturing outside of China could lead to an increase in Chinese refining capacity, limiting the benefits for refineries outside of China.

Ghana's ambitions to refine its lithium are therefore taking place in a challenging global context: fierce competition from low-cost Chinese refineries and uncertainty about growth in demand for and pricing of lithium chemicals outside of China.



Photo by Maroke for iStock

The potential viability and benefits of a Ghanaian refinery

We have modeled a possible Ghanaian battery-grade carbonate refinery that starts operating in the next few years in order to assess its viability and benefits for the country in this context.

Modeling assumptions

A lithium carbonate refinery: We focused on a lithium carbonate refinery for several reasons. Carbonate and hydroxide refineries currently result in similar margins. However, with LFP batteries expected to become increasingly dominant in the longer term, carbonate demand is likely to grow more than hydroxide demand (assuming any Chinese export controls on LFP technology do not fundamentally change this trajectory).[74] Moreover, most of the planned refineries outside of China that we are aware of will produce hydroxide.[75] Given this, Wood Mackenzie expects a larger supply deficit for carbonate than hydroxide in the long term.[76] If so, a carbonate refinery should face slightly less fierce competition and may generate a slightly higher profit than a hydroxide refinery. However, the results we set out below will not have been materially different whether we modeled a carbonate or a hydroxide refinery.

Production of battery-grade carbonate: We assumed the refinery produces battery-grade rather than technical-grade carbonate because technical-grade chemicals are likely to remain in surplus into the longer term.[77] The government could explore the potential for establishing technical-grade lithium value chains in the region, such as for grease and dyestuff. However, the global surplus raises questions about whether these value chains would benefit from Ghanaian supply—and even if they did, whether the refinery would need to sell at particularly low prices in order to compete.

Production capacity of 20,000t/y of lithium carbonate: We estimate that this capacity will require the annual volume of spodumene concentrate available from the Ewoyaa mine if Piedmont exports 50 percent of production. The optimal size will depend on multiple factors. However, capacity of 20,000t/y is currently typical of refinery projects, as it strikes a reasonable balance between scale and increasing requirements for larger plants, such as the need to establish new power generation capacity.

Two scenarios for the lifetime of the refinery: In our "current Ewoyaa" scenario, the refinery only uses Ewoyaa's current reserves. We assumed that the refinery only operates for 9 years in this scenario.[78] Irrespective of the economics, investors are unlikely to commit funding to such a short-term project given the time typically required to finetune operations and qualify to supply battery manufacturers, as well as the greater risk that they cannot recoup their investment. However, given the current discussions related to the Ewoyaa project, we have still modeled it. The "20 year" scenario entails the refinery operating for 20 years, which is the typical lifetime that companies and investors plan on when designing and making investment decisions on refineries. For the refinery to operate for this longer period, further discoveries by Barari or other companies currently exploring in the country, or the identification of other sources of feedstock, are necessary. The government could scope the potential for imports from within West Africa, as Nigeria currently produces spodumene concentrate and Mali is soon to start. However, combining different sources of spodumene concentrate will create technical challenges for the refinery. The specific source of imports and their characteristics will therefore need to be factored in at an early stage.[79]

High capital and operating costs: Like other refineries outside of China, a carbonate refinery in Ghana will face high costs. However, further research is required to confidently estimate the costs of a potential refinery in the country. We have based our assumptions on the estimated costs of these refineries, either from actual operations or as outlined in their feasibility studies—excluding the Australian refineries already in operation due to their particularly severe challenges. We assumed the expected average capital cost and cost of capital for these refineries, the same recovery rate, and an operating cost around the midpoint of these refineries.

However, these assumptions are likely to underestimate the actual cost. First, as the Australian experience demonstrates, there is a reasonable chance that the feasibility studies for the European and North American refineries significantly underestimate costs. Second, some costs are likely to be higher for a Ghanaian refinery than other refineries. For example, many refineries assume a cost of capital of around 8 percent. Given Ghana has a higher country risk premium than the countries hosting these refineries, its cost of capital is likely to be significantly higher.[80] As shown in the Appendix, this would substantially worsen the economics.

As with Ghana's mining companies, a Ghanaian refinery will need to import both sulfuric acid and sodium carbonate. This will likely result in higher reagent costs than for the North American refineries, for example.[81] Electricity costs for industrial users appear competitive with many other refinery countries, but electricity supply constraints mean new power generation capacity may be required in Ghana.[82] We assumed that the refinery is able to sell all its aluminum silicate and sodium sulfate byproducts to avoid the cost of disposal. However, further research is required to establish this likelihood, and the government will likely need to develop a strategy to achieve this outcome. That said, the Ghanaian refinery could have one cost advantage given its potential access to low-cost gas, depending on its proximity to pipeline infrastructure and Ghana's continued oil production.

Export of the refinery's lithium carbonate: Ghana's prospects for moving further along the battery value chain depend more on the size of the EV and ESS markets in the country and region than the establishment of lithium refining.[83] Ghana's automotive manufacturing sector is expanding. It also has relatively promising conditions for EV adoption compared to many other countries on the continent, particularly since the introduction of its National Electric Vehicle Policy.[84] Ghana, as well as several other countries in West Africa, has started manufacturing electric two-wheelers, which tend to use LFP batteries.[85] Broader EV manufacturing is also showing signs of promise.[86] However, even if EV demand in the region increases sufficiently over the next few years to incentivize the establishment of LFP cell manufacturing, the experience of Europe and the U.S. shows that cathode manufacturing does not automatically follow, at least not immediately. Cell manufacturers may still choose to import cathodes if their lower manufacturing costs override the benefits of regional supply. Even if the economics favor regional cathode manufacturing, cathode manufacturers will wait to ensure that cell manufacturing is fully established before they invest.

Two potential export markets for Ghana's carbonate: The refinery could sell to the established market in China. It could also sell to ROW depending on how cathode manufacturing develops. While the ROW is made up of markets that are geographically spread—including Europe, Japan, South Korea and the U.S., and possibly Morocco—current prices are similar and may remain so. Moreover, the cost of transporting lithium carbonate is not a significant factor, given the relatively small volumes that a refinery produces. Therefore, if Morocco develops cathode manufacturing, for example, exporting carbonate there is unlikely to fundamentally change the economics of the refinery compared to exporting carbonate to the U.S.

Three price scenarios: Our low-price scenario is based on current prices of around $10,000/t LCE in China CIF.[87] Our medium-price scenario aligns with the iLiMarkets base case of around $18,000/t LCE. The high case is the iLiMarkets

high-price scenario of $30,000/t LCE. This results in the lithium carbonate prices in the ROW market (set out in Table 4) based on the current relationship between pricing in these markets.

We have also estimated the most likely market price for spodumene concentrate in these scenarios. This price is based on what Chinese refineries will be able to pay given their estimated average costs; their overcapacity, resulting in spodumene mines capturing most of any available profit margin; and their dominance of the market, meaning that they are currently the price makers. This modeling approach performs reasonably well when tested against carbonate and spodumene concentrate prices over the last few years.[88] Similarly, we calculated the price that ROW refineries, if developed, would be able to pay for spodumene concentrate given their estimated average costs. They will only be able to break even by paying lower prices for their spodumene concentrate, and it therefore remains to be seen how many of these refineries are actually developed. The spodumene concentrate price in the ROW in the medium-price scenario is similar to that of the $1,587/t assumed by Atlantic Lithium in its feasibility study for the Ewoyaa project. In line with current market expectations, we assumed there is no price premium for production outside of China in these scenarios, but in the next section we analyze the implications of such a premium.

Table 4. Modeled scenarios for the price of lithium carbonate (Li_2CO_3) and spodumene concentrate (SC6) exports to China and the ROW (USD per metric ton, CIF)

	Low price		Medium price		High price	
	China	ROW	China	ROW	China	ROW
Li_2CO_3	9,500	10,000	18,000	18,500	30,000	30,500
SC6	800	495	1,930	1,560	3,530	3,060

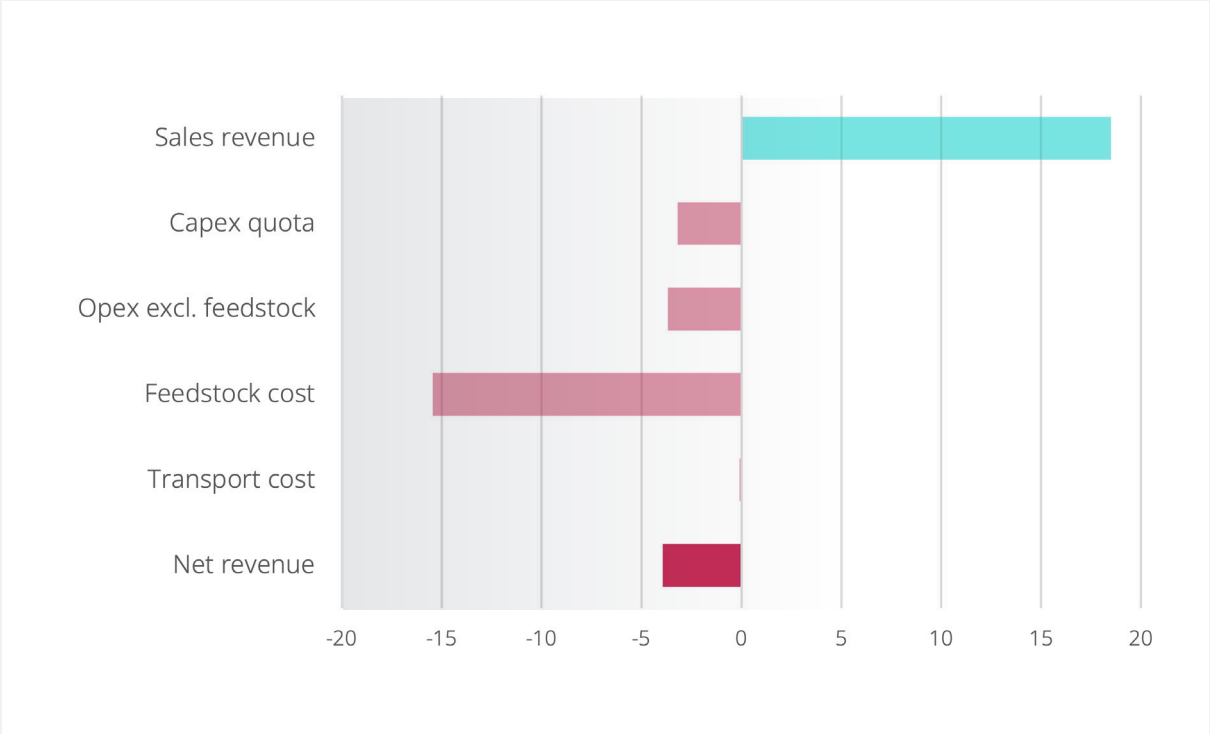
Private vs. state-owned refinery. We assumed that the refinery is privately owned, either by Barari or another company.[89] However, we also considered the implications of the state financing and owning the refinery.

Finally, to enable a clear assessment of the economic fundamentals, we did not apply any taxes to the refinery. Our assumptions are described in further detail in the Appendix.

Potential viability of a Ghanaian refinery

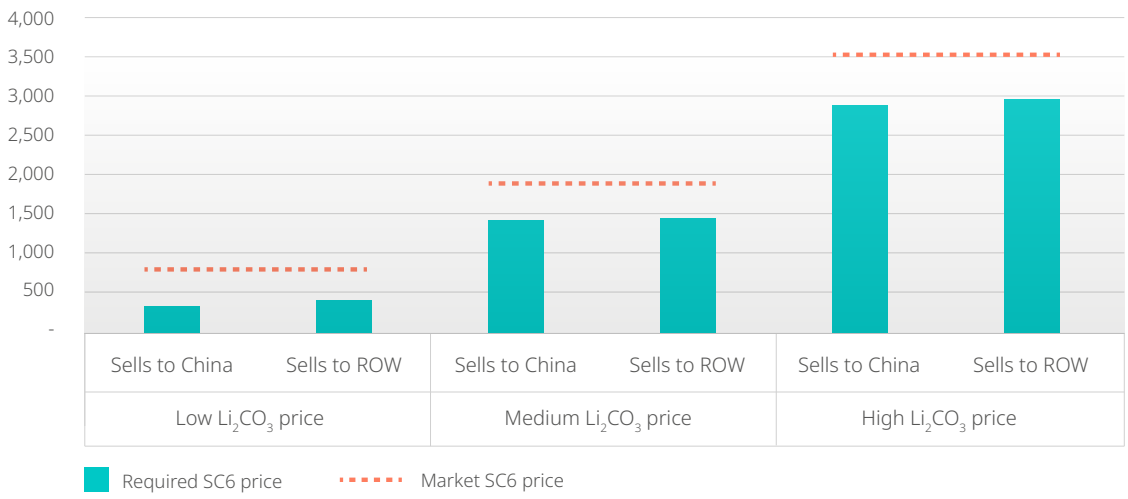
A Ghanaian refinery is unlikely to be viable in any scenario if it pays the market price for spodumene concentrate. If the modeled refinery pays the market price for its feedstock, it makes a loss for every metric ton of lithium carbonate it produces. This is the case whether it only has access to Ewoyaa's current reserves or it secures enough feedstock to operate for 20 years; whether it sells to China or the ROW; and whether prices are low, medium or high. Figure 9 shows these losses for a Ghanaian refinery exporting carbonate to the ROW in the current Ewoyaa, medium-price scenario. The results in the other scenarios are set out in the Appendix. The refinery is also likely to make a loss if it has larger processing capacity and/or lower operating expenditure, also discussed further in the Appendix. The efficiency of Chinese refineries means that the market price for spodumene concentrate will be higher than a Ghanaian refinery could absorb.

Figure 9. Net revenue of a Ghanaian refinery exporting to ROW in current Ewoyaa, medium-price scenario (thousand USD per metric ton of lithium carbonate)



Our modeled refinery only breaks even if it pays Barari (or other spodumene concentrate producers) less than the market price for its feedstock. Figure 10 (on the next page) shows these prices for a refinery that only has access to Ewoyaa's current reserves. However, as outlined in the Appendix, a 20-year refinery also only breaks even if it pays below-market prices.

Figure 10. Spodumene concentrate (SC6) prices needed for a Ghanaian refinery to break even vs. the modeled market price, at different lithium carbonate (Li_2CO_3) prices (USD per metric ton)



Barari expects to generate large profits from the Ewoyaa mine according to its feasibility study. Our modeling suggests that the mine remains profitable in most of these scenarios, even if it receives less than the market price for half of its spodumene concentrate.[90] It only generates less than the assumed required internal rate of return—8 percent—in our low-price scenario.

That said, the feasibility study assumptions are likely overoptimistic about the profitability of the mine. For example, mining projects typically experience development cost overruns of around 40 percent.[91] Given that our assumed costs for the refinery are also likely underestimated, further sensitivity analysis is required to assess the risks to the viability of both the Ewoyaa mine and a potential refinery.

Potential benefits and costs of a Ghanaian refinery

Our modeling suggests that a Ghanaian refinery could be viable if it pays less than the market price for its feedstock. However, this viability does not necessarily mean that Ghana would benefit from having a refinery.

In all our scenarios, including if the refinery able to access sufficient feedstock to operate for 20 years, Ghana generates more overall value from Barari selling to China the half of the spodumene concentrate not going to Piedmont. This is because, as noted above, for the refinery to merely break even, it would need to pay less for the spodumene concentrate than the price that Chinese refineries would be willing to pay. In that sense, building a refinery would reduce value rather than adding it. Table 5 shows the value generated by exporting the spodumene concentrate to China compared to refining it in Ghana in the current Ewoyaa, medium-price scenario.

Table 5. Annual net revenue generated by exporting spodumene concentrate (SC6) vs. lithium carbonate (Li_2CO_3) in current Ewoyaa, medium-price scenario (USD millions)[92]

	SC6 to China	SC6 to ROW	Li_2CO_3 to China	Li_2CO_3 to ROW
Sales revenue	309	249	360	370
Ewoyaa project cost	-82	-82	-82	-82
Capex quota			-64	-64
Opex excl. feedstock			-74	-74
Transport cost	-8	-8	-2	-2
Net revenue	**219**	**159**	**138**	**148**

Notes: A gradient from green to red, with yellow and orange as intermediates, indicates the most to least beneficial options for Ghana.

This outcome also does not change at different prices, as Table 6 shows.

Table 6. Annual net revenue generated by exporting spodumene concentrate (SC6) vs. lithium carbonate (Li_2CO_3) in current Ewoyaa scenario at different Li_2CO_3 prices (USD millions)

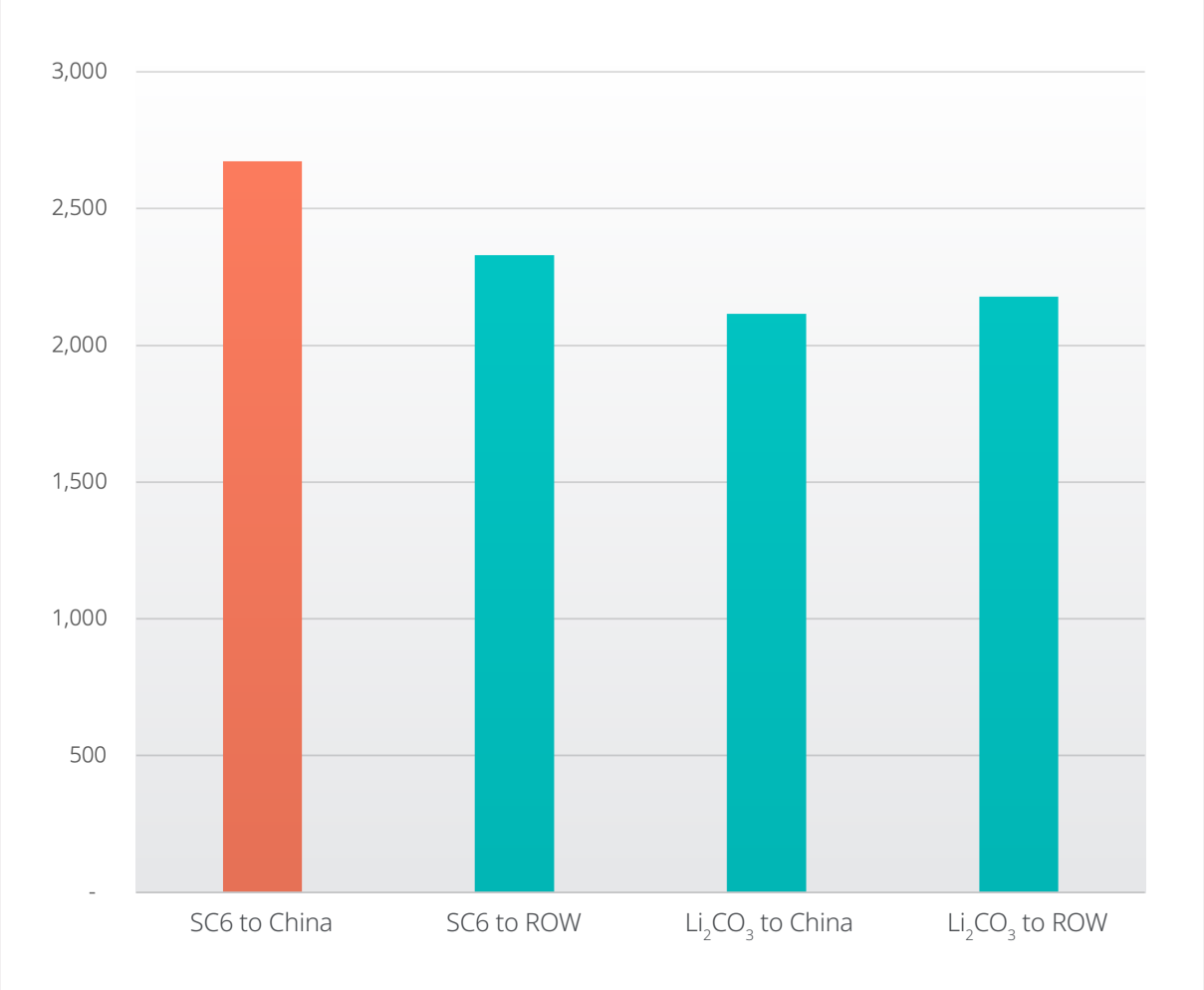
Li_2CO_3 price	SC6 to China	SC6 to ROW	Li_2CO_3 to China	Li_2CO_3 to ROW
5,000	-59	-101	-122	-112
10,000	48	-1	-22	-12
15,000	155	99	78	88
20,000	261	199	178	188
25,000	368	299	278	288
30,000	475	399	378	388
35,000	581	499	478	488
40,000	688	599	578	588

Notes: A gradient from green to red, with yellow and orange as intermediates, indicates the most to least beneficial options for Ghana.

The government would, therefore, generate less revenue from its lithium by building a refinery, even if cathode manufacturing sufficiently develops in the ROW and the refinery benefits from the slightly higher prices. Barari receives less revenue from its sales to the refinery and, therefore, pays lower royalties, profit taxes and state dividends in all the scenarios we looked at.

Based on previous NRGI modeling of the Ewoyaa project using Atlantic Lithium's feasibility study assumptions, the government generates revenue of $2.7 billion over the lifetime of the Ewoyaa project if Barari exports half of the spodumene concentrate to China in the current Ewoyaa, medium-price scenario. As Figure 11 shows, the most revenue Ghana receives over the lifetime of the Ewoyaa project by refining half of the spodumene concentrate domestically is $2.2 billion—$500 million less than if it exported the concentrate.[93] To put that number into perspective, it is more than half the total revenue that the government collected from mining in 2022, and 13 times the profit that the Mineral Income Investment Fund made in 2023.[94] The revenue loss is even greater—over $600 million—in the high-price scenario. Even if the refinery is able to access sufficient feedstock to operate for 20 years, the loss remains significant: over $300 million in the medium-price scenario.[95] (Though in practice, government revenues are likely to be lower across all these scenarios, as models tend to overestimate them.[96])

Figure 11. Total government revenue from the Ewoyaa mine from exporting spodumene concentrate (SC6) vs. lithium carbonate (Li_2CO_3) in current Ewoyaa, medium-price scenario (USD millions)[97]



Taxing the refinery would not compensate for the lower government revenues from Ewoyaa. Instead, taxes on the refinery would increase its costs, further reducing the price it could pay for spodumene concentrate from Ewoyaa while still breaking even. Since Ewoyaa, with its royalties, will be taxed at a higher rate than the refinery, taxing the refinery would result in lower government revenue overall.

Government revenues could be even lower if the government is required to offer tax concessions to Barari to maintain its profit margins and ensure it continues its plans to develop Ewoyaa.[98]

These lower government revenues from the Ewoyaa project are an implicit subsidy to the refinery. Instead, the government could require the refinery to pay the market price for its spodumene concentrate but offer direct financial support to the refinery, such as through grants, low-cost loans or subsidized energy. Alternatively, the government could finance and own the refinery itself. However, in doing so, it would incur the losses set out in Figure 9. Therefore, either way, constructing a refinery in Ghana will likely have a negative rather than positive impact on public finances.

The government will need to account for the opportunity costs of lower government revenues or the use of public funds. For example, $500 million is considerably more than the amount that the government budgeted for kindergarten, primary and junior secondary education in 2024.[99] It is also considerably more than the amount allocated for agriculture.[100] The government will also need to consider the potential trade-offs between the pursuit of lithium refining and other ways that Ghanaians can benefit from their mineral wealth. For example, the government could use these funds to instead provide much-needed grants or low-interest loans to local companies to enable them to supply goods and services to mining operations.[101] It could also use them to support moving along other mineral value chains, such as the establishment of alumina refineries and an integrated aluminum value chain.[102]

The government might consider these opportunity costs worthwhile if the refinery would generate other significant benefits. Further work is required to quantify these other benefits, but the potential for them appears uncertain. Job creation may be limited; for example, a refinery with the capacity to produce 20,000t of lithium carbonate a year may require 1,000–1,500 workers during the construction phase but would typically employ no more than 200 workers once operational.[103] As noted above, the refinery's byproducts could potentially be used in the Ghanaian economy. For example, the refinery could sell its aluminum silicate to road construction companies. This could potentially make closing the road infrastructure gap in Ghana slightly cheaper. However, the government will need to monitor projects in China to determine how much aluminum silicate can be used before road functionality is impaired.

The extent to which a refinery would stimulate other sectors is unclear. As noted above, it will not be a key factor in whether Ghana ultimately moves further along the battery value chain. Other sectors may benefit from knowledge spillovers. The technical know-how and capabilities required for refining are highly specific, but some of them may be transferable—including through the workers employed at the refinery—if the government puts in place the necessary provisions. For example, the knowledge gained from the chemical engineering involved might be transferable to other sectors, such as petrochemicals or fertilizers.

Other potential costs of a Ghanaian refinery

Given that new power generation capacity would increase the costs for the investor and/or the government, there is a risk that the existing electricity supply would be diverted from other productive and social needs, or would increase the price that households and other businesses must pay.[104] Electricity prices for other users could be further impacted by a refinery if it uses cheap associated gas to generate its heat.

As previous government plans have acknowledged, industrial users receiving low-cost associated gas would mean power plants receiving more of the country's higher-cost, unassociated and imported gas.[105]

The implications of the refinery's large water requirements for other users must also be accounted for. A 20,000t/y refinery could use about 800 million liters of water a year. This is equivalent to the average annual consumption of around 90,000 Ghanaians—nearly double the population of Ekumfi, a town near the Ewoyaa project.[106] Already, the Ghana Water Company Limited has warned of severe water shortages in the lithium mining area due to illegal small-scale gold mining.[107]

The refinery also comes with considerable risks for the environment as well as the health and livelihoods of local communities. As noted above, sulfuric acid leaching produces sodium sulfate, which, if discharged in lakes or rivers, can harm ecosystems and make the water unsafe to drink. It also emits various pollutants that can cause health issues and problems, such as acid rain that could harm local agriculture production. Ghana appears to have already experienced such impacts from its gold mining sector. One study found that between 1997 and 2005, farms within the vicinity of mines were nearly 40 percent less productive than similar farms further away, and that farming households were 18 percent more likely to be poor.[108] The government could explore using alkaline pressure leaching rather than sulfuric acid leaching, like some planned European and North American refineries. However, this process is still unproven at scale, could further worsen the refinery's viability and could have greater opportunity costs in terms of energy and water use.

The government must therefore conduct a rigorous cost-benefit analysis that accounts for these various costs and possible benefits.[109] However, our analysis suggests that even if the refinery could secure more feedstock than the Ewoyaa mine currently offers, and cathode manufacturing sufficiently develops in the ROW for Ghana to benefit from its slightly higher prices, the benefits of constructing a refinery are currently limited. They are likely outweighed by the foregone government revenue, potential diversion of energy and water from other needs and environmental and social impacts.



Photo by GravityGh Studios for iStock

→ **Box 1**

Whether a sulfate plant provides a useful alternative

As is the case with much of the technology needed to drive the energy transition, there is significant investment in research and innovation of lithium refining processes and products. Some companies are considering separating the two refining stages and performing them at different locations. Refineries currently produce lithium sulfate in aqueous form, before converting it to carbonate or hydroxide. With this new process, the company dries the sulfate so it can be transported. It exports this intermediate product to a refinery elsewhere, which then converts it into carbonate or hydroxide.

The economics appear worse than the current integrated approach because of the intermediate drying step. iLiMarkets estimates that it could increase the operating cost of converting spodumene concentrate to carbonate by up to 18 percent and to hydroxide by up to 7 percent.[110] However, it will enable companies to offer a product to refineries that requires them to deal with less waste. Because aluminum silicate is produced in the production of lithium sulfate, it is the sulfate plant that will have to dispose of it. Moreover, by exporting less waste, it will reduce both shipping costs and the embedded carbon of the resulting lithium.

In Australia, Alkemy Capital Investments is piloting the production of sulfate as an intermediate product.[111] It hopes that this might increase demand for its product in Europe, given the continent's strict environmental regulations. However, given that a market for sulfate has not yet been established, whether the company will be able to secure demand—and at prices that provide a return—remains to be seen.[112]

Sinomine has also announced a plan to build a sulfate plant in Zimbabwe.[113] It will then send the sulfate to its refineries in China. Sinomine's impetus does not appear to be to reduce the refineries' waste disposal needs, as this does not tend to be a challenge in China. Rather, it appears to be responding to the Zimbabwe's government push for lithium mining companies to increase value addition in the country. The pricing of this sulfate production will be particularly uncertain because Sinomine will sell it to a related party. As a result, there are significant transfer pricing risks.

In light of this, we would not recommend Ghana consider a sulfate plant. The economics appear worse than for carbonate and hydroxide refineries, and Barari would need to sell its spodumene concentrate at an even lower price for the plant to break even. Demand for dry sulfate is currently unproven, and a plant could struggle to sell it. Even if it does sell it, the government would find it challenging to ensure it is priced correctly given the lack of a market to compare prices to. Ghana will, therefore, likely benefit even less from a sulfate plant than a carbonate refinery.

A mine-and-monitor approach

At this time, instead of pursuing a lithium refinery, the government would benefit from ensuring the Ewoyaa mine starts as soon as possible while monitoring how the conditions for lithium refining evolve. This would have several advantages, as set out below.

Further development of Ghana's lithium sector

More lithium is a prerequisite for any refinery prospects. Investors are unlikely to invest in a refinery that only has access to Ewoyaa's current reserves. The government could—and should—engage other West African lithium producers on coordination of feedstock supply. However, this comes with political and technical challenges. The government should also encourage more discoveries and developments in Ghana. Such developments would provide investors with more certainty on stable and nearby feedstock supply over the long term.

The government could also use the licensing process for new lithium developments to gather data on the feasibility of a Ghanaian refinery. It could require mine feasibility studies to include the prospect of domestic refining. It could use this data to develop a repository of potential feedstock, mine-specific considerations and refinery options.

Further development of the sector will be more likely if Ghana does not attempt to force refining in these early stages, given the likely impact on project profitability. However, the government could also encourage exploration in other ways. For example, it could revise the VAT Act to grant refunds of VAT that companies incur during exploration before they reach production.

Allowing companies to claim VAT refunds only once they reach production increases the ex-ante costs of exploration given the risk that they might not reach the production stage, and may still cause cash-flow problems for companies that do.[114]

The potential for a premium for non-Chinese supply to emerge

At the same time as working to develop Ghana's lithium sector, the government should monitor the conditions for lithium refining. First, cathode manufacturing must further develop outside of China in order to avoid the refinery having to sell its carbonate to Chinese manufacturers and generating even lower benefits for Ghana. Second, over time, a premium for production outside China may emerge in the ROW. As Table 7 (on the next page) shows, if our modeled refinery is able to access sufficient feedstock to operate for 20 years, and the ROW price premium is sufficiently large—at least $3,000/t—Ghana would benefit from it. The country would generate more value by refining spodumene concentrate and exporting lithium carbonate to the ROW than by exporting concentrate to China.

Table 7. Annual net revenue from exporting spodumene concentrate (SC6) vs. lithium carbonate (Li_2CO_3) at different price premiums for non-Chinese supply in 20-year refinery, medium-price scenario (USD millions)

ROW price premium	SC6 to China	SC6 to ROW	Li_2CO_3 to China	Li_2CO_3 to ROW
-1000	219	135	161	141
-500	219	145	161	151
0	219	155	161	161
500	219	165	161	171
1000	219	175	161	181
1500	219	185	161	191
2000	219	195	161	201
2500	219	205	161	211
3000	219	215	161	221
3500	219	225	161	231
4000	219	235	161	241

Notes: A gradient from green to red, with yellow and orange as intermediates, indicates the most to least beneficial options for Ghana.

The prospect of other lithium products

Ghana should keep an eye on the evolution of new lithium products. For example, some companies are piloting the production of lithium phosphate instead of lithium carbonate or lithium hydroxide. Lithium phosphate could be a more efficient way to produce LFP cathode active material than using lithium carbonate. Instead of a cathode manufacturer needing to add iron and phosphate to carbonate, it would only need to add iron. Cathode manufacturers therefore might be willing to pay a premium because of the additional efficiency and resulting cost saving.

While some Chinese refineries are currently producing small volumes of lithium phosphate, it is largely still at the conceptual stage. For example, a pilot project in Australia is yet to reach a final investment decision on commercialization.[115] If the concept is proven, the economics are reasonable and a market develops, being an early entrant could provide Ghana a premium that makes refining a more feasible and beneficial prospect for the country (possibly even without a premium for non-Chinese supply).

The economics of lithium refining could change significantly over the next few years, given the dynamic nature of the market, technological and geopolitical landscape. If and when Ghana returns to its refining plans, the government should work with potential investors to consider the whole range of possible lithium products based on the outlook at that point in time.

A risk to Ghana of this mine-and-monitor approach is that its lithium could be locked into long-term offtake agreements by the time the country is in a position to benefit from a refinery. However, the government can manage this risk, as spodumene concentrate agreements typically last around five years. It will need to stay engaged with Barari and any other companies that develop lithium mines on their export plans, and coordinate its approval of offtake agreements with any evolutions in its refining strategy.

Adhering to the principle of doing no harm

The government must place the principle of doing no harm at the core of its strategy, irrespective of whether it pursues refining in the coming years or takes a mine-and-monitor approach. Both lithium mining and refining can cause significant environmental and social harms.[116]

The government should prohibit mining and value addition in areas of particularly high environmental and social sensitivity. The Environmental Protection (Mining In Forest Reserves) Regulations, 2022 encouragingly provides for such no-go zones in several areas, including those of globally significant biodiversity and high conservation value as well as cultural sites.[117] However, it enables the President to grant exceptions for areas of globally significant biodiversity. The previous government had granted mining licenses for other minerals in some forest reserves due to this provision (in addition to illegal artisanal mining taking place).[118] After significant opposition from Ghanaian civil society, among others,[119] the previous government had laid a bill in parliament to repeal this regulation and declare forest reserves as no-go zones.[120] However, parliament is yet to pass the bill.[121]

The government should also not proceed with mining or refining when local communities have not been meaningfully involved in decision-making, or when the right to free, prior and informed consent has not been respected.[122] Local communities have raised concerns about a lack of sufficient engagement prior to permitting decisions as well as resettlement and compensation provisions when projects do proceed.[123]

For mining and refining projects outside of no-go zones that have received the necessary consent, the government must still account for potential environmental and social costs when granting permits to operators. As part of this, the government could consider delinking procurement and payment for environmental and social impact assessments (ESIAs) from the companies involved in projects. Companies procuring and paying the contractor conducting these assessments raises conflict-of-interest risks, which may bias their outcomes. Even in the absence of bias, the current approach undermines how much citizens can trust ESIAs.[124]

Avoiding environmental and social impacts is critical, first and foremost, for reducing harm to people in Ghana. However, it is also increasingly important for attracting investment and, therefore, achieving the government's refining ambitions. For example, Mercedes-Benz will now only work with suppliers that purchase minerals from mines audited by the Initiative for Responsible Mining Assurance and that comply with the Organisation for Economic Co-operation and Development's due diligence guidelines.[125]

Transparency and trust

The government should be transparent in its decision-making and involve citizens at every step to build trust. Given the broad public support for a Ghana lithium refinery, the government is under pressure to deliver. Establishing or facilitating value-addition projects is also becoming increasingly important for the social license to operate for mining companies in the country. However, as this report has set out, a Ghana lithium refinery faces challenging economics. Currently, a refinery is more likely to reduce rather than add value for Ghanaians, whether privately or state-owned. Trust is essential to manage public expectations and avoiding either pursuit of lithium refining at all costs or a backlash against the mining companies if a refinery is not constructed.

As a first step, the government should disclose the scoping study for a lithium refinery conducted by Barari. Going forward, it should ensure adherence to the Extractive Industries Transparency Initiative, of which Ghana is a member. The government should disclose and consult with the public on any subsequent feasibility studies, ESIAs and cost-benefit analyses.[126] It should also encourage informed debate about the trade-offs involved in pursuing a refinery, especially given the considerable opportunity costs. It must ensure these processes are inclusive, and that impacted communities and marginalized groups are not only included but active participants engaged in shaping decisions.

Transparency is also critical because public support for lithium refining means it is at risk of "state enchantment," where narrow private interests are presented as the national interest without recognition of the commercial elements at play.[127] For example, civil society has raised questions about the beneficial ownership of a Ghanaian gold refinery that has been granted an advantageous permit to refine gold purchased by the Bank of Ghana.[128] Potential governance challenges also exist in other areas, such as the design of the policy and legal framework, provision of any financial incentives and management of environmental and social impacts.[129] By potentially justifying and rushing political decisions, public support for lithium refining could create increased opportunities for wrongdoing by unethical actors. Accountability actors must, therefore, rigorously scrutinize any plans to build a refinery and ensure they benefit all Ghanaians and not just a select few. To do so, these actors should remain particularly alert to potential issues around licensing and contracting procedures for the refinery, including the beneficial owners of those involved, any track records of controversy or criminality, and any potential conflicts of interest.

Conclusion

Ghana's ambitions to refine its lithium appear challenging. Given the current outlook, any refinery built over the next few years is unlikely to generate much benefit for Ghanaians. The government will likely receive less rather than more revenue from its lithium because of having a refinery. A refinery will also likely create limited direct jobs, and the stimulus for other sectors is uncertain. Additionally, a refinery will likely cause environmental and social harms and have significant opportunity costs. These potential opportunity costs include not only investment in other sectors or funding to meet social needs, but also potential trade-offs between pursuit of lithium refining and other ways that Ghanaians can benefit from their mineral wealth. For example, the political capital, time and money the government would need to spend (or forgo) could reduce its ability to support local suppliers of mining operations or the value addition of other minerals. Instead, the government would benefit from adopting a mine-and-monitor approach. This would not only entail supporting the discovery and development of more lithium in Ghana but also monitoring how conditions for lithium refining evolve. The market, technological and geopolitical landscape is very dynamic, and the economics of lithium refining could change significantly over time.

If the government still decides to pursue lithium refining in the next few years, it should work with potential investors to avoid the biggest pitfalls and increase the chances of success. As part of this, it should ensure the refinery replicates tried and tested designs from China, assess the feasibility and benefits of developing capacity to produce key reagents, and develop a strategy to use the refinery's byproducts. In any case, the government should be transparent in its decision-making and involve citizens at every step. Trust is essential for managing public expectations and building an understanding of the trade-offs involved. By building trust, the government will improve the investment environment and therefore the prospects for lithium refining in the longer term.



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Appendix

Modeling assumptions

Table 8. Cost assumptions for China, the rest of the world (ROW) and Ghana refineries

	China	ROW	Ghana, current Ewoyaa	Ghana, 20 years
Capex intensity ($/t/y)	7,000	20,000	20,000	20,000
Cost of capital (%)	4	8	8	8
Capex quota ($/t)	500	2,000	3,200	2,000
Operating cost ($/t)	3,000	4,000	3,700	3,700
SC6 to Li_2CO_3 conversion rate	7.5	8.0	8.0	8.0

Our assumed costs for a Ghanaian refinery are likely overoptimistic, given that they are based on the estimated costs of the ROW refineries, either in reality or as set out in their feasibility studies (excluding the Australian refineries that are already operating, given their particularly severe challenges).

A Ghanaian refinery is likely to face a higher cost of capital than these other refineries due to the country's high risk premium. As of January 2025, Ghana's risk premium is estimated at around 12 percent. This is compared to 0–1 percent in, for example, Australia, Austria, Canada, Finland, South Korea and the U.S.[130] If the refinery has a cost of capital of 15 percent rather than 8 percent, its capital expenditure quota increases to $4,200/t in the current Ewoyaa scenario and $3,200/t in the 20 years scenario.

A larger refinery than our assumed capacity of 20,000t/y of lithium carbonate would likely have a lower capital intensity, as lithium refineries typically benefit from economies of scale. For example, if a Ghanaian refinery could use all the production from Ewoyaa, it could double its capacity to around 40,000t/y. This larger refinery could have a capital intensity around 24 percent lower than our assumption, at around $15,200/t/y of carbonate.[131] However, this lower capital intensity does not materially affect the results. Ghana would still generate more value by exporting spodumene concentrate to China than by constructing a domestic refinery.

We based our operating cost assumption on reagent and energy costs at the higher end of the range of estimated costs for the other ROW refineries. However, either of these costs could be even higher given the limited reagent market in the region and the potential need to construct new power generation capacity. We assumed no waste disposal costs compared to the $1,200/t expected for some ROW refineries. This assumption significantly reduces the overall operating cost (to below our assumed operating cost for the modeled ROW refinery). However, further research is required on the feasibility of the refinery selling all its byproducts.

Table 9. Operating cost assumptions for a Ghanaian refinery (USD per metric ton of lithium carbonate)

Sulfuric acid	480
Sodium carbonate	1,100
Other reagents	350
Energy	1,200
Waste disposal	0
Labor	300
Maintenance	250
Total	3,680

In contrast, it is possible that we are overestimating energy costs given Ghana's electricity costs for industrial costs are currently competitive relative to many countries, and the refinery could potentially access low-cost gas to generate the necessary heat. A Ghanaian refinery could also have lower labor costs than other ROW refineries. If we reduce energy and labor costs to the minimum observed for lithium carbonate refineries (as set out in Table 2) to $563/t and $150/t, respectively, the refinery has a total operating cost of $2,893/t. However, this lower operating cost does not materially affect the results. Ghana would still generate more value by exporting spodumene concentrate to China than by constructing a domestic refinery.



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Additional results

Table 10. Net revenue of a Ghanaian refinery (USD per metric ton of lithium carbonate)

Operating lifetime	Current Ewoyaa						20 years					
Sells to	China			ROW			China			ROW		
Lithium carbonate price	Low	Med	High	Low	Low	Med	High	Low	Low	Med	High	Low
Revenue	9,500	18,000	30,000	10,000	18,500	30,500	9,500	18,000	30,000	10,000	18,500	30,500
Capex quota	3,202	3,202	3,202	3,202	3,202	3,202	2,037	2,037	2,037	2,037	2,037	2,037
Opex excl. feedstock	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680
Feedstock cost	6,384	15,451	28,251	6,384	15,451	28,251	6,384	15,451	28,251	6,384	15,451	28,251
Transport cost	100	100	100	100	100	100	100	100	100	100	100	100
Net revenue	-3,866	-4,433	-5,233	-3,366	-3,933	-4,733	-2,701	-3,268	-4,068	-2,201	-2,768	-3,568

Table 11. Spodumene concentrate price that a Ghanaian refinery needs to break even (USD per metric ton)

Operating lifetime	Current Ewoyaa						20 years					
Sells to	China			ROW			China			ROW		
Lithium carbonate price	Low	Med	High	Low	Low	Med	High	Low	Low	Med	High	Low
Required price	327	1,390	2,890	390	1,452	2,952	473	1,535	3,035	535	1,598	3,098

Table 12. Annual net revenue generated by exporting spodumene concentrate (SC6) vs. lithium carbonate (Li_2CO_3) in 20-year refinery, medium price scenario (USD millions)[132]

	SC6 to China	SC6 to ROW	Li_2CO_3 to China	Li_2CO_3 to ROW
Sales revenue	309	249	360	370
Ewoyaa project cost	-82	-82	-82	-82
Capex quota			-41	-41
Opex excl. feedstock			-74	-74
Transport cost	-8	-8	-2	-2
Net revenue	219	159	161	171

Endnotes

1. This figure shows the break-even prices for a refinery that has access to only Ewoyaa's current reserves.
2. NRGI, "NRGI's Lithium Mining Tax Model for Ghana," June 2024, resourcegovernance.org/sites/default/files/2024-08/NRGI-tax-model_Ghana_lithium_June_2024_0.xlsm.
3. In 2024, the government budgeted GHS 5,778 million or $408 million (at the average exchange rate for 2024 reported by the Bank of Ghana) for basic education. UNICEF, *Education Budget Brief 2024* (2024), www.unicef.org/ghana/media/6391/file/EDUCATION%20BUDGET%20BRIEF%202024.pdf.
4. A refinery requires around 40,000 liters of water to produce 1 metric ton of chemical. Average water consumption per person in Ghana is around 8,879 liters a year based on annual municipal consumption of around 300 billion liters (in 2020) and a population of 33,787,914 (in 2023). Doris Dokua Sasu, "Total water withdrawal in Ghana 2020, by sector," Statista, 29 January 2024, www.statista.com/statistics/1446802/annual-total-water-withdrawal-in-ghana-by-sector/; World Bank, "Ghana," accessed 3 March 2025, data.worldbank.org/country/ghana.
5. Government of Ghana and Barari DV Ghana Ltd, *Mining Lease Agreement* (2023), www.mincom.gov.gh/wp-content/uploads/2023/11/BDL_ML-AGREEMENT_102023_31.pdf.
6. Atlantic Lithium, *Ewoyaa Definitive Feasibility Study: DFS Confirms Project's Economic Viability and Indicates Low Capital Intensity and Exceptional Profitability Potential* (2023), www.londonstockexchange.com/news-article/ALL/ewoyaa-definitive-feasibility-study/16019880.
7. Lithium is currently produced from two main sources: hard rock and brine. Spodumene ore is the most common source of hard rock lithium.
8. Barari will produce a combination of concentrate with lithium oxide (Li2O) content of 6 percent and concentrate with Li2O content of 5.5 percent according to the Ewoyaa feasibility study. Atlantic Lithium, *Ewoyaa Definitive Feasibility Study*.
9. Sabrina Jardim, "Atlantic achieves positive drilling results at Ewoyaa target," *Mining Weekly*, 7 May 2024, www.miningweekly.com/article/atlantic-achieves-positive-drilling-results-at-ewoyaa-target-2024-05-07.
10. Darren Parker, "CAA Mining actively drilling for lithium in spodumene in Ghana – research firm," *Mining Weekly*, 6 December 2023, www.miningweekly.com/article/caa-mining-actively-drilling-for-lithium-in-spodumene-in-ghana-research-firm-2023-12-06.
11. Piedmont had plans for two refineries in the U.S. It is currently still planning to proceed with the other refinery. However, it has also recently announced a merger with Sayona Mining. It is unclear how this will affect its plans. See: Piedmont Lithium, "Piedmont Lithium Reports Q2 2024 Results: NAL Achieves Steady-State Production; Shipments Shift to Contract Customers," Press release, 8 August 2024, www.piedmontlithium.com/wp-content/uploads/Press-Release-Exhibit-99.1-Q22024-US.pdf; Piedmont Lithium, "Piedmont Lithium and Sayona Mining To Merge: Creates a Leading North American Lithium Producer and Developer," Press release, 19 November 2024, www.piedmontlithium.com/piedmont-lithium-and-sayona-mining-to-merge/.
12. National Democratic Congress, *Resetting Ghana: Jobs, Accountability, and Prosperity – NDC 2024 Manifesto* (2024), cdn.modernghana.com/files/912024122209-k5fri7t2h0-resetting-ghana-ndc-manifesto-2024--full-text-1.pdf.
13. *Reuters*, "Livista Energy partners with CAA Mining to process lithium in Ghana," 6 February 2023, www.reuters.com/business/energy/livista-energy-partners-with-caa-mining-process-lithium-ghana-2023-02-06/.
14. Thomas Scurfield, Matthieu Salomon and Silas Olan'g, *Six Keys to Unlocking Equitable Value Addition in Mining* (NRGI, 2024), resourcegovernance.org/publications/six-keys-unlocking-equitable-value-addition-mining.
15. Denis Gyeyir, Thomas Scurfield and Nicola Woodroffe, "Five Considerations for Parliament Before Ratifying Ghana's First Lithium Agreement," NRGI, 1 August 2024, resourcegovernance.org/articles/five-considerations-parliament-ratifying-ghanas-first-lithium-agreement; Thomas Scurfield and Denis Gyeyir, *Assessing the Fiscal Regime in Ghana's Lithium Agreement* (NRGI, 2024), resourcegovernance.org/publications/assessing-fiscal-regime-ghana-lithium-agreement.
16. The process for producing lithium chemicals from spodumene concentrate and brine differs. Extracting lithium from brine deposits does not involve conventional mining techniques. Companies pump the brine to the surface, concentrate it through evaporation, and then typically convert it to carbonate on-site. This carbonate can either be used directly or further converted into hydroxide in a separate process.
17. There is no comprehensive source of information on refining capacity in China. Capacity appears to be around 1,200–1,400 thousand metric tons (kt) of lithium carbonate equivalent (LCE) based on production of around 700kt LCE in 2024 and an estimated use rate of 50–60 percent. iLiMarkets provided this data directly to NRGI.
18. A joint venture between IGO, an Australian company, and Tianqi Lithium, a Chinese company, opened the first Australian refinery in 2021. The joint venture had a phase one target of 24kt year but is currently operating significantly below capacity. It had planned a second phase to construct another train and expand the refinery's capacity to a total of 48kt a year. However, it cancelled these plans at the start of 2025. Albemarle started operations at its Australian refinery in 2022. The company had a phase one target of 25kt a year but is also not currently operating at full capacity. It initially intended for the refinery to expand in several phases to reach an ultimate capacity of 100kt. It started construction of a second train but has since announced that it will put this train in care and maintenance, and cancel further expansion plans. See: Mark Burton and Annie Lee, "Tianqi Lithium Warns of 2024 Loss, Halts Australia Expansion," Bloomberg UK, 23 January 2025, www.bloomberg.com/news/articles/2025-01-23/china-s-tianqi-lithium-issues-profit-warning-and-halts-expansion; Tage Erikson, "Albemarle curtails lithium processing project in Australia," Batteries and Energy Storage Technology, 15 November 2024, www.bestmag.co.uk/albemarle-curtails-lithium-processing-project-in-australia/.
19. A joint venture between POSCO Holdings, a South Korean company, and Pilbara Minerals, an Australian company, operates the refinery. It started operating in 2023 with a capacity of 21.5kt a year and completed an expansion to 43kt a year in late 2024.
20. S&P Global, "Tesla starts operations at Texas lithium refinery," 16 December 2024, cilive.com/commodities/metals-mining/news-and-insight/121624-tesla-starts-operations-texas-lithium-refinery.
21. Lithium refineries are currently operating in Germany, Russia and the U.K., but they do not refine spodumene concentrate. Their feedstock is technical-grade carbonate, which they then refine into battery-grade carbonate or hydroxide.
22. For example, in the U.S., Piedmont has canceled one of its planned refineries, and Albemarle has put its refinery on hold. In Europe, Galp has canceled its planned refinery in Portugal, and Vulcan Energy Resources are facing at least a two-year delay in the start-up of their German refinery. See: Piedmont Lithium, "Piedmont Lithium Reports Q2 2024 Results"; Jessica Holdman, "Major electric vehicle lithium project paused. Other SC battery recycling investments continue," *South Carolina Daily Gazette*, 18 March 2024, scdailygazette.com/2024/03/18/major-electric-vehicle-lithium-project-paused-other-sc-battery-recycling-investments-continue/; *Reuters*, "Galp drops plans to build Aurora lithium refinery in Portugal," 27 November 2024, www.reuters.com/markets/commodities/galp-drops-plans-build-aurora-lithium-refinery-portugal-2024-11-27/; *Reuters*, "Vulcan pushes back large-scale production date for German lithium plant to 2027," 11 November 2024, www.reuters.com/business/energy/vulcan-pushes-back-large-scale-production-date-german-lithium-plant-2027-2024-11-08/.

23. There is no comprehensive source of information on Chinese refining capacity. Chinese capacity of 1,200–1,400 thousand tonnes (kt) of lithium carbonate equivalent (LCE) is based on the production of around 700kt LCE in 2024 and an estimated use rate of 50–60 percent. Initial capacity of Tesla's U.S. refinery has not yet been announced.

24. A small amount of lithium is also currently converted to lithium chloride, either directly from brines or from carbonate.

25. iLiMarkets.

26. Estimates vary given data challenges. For example, iLiMarkets estimates cathode manufacturers currently consume around 93 percent of lithium chemicals, while Benchmark Mineral Intelligence estimates they consume slightly less than 90 percent.

27. iLi Markets.

28. China is home to a still large but lower share of NMC cathode manufacturing of around 75 percent. South Korea hosts 20 percent of NMC cathode manufacturing. See: International Energy Agency (IEA), *Global EV Outlook 2024* (2024), www.iea.org/reports/global-ev-outlook-2024.

29. IEA, *Global Critical Minerals Outlook 2024* (2024), www.iea.org/reports/global-critical-minerals-outlook-2024. The geographical breakdown refers to the country where the production occurs. Mining and refining shows total production—not only that used in EVs. Graphite refining refers to spherical graphite production only.

30. Cathode manufacturers have slightly stricter purity requirements than manufacturers of non-battery products. "Battery-grade" chemicals must have purity of more than 99.8 percent, while "technical-grade" chemicals must have purity of 99.3 percent. While cathode manufacturers sometimes blend technical-grade chemicals with battery-grade chemicals depending on the prevailing market conditions, most technical-grade chemicals are used for other purposes. The largest non-battery use of carbonate is in grease and dyestuff. Lithium grease is versatile and widely used, particularly in automotive and industrial settings. Lithium improves the color and heat and water resistance of dyestuff. The largest non-battery use of hydroxide is in specialist glass and ceramics that need to withstand high temperatures, such as glass in ovens. Spodumene concentrate that has a very high lithium and very low iron content can be used directly in the manufacturing of glass and ceramics, but it is more common for lithium chemicals to be used. Only the Greenbushes mine in Australia can currently produce spodumene concentrate of this quality.

31. iLiMarkets.

32. A refinery requires around 75–150 mega-watt hours of electricity, 12–18 metric tons of steam and 40,000 liters of water to produce 1t of chemical.

33. Mervyn Stevens, "Cathode manufacturing: solutions for sodium sulphate," Worley, 29 May 2024, www.worley.com/en/insights/our-thinking/resources/cathode-manufacturing-solutions-for-sodium-sulphate.

34. Matt Blois, "What to do with the battery industry's sodium sulfate waste?," *Chemical and Engineering News* 102, no. 21 (2024), cen.acs.org/energy/battery-industrys-sodium-sulfate-waste/102/i21.

35. Lithium carbonate and lithium hydroxide refineries currently generate similar margins. Producing carbonate is slightly more expensive than producing hydroxide because it requires more spodumene. However, this is currently reflected in a price differential, with carbonate prices slightly higher than hydroxide prices. Hydroxide prices were higher than carbonate prices until around 2021. There was limited spodumene concentrate production until around 2017, so most lithium chemicals were produced from brine. As a result, most hydroxide was produced from carbonate. Given the cost of this additional step, hydroxide commanded a price premium. Given the higher hydroxide price and that hydroxide is cheaper than carbonate to produce from spodumene concentrate, when spodumene concentrate production ramped up, most of the new refining capacity was for hydroxide production. The subsequent increase in hydroxide production eroded the price premium relative to carbonate.

36. Some refineries integrated with low-cost spodumene mines have managed to continue generating reasonable profits.

37. Spodumene concentrate prices have also fallen, which has reduced the feedstock cost for refineries. However, other costs are reasonably unaffected by lower lithium prices, and therefore the overall effect on profitability is negative.

38. S&P Global database: www.spglobal.com/market-intelligence/en/solutions/products/resources/capital-iq-pro-metals.

39. iLiMarkets.

40. Rho Motion, "Over 17 million EVs sold in 2024 – Record Year," 14 January 2025, rhomotion.com/news/over-17-million-evs-sold-in-2024-record-year/.

41. Lucy Tang, "China's leading lithium salts producers post higher 2023 output, as inventories pile up," S&P Global, 29 March 2024, cilive.com/commodities/metals-mining/news-and-insight/032924-china-leading-lithium-salts-producers-post-higher-output-inventories-pile-up; Christopher Williams, "Lithium market could see modest recovery in 2025," Mining.com, 26 December 2024, www.mining.com/lithium-market-could-see-modest-recovery-in-2025-adams-intelligence/.

42. Lucy Tang and Litian Wang, "FACTBOX: China's lithium industry eyes output cuts to shore up market sentiment," S&P Global, 23 September 2024, www.spglobal.com/commodity-insights/en/news-research/latest-news/metals/092324-factbox-chinas-lithium-industry-eyes-output-cuts-to-shore-up-market-sentiment.

43. iLiMarkets modeling using S&P Global price data: www.spglobal.com/market-intelligence/en/solutions/products/resources/capital-iq-pro-metals. The margin for a mine producing spodumene concentrate (SC6) is based on an assumed operating cost of $500/t SC6, which is around the average cost in Australia today. The margin for a refinery producing lithium carbonate (Li_2CO_3) is based on a conversion rate of 8t of SC6 for production of 1t of Li_2CO_3, an operating cost of $2,500/t Li_2CO_3 plus VAT of 13 percent.

44. Wood Mackenzie predicts that the surplus could potentially peak in 2026 at the equivalent of around 26 percent of demand (without "probable and possible" refineries coming online). Battery-grade hydroxide might be an exception, possibly experiencing a slight deficit in the coming years. Allan Pedersen and Mamta Jaswal, "A tale of a looming surplus in the lithium industry: sticky supply to stay?," Wood Mackenzie, 1 August 2024, www.woodmac.com/news/opinion/a-tale-of-a-looming-surplus-in-the-lithium-industry-sticky-supply-to-stay/.

45. iLiMarkets.

46. The U.S. had the most refining capacity until 1995. However, the people involved in these refineries are now retired or have passed away, so the country has lost much of the technical know-how. See: Alessio Miatto, Barbara K. Reck, James West and Thomas E. Graedel, "The rise and fall of American lithium," *Resources, Conservation and Recycling* 162 (2020, www.sciencedirect.com/science/article/abs/pii/S0921344920303517.

47. Albemarle and Tianqi's decisions to move away from Chinese designs—despite already operating refineries in China—was likely partly an attempt to improve safety standards. Other design changes appear to have been an attempt to increase efficiency, but this has not paid off.

48. iLiMarkets.

49. One type of alkaline pressure leaching uses soda ash in what is called the "Metso" process. See: Metso "Lithium Hydroxide Process," accessed 21 March 2025, www.metso.com/commodities/lithium/.

50. iLiMarkets.

51. The Chinese government is currently considering whether to re-classify various technologies into the restricted category, including those required to convert spodumene concentrate to carbonate and hydroxide, and to produce LFP cathodes. If so, companies would be required to secure approval from the regulator before making one of these "technology exports." A technology export is broadly defined under Chinese laws and captures almost all forms of joint ventures, licensing, technical services, and other forms of cooperation. See: Hilary Lau, Calvin Ho and Charles Wong, "How will you be affected by China's battery technology export restrictions?", Herbert Smith Freehills, 10 January 2025, www.herbertsmithfreehills.com/notes/mining/2025-posts/chinas-mofcom-proposes-to-restrict-batteries-related-technologies.

52. Ryan McMorrow, Christian Davies, Kathrin Hille, John Reed and Zijing Wu, "China tightens grip on tech, minerals and engineers as trade war spirals," *Financial Times*, 16 February 2025, www.ft.com/content/d48e9a90-ba6a-42bb-9da7-58db89643f86.

53. Based on reporting of companies listed on stock exchanges outside of China (including Albemarle and Tianqi).

54. Based on company reports compiled by iLiMarkets. We report that the capacity of Albemarle's refinery is 40kt, even though this capacity includes part of the expansion that has been cancelled. This accounts for Albemarle incurring some of the capital expenditure to date on construction of this second train.

55. Ellen Wald, "The US wants to end its reliance on Chinese lithium. Its policies are doing the opposite," *New Atlanticist*, 23 January 2024, www.atlanticcouncil.org/blogs/new-atlanticist/the-us-wants-to-end-its-reliance-on-chinese-lithium-its-policies-are-doing-the-opposite/.

56. See for example: Business Analytiq, "Sulfuric Acid price index," accessed 21 March 2025, businessanalytiq.com/procurementanalytics/index/sulfuric-acid-price-index/; Business Analytiq, "Caustic Soda price index," accessed 21 March 2025, businessanalytiq.com/procurementanalytics/index/caustic-soda-price-index/.

57. See for example: The Observatory of Economic Complexity, "Sodium hydroxide (caustic soda) in aqueous solution in Australia," accessed 21 March 2025, oec.world/en/profile/bilateral-product/sodium-hydroxide-caustic-soda-in-aqueous-solution/reporter/aus.

58. iLiMarkets.

59. iLiMarkets.

60. Alina Racu and Julia Poliscanova, *An industrial blueprint for batteries in Europe: How Europe can successfully build a sustainable battery value chain* (Transport and Environment, 2024), www.transportenvironment.org/uploads/files/An-industrial-blueprint-for-batteries-in-Europe-How-Europe-can-successfully-build-a-sustainable-battery-value-chain.pdf.

61. IEA, *Global EV Outlook 2024*.

62. Alice Yu and Anna Duquiatan, "China, South Korea battery-makers drive growth despite capacity regionalization," S&P Global, 26 July 2024, www.spglobal.com/market-intelligence/en/news-insights/research/china-south-korea-battery-makers-drive-growth-despite-capacity-regionalization.

63. Of planned capacity in Europe, 25 percent was cancelled. European companies, like Northvolt, were not the only ones to cancel plans. Chinese companies, such as SVOLT Energy Technology, also canceled projects. Battery News, "Battery Cell Production [sic]," accessed 21 March 2025, battery-news.de/en/europe-battery-cell-production/.

64. Harry Dempsey, Mari Novik, Kana Inagaki and Christian Davies, "Europe's battery industry hit by EV slowdown," *Financial Times*, 8 July 2024, www.ft.com/content/840f74e6-3ec8-4b42-aa13-2b8c2acddeac.

65. Jakob Fleischmann, Eugen Hildebrandt, Konstantin Huneke, Raphael Rettig and Patrick Scott, "The battery cell component opportunity in Europe and North America," McKinsey & Company, 18 April 2024, www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-battery-cell-component-opportunity-in-europe-and-north-america; Racu and Poliscanova, *An industrial blueprint for batteries in Europe*.

66. Transport and Environment lists four cathode manufacturers in Europe, but one of the them, Northvolt, has recently announced cancellation of its cathode manufacturing plans. See: Racu and Poliscanova, *An industrial blueprint for batteries in Europe*; *Reuters*, "Northvolt goes from Europe battery promise to crisis," 21 November 2024, www.reuters.com/technology/northvolt-goes-europe-battery-promise-crisis-2024-11-21.

67. Based on NMC811 battery production in Europe in 2023. Fleischmann et al., "The battery cell component opportunity in Europe and North America."

68. Racu and Poliscanova, *An industrial blueprint for batteries in Europe*.

69. The Infrastructure Investment and Jobs Act provides about $3 billion for battery material processing grants, with priority given to entities located and operating in the U.S., those owned by a U.S. firm, those using North American intellectual property, and those using supplies that do not originate from a foreign entity of concern. The Inflation Reduction Act provides tax credit of up to $7,500 per EV. Of this credit, $3,750 is dependent on the battery components being manufactured in North America (with 50 percent of the battery component value needing to meet this criterion in order to qualify prior to 2024, and 100 percent of the value by 2029) and none of minerals originating from or being processed in a foreign country of concern. Benchmark Mineral Intelligence estimates that the IRA reduces the capital expenditure of a U.S. cathode facility by up to 30 percent. Benchmark Mineral Intelligence, "How is the post-IRA cathode landscape evolving?", 6 May 2024, source.benchmarkminerals.com/article/how-is-the-post-ira-cathode-landscape-evolving.

70. Racu and Poliscanova, *An industrial blueprint for batteries in Europe*.

71. Prices in American, European and Northeast Asian markets are similar. Chinese prices are typically reported as "Ex Works." This price includes VAT of 13 percent and internal logistics of around $100/t, which we have deducted to estimate the cost, insurance and freight (CIF) price. Prices are from the S&P Global database.

72. William Langley and Chan Ho-him, "European companies step up efforts to decouple from China," *Financial Times*, 9 June 2024, www.ft.com/content/fb448978-e4ff-4f3e-b650-13fda73f58a9.

73. Yu and Duquiatan, "China, South Korea battery-makers drive growth despite capacity regionalization"; Vinachem, "Lithium Market Forecast: Top Trends for Lithium in 2025," 9 January 2025, www.vinachem.com.vn/content/market-and-product-vnc/lithium-market-forecast-top-trends-for-lithium-in-2025.

74. One possible response to any Chinese restrictions on LFP technology is an increased focus on low-nickel NMC batteries. Low-nickel NMC cathodes can also use carbonate. Chinese LFP restrictions would therefore not necessarily change the calculus for a Ghanaian refinery.

75. Latin American countries will continue producing carbonate from their brine reserves.

76. Pedersen and Jaswal, "A tale of a looming surplus in the lithium industry."

77. Pedersen and Jaswal, "A tale of a looming surplus in the lithium industry." Unlike battery-grade chemicals, demand for technical-grade chemicals is likely to increase only at the rate of global economic growth. Supply of technical-grade chemicals, on the other hand, is likely to significantly increase over the coming years. Existing battery-grade refineries will be selling their surplus to non-battery manufacturers, and new battery-grade refineries will also be selling to non-battery manufacturers as they ramp up and await qualification by battery manufacturers.

78. The current mine plan entails 12 years of production. However, if the Ewoyaa lease agreement is ratified by parliament this year, production is expected to start by 2027. Given construction of refineries outside of China is currently expected to take at least 3 to 4 years once an investment decision is reached, we assumed production will not start until 2030.

79. Combining different sources of feedstock would likely make it challenging for the refinery to sell to cathode suppliers for "Tier 1" cell manufacturers. As of February 2025, Tier 1 manufacturers included BYD, CATL, LG Energy Solution, Panasonic and Tesla. These manufacturers produce large volumes of high-quality cells. Cathode suppliers to Tier 1 manufacturers require lithium chemicals of particularly high purity and therefore pay the highest prices.

80. As of January 2025, Ghana's risk premium is estimated to be around 12 percent compared to 0–1 percent in, for example, Australia, Austria, Canada, Finland, South Korea and the U.S. See: Aswath Damodaran, "Country Default Spreads and Risk Premiums," updated 9 January 2025, pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html.

81. World Bank, World Integrated Trade Solution (WITS), "Ghana sulphuric acid; oleum imports by country in 2022," accessed 21 March 2025, wits.worldbank.org/trade/comtrade/en/country/GHA/year/2022/tradeflow/Imports/partner/ALL/product/280700; World Bank, WITS, "Ghana Disodium carbonate imports by country in 2023," accessed 21 March 2025, wits.worldbank.org/trade/comtrade/en/country/GHA/year/2023/tradeflow/Imports/partner/ALL/product/283620.

82. Doris Dokua Sasu, "Electricity prices in Ghana as of March 2024, by user group," Statista, 9 January 2025, www.statista.com/statistics/1310775/electricity-prices-in-ghana-by-user-group/; Statista, "Commercial electricity prices worldwide 2024, by select country," 9 December 2024, www.statista.com/statistics/1369634/business-electricity-price-worldwide-in-selected-countries/. While a need for new power generation capacity could worsen the economics of a refinery, it could provide an opportunity to use the refinery as an anchor for capacity that also serves households and other businesses.

83. Papa Daouda Diene, David Manley, Silas Olan'g and Thomas Scurfield, *Triple Win: How Mining Can Benefit Africa's Citizens, Their Environment and the Energy Transition* (NRGI, 2022), resourcegovernance.org/publications/triple-win-mining-africa-environment-energy-transition.

84. The Energy for Growth ranks Ghana as joint ninth for "readiness" for EV adoption in Africa. Rose Mutiso, Hamna Tariq, Daniel Johansson, June Lukuyu, Audrey Zenner, Murefu Barasa, Michael Dioha and Joel Nana, "Africa EV Readiness and Impact Index," Energy for Growth Hub, accessed 21 March 2025, energyforgrowth.org/article/africa-ev-readiness-and-impact-index-2024-desktop/; Ghana Ministry of Transport, *National Electric Vehicle Policy* (2023), www.mot.gov.gh/files/resources/National_Electric_Vehicle_Policy.pdf.

85. Luvenie Alison, "Top 10 electric motorcycle manufacturers in Africa," BENLG, 26 June 2024, www.benlg.com/top-10-electric-motorcycle-manufacturers-in-africa/.

86. See for example: Energia Africa, "Ghana: Launch of the first 100% electric vehicle," 23 July 2021, greenenergyafricasummit.com/articles/ghana-launch-of-the-first-100-electric-vehicl.

87. Chinese prices are reported as "Ex Works." However, this includes VAT of 13 percent and internal logistics of around $100/t. We deducted these costs to estimate the CIF price.

88. Our model predicts a slightly lower spodumene concentrate price than the actual price. This suggests Chinese refineries have even lower costs than we assumed, possibly because current overcapacity means that they are treating their capital expenditure as a sunk cost.

89. It is unlikely that Barari will own and operate the refinery. Like many value-addition facilities, lithium refineries require know-how that a mining company is unlikely to have.

90. NRGI, "NRGI's Lithium Mining Tax Model for Ghana."

91. In 2017, Wood Mackenzie found that four out of five mining projects are over budget by an average of 43 percent; an EY study of large mining projects in 2021 found an average cost overrun of 39 percent. See: Mark Kuvshinikov, Piotr Pikul and Robert Samek, "Getting big mining projects right: Lessons from (and for) the industry," Wood Mackenzie, 8 February 2017, www.mckinsey.com/industries/metals-and-mining/our-insights/getting-big-mining-projects-right-lessons-from-and-for-the-industry; EY, *How rethinking project management can boost mining's capital productivity* (2021), assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/mining-metals/ey-how-better-project-management-can-boost-minings-capital-productivity-final.pdf?download.

92. The Ewoyaa project cost is the All in Sustaining Cost net of the royalty paid to government assumed in Atlantic Lithium's feasibility study.

93. Figure 11 also shows that, without government intervention, exporting spodumene concentrate to the ROW would generate less value for Ghana than exporting spodumene concentrate to China. This is because the high cost of ROW refineries means that they will need to pay a significantly lower price for concentrate to break even. This has two main implications. First, it increases the likelihood that the concentrate that Barari sells to Piedmont will be underpriced (in addition to the transfer mispricing risk resulting from Piedmont holding a 40 percent stake in Ewoyaa). It therefore reinforces the importance of the government establishing a clear process for pricing spodumene concentrate. It could specify in Barari's lease agreement that prices will be based on a pricing benchmark, such as the Spodumene Concentrate Index (CIF China). Second, the government should account for the identity of the buyer and the potential implications for their ability to pay the market price when reviewing any future offtake agreements of Barari or other spodumene concentrate exporters.

94. Government revenue from mining in 2022 was ₵7,446 million or $900 million (at the average exchange rate for 2022 reported by the Bank of Ghana). The Mineral Income Investment Fund made a profit in 2023 of ₵409 million or $37 million (at the average exchange rate for 2023 reported by the Bank of Ghana). See: Ghana Extractive Industries Transparency Initiative, *GHEITI report on mining sector 2021-2022* (2024), www.gheiti.gov.gh/site/index.php?option=com_phocadownload&view=category&download=548:2021-2022-gheiti-mining-report&id=82:2022&Itemid=54; Minerals Income Investment Fund, "MIIF records 100% increase in profits in 2023," 2023, miif.gov.gh/miif-records-100-increase-in-profits-in-2023/.

95. $300 million is an underestimate because, for simplification purposes, we only modelled the difference in government revenue from the Ewoyaa project as it is currently envisaged in the feasibility study. However, to supply a 20-year refinery, either Ewoyaa will have to operate for longer or other lithium projects will need to be developed. In either of these scenarios, the government will lose additional revenue.

96. In practice, government revenues are likely to be lower than modeled because modeled project economics tend to be simplified, perfect administration of the fiscal regime is assumed, and tax treaties or contracts may mean statutory rates do not apply.

97. NRGI, "NRGI's Lithium Mining Tax Model for Ghana."

98. Barari is even more likely to require tax concessions if it does not have a stake in the refinery. It will then have even less incentive to offer the refinery its spodumene concentrate for less than the market price.

99. The government budgeted, in 2024, ₵5,778 million or $408 million (at the average exchange rate for 2024 reported by the Bank of Ghana) for basic education. UNICEF, *Education Budget Brief 2024*.

100. The government budgeted, in 2024, ₵5,054 or $356 million (at the average exchange rate for 2024 reported by the Bank of Ghana). See: The Peasant Farmers Association of Ghana, "Post-Budget Analysis of the 2024 Budget Statement and Economic Policy of Ghana and its Implications for Agricultural Development in Ghana," 28 November 2023, peasantfarmers.com/upload/POST%20BUDGET%20ANALYSIS-%20PFAG%202024_budget_final.pdf.

101. The procurement of goods and services usually amounts to 50–70 percent of all money spent by mining companies in producing countries. Local procurement by mine operators is therefore also a considerable opportunity for countries to increase government revenue, create jobs and develop new sectors. See: Diene et al., *Triple Win*; Jeff Geipel, "Go backward not forward? A plea for caution on dogmatic approaches to value-addition for green transition minerals," London School of Economics, 28 February 2025, blogs.lse.ac.uk/internationaldevelopment/2025/02/28/go-backward-not-forward-a-plea-for-caution-on-dogmatic-approaches-to-value-addition-for-green-transition-minerals/.

102. Theo Acheampong, "Economic and Social Impact Analyses of the Ghana Integrated Aluminium Industry (IAI) Project," 2–3 October 2024, giadec.com/wp-content/uploads/2024/12/Economic-Social-Impact-Analyses-of-the-Ghana-Integrated-Aluminium-Industry.pdf.

103. iLiMarkets.

104. Ghana's aluminum value chain ambitions, for example, would require almost all the country's hydropower capacity. This would likely increase electricity costs for other businesses and households if no other new competitively priced electricity capacity comes online. See: Theophilus Acheampong and Matthew Tyce, "Navigating the energy transition and industrial decarbonisation: Ghana's latest bid to develop an integrated bauxite-to-aluminium industry," *Energy Research & Social Science* 107 (2024), www.sciencedirect.com/science/article/pii/S2214629623003973.

105. Ghana Ministry of Energy, *Energy Sector Recovery Program* (2019), rise.esmap.org/data/files/library/ghana/Electricity%20Access/Ghana_Energy%20sector%20recovery%20program_2019.pdf. There is a growing likelihood of the industrial use of gas increasing the price for the power sector. Increased gas demand for power and non-power uses, production challenges on some upstream fields and frequent scheduled maintenance on gas facilities mean gas supply deficits are becoming more frequent. With delays in new upstream projects and an uncertain investment climate due to the global energy transition, it is uncertain whether new supply will come online to address this challenge. See: Ghana Energy Commission, *2025 Energy Outlook for Ghana: Demand and Supply Outlook* (2024), www.energycom.gov.gh/index.php/planning/sub-codes?download=723:energy-outlook-for-ghana-2025.

106. A refinery requires around 40,000 liters of water to produce 1t of chemical. Average water consumption per person in Ghana is around 8,879 liters a year based on annual municipal consumption of around 300 billion liters (in 2020) and a population of 33,787,914 (in 2023). Ekumfi has a population of 56,741 (in 2021). See: Sasu, "Total water withdrawal in Ghana 2020, by sector"; World Bank, "Ghana"; Ghana Statistical Service, *Ghana 2021 Population and Housing Census General Report Volume 3A: Population of Regions and Districts* (2021), statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021%20PHC%20General%20Report%20Vol%203A_Population%20of%20Regions%20and%20Districts_181121.pdf.

107. Prince Adu-Owusu, "GWL warns of severe water supply challenges in Cape Coast and Elmina due to 'galamsey' in River Pra," *Joy Online*, 30 August 2024, www.myjoyonline.com/gwl-warns-of-severe-water-supply-challenges-in-cape-coast-and-elmina-due-to-galamsey-in-river-pra/.

108. Fernando M. Aragón and Juan Pablo Rud, "Polluting Industries and Agricultural Productivity: Evidence from Mining in Ghana," *The Economic Journal* 126, no. 597 (2015): 1980–2011, onlinelibrary.wiley.com/doi/abs/10.1111/ecoj.12244.

109. Scurfield, Salomon and Olan'g, *Six Keys to Unlocking Equitable Value Addition in Mining*.

110. iLiMarkets.

111. Alkemy Capital Investments, *First Lithium Sulphate Plant Study* (2023), www.londonstockexchange.com/news-article/ALK/first-lithium-sulphate-plant-study/16095046.

112. In theory, refineries that fully convert spodumene concentrate to carbonate or hydroxide could take on some additional (dry) sulfate from elsewhere. However, it remains to be seen to what extent this happens, as it would entail refineries operating two processes.

113. Godfrey Marawanyika, "Sinomine Says It Will Build Lithium Sulfate Plant in Zimbabwe," Bloomberg UK, 30 September 2024, www.bloomberg.com/news/articles/2024-09-30/sinomine-says-it-will-build-lithium-sulfate-plant-in-zimbabwe.

114. Public information on the amount of revenue that the government is collecting from exploration activities is unavailable. However, the amount is unlikely to be significant—particularly compared to the government revenue and other benefits that will be lost in the longer term because of fewer new mines being developed.

115. Pilbara Minerals commenced a pilot project with Calix, a technology company, in Australia in 2023. After pausing due to the challenging market conditions, the companies have recently recommenced development of the pilot plant. See: Pilbara Minerals, "Construction on Mid-Stream Demonstration Plant Project to resume," 13 February 2025, pls.com/news-stories/mid-stream-restarts/.

116. The Ewoyaa project has already caused problems for the local community and its biodiversity. See: Abigail Teye, "The environmental cost of Ghana's proposed lithium mining on biodiversity," Gh Extractives, 13 March 2025, ghextractives.com/the-environmental-cost-of-ghanas-proposed-lithium-mining-on-biodiversity/.

117. Legal Instrument (LI) 2462.

118. Ghana Web, "A Rocha Ghana, six others sue government over L.I. 2462, demand repeal," 20 September 2024, www.ghanaweb.com/GhanaHomePage/NewsArchive/A-Rocha-Ghana-six-others-sue-government-over-L-I-2462-demand-repeal-1951723.

119. Timothy Ngnenbe, "Revoke L.I on mining in forest reserves with immediate effect — GAAS," *Graphic Online*, 27 September 2024, www.graphic.com.gh/news/general-news/ghana-news-revoke-l-i-on-mining-in-forest-reserves-with-immediate-effect-gaas.html; Ghana Web, "A Rocha Ghana."

120. Emmanuel Ebo Hawkson, "Govt presents L.I. revoking mining in forest reserves to Parliament," *Graphic Online*, 14 October 2024, www.graphic.com.gh/news/general-news/ghana-news-govt-initiates-forest-mining-law-revocation.html.

121. To create the incentive for the government to establish and enforce no-go zones, development partners and other climate finance providers should offer conservation financing. Governments often undervalue the environment due to pressure to prioritize short-term revenue and jobs. Conservation financing—building on lessons from projects such as the Central African Forest Initiative through which the U.S., South Korean and several European governments provide financing to Gabon to maintain its forests—could change this calculus. See: Central African Forest Initiative, "Gabon," accessed 21 March 2025, www.cafi.org/countries/gabon.

122. United Nations, "The UN Secretary-General's Panel on Critical Energy Transition Minerals," accessed 21 March 2025, https://www.un.org/en/climatechange/critical-minerals.

123. These issues were raised by local communities and civil society at a NRGI stakeholder engagement on Transition Minerals and Environmental Legislation in Accra, Ghana on 5 December 2024.

124. Companies could contribute to a basket fund, and a third-party or multi-stakeholder panel would oversee the hiring of the feasibility study contractor from a roster of independent, accredited consultants. An example of this scheme in relation to environmental assessments is the Environmental Service of Salzburg (ESS), which is a joint initiative of the local government of Salzburg, the Chamber of Commerce of Salzburg, the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management and the Salzburg utility provider. The ESS maintains and selects from a roster of independent, accredited consultants to perform environmental consultancies. See: Leila Kazemi, Perrine Toledano and Tehtena Mebratu-Tsegaye, "Tackling the EIA Impact Gap: Addressing Political Economy Realities to Bring Actual Practice Closer to Best Practice," in Jonathan Hobbs and Diego Juffe Bignoli (eds.), *Impact Assessment for Corridors: From Infrastructure to Development Corridors* (The Development Corridors Partnership, 2022), 53–69, developmentcorridors.org/wp-content/uploads/2023/06/Chapter-03-1.pdf.

125. Mercedes-Benz, "Audited raw materials and less cobalt in future battery cells," updated 16 July 2023, group.mercedes-benz.com/responsibility/sustainability/supply-chains/future-battery-cell-audited-raw-materials-less-cobalt.html; Initiative for Responsible Mining Assurance, home page, accessed 21 March 2025, responsiblemining.net/.

126. Requirement 6.4 of the EITI Standard, for example, encourages disclosure of ESIAs. EITI, *EITI requirement 6.4 – Environmental impact of extractive activities: Guidance Note* (2021), eiti.org/sites/default/files/2022-01/en_eiti_gn_6.4.pdf.

127. The Scarab, "What is 'State Enchantment'?," 31 January 2024, brightsimons.com/2024/01/what-is-state-enchantment/.

128. The Scarab, "The strange case of Ghana 'first' gold refinery & its 'broke' investor," 11 August 2024, brightsimons.com/2024/08/11/the-strange-case-of-ghana-first-gold-refinery-its-broke-investor/.

129. Scurfield, Salomon and Olan'g, *Six Keys to Unlocking Equitable Value Addition in Mining;* NRGI, *Diagnosing Corruption in the Extractive Sector: A Tool for Research and Action Annex – Step 4 Research Guide: Socio-Environmental Impacts in the Mining Sector* (2023), anticorruptiontool.resourcegovernance.org/wp-content/uploads/2023/12/NRGI_DiagnosingCorruption_Module_Socio-Environmental-.pdf.

130. Damodaran, "Damodaran Online."

131. We estimated the capital intensity of a larger refinery based on the capital expenditure escalation formula typically used for this purpose: $K2 = K1 * (Q2/Q1)^{0.6}$ where K = capital and Q = capacity.

132. The Ewoyaa project cost is the All in Sustaining Cost net of the royalty paid to government assumed in Atlantic Lithium's feasibility study.

About the authors

Thomas Scurfield is an Africa senior economic analyst at the Natural Resource Governance Institute (NRGI). David Sefa Adjei is an economic analyst for NRGI's Ghana program.

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The Natural Resource Governance Institute is an independent, non-profit organization that supports informed, inclusive decision-making about natural resources and the energy transition. We partner with reformers in government and civil society to design and implement just policies based on evidence and the priorities of citizens in resource-rich developing countries. Learn more at **www.resourcegovernance.org**



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