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Industrial Technology

Implications of an LFP Resurgence

Lithium Americas Corp.

(LAC-TSX, -NYSE; $16.00 Target; Buy Rec.)

Lithium Americas (Argentina) Corp.

(LAAC-TSX, -NYSE; $14.50 Target; Buy Rec.)

Nano One Materials Inc.

(NANO-TSX; Not Rated)

Unless otherwise denoted, all figures shown in US$

Event:

With lithium prices having corrected over the past 12 months reflecting greater supply from low grade Chinese lepidolite and African spodumene, and slower demand growth as Western OEMs recalibrate their BEV rollout plans amid challenge auto sales, we are drawing attention to emerging trends that investors should be aware of as they contemplate timing of their re-investing in the battery supply chain.

One such trend is the longer than previously expected presence of LFP battery chemistry in the battery supply chain. This report frames the adjustment that investors will need to navigate as lithium prices rise from what appears to be the start of a bottoming period.

To keep this report concise, we outline three implications, namely: the lithium carbonate vs lithium hydroxide mix, the need for suitable phosphate and lastly, opportunities in cathode processing. We leave the discussion of particular investment opportunities related to these implications to subsequent reports.

Highlights:

LFP Technology - A Brief History

The end of licensing restrictions has opened the door for China-based battery and EV makers to explore an export policy to serve western markets, and Western OEMS are also able to now include the technology in their vehicle plans. Cost sensitive applications, in particular, are likely to see an increasing use of LFP cathodes, setting the stage for a bifurcation of the supply chain upstream of the cathodes.

LFP Supply Chain Outlook

We provide details of our demand modeling, which has a plug-in hybrid bias toward 2030, elaborating on the need for chemicals to feed both the LFP and high nickel portions of the lithium supply. Supply constraints will continue to cause a volatile market for prices, though the highs and lows in western markets will not be as extreme as the spot pricing in China. We foresee a higher degree of tightness in the carbonate market versus the hydroxide market.

Implications

We outline three implications that investors need to consider given a resurgence of LFP: 1. A tighter market for lithium carbonate supply given fewer and more capital intensive brine and sedimentary resources relative to lithium hydroxide supply served by hard rock mines; 2. Rising phosphoric acid demand and 3. Improvements in downstream LFP cathode materials processing, which offers a way to play the theme separate from upstream materials supply considerations.

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LFP Battery Overview

LFP Technology – A Brief History: Lithium iron phosphate (LFP) batteries were first demonstrated as a viable cathode material in 1996 by Nobel laureate John Goodenough, while working at UT Austin, for which a patent was issued in 1999. From 1997-2001 innovations developed by researchers at Hydro Quebec and University of Montreal established coating techniques that allowed LFP to be commercialized at scale, eliminating the poor electrical conductivity in the first attempts to use LFP in batteries. This led to a new patent being granted in 2001 with the first licensees (Sony and Phostech Lithium) beginning to commercialize the technology.

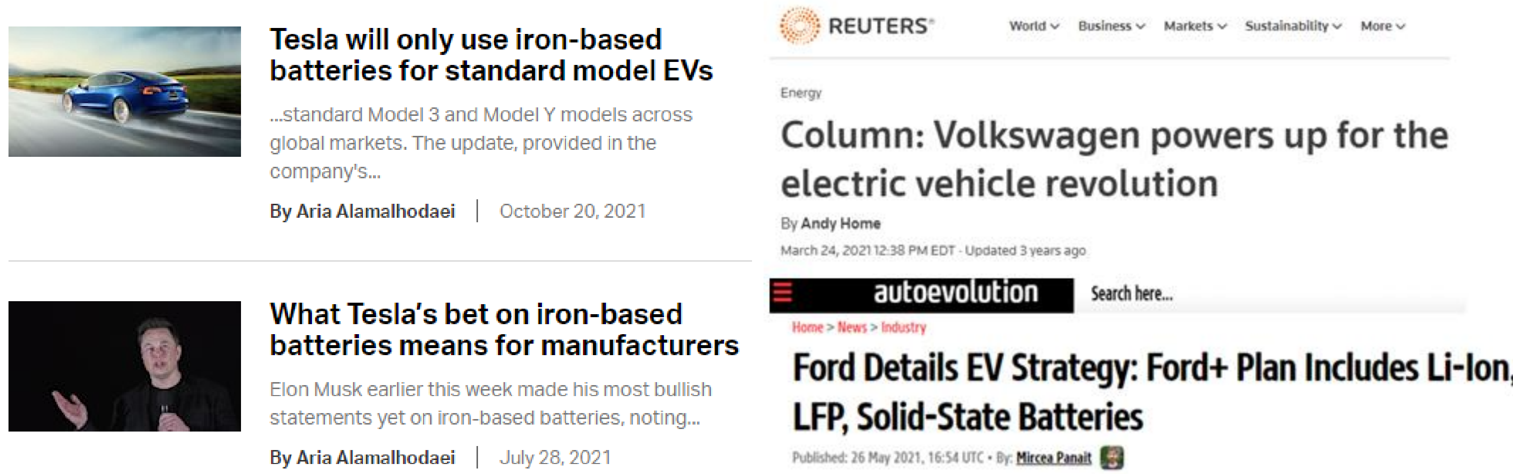
While Hydro Quebec ended up winning a patent dispute with A123 Systems, a US battery startup, which was settled in 2011, the use of LFP cathodes was pursued by every major battery producer and cathode material maker in China, including BYD and CATL. This was the result of IP rights having not been sought by the original patent issued to UT Austin and the subsequent unwillingness of Hydro Quebec to pursue litigation in China in 2011 after the settlement of the dispute with A123. The end result was that within China the LFP technology was available to be used without license, giving rise to a broad adoption of LFP within China. Some reports suggest that there was an agreement made with Chinese regulators that no litigation would be pursued so long as Chinese OEMs did not export products with the technology.

However, outside of China, IP protection on most of the major LFP patents only recently lapsed in 2022, which opened the door for western automakers to adopt the technology without having to pay any licensing fees or royalties. In anticipation of this, in late 2021 Tesla announced (July 2021 and October 2021) that its low end vehicles (standard range Model 3) would use LFP cathodes, and a few months later, Volkswagen followed suit (March 2021), and Ford in May 2021.

This lapsing of licensing has also opened the door to China battery and EV makers to explore an export policy to serve western markets, which has also recently accelerated. According to Reuters, shipments of BEV/PHEV to the EU jumped 112% in the first seven months of 2023, now accounting to 8% of all EVs sold in Europe, up from low single digits previously.

LFP In The West – Pros And Cons: The availability of license-free technology from 2022 onward certainly impacted the adoption of LFP by Western OEMs, both in terms of adoption cost and the ability to innovate the technology without licensing considerations. However, there are other advantages, both in terms of supply-chain and performance.

Figure 1: Western OEMs Announce Plans For LFP Based Batteries


Tesla will only use iron-based batteries for standard model EVs

...standard Model 3 and Model Y models across global markets. The update, provided in the company's...

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Ford Details EV Strategy: Ford+ Plan Includes Li-Ion, LFP, Solid-State Batteries

Published: 26 May 2021, 16:54 UTC • By: Mircea Panait

Source: Reuters, autoevolution.com, TechCrunch+, Tesla, Ford, VW

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Ramping up the supply chain for high-nickel batteries was hindered by the slow development of nickel sulphate supplies. Most of the recent investment for new nickel supply was in Indonesia, where high emissions levels, poor environmental impact and Chinese ownership was increasingly seen as a headwind on western efforts.

In terms of technological factors, LFP chemistries offer a number of advantages compared to high-nickel chemistries despite the lower energy density:

- **Lower cost:** The average price for LFP batteries is now below US$100/kWh more than 6% lower than NMC. In part this is the result of lower iron costs relative to nickel and cobalt. Iron and phosphate supply is more broadly available globally, serving other markets than Li-ion batteries
- **Easier thermal management:** With less stringent temperature controls required, vehicles with LFP batteries have a larger driving range in hot climates than high nickel. Although there is lower performance in cold climates
- **Better life:** LFP cathodes are more robust when subjected to regular 100% charges than high nickel
- **Lower toxicity and higher safety:** LFP does not have a thermal runaway issue like high nickel, whose internal resistance declines as temperatures rise, leading to catastrophic runaway. This is not a phenomenon possible with LFP whose internal resistance does not decline in the same fashion
- **Long cycle life:** More than 3,000 cycles typically with high nickel in the 1,000 to 2,300 cycle range. Under lab conditions, cycle life has been demonstrated out to 9,000 cycles
- **Slower capacity loss:** Leads to longer calendar life

The major disadvantage of LFP is its lower energy density of 125 to 150 Wh/kg, versus the best high nickel batteries above 300 Wh/kg. This has been offset by the chemical stability offered by LFP whose phosphate molecule has a very strong P-O bond. This means nearly all the lithium can be removed on discharge, unlike the high nickel chemistries, which would be irreversibly damaged. As a result, high nickel batteries typically have shorter lives and limits on discharge.

We expect the advantages of high recharge and higher energy density will mean high nickel batteries will have great importance for western EVs, particularly where vehicle range and recharge times are dominant features. Recall that Tesla captured the attention of many western investors (and the rest of the automaker world) by producing what is in fact a high-end vehicle that people wanted to buy. The performance, range and size were enabled by the features and innovations in its high nickel battery. Subsequently, because of the success of Tesla, other western OEMs focused on high nickel chemistries, with a strategy to compete first in the high-end part of the vehicle market.

However, for cost sensitive applications and those where range and weight are less important, we expect LFP to enjoy a large market share. This is because buyers in the mass market low and mid-range urban vehicles and commercial vehicles, are price sensitive. As a result, as we mentioned above highlighting the plans from VW, Ford and Tesla for using LFP on low range models, the dominance of high nickel cathodes in the West appears to be limited to the high-end part of the market.

LFP Supply Chain Advancing: Following the announcements by OEMs, battery and cathode makers began to announce their own plans. ICL Group, an Israeli chemicals company, announced in October 2022 an LFP cathode factory to be built in Missouri. Other US projects that have been announced include Freyr Battery's plant in Georgia, American Battery Factory's project planned for Arizona. Chinese suppliers are also attempting to take advantage of the expected demand for LFP and the impact of the US IRA: Gotion High-Tech aims to bring a LFP plant to Michigan and Ford has partnered with CATL, although the timelines continue to lengthen with the current concern over the US market for EV adoption and US regulatory oversight.

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LFP Supply Chain Outlook

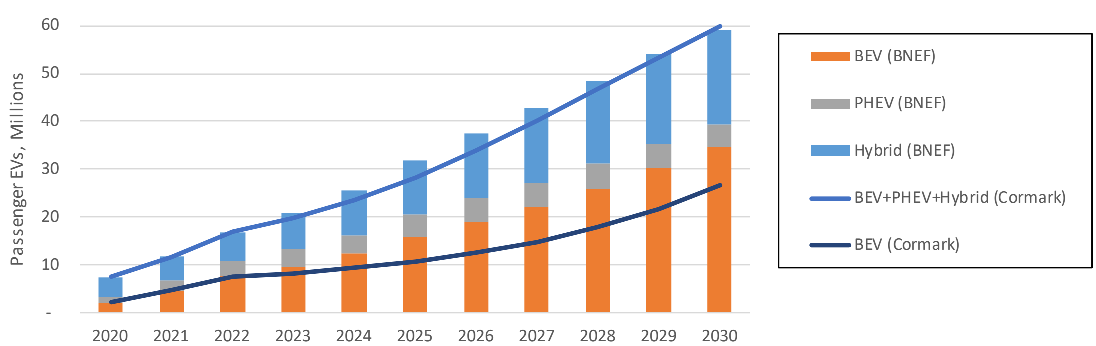
BEV/PHEV Sales Most Significant Assumption: With innovations on cell-to-battery packaging technology helping to improve energy density, as well as addition of manganese to LFP, we expect that LFP cathode batteries will have a longer time horizon than anticipated five years ago, and LFP demand will continue to rise with EV penetration. In this section, we examine the impact of LFP adoption on our cathode model and its implications on the relative demand for lithium carbonate, hydroxide and phosphates.

The single most significant driver of demand for battery materials is the penetration rate of battery use in passenger cars, with mix as a second important factor. Our forecast reaches 16.7 MM BEVs and PHEVs in 2025 as shown in Figure 2. To put this into context we have also included the breakdown of Bloomberg NEF's estimates as they are representative of many other data consultants familiar to the financial community. As shown in the figure, by 2025, BNEF models 20 MM BEVs and PHEVs, with BEVs making up nearly 16 MM of the total. Not only do we model a lower level of sales, but we also expect PHEVs to take more share, accounting for 6.2 MM of our 16.2 MM forecast. Both the penetration of electrification and the mix of vehicle type has an impact on material forecasting as we note below, because BEVs can have 30 to 90 kWh of batteries per vehicles (whereas PHEVs are typically below 30 kWh/ vehicle) though even these sizes are expected to evolve.

For the consumer, EV prices will dictate buying patterns. For OEMs, however, the generation of credits or average fuel economy to comply with regulations will play a crucial role in determining the production levels of each class of vehicles and therefore the mix between BEVs, plug-in EVs and hybrids. ***Note that in Figure 2 our forecast for xEVs totals 60 MM in 2030 versus 59MM from BNEF, with BEvs amounting to 26.6 MM in 2030 versus BNEF's forecast of 34.7 MM. The main reason is we expect that supply constraints of materials will necessitate the spreading around of available batteries over a larger number of vehicles to meet government emissions reductions aims.***

(Note that most long-term analyses take ICE market share in hybrids to 0 because of bans on the sale of ICEs in the 2030s. However, we are already seeing governments roll back those plans as availability of renewable fuels increases, which can have negative carbon footprints. Clearly, while the ICE is declining market share rapidly, it is far from dead. These differing assumptions account for the difference between our forecast and others.)

Figure 2: EV Sales Forecast



Source: Cormark Securities Inc., Bloomberg NEF

As shown in Figure 3, we convert these xEV forecasts into GWh of batteries, by applying average battery pack sizes for BEVs (51 kWh in 2023 ramping to 60 kWh in 2030), PHEVs (24 kWh) and ICE hybrids (10kWh). Although in Figure 2 total xEVs are of a similar level by 2030, we forecast 2.5 TWh of batteries versus BNEF's estimate of 2.8 TWh, both of which include ESS and consumer applications totalling 440 GWh. Other sources of forecasting range from the IEA at 3.5 TWh and other much more battery industry biased data providers such as McKindey, Wood Mackenzie and Benchmark Mineral Intelligence forecasting 5 to 6 TWh.

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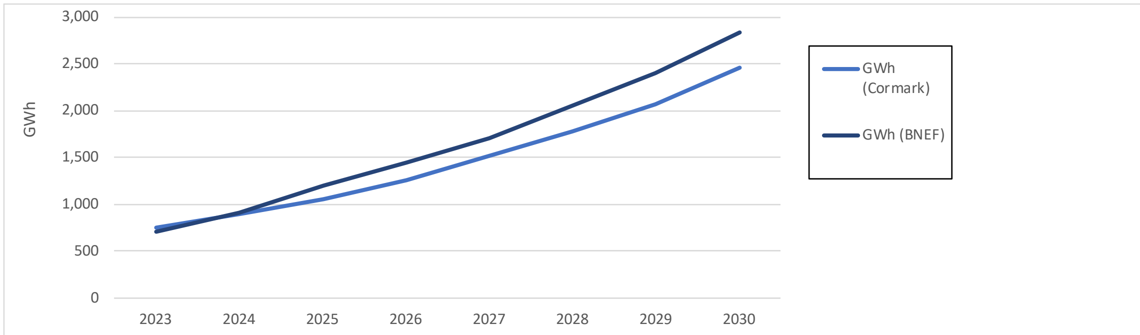
Our biggest criticism of these forecasts, all of which we have studied in detail typically use a bottom-up approach from individual automakers and battery makers, which in our experience covering the automotive space 20 years ago overestimate actual demand as competition whittles down capacity utilization of producers with commercially unsuccessful products.

Figure 3: GWh Forecast Including ESS

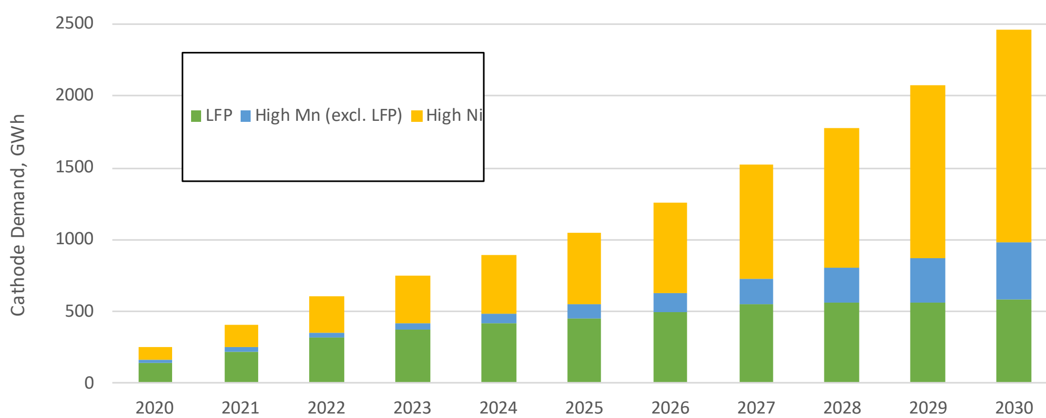


Source: Cormark Securities Inc., Bloomberg NEF

While battery mix is less important a factor for predicting lithium demand given the relative uniform amounts of lithium required from cathode type to cathode type, it is more crucial an assumption for other materials such as nickel, manganese, cobalt and phosphate. There certainly are variations even for lithium among different cathode chemistries, but also between different battery or cathode suppliers even for the same of chemistry. As a result, deriving a forecast for these materials faces another set of challenges. We find the best balance between simplicity and utility in capturing the key factors in our forecast is to divide the cathode types into LFP, high nickel and high manganese. Note that the high manganese denotes both high nickel with a large amount of manganese and chemistries with less nickel but high manganese, nonetheless.

Such a method allows for a simple way to also generate a lithium hydroxide versus lithium carbonate demand forecast as, in general, nickel-based cathodes require lithium hydroxide for processing versus LFP, which typically uses lithium carbonate.

Figure 4: Cathode Demand By Chemistry



Source: Cormark Securities Inc.

This forecast projects LFP mix to fall from more than 50% today to just under 25% in 2030, with high nickel expanding from less than 44% today to 60% by 2030. This is based both on the mix of BEVs versus PHEVs and ICE hybrids, but also on the relative importance of lower range urban vehicles, buses and lower weight commercial vehicles versus high-end, longer-range passenger vehicles. Should LFP costs continue to decline, we view our LFP forecast of 580 GWh by 2030 (up from 370 GWh today) as a low-end case, with upside to 800 GWh by the end of the decade, particularly if the ESS segment's use of LFP expands.

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Implications Of LFP Resurgence

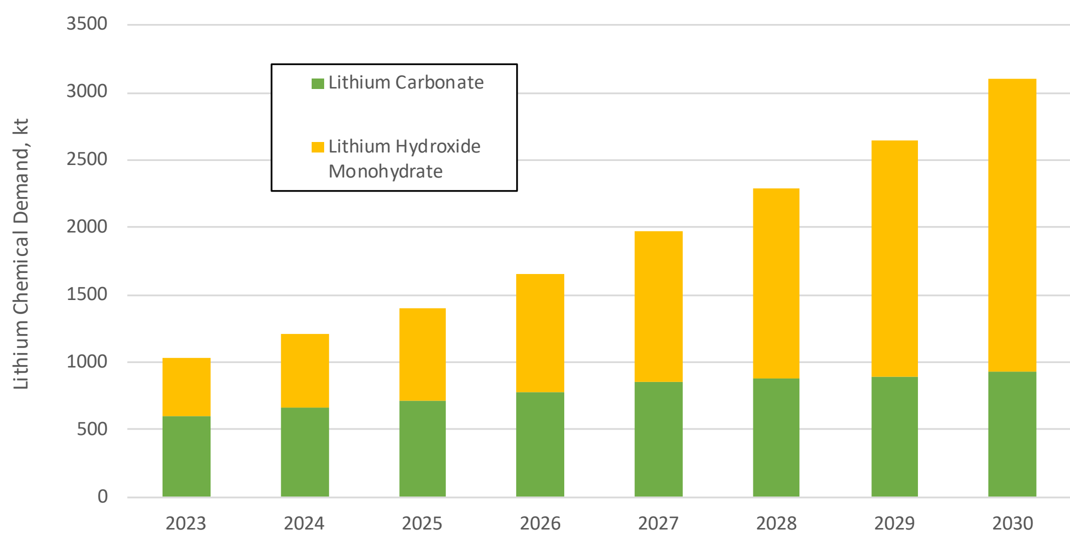
Three Ways To Play The LFP Theme: With this expectation for longer and larger demand outlook for LFP cathode materials in lithium-ion batteries, in this section we highlight three implications.

1. Relative importance of lithium oxide versus lithium carbonate demand
2. Higher phosphoric acid demand
3. Improvements in downstream LFP cathode materials processing

Lithium Hydroxide Supply Versus Lithium Carbonate Supply Chain: The biggest impact that LFP resurgence will have in our view is keeping the brine/sedimentary-to-lithium carbonate supply chain in deficit over the next decade. This is a stark difference to the hard rock/spodumene-to-lithium hydroxide monohydrate supply chain. This position can be elaborated by considering the demand profile implied by our cathode chemistry forecast relative to the supply outlook.

In Figure 5, we use our cathode chemistry forecast shown in Figure 4 to establish demand for lithium carbonate and lithium hydroxide monohydrate, assuming the high nickel and high Mn chemistries require lithium hydroxide. (This requirement stems from diffusion kinetics in the kilns used to produce these cathodes.) The preferred feedstock for producing LFP cathode material is lithium carbonate.

Figure 5: Cathode Demand By Chemistry



Source: Cormark Securities Inc.

As expected, with a high level of annual growth anticipated for high nickel cathodes in the west, relative to LFP, the growth in lithium carbonate demand is relatively modest. However, this must be considered in the context of the supply from brine sources, whose flow sheets are best suited to produce lithium carbonate owing to less processing required.

The number of new brine projects and expansions are relatively modest. For those interested we have discussed our extensive supply model in previous notes. With fewer brine and sedimentary projects, it is possible to conceivably double supply from approximately 350 ktpa today to 700 ktpa by 2030. The hard rock mines producing concentrate for LiOH, however, could be expanded 3x from 450 ktpa today to over 1.2 MM tpa by 2030. The path to get to the 2030 level, however, is key. In Figure 6 where we compare supply and demand of the hydroxide and carbonate markets separately, we see a starkly different outlook.

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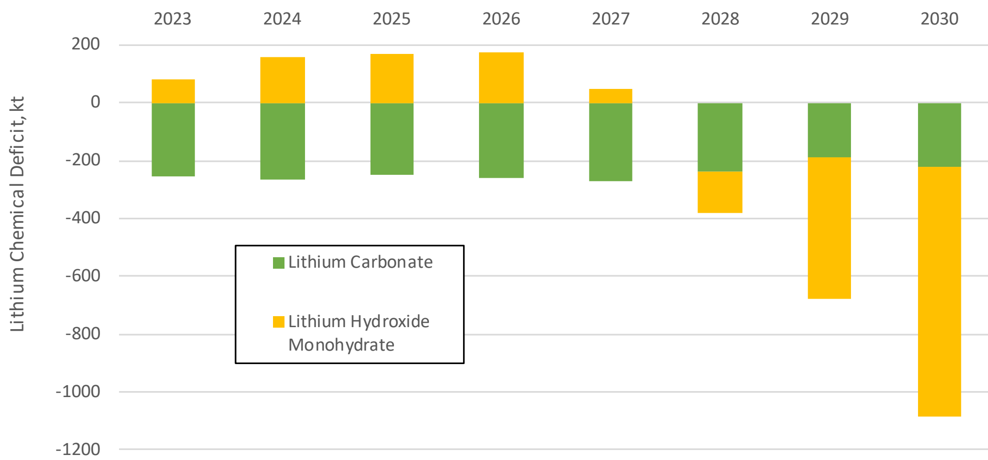
Figure 6: Carbonate Versus Hydroxide Defecit

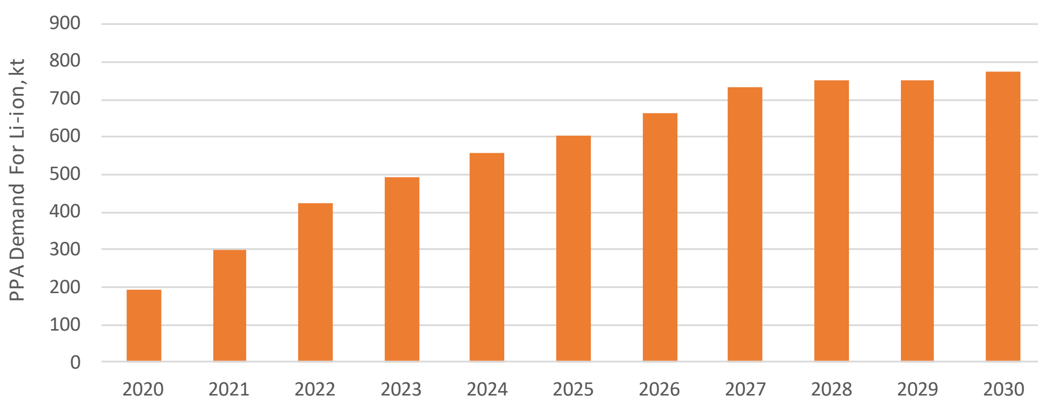


Source: Cormark Securities Inc.

While the hydroxide market is in oversupply today given the relatively slower roll out from western OEMs using high nickel batteries, the market for carbonate is relatively tight and should remain so this decade as brine projects are less numerous and their construction and ramp up more complex and lengthy. We need to caution investors that these forecasts are subject to many assumptions from vehicle and cathode mix to construction and ramp up outlooks that are highly likely to change over the decade.

How to play this implication? A focus on brine operations rather than hard rock is one obvious way to play this theme. Projects like Lithium Argentina's (LAAC-TSX,-NYSE) Cauchari Olaroz, which is ramping up Phase 1, along with its Pastos Grandes collaboration with Ganfeng Lithium, should enjoy a stronger demand outlook. This is also true of Lithium America's (LAC-TSX,-NYSE) Thacker Pass project currently in construction in Nevada, and other nearby sedimentary plays in the region. See our notes for more insight into these projects. (LAC October, 2023; LAAC: January 25, 2024.)

Figure 7: High Purity Phosphoric Acid



Source: Cormark Securities Inc.

Phosphoric Acid Supply: The LFP forecast shown in Figure 4 translates to a demand increase for phosphate chemicals (high purity phosphate – PPA: H_3PO_4) which would increase to 774 kt annually by 2030, with the steepest growth in the middle part of this decade, with slowing growth as 2030 is approaching. Note that this is based on typical usage of 2.2 kg of LFP cathode per kWh of battery.

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In comparison to phosphate producers and developers who have demand forecasts 2x to 3x larger, we note that they have relied on xEV forecasts skewed to BEVs (above 35 MM vehicles vs our 26.6 MM forecast), higher LFP penetration (40% versus our 24%) and greater kWh per vehicle. While such a scenario could play out, we point to slowing demand growth this year over 2023 and actual battery plant and vehicle models outlook. This suggests our assumptions are closer to the mark, especially when considering LFP is more likely to go into lower range vehicles suggesting a kWh/ vehicle assumption should go down on average as LFP wins market share. The developers also tend to include LFP penetration into the consumer electronics, telecom, large power storage, machinery and military markets to a higher degree than we have forecast.

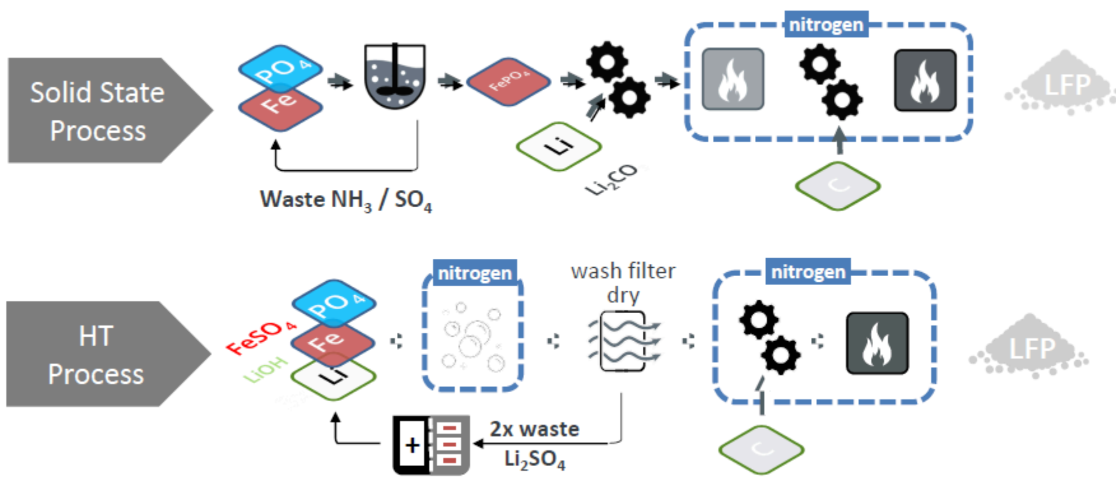
While this suggests that investors can play the phosphate producers, we view the opportunity as having significantly more risk than those associated with either lithium producers or downstream processors, such as NanoOne (NANO-TSX) (see next section). The reason is simply that the supply picture is very challenging to assess relative to the demand picture that as we note above is subject to a high degree of pure BEV penetration assumption, which is not currently playing out.

How to play this implication? In a separate report published in conjunction with this one (HERE), we provide insight into producers of phosphate, which could offer exposure to this implication.

Downstream Processing Improvements: We had the opportunity in autumn 2023 and again in January 2024 to tour Nano One's Montreal facility, where the company is converting the Candiac facility to its proprietary One Pot LFP process. In discussing this project, management provided a detailed review of the LFP cathode material process, which we show in Figure 8.

The solid-state process is widely deployed in China, producing medium to high quality LFP materials at a mid-point cost. However, not only does it produce a substantial amount of sulfate waste, the availability of iron phosphate benefits from its being a by-product of the titanium supply industry for pigments. The hydrothermal process produces high quality material, but its capex and opex are high, and it produces a large amount of lithium waste.

Figure 8: LFP Process Comparison



Source: Nano One Inc.

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How to play this implication? We expect that the high level of waste and energy intensive processes will lead to innovation in the LFP cathode processing. As shown in Figure 9, Nano One's process mixes lower cost feedstocks directly in an aqueous solution, which is then dried and kiln-fired. As a result, there is no iron phosphate precursor required, and the waste and number of steps are reduced significantly.

Figure 9: Nano One LFP Process

Source: Nano One Inc.

NanoOne is targeting production at its 25,000 tpa commercial LFP plant in 2027, with a longer-term plan to scale to 50 to 100 ktpa over 8 lines.

As Nano One has a patented and scalable process that has a low environmental footprint and low cost of production, we believe investors can play the LFP resurgence theme with an investment in Nano One. We expect to discuss this opportunity in more detail in subsequent reports.

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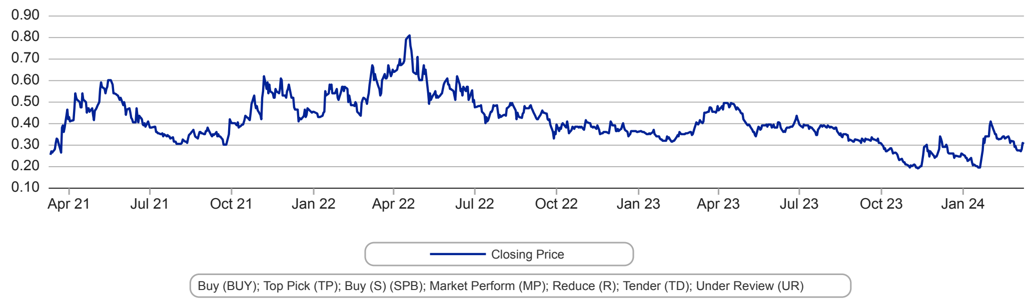
Updated March 11, 2024
*Information updated monthly on or about the 5th of each month

Arianne Phosphate Inc. Rating History as of 03/08/2024



Lithium Americas (Argentina) Corp. Rating History as of 03/08/2024

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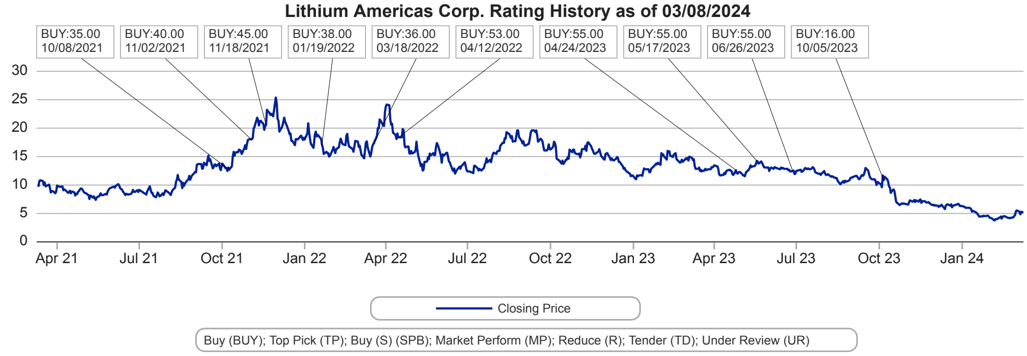

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The analyst viewed the material operations of Lithium Americas Corp..
The company paid for certain travel expenses related to a site visit by the analyst.