BATTERY MATERIALS REVIEW

Volume 5 Issue 2 9 February 2022

News & analysis of the international battery materials markets batterymaterialsreview.com

DATA
EVs and Batteries: The Year in Review 5

FINANCING
Better start to the year in 2022 15

NEWS & VIEWS
Tesla won't launch any new models soon 18

ASSET ALLOCATION
Stick with lithium but focus on explorers 23

Identifying the pinch points in the LFP supply chain

The magnitude of the growth in adoption of LFP batteries in 2021 caught many in the industry by surprise.

But certainly now LFP batteries are accepted as a core mass market battery chemistry. Even despite that, when one asks about the supply chain, most people assume that, because the raw materials for LFP are based on iron and phosphate, two very common materials, there will be no problem.

But since most industry participants suggested there would be no problem with other battery raw materials, we felt it behoved us to check out the supply chain in more detail.

And - what a shock - a closer look at the LFP supply chain indicates to us that there may very well be raw material supply chain issues to come for LFP. Read on for more details.

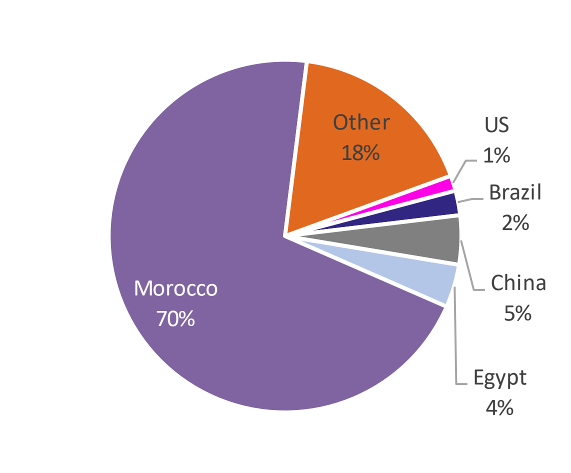
Continued overleaf

Focus...Pinch points in the LFP supply chain

How is LFP manufactured?

Before we discuss pinch points, let's make sure we understand the LFP supply chain. It's actually quite long and there are a number of moving parts.

Global phosphate rock reserves by country



Source: USGS

The starting point is phosphate ore, which is then processed into phosphoric acid. As with many minerals associated with the battery demand story, there doesn't on the surface appear to be a shortage of phosphate rock reserves in the world, with c.71Bt of known material (source: USGS). But it's fair to say that much of that is not suitable for production of phosphoric acid (p-acid).

There are two methods by which phosphate may be processed into p-acid; the wet process or the pyrogenic (Turner) process. To be amenable to be used in the wet process an ore (or concentrate) must boast a P2O5 grade in excess of 30%, a CaO/P2O5 ratio less than 1.6 (calcium in the form of calcium carbonate uses up acid during the refining process) and a MgO content less than 1% (MgO increases the viscosity of acid during the refining process resulting in low yields).

It's fair to say that there is a declining amount of suitable ore in the world, and a lot of ore now needs to be beneficiated to reach required specifications. The Turner process does not require such high grade ores, but it has some quite substantial issues associated with it.

The differences in the methodologies for production of phosphoric acid are substantial. The Turner process is used extensively in China and is a power-intensive and waste-intensive process. The Wet process has historically been higher cost but is used more widely in the Western World since it is a much more environmentally-acceptable process.

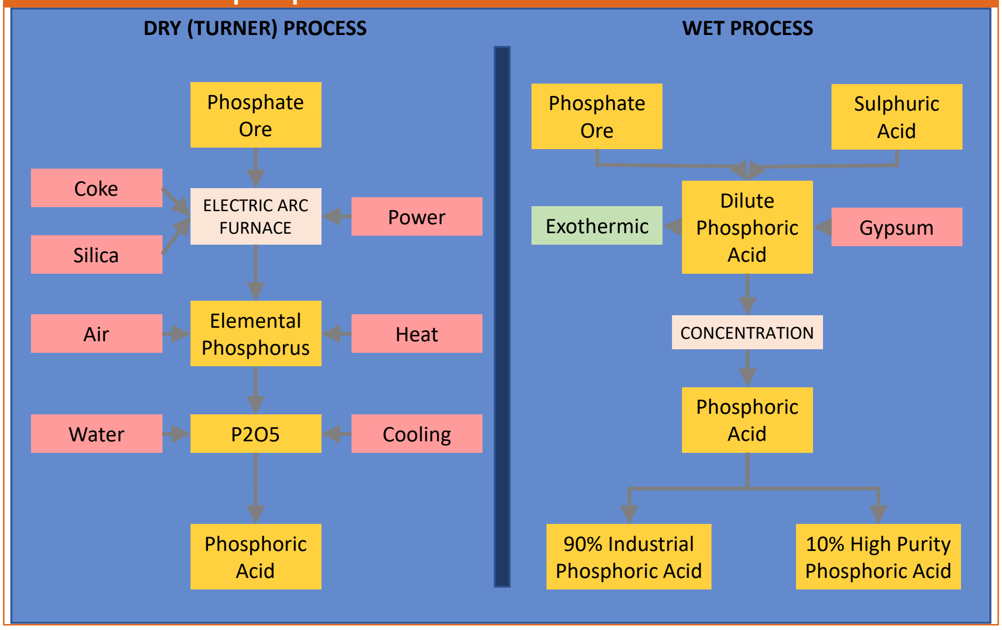
Pyrogenic vs Wet production of phosphoric acid

Under the Turner (pyrogenic) Process, phosphate ore is fed into an electric arc furnace with coke and silica, and heated at high temperature. This is a power-intensive process and results in production of elemental (yellow) phosphorus, as well as large amounts of slag (waste material). The elemental phosphorus is then heated in air to form P2O5 (plus carbon monoxide and large amounts of dust), which is then added to water and cooled to produce phosphoric acid.

This is a dirty process which is power intensive and produces large amounts of waste. It remains the primary method for phosphoric acid production in China, although some more modern plants are now utilising the Wet Process. One has to assume that, going forward, this process of manufacturing p-acid will be not be acceptable to OEMs from an ESG point of view.

In the Wet Process, phosphate ore is combined with sulphuric acid. This is an exothermic process (ie it produces heat, which may then be used for other industrial processes). The other by-product is the building material gypsum. This reaction produces a dilute form of p-acid, which must then be further concentrated. The problem with this process is that it produces a much smaller amount of purified phosphoric acid (c.10% vs 100% for the Turner Process). But it is considerably cleaner and produces re-usable heat

Process chains for phosphoric acid manufacture



Source: BM Review

Focus...Pinch points in the LFP supply chain...

and gypsum. The p-acid produced which is not suitable for LFP manufacture can be used to make fertilisers or for other industrial applications.

The p-acid produced by both processes is in aqueous form and is expensive to move, hence most LFP manufacturing plants are sited close to acid plants to cut down on transportation costs.

Lithium iron phosphate manufacturing

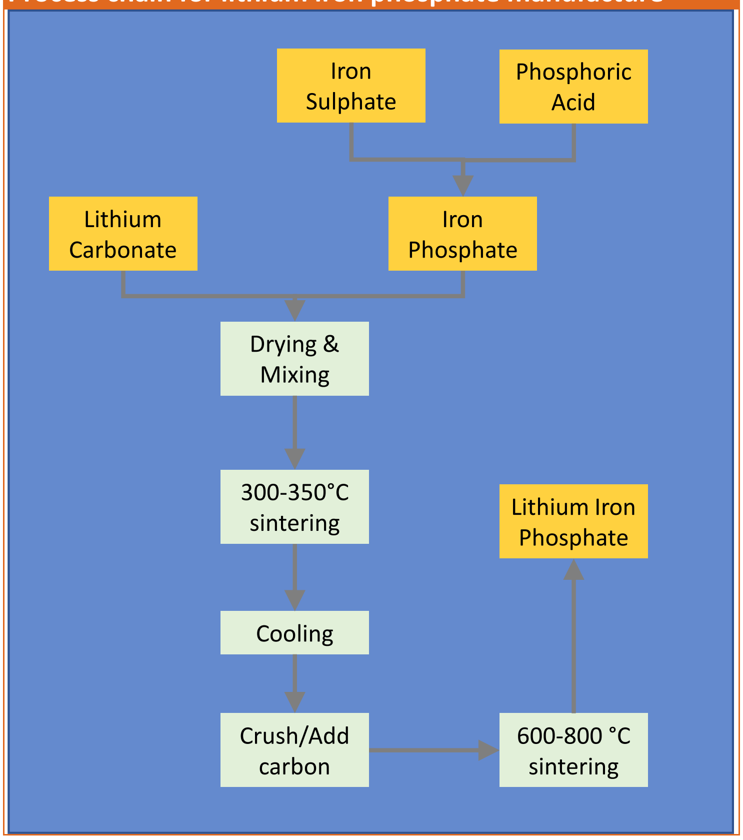
The next stage is for p-acid to be combined with iron sulphate. In the West, iron sulphate is generally a by product of steel production (it is produced during the cleaning process for steel, when sulphuric acid is used to clean the surface of steel). In China it is generally a by-product of ilmenite smelting to form TiO_2.

The iron sulphate is combined with the phosphoric acid to form iron phosphate which, in turn, is reacted with lithium carbonate (or hydroxide) in an Electric Arc Furnace to produce lithium iron phosphate. Since an EAF is used, the LFP production process is relatively power-intensive, which increasingly is likely to need to come from clean sources to satisfy the ESG requirements of the auto industry. Alternatively, heat produced from Wet phosphoric acid production could be used to power the process.

There is a liquid phase method for production of LFP which is less power-intensive, but it is not so scalable and requires a different slate of raw materials, including iron nitrate and ammonium phosphate.

The LFP which is produced from this process is then suitable to be used for cathode manufacture. The production of cathode and cell is outside the scope of this study, so we will stop here with the lithium iron phosphate product, which is solid and can therefore be easily transported to an LFP cathode plant.

Process chain for lithium iron phosphate manufacture



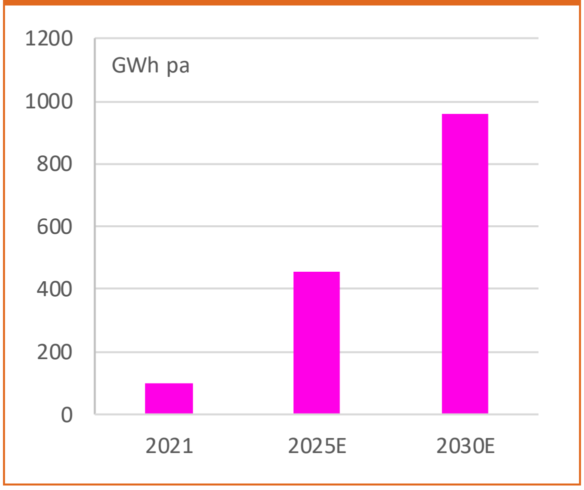
Source: BM Review

Regional and process trends

Up until now over 95% of LFP cell production has been based in China, with China dominating the upstream supply chain as well. China benefits from what, up until now, have been low cost, abundant raw materials, poor environmental governance and the ability to source iron sulphate for free.

But that raw material abundance was based on maybe 80-100 GWh per annum of LFP cell production and that number is going to ramp up hugely,

Growth in LFP cell demand



Source: BM Review estimates

and additionally LFP cell and supply chain production capacity is going to be needed outside China as well.

With ESG taking pride of place with auto producers it seems unlikely that the Turner process can continue to dominate p-acid production. It has multiple negatives; it is power (ie carbon) intensive, it causes air pollution and it generates a lot of harmful waste materials. Realistically we expect Western OEMs to insist on the Wet process going forward. But that requires c.10x more phosphate rock material to make the same amount of purified phosphoric acid, and it requires higher grade phosphate rock.

Our calculations suggest that a 20GWh battery plant would need c.2Mtpa of phosphate rock or concentrate production (at 30% P_2O_5) for the Wet Process vs c.300Ktpa of rock or concentrate (at 20% P_2O_5) for the same amount of cells using the Turner process. Based on our current forecasts we would expect c.500GWh of LFP battery demand in 2025E and 960GWh by 2030E. Even assuming some residual production using the Turner process by 2025E, that would still translate into over 50Mtpa of 30% P2O5 concentrate and nearly double that by 2030E. That's a lot of phosphate!

A large investment will also be needed in the production chain outside China as well, when LFP starts to take off. While LFP cathode can be shipped, to protect regional supply chains it makes much more sense to develop production capacity close to the regions where the cells will be needed.

While North America already has a substantial phosphate and phosphoric acid production industry (although it would need to develop more reserves), Europe is light on available capacity. North Africa (particularly Egypt and Morocco, which is the world's second-largest phosphate rock producer after China) could potentially be a viable source for the European LFP supply chain.

Identifying the pinch points

At this point we're not far enough through in our analysis of the LFP supply chain to quantify the demand (and hence shortages) at different levels of the chain, but below we list the areas where we see potential issues:

Phosphate rock: Even though most industry participants do not believe that phosphate rock may be a pinch point for the LFP production chain, with the Turner process for phosphoric acid production likely to be consigned to history, P2O5 grade in rock will become of greater importance. High grade material is substantially scarcer than low grade material, which would need to be beneficiated. In addition, material with high calcium and magnesium levels (whether able to be upgraded or not) will be unsuitable for this process. While we do not see phosphate rock as an immediate pinch point, it has the potential to become one within the next 3-4 years as demand ramps up in China and elsewhere.

Sulphuric acid: While sulphuric acid is easy to source in most developed countries, it is considerably more difficult to source in regions with scarce transportation infrastructure, unless they tend to be regions where large amounts of sulphur are produced.

Because of the cost of transport and the low value of phosphate rock, phosphoric acid plants tend to be located closed to rock production hubs, which often are not located close to sources of acid and/or sulphur. While there is no global shortage of sulphuric acid, local pinch points may exist. In fact, China is a net importer of sulphur for use in sulphuric acid. Further Wet process p-acid capacity additions can only exacerbate this issue.

High purity phosphoric acid: Given the increasing focus (due to more stringent ESG priorities) on Wet process phosphoric acid production, it is possible that high purity phosphoric acid could be a bottleneck. Given that only 10% of p-acid produced via the Wet process can economically be used for LFP production, acid facilities will need to be upscaled to produce sufficient material. This could result in overproduction of p-acid for other applications such as fertilisers.

Iron sulphate: In my view, this has the potential to be a major pinch point, even in the near-term. Ex-China, iron sulphate is likely to be sourced from polishing of steel. To supply to LFP manufacture, the shavings from that process need to be further cleaned, which comes at a cost (both capital and operating). In China, up until now, the iron sulphate has been sourced for free from the TiO2 smelting industry.

But there is an emerging problem; the quality of the iron sulphate waste material is not uniform. Up to now, because relatively small amounts were needed, the battery industry has been able to pick and choose high quality material from the waste and pay nothing for it.

In the tonnages that will be necessary going forward, that is unlikely to be possible and, indeed, there may not be enough high quality material. It is likely that (1) there will now be a cost component to sourcing the iron sulphate; and (2) that some of the iron sulphate may need to be further processed to get to the right spec.

This will have economic impacts on the production of LFP in China. Ex-China investment in iron sulphate production capacity has been impossible up to now because it is free in China. Going forward, that must change if Europe and the US are to develop viable LFP supply chains.

A 20GWh LFP cell factory will use the following in a year:

- 2.1 Mt of 30% P2O5 phosphate rock (Wet process)
- 1.9 Mt of sulphuric acid (Wet process)
- 13 Kt of lithium carbonate

Source: BM Review estimates

Many thanks to Yves Caprara who made significant contributions to the development of this article.