BATTERY MATERIALS REVIEW

2022 YEARBOOK

The state of play in Battery Materials

FEBRUARY 2023

Contents

Foreword

The battery sector is going through a period of rapid expansion, as are sectors related to it. For many years the battery materials sector has been seen as the poor cousin of the Downstream parts of the industry; dirty and irrelevant. Now it is slowly being understood by industry players and governments that under-investment in the battery raw materials industry has substantial implications for the rest of the battery industry.

This inaugural edition of the *Battery Materials Review Yearbook* presents a review of what happened in the battery raw materials sector in 2022 and draws attention to those thematics which we regularly cover in *Battery Materials Review* and which we see as important to the industry. It provides a snapshot of the key themes that are relevant in the battery raw materials at present and we hope it will be of use to both those within the raw materials industry directly and those looking into it from outside.

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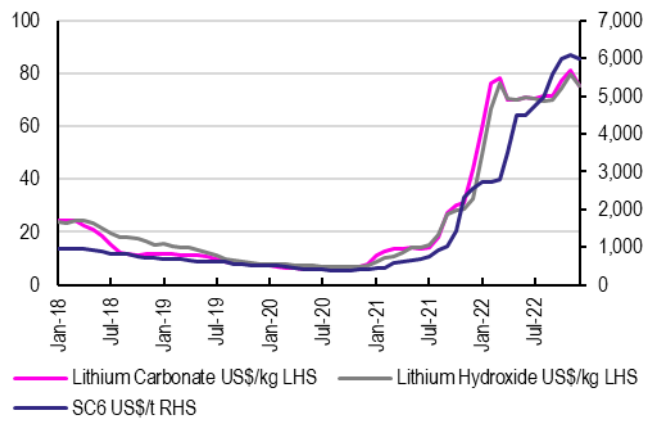
Lithium

What a year 2022 was for lithium! Written off by many commentators at the start of the year, prices were squeezed up strongly in the first quarter, took a bit of a break in the middle of the year and then were squeezed up strongly in the fourth quarter before weakening in December.

Chinese Lithium chemical prices, 2018-22



Source: BM Review, Westbeck Capital

The focus, and indeed, what many of the less-experienced analysts in the sector got wrong on their calls was supply. The industry once again failed to bring on the amount of capacity that had been planned and, as a result, the supply/demand balance was much tighter than most had expected.

While a number of commentators (us included) had expected the market to remain tight in 2022, no-one in their wildest dreams had forecast that prices would rise as far as US$80/kg for battery grade lithium carbonate or that SC6 prices on a CIF China basis would touch over US$6000/t.

While a number of the bulge bracket banks generated a lot of column inches by calling for lithium's demise, their analysts were once again left with egg on their faces as lithium prices continued to rise.

A number of factors came to the fore in 2022, and we summarise several of them below.

Complexity of adding new supply

It remains exceedingly complex to add new supply in lithium. There is a perception amongst generalist analysts that adding supply is easy. It just isn't.

Even in hard rock, the most commodity-like of all the lithium products, it's proven exceedingly complex to get new assets into production, and even to add Brownfield capacity.

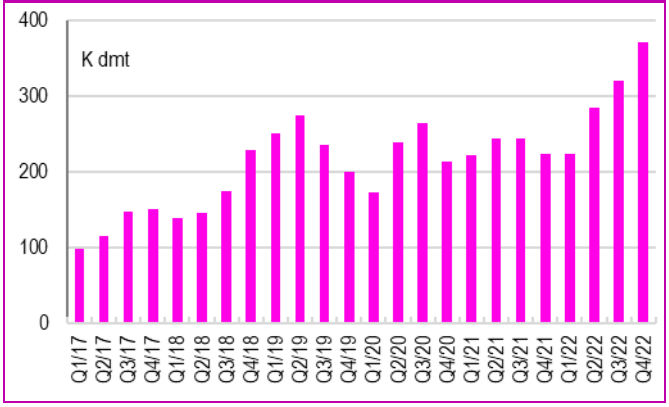
We can't name a single Spodumene Concentrate (SpodCon) development project that's come into production on time and has been anywhere close to hitting its specification and recovery parameters within the first six months of operation. Some have taken considerably longer to hit that level.

And, given that SpodCon production only relies on physical separation methodologies such as dense media separation and/or flotation to produce a concentrate, that is really saying something.

Both lithium carbonate production from brines and lithium carbonate/hydroxide production from hard rock require actual chemical techniques and have substantially more stringent purity requirements for their products, if they're to be referred to as battery grade. And that makes processing into these products considerably more difficult.

And, don't forget, when we talk about qualification into battery grade (BG) material, we're not talking about the ability to hit a certain purity level. We're talking about *the ability to hit a certain purity level on a consistent basis*. And that is what is complex, and particularly difficult when you're processing an orebody that may have chemical and physical properties that vary across of it.

SpodCon production by Australian miners, 2017-22



Source: BM Review, Company data

Lithium continued

For instance, in spodumene-rich pegmatites, it's been found that the weathered material close to surface has different physical properties than fresh material, and the material close to the contact zones on the edges of the pegmatite also has different chemical and physical properties. Hence recoveries may be impaired if a large amount of material from these zones is processed.

In lithium hydroxide conversion, the technical specifications of the material are key, particularly for high nickel cathode material where 10-20 parts per million (ppm) of iron either way can make a difference. One just needs to see how long it's taking the two new Australian lithium hydroxide (LHM) converters to ramp up to capacity to understand how complex it is.

Tianqi Lithium had first production from its Kwinana converter in May 2022; it is still a long way from hitting capacity. Albemarle had first production from its Kemerton converter just weeks later in July but it seems no nearer to hitting its actual capacity. Both plants are producing only small amounts of material as we write this in January. It's still not known when they will reach full production capacity.

It's therefore no surprise that sell-side forecasts for lithium production have been wildly inaccurate so far in this cycle, and that's meant that pricing forecasts have been wrong as a result.

Difference between Battery Grade and non-BG material

One of the factors that continues to be an issue when considering new lithium supply is the difference between battery grade (BG) and non-BG material and what is necessary to upgrade non-BG material to battery grade.

One of the factors that non-specialist analysts persist in getting wrong is that they suggest that 100% of all lithium chemical production from brine and SpodCon is battery grade. The problem is – it's NOT.

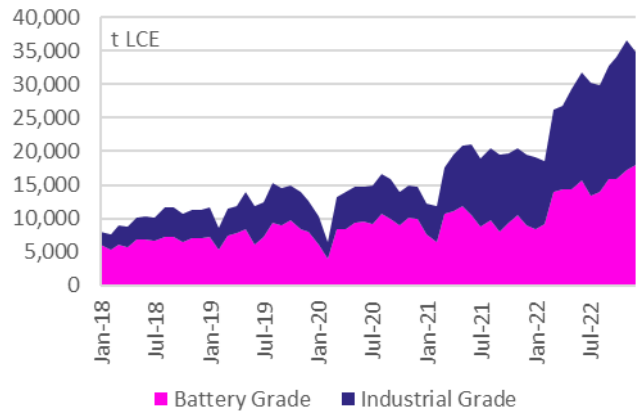
While some brine assets can produce a large proportion of BG lithium carbonate, others cannot. There is often variation over the same orebody with, for instance, Albemarle's Atacama assets in Chile producing c.20 percentage points more battery grade product on average than SQM's.

Many of the new development projects in Argentina are expected to produce only 70% (or lower) battery grade material, particularly in their first few years of operation. Non-BG material needs to be upgraded and the availability of upgrading capacity is likely to be a bottleneck in the industry. There is also a recovery impact to upgrading, with 5-15% of the lithium units lost.

A similar situation is seen in lithium hydroxide conversion from SpodCon, and from lithium carbonate. Either lithium recoveries are low or, if lithium recoveries are higher, a fair proportion of the material may not be batter grade. As noted, this is particularly prevalent for high nickel cathode formulations.

Note that a high proportion of Chinese lithium carbonate production currently is non-BG, and only c.70% of lithium production from Latin American brine sources is battery grade as well. Unless analysts are correcting for the amount of BG material in their models, they are likely overstating production…

BG and non-BG lithium carbonate output in China



Source: BM Review, Westbeck Capital, SMM

Evolution of Chinese lepidolite supply

The enlargement of the Chinese lepidolite industry has been one of the major talking points of 2022. While many commentators were in denial about its potential impact in the early part of the year, concerns about it have since become more nuanced.

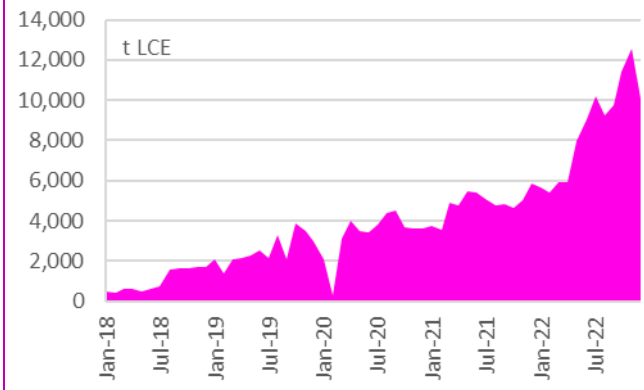
Lithium continued

While we as China specialists for most of our career would not bet against China successfully upscaling its lepidolite production substantially, we flag concerns regarding both of the points above.

ie how fast China can raise its production and also how much of the material can be battery grade?

And these are both key considerations within the context of the Chinese lepidolite supply environment.

Chinese lithium carbonate output from lepidolite



Source: BM Review, Westbeck Capital

There are obviously other substantial issues as well with lithium supply from lepidolite, with waste production a key concern. Depending on the in situ grade of the lepidolite, anywhere between ten and twenty tonnes of waste may be generated for each tonne of lithium carbonate; that's a lot of waste. And disposal of that waste is a big issue, both from an environmental and a cost standpoint.

With a high proportion of lithium carbonate production from lepidolite not attaining battery grade, upgrading capacity will be at a premium. So far, we're just not seeing enough being built and it will likely take years for enough to be built.

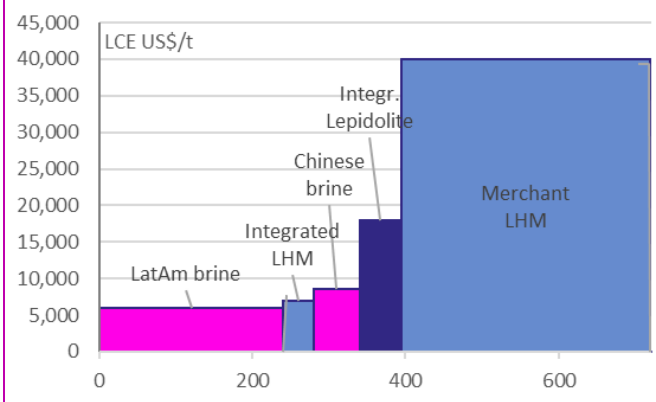
So while we do see lepidolite as a key source of lithium units going forward, we're not that worried about an oversupply of BG lithium chemicals from it in the near-term for now.

Cost curve impact of lepidolite supply

The other factor to be aware of with lepidolite is its impact on the global lithium chemicals cost curve. Because it will be substantial, and that could have significant implications for the future outlook for lithium pricing.

In simple terms, lithium chemical production from lepidolite is high cost. If one looks at the cost curve currently, Latin American brine operations are the cheapest, with operating costs below US$10/kg; integrated lithium hydroxide operations (those with captive spodumene concentrate mining are next), followed by integrated lepidolite operations, then non-integrated lithium hydroxide and carbonate production capacity utilising lepidolite and spodumene concentrate.

Global lithium cost curve illustration, 2022E



Source: BM Review

If we look at a mature industry, we generally find the marginal cost of production at around the sixty-fifth percentile of the cost curve.

Admittedly lithium is not a mature industry and more about that in a moment but, assuming it was, with the current structure of the industry, the sixty-fifth percentile would probably be in non-integrated (merchant) lithium hydroxide facility territory and at c.US$40/kg (based on current SC6 prices). If we were looking at the industry two to three years ago, it would have been squarely in brine territory and at around US$7-8/kg.

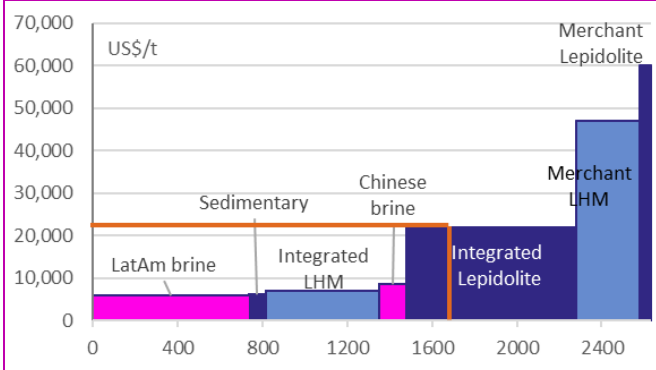
But if we believe that a surge of Chinese lepidolite capacity is going to come into the industry then three things will happen:

Lithium continued

- The average price of lithium chemicals will fall and so will SpodCon prices, taking merchant LHM production costs down;
- Lepidolite production costs will increase as lower grade orebodies are mined and cost inflation impacts, pushing them up the cost curve. Non-integrated lepidolite operations will also spring up; and
- The sixty-fifth percentile of the cost curve is likely to be in lepidolite territory, where costs are likely to be of the order of US$20-25/kg.

So then the industry is damned if it does and damned if it doesn't! By that we mean that if there isn't a wave of lepidolite capacity then there won't be enough supply in the industry and prices will remain at elevated levels for longer. And if there *is* a wave of lepidolite capacity then the marginal cost of production will remain at elevated levels and ***prices will never fall back to the levels that they've come from***. If prices *did* fall back, then it wouldn't be economic for the lepidolite capacity to operate, and it would have to close down…

Global lithium cost curve illustration, 2025E



Source: BM Review

This is something that a lot of sellside analysts do not seem to understand when they set their long-term prices for lithium.

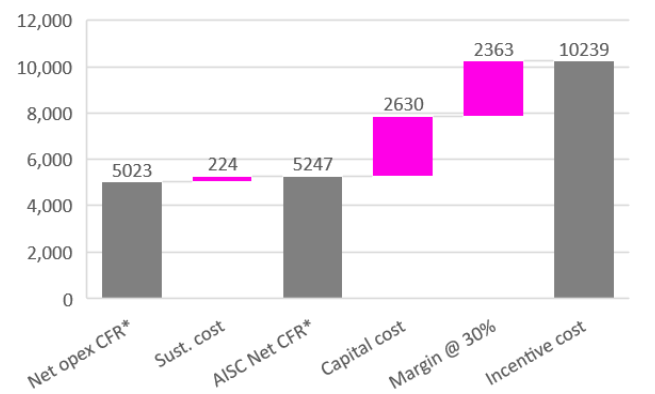
Indeed, the current consensus long-term price forecast for lithium carbonate is US$17/kg. While that's up from the US$12.50/kg that it was at in December 2021, it's still materially below what we calculate as the marginal cost of lepidolite production capacity in China currently at US$20-25/kg.

And, let's face it, we're in an inflationary environment and operating costs are only likely to go in one direction over the next few years...

And, of course, in a rapidly-growing market one needs to set long-term price assumptions utilising an element of capital costs as well. Because the industry still needs to grow, and it needs to grow rapidly. And no company is going to make an investment decision to spend money on a capital project unless they have the potential to generate returns at well over the cost of capital.

And, in a rising interest rate environment, the cost of capital is also increasing substantially. Interest rates for project finance are rising and, because interest rates on cash are rising, the cost of equity is increasing as well. That means that new projects must be sure to generate a higher IRR to guarantee they can get financed. If they cannot then they will be left on the shelf.

Calculating incentive costs for brine assets (2020)



Source: BM Review

Which means that, ***while the lithium industry is still in rapid expansion mode, prices must stay materially above the marginal cost of production***. Given that this period of supranormal growth is likely to last for at least another ten years, we would expect the period of supranormal margins to continue for that long as well.

Growth of LFP and balance of carbonate vs hydroxide

One of the developments which has surprised the industry the most over the past 18 months has been

Lithium continued

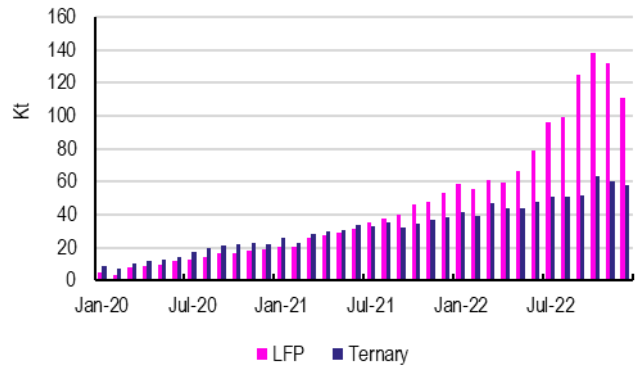
the magnitude of the growth in LFP (lithium iron phosphate) cell manufacturing capacity and demand.

LFP now accounts for c.60% of all Chinese cell output and c.40% of global cell production, after being widely discounted only 30 months ago.

Given LFP's cheapness compared to most ternary formulations it has gained substantial market share and that looks set to continue. Technological improvements within cells such as the use of silicon in anodes, improved cell energy density and cyclability and pack improvements such as the BYD Blade battery and cell to chassis technology have improved pack energy density to make LFP packs more competitive on a US$/kWh basis with ternary formulations.

In the length of a short two years LFP has become the chemistry of choice for mass-market vehicles in China and we feel that that is likely to be the case for markets outside China as well, going forward. That means that lithium carbonate will likely continue to be an important source of lithium going forward, something which was not considered likely only two short years ago.

LFP vs NCM precursor output in China



Source: BM Review, ICCSino

While we see a considerable LFP supply chain under construction in China, we worry about considerable underinvestment in the LFP supply chain in Europe and North America and believe that this is likely to become of key importance in the years to come.

The balance between lithium hydroxide and lithium carbonate looks slightly overweighted towards hydroxide in many regions and it's possible that further carbonate conversion additions will be necessary ex-China going forward.

The changing reality of lithium pricing

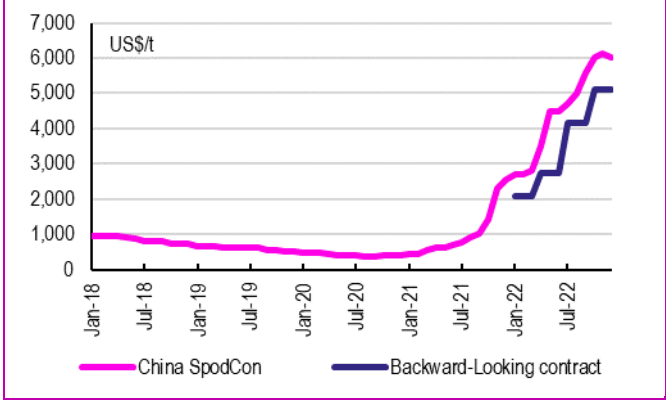
One key thematic in lithium in the past 2-3 years has been the higher contribution of the spot market to lithium pricing.

Prior to 2020 the bulk of lithium chemical prices were on annual or multi-year pricing contracts between lithium producers and consumers. While there was a small spot market in China (particularly for lithium hydroxide and spodumene concentrate) it was not particularly substantial as a percentage of the whole market.

In the past few years all that has changed.

Spot tonnage is a much more substantial percentage of overall volumes and those backward-looking fixed price contracts have been renegotiated to be quarterly and to point at the previous quarter's spot prices. These new quarterly contracts do not necessarily reach the same levels as spot prices but they do move in the same direction as spot prices when considered on a quarterly average basis.

China SpodCon vs quarterly contract pricing



Source: BM Review

As a result of these changes the spot price, which was treated as a bit of a joke by many analysts previously, is of much greater importance as an indicator of prices.

While spot lithium prices are of more interest, we remain wary of lithium chemicals futures prices. There was some excitement in November 2022 when there

Lithium continued

was considerable volatility in the Wuxi lithium carbonate futures contract. Given that the volume represented by the Wuxi lithium carbonate contract is minuscule, we suggest that price fluctuations in such contracts are, for the moment, irrelevant. We hope to see more volume trade on futures contracts going forward but, for now, they simply don't matter.

Prices to stay higher for longer

If we had a penny for every time we're asked for our lithium pricing forecasts, we'd certainly be millionaires by now!

We strongly believe that market consensus is wrong in the medium-term (next 10 years) on lithium pricing. We believe that the market is:

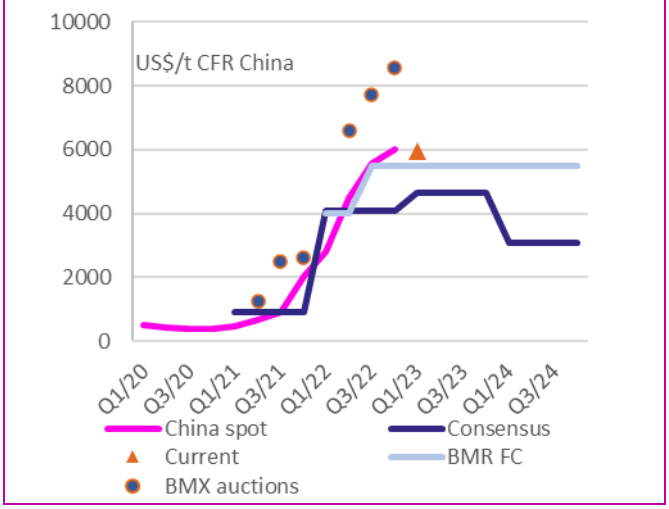
1) Overestimating the ease and rapidity of adding new lithium supply;
2) Overestimating the amount of new lithium supply that will be battery grade;
3) Underestimating the amount of material lost due to low battery yields in cell manufacturing plants, therefore underestimating demand;
4) Underestimating the impact on pricing of higher cost production technologies (like lepidolite) coming into the market;
5) Underestimating the impact of inflation (high power prices, weakening US dollar vs commodity currencies);
6) Underestimating the impact of higher cost of capital and need for strong returns on new investment in a rapidly-growing market.

All of this suggests to us that spodumene concentrate and lithium chemical prices will remain stronger for longer over the next five to ten years.

Sellside consensus has prices falling by nearly 50% between 2022 and 2024. We do not believe that that will be the case.

In fact, we do not expect lithium chemicals prices to fall materially back below US$25/kg any time in the near future (next ten years). We expect prices to be US$60/kg on average for lithium carbonate and hydroxide over the next three years. Some commentators are calling for lithium chemical prices to exceed US$100/kg.

Actual vs consensus and BMR SC6 price forecasts

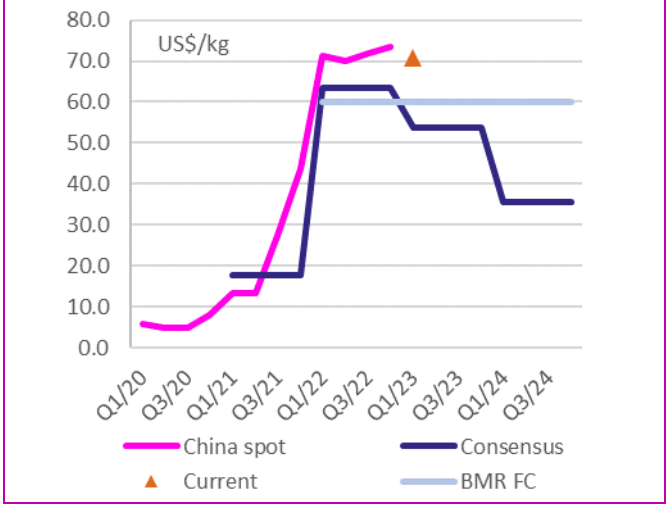


Source: BM Review

While the US$100/kg level is very possible for short periods, in our view, we don't at this stage believe that they will exceed that level over the longer term because it will put too much pressure on the downstream industries.

We do, however, expect that prices will become more cyclical (and hence more volatile) during the next three to four years, which will make them more difficult to call on a short-term basis.

Actual vs consensus and BMR LC price forecasts



Source: BM Review

Nickel

The nickel market in 2022 was very much dominated by three factors:

- Russia's invasion of Ukraine which threw the future role of Norilsk Nickel into uncertainty;
- The LME nickel short squeeze which led to the unravelling of the LME as the world's premier market place for nickel trading; and
- The continued emergence of Indonesian HPAL and NPI/matte/CAM capacity.

Nickel prices were volatile; spiking at the start of the year on news of the Ukraine invasion, and then falling back by mid-year, before recovering again into the end of the year.

Most commentators feel that there will be a surplus of low grade nickel capacity in 2023, but they are split about the high grade part of the market. Some feel that there will be sufficient upgrading capacity to push the higher grade market into oversupply, particularly in the context of weaker demand growth for stainless steel and EVs, but many also believe that the higher grade market will remain in deficit.

Some "specialists" under-forecasting nickel demand for EVs

We believe that many commentators are under-forecasting nickel demand in EVs because of a technical error in modelling.

When trying to model materials demand, most analysts will forecast EV sales (or production), then chemistry split and then expected battery size.

An average, battery size for EVs globally is of the order of 50-60kWh (smaller in China which is the biggest market, but larger in Europe and US which are smaller markets).

But there is a problem with this approach because generally LFP batteries are used for mass market vehicles with smaller batteries and high-nickel ternary batteries usage is focused on premium vehicles with larger batteries.

If we take an average battery size and apply that to the split of EV battery types, then we might end up under-forecasting nickel demand by as much as 22% for each 10m units of EV sales. That's over 50Kt of nickel metal equivalent demand… The figure below shows the difference between utilising an average battery size approach and modelling using different battery sizes for each different chemistry.

Comparison of how nickel use in EV batteries is modelled

Average battery size

Formulation	Market	Mid-nickel	High-nickel	LFP
Share		36%	24%	40%
Battery size kWh	57	57	57	57
Sales m units	10	3.6	2.4	4.0
Market size GWh	568	204	136	227
Nickel usage t/GWh	423	641	800	0
Nickel demand Kt	**240**	**131**	**109**	**0**

How it should be modelled

Formulation	Market	Mid-nickel	High-nickel	LFP
Share		36%	24%	40%
Battery size kWh	57	60	80	40
Sales m units	10	3.6	2.4	4.0
Market size GWh	568	216	192	160
Nickel usage t/GWh	514	641	800	0
Nickel demand Kt	**292**	**138**	**154**	**0**
Variation	***22%***			

Source: BM Review

We believe that this technical error is a key factor in underestimating demand for nickel in the short- to medium-term, causing the potential magnitude of the high grade nickel deficit to be understated.

Ukraine invasion causes price spike

The first price spike of the year came about in March after rumours about sanctions on Russia after its invasion of Ukraine on 24 February.

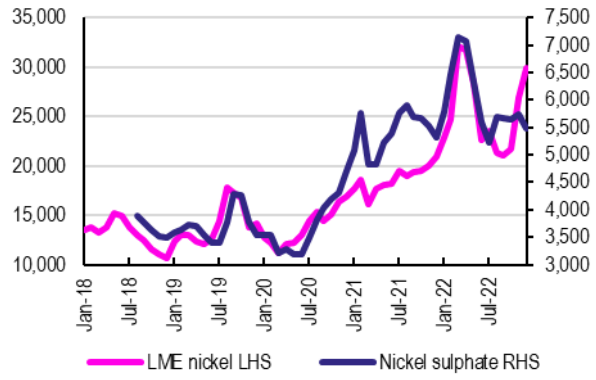
This was relevant because Russia comprised 11% of global nickel production in 2020 and in 2021 Norilsk Nickel produced 193Kt of nickel, c.25% of global class 1 nickel production.

If the West had imposed sanctions on Russian nickel products, then it would have had a profound impact on nickel supply/demand balances and that led to prices starting to increase on speculative activity.

That speculative price increase though was pushing up against a huge short position held by Tsingshan, the Chinese stainless steel and NPI manufacturer.

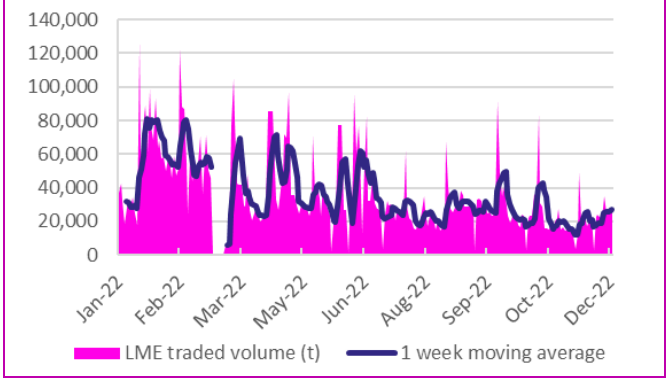
Nickel continued

LME nickel and nickel sulphate prices (US$/t)



Source: BM Review, Westbeck Capital

LME nickel trading volumes



Source: BM Review, Westbeck Capital

The market activity led to a substantial short squeeze (when it's speculated that Tsingshan and related entities started to cover) in which prices doubled to as high as US$100,000/t before the LME cancelled all trades on 8 March 2022 and rolled back to the close of 7 March 2022. This caused ructions with traders who had made substantial paper profits out of the move.

While the contract resumed trading on 16 March and prices fell back over the course of the second quarter, the damage had been done to the LME nickel contract.

Death knell for LME nickel contract?

The cancellation of the trades and the confusion that followed the nickel price spike looks like it may have resulted in the London Metal Exchange losing its position as the world's premier metal market.

A number of traders have initiated legal action against the exchange and, in the aftermath of the chaos, volumes have dropped away substantially. The Shanghai Metal Exchange has been a major beneficiary and a number of other exchanges, such as the Chicago Mercantile Exchange are reportedly considering launching a nickel contract.

But an increasingly important question is whether refined nickel is the right material for a contract or whether a new contract launch should embrace an intermediate material such as MHP (Mixed Hydroxide Product) or even a material more suitable for cathode manufacture, such as Nickel Sulphate?

Because the chaos on the LME has also flagged an increasingly important issue, the divergence between market dynamics and prices for nickel intermediate products and refined nickel prices.

For large parts of this year, prices of the two products have gone in different directions and, with nickel sulphate being the primary raw material product for cathodes and a larger proportion of nickel sulphate being derived from MHP from HPAL or from nickel matte and NPI plants, many market participants are asking whether the price relationship between the two products is set to structurally break down? Certainly, low refined nickel inventories on the LME are currently leading to a substantial disconnect.

Laterites changing the structure of the industry?

The development of production in Indonesia from laterite nickel deposits has caught many by surprise. With the help of low-cost Chinese financing and labour, a number of HPAL projects have been developed quickly and, with Chinese technical innovation, the NPI-matte-intermediate processing route has allowed supply to be developed very quickly for the battery raw material industry.

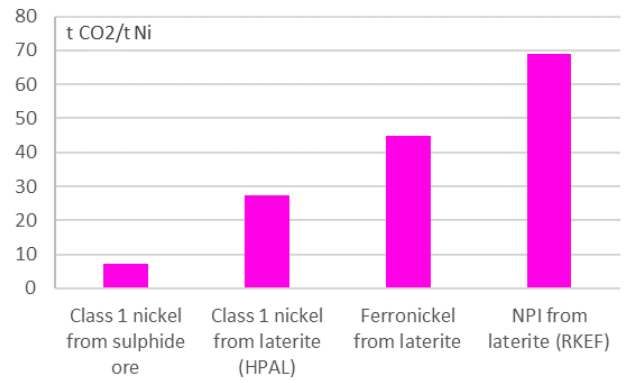
2022 marked the first time when a significant amount of battery intermediate material was derived from the NPI-matte-intermediate process, and this trend looks set to continue in coming years.

But, there are a number of issues associated with these processing pathways:

Nickel continued

1) They are power-intensive. HPAL itself is power intensive and the NPI-matte-intermediate process is what we in the industry call a double pyromet(allurgical) process, ie it uses two pyrometallurgical (high power consumption) processes. Given that Indonesia's power is almost entirely produced by coal, that means that production of nickel using these techniques is substantially more carbon-intensive than other forms of nickel production.

Carbon intensity of nickel production



Source: BM Review

2) There are other ESG implications of the development of the Indonesian nickel industry. These processes require a substantial clearance of rainforest around the mines, and they generate a lot of waste, much of which is acidic. Disposal of that waste is an issue.
3) Given the power intensity of these processes, there is likely to be an impact on the cost curve if hydrocarbon prices rise, as looks likely in coming years. While some metals like aluminium and zinc are known as power analogues, nickel has not historically been known as such, but there is every sign that nickel prices could become more correlated with power costs going forward.

There are other technologies out there (the traditional production process using sulphide ore, for instance) which are more environmentally-friendly than the production of nickel from laterite ores using hydrometallurgical processes.

Are OEMs paying lip service to ESG in the nickel industry?

It very much seems so to us. In the past year, a number of high-profile OEMs have signed up offtake agreements with Indonesian HPAL and NPI-matte-intermediate producers, despite the quite significant ESG issues associated with these processes.

And, while we have seen a few OEMs tying up sulphide nickel offtake tonnages, we have not seen OEMs looking to invest in ultramafic sulphide projects in regions like Canada and Brazil which already benefit low-carbon intensity hydroelectric power and benefit from carbon-fixing properties in waste material which would substantially lower GHG footprints.

We have seen precisely one OEM (General Motors) take a bet on a non-commercially-proven hydrometallurgical nickel laterite technology which, if successful, could lower the carbon footprint of nickel processing almost to nothing.

If OEMs were serious about ESG, we understand that they need to lock up supply now, but we would expect to have seen them pushing substantial amounts of capital into cleaner projects and technologies. So far that investment has been conspicuous by its absence…

Cobalt & Manganese

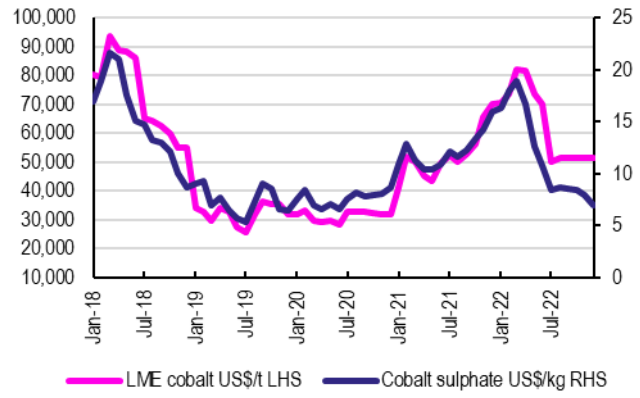
2022 was a difficult year in both the cobalt and high purity manganese sectors, with prices heading south since March.

In our view, this was more down to the overarching Chinese macro conditions than any particular weakness in battery materials demand. Both cobalt and high purity manganese suffer from the fact that the battery sector is not a majority user in terms of volumes, and hence price behaviour is often governed by factors outside the battery sector.

Cobalt intermediate price disconnect

As in nickel, we've seen more active trading in the cobalt intermediate market, where cobalt sulphate prices have been much more active than LME cobalt, which has continued to struggle with low volumes.

LME cobalt vs China cobalt sulphate price, 2018-22



Source: BM Review, Westbeck Capital

The growth in adoption of high nickel (hence low cobalt) batteries, coupled with the very substantial acceleration in take-up of LFP batteries, as well as weaker industrial activity in China, has meant that cobalt demand for batteries grew slower than most commentators were expecting in 2022.

In the latter part of the year, the slowdown in consumer batteries demand was also impactful with key consumer segments which had supported demand during Covid, such as wearables, smartphones and power tools, all seeing a deceleration of demand growth.

Adding this into mine start ups and restarts in DRC, which resulted in an increase in available supply of cobalt products, has seen the cobalt market crumble and with further mine restarts likely in 2023, it's difficult to see too much hope of a near-term recovery.

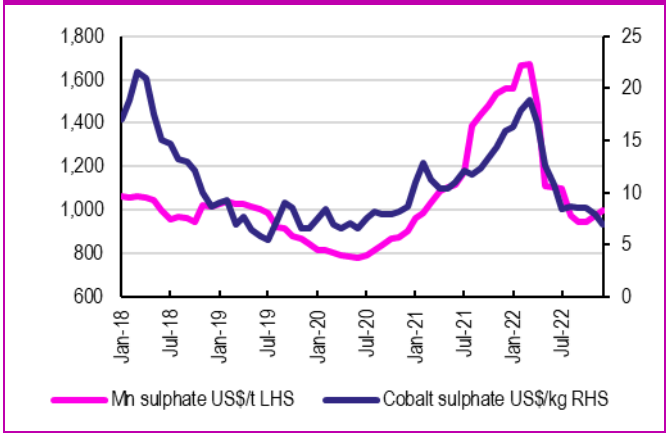
Another factor which should be borne in mind is recycling. A focus on recycling of consumer batteries in many countries has resulted in higher recovery of material to recycling so we flag secondary as a potentially important area for supply growth in coming months and years.

High Purity Manganese prices weak but more demand around the corner?

High Purity Manganese (HPM) is one of those segments which suffers badly from price opacity; it's very difficult to get much data on what actual pricing is doing in the key battery intermediates, SF-HPEMM (Selenium-Free High Purity Electrolytic Manganese Metal) and HPMSM (High Purity Manganese Sulphate Monohydrate).

We have access to Chinese MSM prices, which give some indication, but not really to pricing in the key battery intermediates. On the face of things MSM prices were down in 2022, almost in lockstep with cobalt prices. This suggests that the price series that we track is not a selenium-free one. We understand that ex-China selenium-free HPMSM prices held at above c.US$2000/t during the year.

China MSM prices vs cobalt sulphate prices, 2018-22



Source: BM Review, Westbeck Capital

As high nickel/manganese batteries become more widespread we expect the specifications for high purity manganese to tighten up and selenium-free material to trade at a substantial premium to lower spec material.

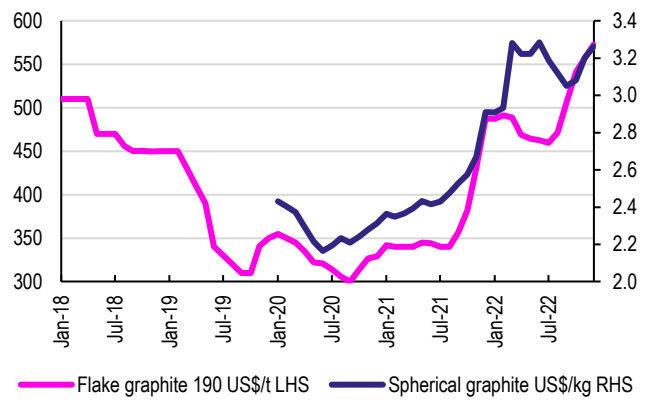
Graphite & anode materials

2022 has been quite a year for graphite, and particularly for its use in lithium-ion batteries. Data from Benchmark Minerals Intelligence suggests that 2022 is the first year in which demand for natural graphite from the battery sector was more than 50% of flake graphite demand.

The huge increase in cell capacity seen in China, coupled with the inability of synthetic graphite manufacturers to expand output to the extent necessary to keep up with demand growth, has seen a substantial acceleration in flake graphite processing investments, leading to strong demand for flake.

Flake prices in China were up 17% in 2022 and spherical graphite prices up 12%, substantially outperforming most cathode materials, with the exception of lithium.

Chinese flake and spherical graphite prices, 2018-22



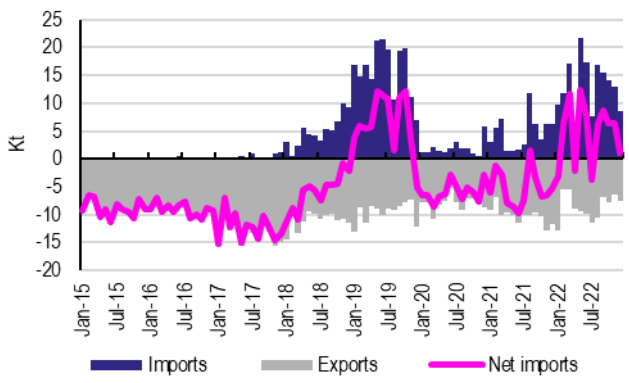
Source: BM Review, Westbeck Capital

But one wouldn't know that from the performance of graphite equities, which have been down almost across the board…

China became a flake graphite net importer in February and remained so for most of the year. While China also became a net importer in 2019 before falling back to a net export position in 2020, we believe it is set to remain a net importer for some time to come now as cell capacity growth really accelerates.

However, it's not flake graphite where we necessarily expect the bulk of the bottleneck to emerge; it is in **anode materials** where we see a real problem emerging in the short to medium term.

Chinese flake graphite trade balance, 2015-22

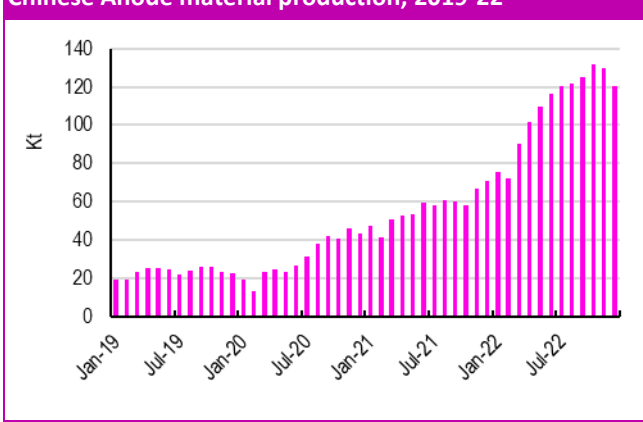


Source: GlobalTradeTracker, BM Review

We see a real shortage of ex-China projects for the upgrading of flake graphite into spherical graphite. In May's edition of *Battery Materials Review* we flagged that the Midstream graphite "gap" could be worse than the lithium shortage in the Western World.

Of the nine companies with midstream graphite projects in the Western World, four are currently at the pilot plant stage and none beyond that. Yet cell manufacturing facilities have been committed to and are already under construction. It seems highly unlikely that very many of these plants can start production before 2024, and even within that, when they will be able to produce material to spec on a consistent basis is anyone's guess.

Chinese Anode material production, 2019-22



Source: ICCSino, BM Review

Because, like in lithium, it's very complex to get these plants into production and, once in production, optimised. Material then needs to be qualified by cell producers and that can easily take 6-12 months. Realistically there can't be very much battery grade

Graphite & Anode continued

anode material out of these plants until 2025, maybe 2026. And since cell capacity is ramping up before that, and Chinese anode materials supply is likely to be needed for China, that's likely to be a problem.

Can synthetic graphite make up the difference?

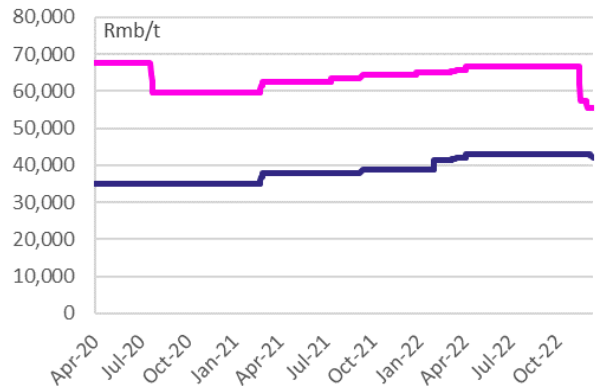
Realistically not, in our view. For two primary reasons – (1) that supply is constrained and is likely to remain that way, and (2) that synthetic graphite is extremely power (carbon) intensive, much more so than even thermal purification of natural graphite.

Synthetic supply is likely to be constrained because its primary raw materials are products derived from oil refining and oil refinery capacities are flat or dropping, certainly not increasing. That means that anode material derived from natural flake graphite is gaining market share and, with advances in processing, such material is of higher quality than was perhaps available in the past.

Indeed, naturally derived anode materials, when mixed with silicon, have improved very substantially in quality in recent years, and are now sought after by cell manufacturers.

From an ESG point of view, synthetic graphite compares poorly with natural graphite. The manufacture of synthetic graphite from petroleum coke requires baking the material at temperatures of 850-1200°C for 4-6 **WEEKS**. This is an order of magnitude more power-intensive than any natural graphite processing.

Chinese artificial graphite vs spherical graphite prices



Source: Westbeck Cap, Shanghai Metal Market, BM Review

The power intensity of synthetic graphite production has been an issue, with a number of closures of capacity within China due to power shortages. Increasingly, because of higher power prices pushing up costs of synthetic graphite processing (and hence prices), focus has shifted increasingly to naturally-derived spherical graphite, which sells at substantially lower prices.

Other technologies could be important

We can't talk about anode materials without talking about emerging technologies. Within that silicon is the most important material which is being increasingly integrated into graphite anodes to improve their capacity.

Small amounts of silicon (5-10%) can have a substantial impact on the viability of batteries and, indeed, integrating silicon anodes (actually silicon-graphite anodes) with LFP cathodes is substantially improving the efficacy of LFP cells and batteries.

We expect the percentage of silicon in anodes to increase over the next 10 years but still expect graphite to be the primary anode material within that time.

Another technology which is important in anode materials is the production of hard graphite from lignin-rich materials.

Hard graphite is increasingly important as an anode material in sodium-ion batteries which have applications in two-wheeler electric vehicles and ESS (Stationary Energy Storage) applications.

While there are a number of pilot plants in operation to produce graphite from lignin, they are still a few years away from commercial production.

Cathode materials

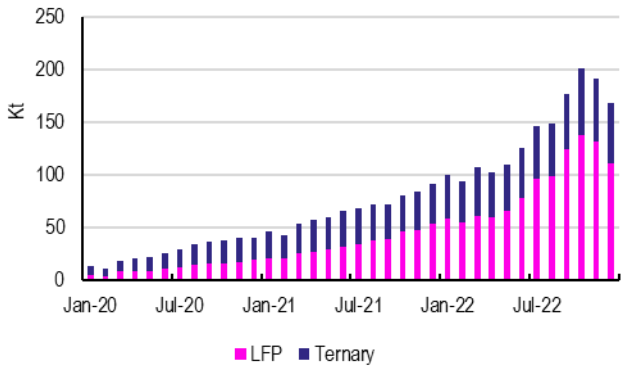
2022 saw the LFP (lithium iron phosphate) chemistry continuing to gain market share from ternary (NCM and NCA) chemistries in China, the world's fastest-growing EV market.

While ternary chemistries continue to dominate in the premium electric vehicle category, LFP - thanks to improvements in cell architecture and energy density (and its lower cost) – is rapidly gaining market share in mass market vehicles and in ESS.

The emergence of BYD's Blade battery architecture, along with cell to pack and cell to chassis technology in recent years has increased pack energy densities for LFP so that they are now within touching range of pack densities for ternary formulations.

This is possible because LFP cells are more thermally stable than ternary formulations and require less in terms of temperature management systems and other packaging.

China ternary cathode production by type, 2021-22

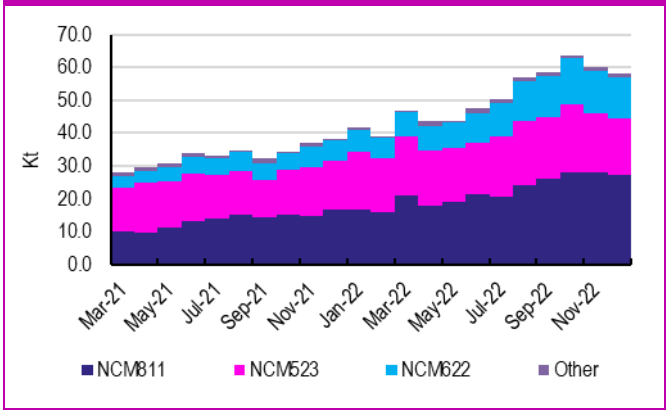


Source: ICCSino, BM Review

2022 saw continued substantial build out of LFP cathode and cell manufacturing capacity at the expense of ternary capacity. China is now a major exporter of ternary cathode and ternary cathode materials for cell manufacturers based outside China.

Within ternary cathode we continue to see high nickel chemistries such as NCM811 taking market share away from 5-series and 6-series cells.

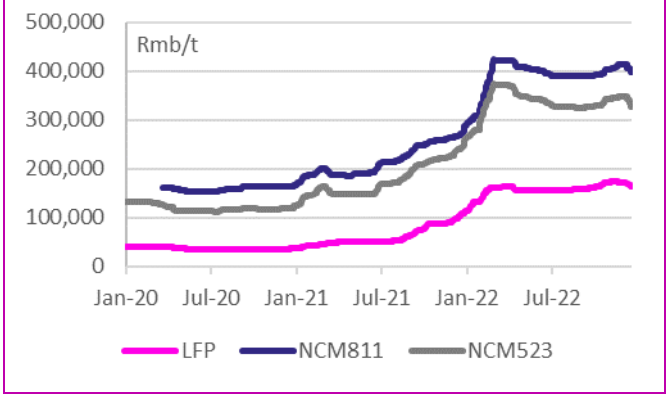
China ternary cathode production by type, 2021-22



Source: ICCSino, BM Review

LFP continues to be a substantially cheaper cell solution, despite the significant increases in lithium prices in 2022. On a dollar per kilowatt-hour (US$/kWh) basis, LFP cells continue to be better value than NCM

Chinese LFP and ternary cathode prices, 2018-22



Source: ICCSino, Westbeck Capital, BM Review

2023 should be an interesting year, with many Chinese commentators suggesting that China has overbuilt capacity in LFP cathode and LFP cell manufacturing, which could put pressure on margins of cathode producers.

On the ternary side, the Korean producers continue to dominate in the high volume, high nickel space, with Chinese cathode producers still focused predominantly on 5-series and 6-series cathodes.

Capital raising review

2022 Battery Raw Materials fundraising deals of the year

Date	Company	Segment	Type	Amount US$bn
Jun-22	Zhejiang Huayou Cobalt	Cobalt	Equity	2.6
Jul-22	Tianqi Lithium	Lithium	Equity	1.7
Apr-22	Iluka Resources	REE	Debt	0.9
Jan-22	Shalina Resources	Cobalt	Debt	0.6
Oct-22	Albemarle	Lithium	Debt	0.5
Nov-22	Lygend Mining	Nickel	Equity	0.5
Jul-22	EnergyX	Tech	Equity	0.5
May-22	Albemarle	Lithium	Debt	0.5
Apr-22	Mineral Resources	Lithium	Debt	0.3
Nov-22	Talga Group	AAM	Debt	0.3

Source: BM Review

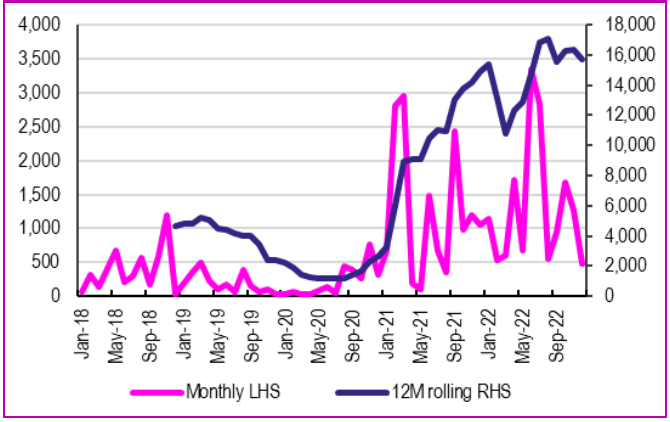
2022 Midstream fundraising deals of the year

Date	Company	Segment	Type	Amount US$bn
Jul-22	Shanghai Putailai	Anode	Equity	1.3
Nov-22	Ningbo Shanshan	Cathode	Equity	0.8
Jul-22	Ronbay Tech	Cathode	Equity	0.8
Feb-22	Canmax	Li Chems	Equity	0.7
Nov-22	Sinoma	Separators	Equity	0.7
Nov-22	ClosedLoop	Recycling	Equity	0.7
Jun-22	Dynanonic	Cathode	Equity	0.5
Apr-22	EcoPro BM	Cathode	Equity	0.4
Oct-22	Group 14 Tech	Anode	Equity	0.4
Jul-22	Ningbo Shanshan	Cathode	Equity	0.3

Source: BM Review

2022 was a pretty disappointing year for fundraising activity in the battery materials sector, particularly after the increase in activity in 2021 promised so much. Admittedly, total funds raised across the sector managed to eke out a small increase of 5% y/y, but this was mainly due to expansion of funding in segments which had been lagging behind in 2021, such as graphite, cobalt and vanadium, and not down to any acceleration in activity in the key segments.

Value (US$m) of capital raised in batt. materials, 2018-22

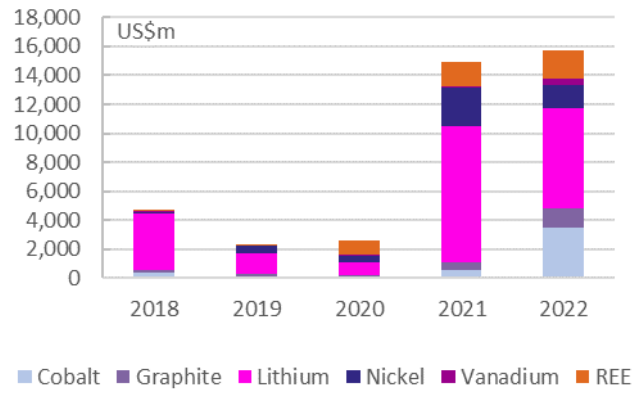


*Source: BM Review. *Lithium, Cobalt, Nickel, Graphite, REE*

In fact, the total funds raised in lithium were down 27% y/y and in nickel down 39% y/y. That's not really the direction of travel that's needed.

It was also noticeable that three out of the top ten Upstream deals of the year and six out of ten top Midstream deals were for Chinese companies. This emphasises once again how much funding support the industry is getting in China compared to the West.

New funds raised by material, 2018-22



Source: BM Review

Admittedly, much of this decline in Western World fundraising activity was due to the weak performance and volatility of equity markets. With global equity markets down double-digit percentages for 2022 and battery materials equities not faring any better, it was perhaps not a surprise that it was considerably more difficult for companies to raise equity than in 2021.

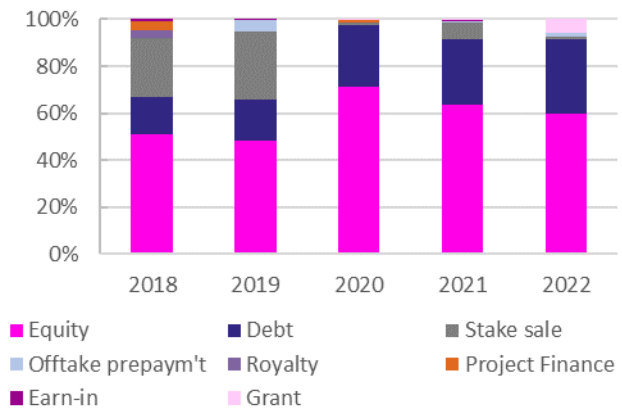
But this just emphasises the need to raise money away from equity markets. While some governments (Australia, Canada, US) did start to step up to the plate to make funds available to upstream development projects in 2022, the EU was again conspicuous by its absence.

Another group which was conspicuous in its absence was OEMs and cell makers. We tracked four (yes, that's correct, only four) instances of OEMs making

Capital raising continued

capital available for development-stage companies in 2022, and that's just not enough.

New funds raised by instrument, 2018-22

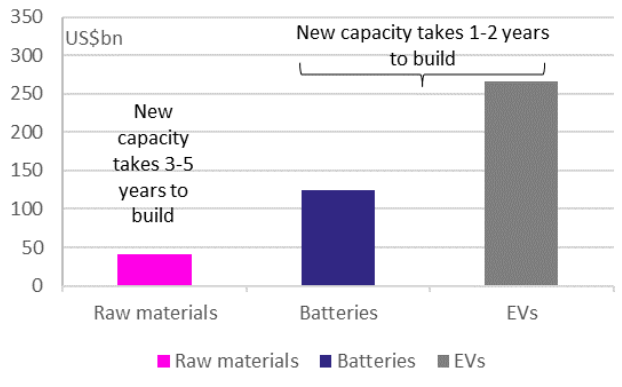


Source: BM Review

We can just about understand European governments not getting the whole battery raw materials shortage theme, but OEMs? They have no such excuse and their continued failure to make capital available to the upstream end of the business is hurting their own profitability.

While we're on that topic of funding for battery materials, let's just recap on the ongoing issue of underinvestment in battery raw materials production capacity vs the downstream end of the business. Updating our data shows that in 2022 US$15.7bn was raised or allocated for the battery raw materials sector, US$45.3bn for the batteries sector and US$105.0bn for the EVs sector.

Cumulative capital raised or allocated, 2018-22



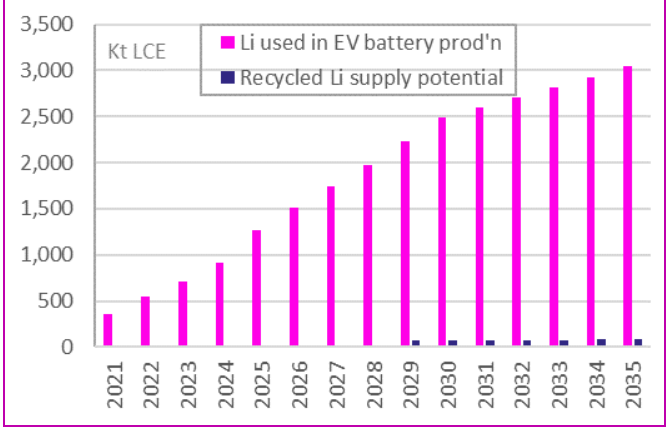
Source: BM Review

The magnitude of the continuing under-investment in the battery raw materials sector continues to shock. And, as we make clear in our chart, it's not just the structural underinvestment that's relevant; it takes considerably longer to build a mine than a cell or EV manufacturing plant, so we are building in a temporal shortage in material as well.

We think that OEMs are starting to get their heads around the funding imbalance, although we're still not seeing enough action, in our view. But governments, particularly European ones, are still some way away. We have a number of interactions with governments, and they often cite that, even though they haven't invested in primary extraction, they *have* invested in recycling, so everything should be OK shouldn't it?

They seem surprised when we scream and tear our hair out! There's no point in investing in recycling until there's enough primary material in the market *to* recycle. We need to increase lithium production over **SIX TIMES** between 2021-30E. The average lifetime of an EV battery is 10-12 years. How much material will be available for end of life recycling by 2030? Answer, a minute amount and not enough to affect the supply/demand balance. Only investment in primary extraction will solve this problem…

Contribution of recycling to lithium demand



Source: BM Review

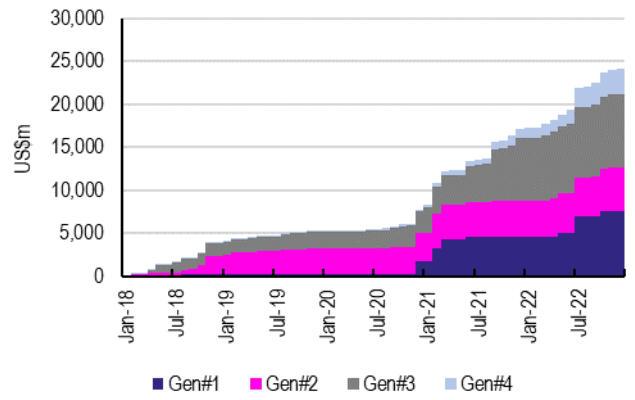
Another segment where there is a problem with funding is in the early-stage end of the mining industry. To some extent, and certainly with higher prices, there is now enough funding available at producers given that cash generation has gone

Capital raising continued

through the roof. It's at the developer/explorer end of the business where funding is necessary, and we're just not seeing that at this time.

The chart below shows lithium fundraising split by the generation of the assets. First and second generation assets were in production in 2020, third generation were in development and fourth generation are exploration assets. Contrast the amount of funding going into exploration assets at the moment with later-stage assets. It's simply not enough.

Lithium fundraising by asset generation

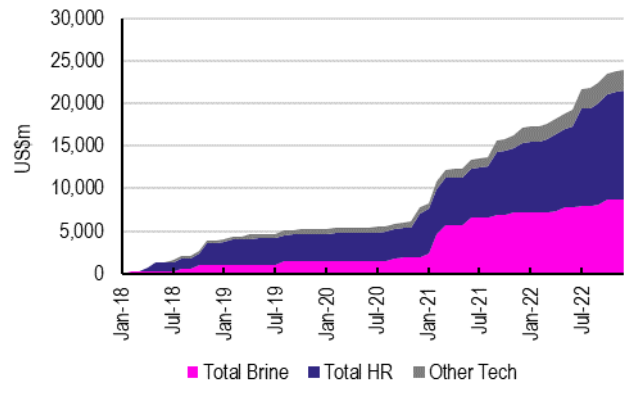


Source: BM Review

Lithium: Hard Rock the focus

In lithium we've seen the bulk of funds over the past year heading into hard rock projects, with the majority of that destined for Australia, although Canada is a rapidly growing component of hard rock funds sourced, and we expect to see considerable funding heading into that country going forward. Brazil is also a country where we may very well see more activity.

Lithium fundraising by type



Source: BM Review

Brine activity has been roughly constant, with substantial focus on Argentina given the uncertainties associated with Chile's constitution and mining charter during the year. A fair number of companies operating in Brine are majors and it's difficult to track fund flow from them because they're generally allocating funds rather than raising them.

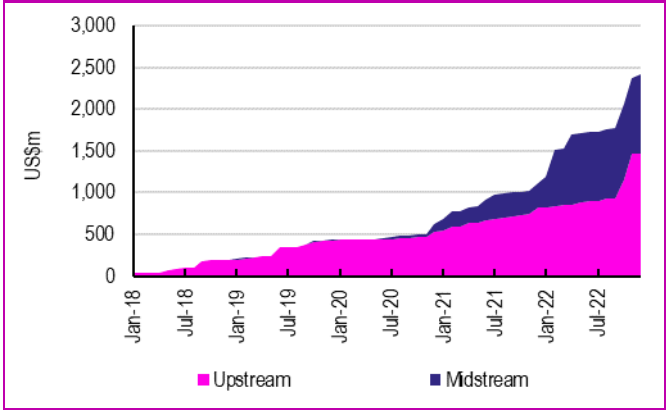
Graphite: Midstream coming into focus

We saw a 171% y/y increase in graphite funding in 2022. While this looks great, the US$1.3bn is probably in line with the sort of levels we want to see and the US$484m for 2021 was an order of magnitude below the sort of levels we want to see.

Having said that there was certainly better focus on graphite and this is positive, given we suggest that the coming midstream supply gap in graphite could be as bad as what we've seen in lithium over recent years.

We certainly saw more funding being made available for midstream. Some of this was in the US and some in Europe. But we believe that we certainly need to see more, given that midstream assets are more capital-intensive than upstream assets.

Graphite fundraising by value chain segment



Source: BM Review

Nickel: laterite fundraising activity up

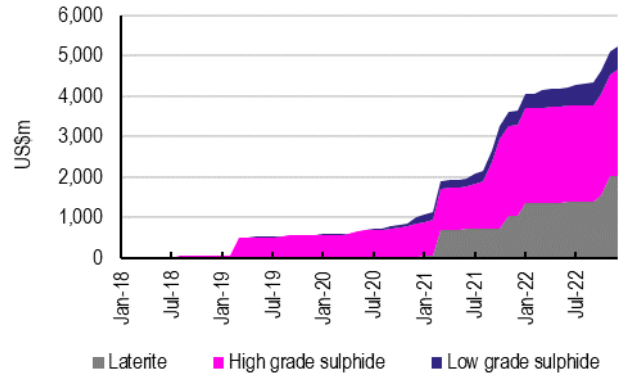
We saw greater activity in fundraising for HPAL and NPI/matte laterite projects in 2022, although in our view this is the wrong way for the industry to go. We don't like the carbon-intensity of the HPAL and NPI/matte route and want to see more focus on sulphide orebodies. We also note that sulphide projects hosted by ultra-mafic rocks carry the ability

Capital raising continued

for waste material to fix carbon dioxide, which gives them an advantage from a carbon-intensity basis.

It remains a surprise to us that OEMs and other market participants continue to focus on signing up environmentally unfriendly pyrometallurgically-focused laterite projects which rely on hydrocarbon-powered grids in Indonesia and fail to invest in sulphide projects in Canada and Brazil which rely on clean hydroelectric-powered electricity!

Nickel fundraising by ore type



Source: BM Review

Australia remains an open market for high-grade sulphide projects. But the problem is that the bulk of these high-grade sulphide projects are small and are only going to produce tens of thousands of tonnes of contained nickel a year, not enough to really impact supply/demand balances.

We would like to see more fundraising going into nickel sulphide projects ex-Australia, since there are some interesting projects coming to the fore in Canada, Brazil and parts of Africa, most of which regions benefit from low-carbon intensity power which will be much more environmentally friendly for nickel production than laterite production methods.

Capital capacity vs requirement

The imbalance between capital capacity and the requirement for capital in the battery raw materials industry is at the heart of the issues that the industry is currently experiencing, in our view.

What *is* capital capacity?

Capital capacity is a term that we've coined to explain the ultimate amount of capital that an industry segment should be able to access. Capital capacity for an industry is basically the sum of the capacities of the companies in that industry.

For an individual company, we're realistically primarily talking about debt and equity funding (with a focus on equity), but there are other funding sources including royalties/streams, government grants, earn-ins and offtake prepayments and a plethora of new funding instruments starting to come to the market.

As can be seen from the chart in the ***Capital Raising*** section, equity funding has been the key source of capital in the battery raw materials industry over the past five years and this is likely to continue.

Capital capacity of US$100m mkt value company

Source: BM Review

While debt funding is a more common form of funding for producing operations in manufacturing and, indeed, in raw material extraction, it's often a risky instrument for development projects, and even more so in battery raw materials. In basic terms debt is risky for development projects because of the potential for development timeline overruns and hence cost-overruns. A substantial proportion of failures in raw material projects come about because companies run out of money in the construction phase. In battery materials it is even more fraught because of the complexity of the industry. There have already been a number of failures in battery raw material development projects that have been caused by taking on too high a debt load.

So, industry best practice for battery materials development projects is not to over-leverage.

A listed company can likely access development capital in the form of equity and debt to a level of 80-90% of its market capitalisation. Companies will not want to access more than 50% of their capitalisation as equity otherwise existing shareholders will be diluted too much, and they will (as best practice) not want to borrow more than 50% of their market value as debt.

So, when we estimate the capital capacity of a listed company, we're effectively talking about its market value (ie equity capacity + debt capacity + other funding sources).

But not all companies are listed, and for unlisted companies in production we assume a capital capacity in line with the value of their revenues (most companies in this sector would be valued at c.1x EV/Sales (it can be a higher multiple for downstream segments like cells and EV manufacturing). For development companies we make an assumption on valuation.

Once we have established the capital capacity of individual companies we can then calculate capital capacity for an industry segment by adding the capital capacity for all the individual companies together.

What is capital requirement?

The capital requirement for the EV event is also easy to calculate. It's simply the eventual capacity of EVs, cells, battery raw materials needed, multiplied by the cost to build that capacity.

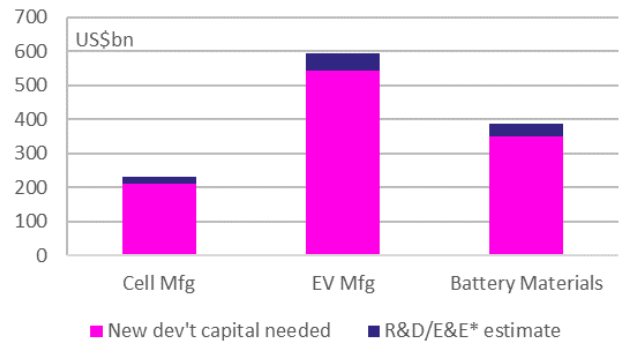
We've done our own work on calculating the cost of new capacity because we believe most of the work in the market at the moment substantially understates the cost of new assets:

- For instance, a cell factory in Europe costs nearly three times more in US$/kWh than a comparable factory in China.

Capital capacity vs requ't

- A lot of work on battery raw materials blends Brownfield and Greenfield development costs. While there *are* Brownfield expansions, the bulk of new supply will come from Greenfield.
- Most work on battery raw materials only considers construction capex and doesn't include any allocation for funds spent on exploration and evaluation, and also doesn't consider funds raised for exploration projects that don't make it to construction.
- Similarly most analysis doesn't factor in requirements for R&D in the EV segment and in the cell manufacturing segment.
- Most industry analysis doesn't factor in the likely impact of inflation on capital costs.

Capital requirement for key parts of EV value chain, 2021-30E

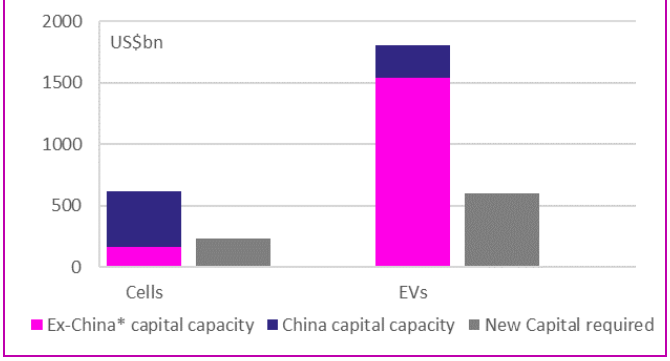


*Source: BM Review. *E&E=Exploration & Evaluation*

Downstream segments are healthy

In a healthy industry, the capital capacity should more than exceed the capital requirement. And, indeed, we can find the very definition of a healthy industry in cell manufacturing and EV manufacturing.

Capital capacity of US$100m mkt value company



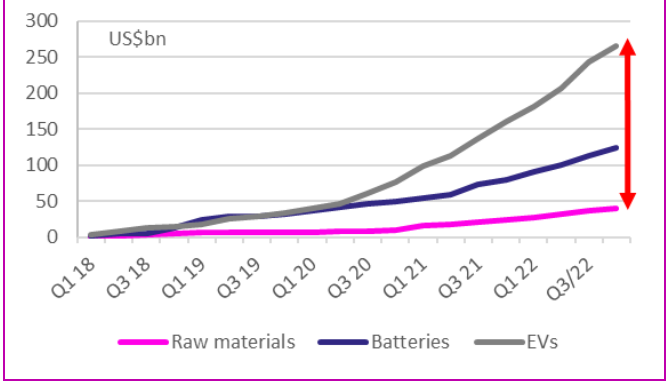
Source: BM Review. Ex-Russia

As can be seen from the preceding chart, capital capacity in the EV and cell manufacturing sectors is multiples of the capital requirement for the next 10 years' worth of development.

Houston, we have a (big) problem!

But something's not right in the battery supply chain, and to explain what's not right we'd like to reference a chart that we publish every quarter in *Battery Materials Review*. This tracks the amount of capital raised or allocated for each segment of the supply chain and you can clearly see that there's a huge disparity between the segments.

Cumulative capital raising by segment, 2018-22



Source: BM Review

Now, if we refer to the chart to the left, we know that the *capital requirement* for EVs is two and a half times more than for cell manufacturing, and that's backed up by this chart.

In fact, our quarterly data for cell manufacturing and EVs focuses more on ex-China capital raised than on Chinese capital, so it makes sense that there would be more ex-China capital raising for cells since currently we are developing an ex-China industry for that, when we've seen the bulk of investment in China up to now.

So it's not a surprise to see cell manufacturing in the Western World punching above its weight.

What *is* a surprise is that **raw materials capital raising is substantially underperforming the Downstream part of the industry**. Over the past four years the ex-China EV industry has raised capital at over seven times the rate of the raw materials industry, and the cell manufacturing industry at nearly four times.

Capital capacity vs requ't

***That* is a big problem.**

Because if you look at the capital requirement chart, more money needs to be raised for battery materials than for cell manufacturing, and battery materials should be raising funds at a rate of about 70% of what the EV sector is raising at, not 14%!

And there's another problem; time. Because, on average, it takes 1-3 years to build a cell or EV manufacturing plant. *But it can take between five and fifteen years to build a new mine*.

So not only are we seeing a massive structural capital shortage in the battery raw materials space, we're also building in a time lag.

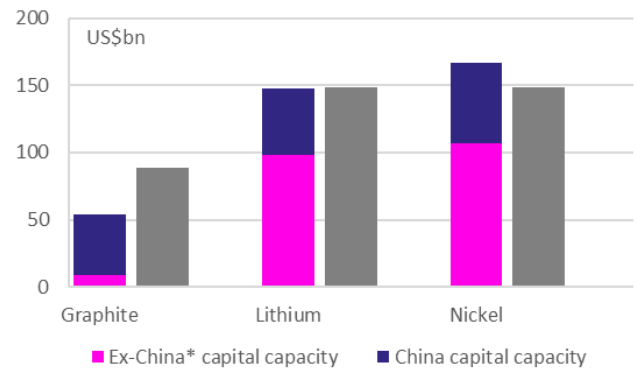
So, why is this happening?

It all comes down to the capital capacity of the raw materials segment.

Mining is a capital-constrained industry

As we discussed earlier, in a healthy industry the capital capacity of the industry should more than exceed the capital requirement for expansions. Contrast the chart we showed earlier for cell and EV manufacturing with the chart below that looks at capital capacity vs requirements for battery raw materials.

Regional capital capacity vs requirement for key battery raw materials, 2021-30E



Source: BM Review

In this chart you can clearly see that only in Nickel does capital capacity (just) exceed requirement, while in lithium and graphite it's lower. We didn't plot high purity manganese on this chart, but rest assured the comparison is even more striking in that segment, and the relationship also holds true for cathode materials.

We have a problem here insofar as battery raw materials are relatively small sectors, which means there are no majors or supermajors. **There just isn't enough capital within the battery raw materials industry to finance the huge developments that are needed**. Capital needs to come into mining from outside the industry.

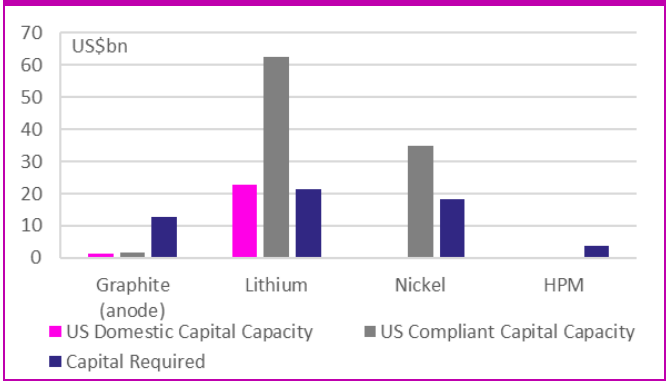
US: IRA is a game-changer

In the preceding chart, we've split capital capacity between China and Ex-China. This is because of the identified need for Europe and the US to develop more regionalised supply chains away from China.

But you can also see that if you back out China's capital capacity then there is a real problem in the Western World, because the available capital capacity for ex-China is well below what will be required.

Somebody in the US was obviously paying attention to this analysis because midway through 2022 the US published the *Inflation Reduction Act*. One of the key parts of the Inflation Reduction Act which resonated for us was that the US was realistic about how much of a raw materials industry it could develop domestically.

US and IRA-compliant battery materials capacity vs requirement, 2021-30E



Source: BM Review

Under the IRA, friendshoring became a thing. Friendshoring means opening the US cell manufacturing and EV manufacturing industry up to raw materials derived from friendly countries. Effectively, for mining, this means Australia and Canada.

Capital capacity vs requ't

So, when we plot US as well as "US & Friends" capital capacity vs the requirement, we see that, except in anode materials and high purity manganese, the US and its friends seem likely to be able to access enough capital for what it's going to need.

Europe now has a BIG problem

But, while the terms of the IRA allow the US to access non-US battery raw materials, Europe has no such legislation in place. In fact, we always get a bit sad when we think of the situation that Europe finds its battery industry in now.

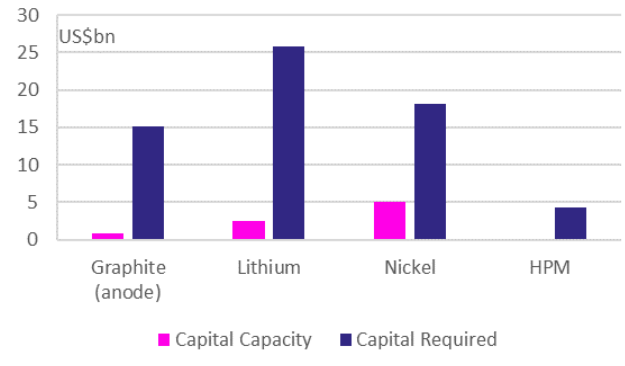
Because the EU was an early mover in recognising the potential, as well as the potential risks of the battery and EV event. Way back in 2018, while the US and other countries were worrying about other things.

But, while the Biden Government has moved rapidly to put policies in place to support the EV event, the EU has frittered lots and lots of time away, talking. And talking. And then a bit more talking.

And, while the EU has made copious funding available to its cell manufacturing and EV industry, it has made precious little available to raw materials production. And now it is in danger of being left behind.

The chart below looks at Europe's battery raw materials capital capacity and requirement, and it's scary.

Europe battery raw materials: capital capacity vs requirement, 2021-30E



Source: BM Review

Europe has only a fraction of the capital capacity it needs, and we are just not seeing any level of top-down political support either at the EU or at the country level for primary materials supply in Europe.

It's all very well investing money in Downstream, but unless Europe wants to continue to be beholden to China for its battery raw materials it needs to enable streamlined planning and start allocating capital for raw materials projects pretty damn quick.

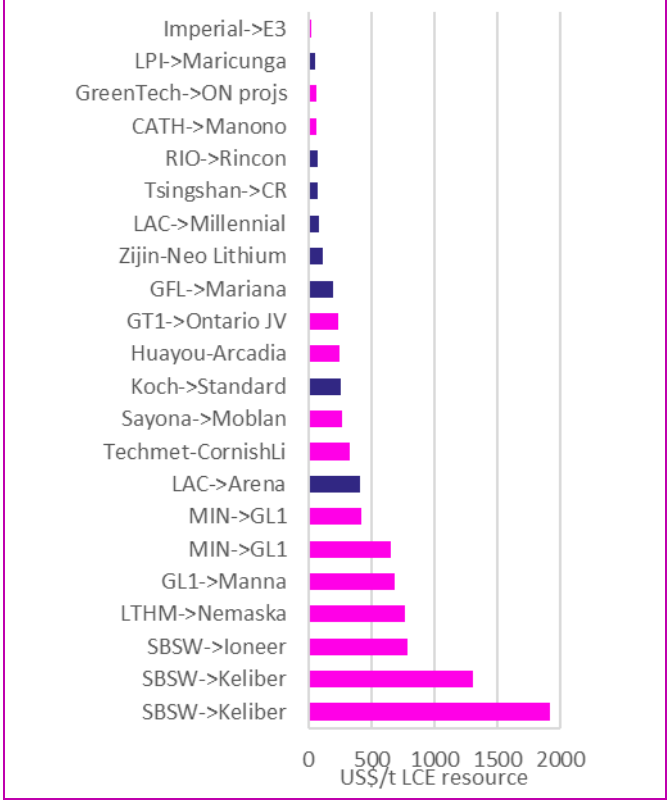
Otherwise its EV manufacturing industry will be like a house with no foundations, and it only takes one big bad wolf to come along and blow, and we know what happens to houses without foundations…

M&A Review

As with financing, it was a weak year for M&A in 2022 in battery materials with only 36 deals valued at US$5m or more. Lithium and nickel were the two segments that saw the most activity, with US$3.7bn worth of deals in lithium and US$3.0bn in nickel.

The biggest deal of the year in lithium was Livent's acquisition of the Nemaska assets although, in terms of total funds spent, Sibanye-Stillwater's two investments in Keliber totalled more. We also saw a number of investments in other hard rock assets, predominantly in Australia, although we are now starting to see increasing grassroots activity in Canada and Brazil.

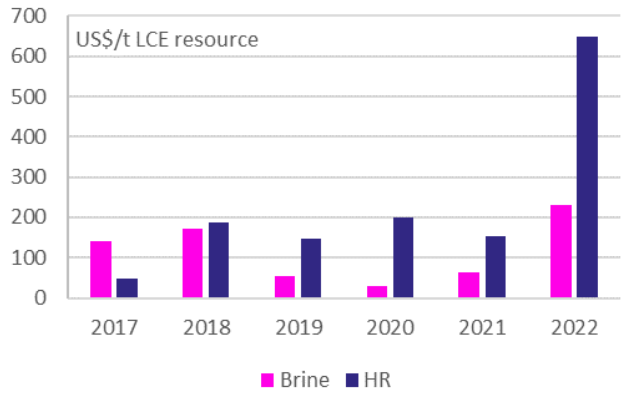
Multiples for lithium M&A, July 2021-December 2022



Source: BM Review. Brine: Blue; Hard Rock: Pink

Sibanye-Stillwater seems to be prepared to pay the most on a transaction multiple basis, but there have also been some big deals in Western Australia. Spodumene hard rock assets, in general, sold at a substantial premium to brine and other assets over the course of the year.

Average multiples for brine and hard rock, 2017-22

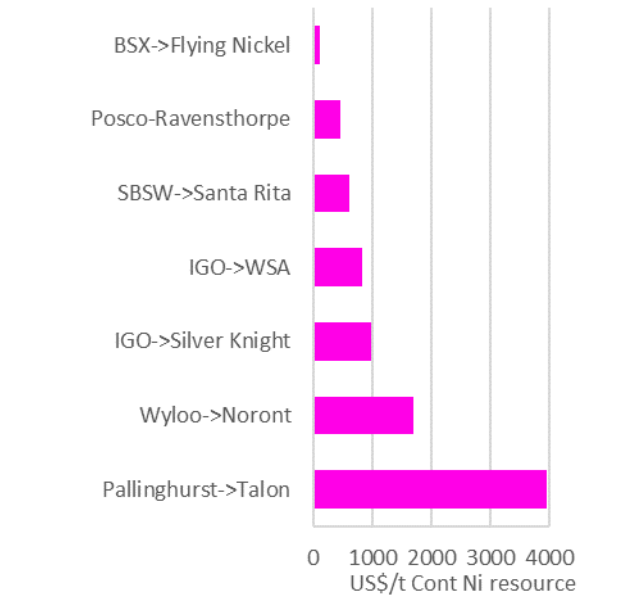


Source: BM Review

That's a substantial turnaround in just five years; prior to 2018 brine assets were much more sought-after and attracted premium multiples.

In nickel, the biggest deal was the acquisition of the Yabulu refinery in Australia by the Zero Carbon Investek consortium for US$1.4bn in December, followed by the IGO Ltd takeout of Western Areas in mid-year. Sulphide assets continue to trade at quite a substantial premium to laterite assets.

Multiples for nickel M&A, 2021-22



Source: BM Review. Brine: Blue; Hard Rock: Pink

Exploration Review

While it hasn't been a great year for attracting financing to the exploration part of the industry, things have been looking up in terms of discoveries, and a number of companies have had considerable exploration success. *Battery Materials Review*'s **Exploration Radar** successfully identified a number of stocks at an early stage which went on to record extremely positive share price performance.

Our chilli rating system identifies which drill results we believe are hot (rated with one, two or three chilli's on our system!). When considering results, we're looking at grade and intercept length but we're also considering depth and potential size of the deposit.

Below is a list of stocks which received more than one chilli rating during the year

Lithium: Excitement for Quebec discoveries

While there is some exploration continuing in brine in Argentina and Chile, the focus of stock market attention for lithium exploration at the moment seems to be in hard rock. In the early part of the year Australian project news predominated, but as the year continued, news of some amazing results coming out of Quebec came over the newswires, and focus shifted to that region.

There is genuine excitement in hard rock circles about the potential in Quebec and this is emphasised by the movement of successful Australian hard rock development teams to these Canadian projects.

Chris Evans, formerly COO of Altura Mining (who built Altura's Pilgangoora project), was an early mover, taking over as MD of Winsome Resources in 2021, but over the course of the year, Patriot Battery Metals has appointed Ken Brinsden (former MD of Pilbara Minerals and the man who delivered the Pilgangoora project) as Non-Executive Chairman, and Winsome has also added Stephen Biggins, who took Core Lithium's Finniss project to within a few months of production, as Non-Executive Chairman.

We continue to be excited by Quebec, not least because of its proximity to infrastructure and ability to tap low-carbon hydroelectric power for processing, but also because of the potential to develop cathode clusters in the region, utilising locally-derived nickel, cobalt and lithium, and locally-processed manganese.

BMR Exploration Radar projects with more than one rating in 2022

Company	Project	Location	Material	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
Atlantic Lithium	Ewoyaa	Ghana	Lithium	1						1	1			1	
Ardea Resources	Emu Lake	WA	Nickel	1	2			1							
Lunnon Metals	Kambalda	WA	Nickel	2	2			1		2	2			2	1
Sama Resources	Grata	Ivory Coast	Nickel	1		1		1							
Patriot Battery Metals	Corvette	QC	Lithium	1				2	1						1
Frontier Lithium	PAK	ON	Lithium		2				1	2	2	1		1	2
Azure Minerals	Andover	WA	Nickel		1	1				1				1	
Panoramic Resources	Savannah	WA	Nickel		1						1		2		
Core Lithium	Finniss	NT	Lithium			1					1				
Aston Minerals	Edleston	ON	Nickel			1	1								
Power Nickel	Nisk	QC	Nickel			2								1	
Estrella Resources	Carr Boyd	WA	Nickel			1			1		1				
Talon Metals	Tamarack	US	Nickel			2				1		2			
Defense Metals	Wicheeda	BC	REE			1							1	1	
Canada Nickel	Various	ON	Nickel					1	1		1				
Widgie Nickel	Gillet North	WA	Nickel						1			1			1
Talga Group	Vittangi	Sweden	Graphite							1		1			
Lithium Ionic	Various	Brazil	Lithium							1	1	1		1	
SPC Nickel	Lockerby Ea	ON	Nickel							1		1			
Lomiko Metals	La Loutre	QC	Graphite									1	1		1
Manitou Gold	Goudreau	ON	Nickel									1	1		
Leo Lithium	Goulamina	Mali	Lithium											1	1

Source: BM Review

Exploration Review cont'd

Lithium exploration also continues in Ontario, Canada around the so-called Electric Avenue, which also boasts a number of exciting pegmatite occurrences, but we are not really seeing the same magnitude of exploration spend in that area.

Outside Canada and Australia, we are seeing a fair amount of activity in Africa, but it is really Brazil which has attracted our attention. Industry watchers will be aware that AMG already has a hard rock mine in production there and Sigma Lithium hopes to bring its new mine into production in 2023. Recent changes to the regulatory regime around lithium have put Brazil on the map for exploration and there are now a number of junior miners exploring in the area. While Quebec has engendered a lot of column inches, Brazil seems (for now) to be skating under the radar, despite some pretty interesting occurrences. Interestingly, it also benefits from mining infrastructure and low-cost, low-carbon HEP.

A key theme in terms of equity markets during the year has been the shifting in listings to Australia. There is very much a view around the industry that the North American shareholder base does not understand or value early-stage lithium projects properly, and a number of companies have therefore pursued Australian listings to open up premium valuations and the ability to finance early-stage hard rock projects at more friendly valuations.

Nickel: look to Canada for most potential

Focus for development dollars continues to be on the laterite projects in Indonesia, with multi-billion dollar cheques being signed and contemplated for a number of HPAL and NPI/matte projects.

In exploration, the Australian market continues to focus on high grade sulphide projects in Western Australia. While these projects are high grade, they are almost all underground and small in scale. In terms of large-scale projects which could genuinely make a difference to nickel market balances, the focus would be on sulphide projects outside Western Australia.

Brazil has been and continues to be a focus, with Centaurus Metals' Jaguar project now moving into the evaluation stage. But, for us, Canada is the most exciting region given its existing nickel industry and infrastructure, and the fact that large swathes of the area around Sudbury have not been explored using modern techniques. We are seeing a number of interesting opportunities develop around both low-grade and high-grade nickel orebodies in Canada.

The other attractive aspect of some of the Canadian nickel occurrences is that they are hosted in ultramafic rocks which are alkaline in nature and when left as surface waste material they have the ability to fix carbon dioxide from the atmosphere. While this feature is not unique to Canadian nickel occurrences, a number of projects under evaluation do feature it and it is not something which seems to be particularly well-understood by the supposedly ESG-conscious autos industry.

Graphite: still looking

While there is a plethora of natural graphite projects in advanced evaluation and development, some exploration is ongoing in Canada, Brazil, Australia, Greenland and parts of Africa.

As we have mentioned before, we do not see a bottleneck in graphite in the upstream part of the business; it is more in the midstream part of the business where we see an issue.

Mines taking longer to build

One of the major imbalances in the battery industry currently is the amount of time it takes to develop and build new battery raw materials operations.

In general, it takes 1-3 years to build a new cell manufacturing facility in China, and it may take 3-5 years to build a similar facility in the US and Europe. It generally takes longer ex-China due to more stringent planning processes.

But it takes substantially longer to build a mining operation, from discovery to production. And how long it takes can also vary substantially between countries.

In a recent article in *Battery Materials Review*, we compared the amount of time it took to build Core Lithium's Finniss hard rock lithium mine in Australia's Northern Territory with Savannah Resources' Mina do Barroso project in Portugal.

Both were discovered at about the same time. Yet, while Finniss is now targeting commercial production in 2023, Mina do Barroso is still stuck in Portugal's labyrinth of planning regulations and will not even be in a position to complete its feasibility study until mid-2023.

And this is by no means a one-off story. On average it takes 50-100% more time to develop projects in the US and Europe than it does in Australia and Latin America.

And a number of high-profile projects, such as Rio Tinto's Jadar project in Serbia, never make it at all.

A recent analysis by Albemarle showed that it could take anywhere from eight years to 17 years from discovery to build new integrated lithium projects.

And time is not the only factor that makes developing projects difficult. Rule of law is also a problem in some areas. AVZ Minerals is currently caught up in legal challenges over its Manono project in Democratic Republic of Congo. Serbia's government cancelled Rio Tinto's licence to develop the Jadar project with seemingly very little consultation. Both companies had invested hundreds of millions of dollars in getting to the advanced position they were in.

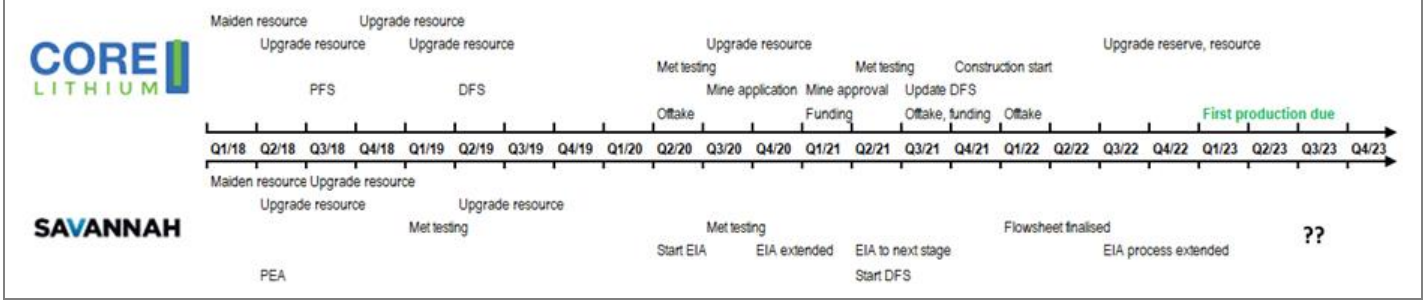
The juxtaposition between national and regional government compared to local issues is an increasingly important thematic in the industry.

There is a general acceptance amongst top-level governments that there needs to be greater investment in primary metal production, but nimbyism (nimby stands for not-in-my-backyard) at the local level as well as unhelpful and opaque planning regulations are derailing attempts to increase production.

Politicians need to understand how damaging anti-mining rhetoric can be in some instances as well. Lumping all mining together (as the UN Secretary General has done in a number of speeches) and not splitting metal mining out from coal mining is a dangerous approach. Implying that all mining is dirty and environmentally damaging is equally so, and untrue as well.

As we have noted previously, **there can be no Energy Transition without investment in primary resource extraction**. Governments need to be helping to enable that, not the opposite…

Core Lithium (Australia) vs Savannah Resources (Portugal) development timeline, 2018-23E



Source: Company data, BM Review

Risks of resource nationalism

One of the recurring risks which can impact the economics and development of the mining industry is resource nationalism. When material prices are performing well it is relatively commonplace for countries in which a mine is being developed or operated to want to extract a greater share of the economics of that operation.

Given the levels to which lithium prices have risen over recent years, it is only natural that governments will seek to extract a greater share of the pie, and in other materials it is possible that we may see further moves as well.

We have already seen the first shot of what could very well be a very long encounter from Argentina. In its FQ2/23 Quarterly Activities Report in January 2023, Allkem noted that it had been advised by the Argentinean government of its intention to "remove the export benefits which currently apply to lithium chemical production". The company advised that such changes could result in an impact of 1-4% of revenue.

While that is not a huge impact with lithium chemical prices at the level that they are at currently, it could be a more significant impact if lithium prices were to fall.

Realistically, in our view, it is unlikely that that will be the final move by the Argentinean government. Or by other governments. Other moves will be likely over coming years.

Such moves are likely to increase the cost structures of mineral development projects which will force up the cost of operation (and cost curve) and extend the payback period for new projects.

While we very much understand governments' needs to extract as much value as possible for the utilisation of a country's natural resources, governments have to understand the substantial risk that mineral developers are taking with their investments in projects, and hence that they need to generate a substantial return to offset that risk.

Governments need to be careful that higher government take from raw material projects does not discourage investment in new projects, because that is not the result that any industry participant wants and is particularly important in the battery raw materials industry, where it is already proving extremely difficult to attract sufficient investment in the sector.

Our preference when it comes to government take is for a sliding scale royalty approach where governments set different royalty rates at different pricing levels for the material. In our view, best practice for governments looking to set royalties is:

- We believe that governments should focus their tax collection below the operating profit line to ensure a long-term and sustainable mining taxation regime. Of course, such an approach requires the miner to utilise best practice and not try to cheat the government by using transfer pricing or by artificially inflating costs.
- Where there is both state and Federal taxation, countries and states must work together to ensure they do not overtax the industry.
- Governments should engage with the industry ahead of the introduction of new taxation. Where governments do not engage, both they and industry tend to suffer.
- Governments should not look to tax more than 40-45% of gross profit for an operation; if they do so they are likely to find that they don't have a mining industry in the long run!
- Governments should not look to overuse the application of a free carry mechanism. While free carry is routinely used in emerging markets, government free carry over 15% tends to put off the overseas investors necessary to get most projects off the ground.

We expect to see more governments looking to collect rent from their battery material resource endowments over time. As a result, we expect the cost curve to rise substantially from current levels. That will mean that prices must remain stronger for longer in order to continue to generate positive returns for investors.

Recycling not a solution

When we speak to politicians and government representatives, particularly in Europe, about the shortage of capital for investment in battery raw materials projects, they often answer with the same refrain, "But we're investing lots in recycling so surely we don't need to invest in primary material production?"

Our answer. "Yes, you do."

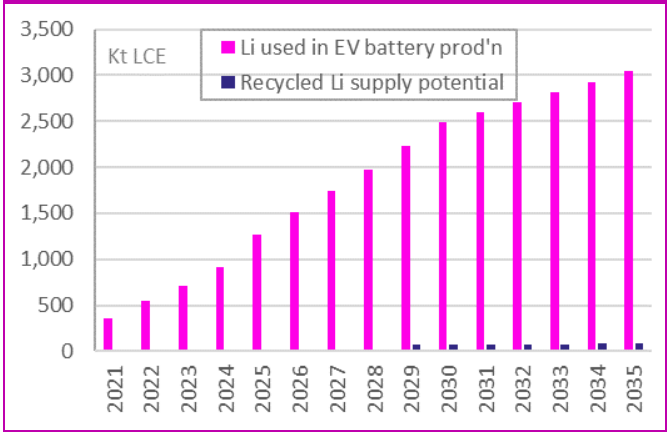
The problem is twofold:

1) EV batteries have a long life. Currently they last about 10-12 years and that may very well extend by several years as technologies advance. In addition, EV batteries may be used for end of life applications such as Energy Stationary Storage (ESS) which could extend their lifetimes by 6-7 years.

2) The battery materials markets are not mature markets, they're immature ones, which are growing extremely rapidly. Global lithium demand is set to rise SIX TIMES between 2021-30E and ELEVEN TIMES between 2021-40E.

So, if one considers the amount of lithium that is used in EV batteries in 2021, that on its own will be a tiny percentage of the amount of lithium which will need to be used in 2031-33E when those batteries may come to the end of their lives and, maybe as much as 50% of those batteries will go into second life applications, so only 50% of that material will be available for recycling.

Contribution of recycling to lithium demand

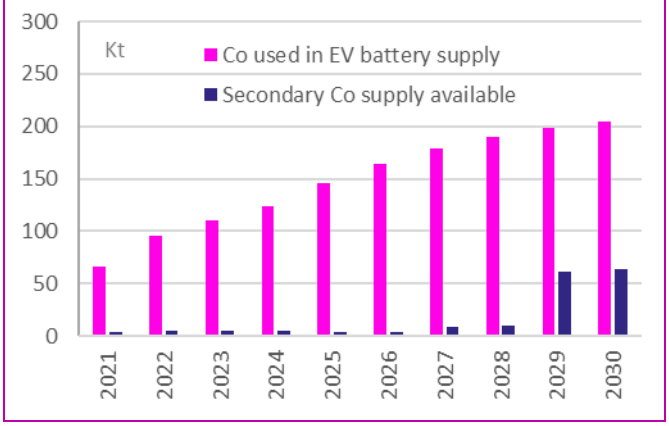


Source: BM Review

The chart above shows our calculations regarding the amount of lithium available from end of life batteries which will be available for lithium supply over the next 15+ years…frankly it's not very much. And, of course, one also has to factor in recovery factors; some of that lithium will be lost in recycling.

While there's more cobalt around in batteries it, also, is not likely to be enough to make a substantial contribution to supply of raw materials for the lithium-ion battery industry any time soon.

Contribution of recycling to cobalt demand



Source: BM Review

So, we very much conclude that recycling is a white elephant; investing in huge amounts of recycling capacity is not going to help supply substantial amounts of material to feed the battery event.

Which is not to say that the recycling industry can't be profitable. Because it can. There are enough faulty batteries, cells, anodes and cathodes around that there will be an ongoing need for recycling of that material, and it may very well be profitable over the next 10-15 years, but overinvestment in recycling capacity with the view that it's going to solve all our problems regarding the supply/demand gap is not the answer.

It won't replace investment in primary materials supply and that should be the focus for government entities.

Are OEMs serious about ESG?

Are some OEMs all mouth and no trousers? Well that certainly seems to be the case when it comes to ESG in the battery raw materials sector. And we can't quite put our finger on whether that's down to ignorance or apathy?

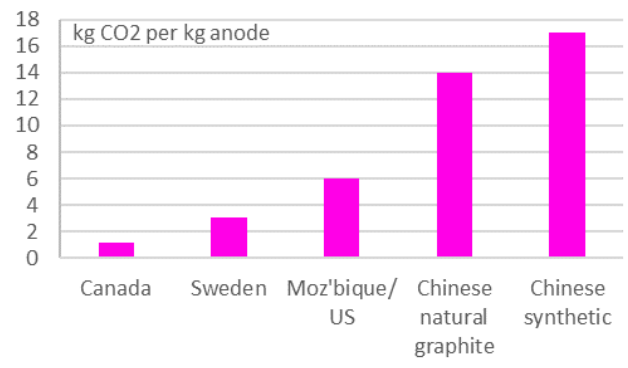
For many years we've been hearing from OEMs about how they are seeking to clean up the battery supply chain. They cried foul of cobalt produced in the DRC and stated, on the record, that they are focusing on greenhouse gas intensity.

We know from our own conversations with junior development companies in multiple segments across battery raw materials that OEMs ask about their environmental and social exposure and guidelines.

We began to get the impression that things may not be as they seem in OEM-land at Volkswagen's Power Day in March 2021 when we noticed in a slide Volkswagen's intent that 100% of its cells would be made of synthetic graphite.

Given that synthetic graphite anodes can be up to four times more carbon-intensive than natural graphite anodes, that raised a red flag to us that either Volkswagen didn't understand that – or it didn't care.

CO2 emissions of anode production



Source: Minviro, BM Review

The next nail in the coffin was Volkswagen's announcement that it had signed a nickel and cobalt procurement agreement with Tsingshan Group and Huayou Cobalt. While many were delighted that Volkswagen had locked up its nickel and cobalt supply, we were stunned.

Why had Volkswagen, one of the biggest proponents of sustainable supply chains, signed up to a supply agreement with some of the least-environmentally friendly producers?

Both Tsingshan and Huayou Cobalt produce the bulk of their nickel and cobalt in Indonesia, via the mining of laterite ores. There are two existing methods for the production of nickel from laterites; HPAL (High Pressure Acid Leach) and NPI/matte.

As we illustrated in the Nickel section of this report, HPAL is twice as carbon-intensive as the traditional pathway for producing nickel from sulphide ores, and the NPI/matte route is nearly six times more carbon-intensive. It's made all the more bad because 50% of Indonesia's grid power is derived from coal and 29% from gas.

And Volkswagen isn't the only OEM that's signed up for nickel supply from Indonesia. Ford and Tesla have also done so, although at least they have attempted to diversify their supply of nickel by including cleaner sources as well.

And, by the way, while we're seeing big growth in Indonesian nickel supply, those aren't the only sources out there. General Motors has signed an agreement with Vale to source cleaner materials mined in Canada, and has even put money into an experimental process to use hydrometallurgical processing for laterite ores. Stellantis has tied up an agreement with Terrafame to utilise nickel which is produced using bioleaching and has minimal GHG intensity.

And this issue of automakers signing up contracts utilising GHG-intensive production pathways is a problem for another reason as well.

There are plenty of miners out there looking to develop lower-carbon intensity processing pathways who can't get funding. If OEMs take the easy route for sourcing these materials, they're effectively deterring further investment in cleaner pathways. And that's going to be a problem for everyone further down the line.

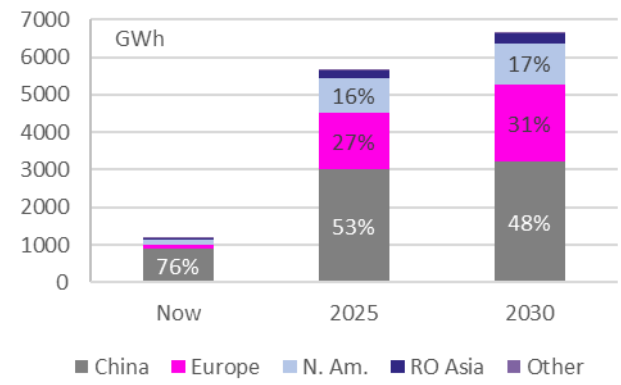
Here come the gigafactories!

At the beginning of 2022, *Battery Materials Review*'s Gigafactory Monitor was tracking just under 4TWh of announced Gigafactory capacity planned for 2025 and just over 4TWh of capacity planned for 2030.

By the end of 2022, we were tracking 5.7TWh by 2025 and 6.7TWh by 2030. That's an increase of 46% and 63% for the two periods. And the announcements keep coming.

Thanks to the Inflation Reduction Act, the most rapid increase in announced Gigafactory capacity has been in North America, where we're now expecting over 1TWh of capacity by 2030.

Announced Lithium-ion Gigafactories by region



Source: BM Review

But China still very much dominates planned battery capacity, both this decade and next.

While Europe is in second place, we worry that the ongoing energy crisis in Europe, coupled with the difficulty in doing business due to the complexity of the planning process, may very well discourage companies from building cell manufacturing assets in Europe.

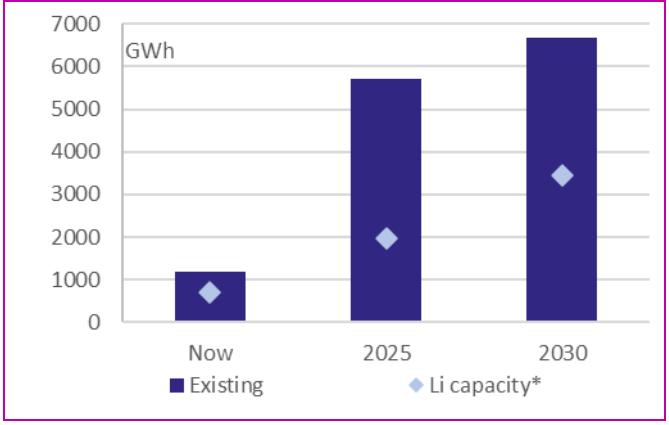
Adding in the magnitude of tax credits available through the IRA in the US, it's becoming quite important that the EU in general and European governments in particular act quickly to secure their own battery manufacturing assets before companies decide to re-site in the US.

While we have done, and are seeing, a considerable amount of cell manufacturing capacity announced globally, one of the aspects that continues to concern us is the ability of the raw materials industry to supply that capacity.

Every month in *Battery Materials Review* we produce our Gigafactory Monitor which tracks the number of announcements in a particular month and adds them onto the projects already being tracked. We compare the announced capacity with what we forecast for demand in those years and what the lithium production industry is realistically going to be able to supply.

We are already seeing a substantial imbalance, with Gigafactory capacity in both years (2025 and 2030) significantly exceeding both cell demand, and the capacity to supply raw materials.

Announced Gigafactory capacity vs lithium capacity



*Source: BM Review. *Lithium forecasts based on BMR f/cs*

Now, we're certain that some announced Gigafactories will fall by the wayside, just like the recent failure of Britishvolt, but we're not convinced that enough will do so to push supply and demand into balance.

Which means that, in our view, there is a material risk that we'll have substantial overcapacity in Gigafactories by 2025 which will continue til the early-2030s. And given that these Gigafactories are big capital items, that doesn't bode well for the cell manufacturing industry and its future returns and profitability.

We can't help but feel that, rather than throwing more money into cell manufacturing in an industry that's likely to be in overcapacity, OEMs and cell manufacturers should be looking to make funding and support available to raw material developers. Failure to do so will likely have substantial ramifications for both industries…

Battery size vs range: trade-off

A few years ago when we analysed the EV industry the overwhelming requirement in developing new EVs was range. This infatuation with range was related to the early days of electric vehicles when early movers (specifically Tesla) were trying to justify their existence and highlight that EVs could be viable to replace ICEs.

In the pursuit of range, the industry targeted more and more energy-dense and larger batteries. More energy-dense batteries generally means more expensive, and bigger also means more expensive, and utilising more materials.

But in a materials-deficient world, that's not a great situation to be in.

And, at the end of the day, who needs an EV with a 1000km (600 mile) range when most ICEs have ranges of 400-500 miles and the average daily drive is less than 25 miles per day? Sure, in the US and some other larger countries, it can be as high as 35-40 miles per day on average, but rarely above that.

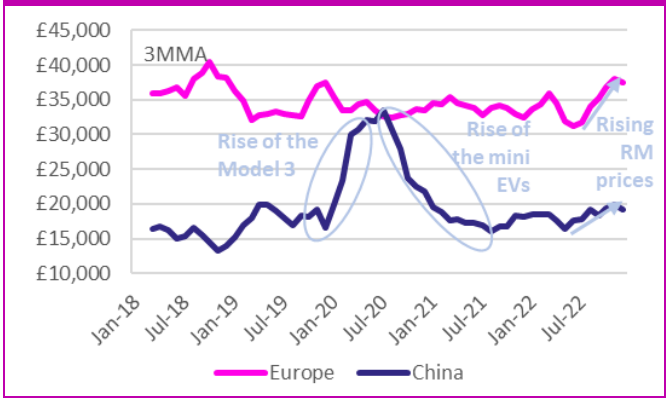
Average daily driving distances

Source: BM Review

A key issue for EVs is when they can reach price parity with ICEs, and that's increasingly less likely to happen in a market where raw materials prices are driving up battery costs.

And indeed, in recent years it's been price that's decided EV sales, not range. If we look at the most mature EV market in the world, China, the best-selling car over the last several years has been the Wuling HongGuang Mini EV, a tiny vehicle with a 10kWh battery which retails at less than US$10,000.

Wtd avge price of top 10 European/Chinese PEVs



Source: EVvolumes, Westbeck Capital, BM Review

Indeed, if we look at the average battery size of the top ten selling Chinese EVs over the past three years, we see a fall in battery size and that cheaper vehicles predominate. The average battery size of the best-selling vehicles in China is sub-40kWh and, even in Europe, the average battery size of the top ten selling EVs is sub-55kWh; it's not about range, it's about price.

But the problem is still that battery sizes (and hence prices) are too big. It's clear that the consumer in recent years is elastic to price and that mass market buyers simply can't afford EVs with huge batteries.

Our analysis shows that the median EV selling price in Europe has fallen by £5-10,000 per unit in recent years. But the problem is that the median selling price for EVs is currently at £25-30,000 and the median selling price for ICEs is £15-20,000 per unit, so EVs are still a long way off mass market in terms of price.

We believe that it will only be if OEMs reduce battery sizes (and hence EV prices) that they can attain truly mass market EV sales volumes.

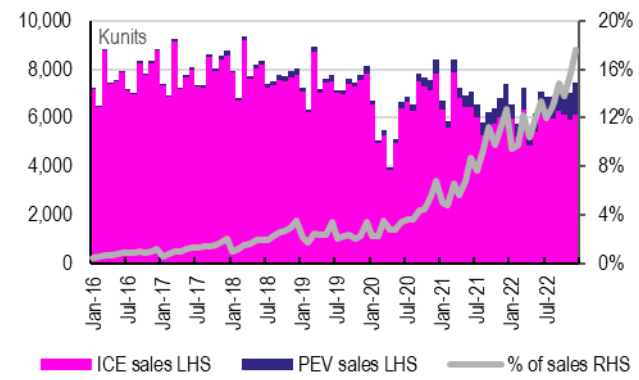
And there's also an extremely positive knock-on impact of that. If the average EV battery size is 50kWh rather than the 60kWh we currently use in our models, then the autos industry could sell an additional 7m units in 2030 than we currently model. That means more EV facilities running at higher capacity utilisation and more profitability. It also means more progress towards net zero targets than is currently possible, and not so much pressure on the battery raw materials supply chain.

It's a no-brainer for us. We wonder if it will be for OEMs?

Electric Vehicles

2022 was another stellar year for EV sales with global new car EV penetration reaching c.18% on average, up from 12% in 2021 and sub-6% in 2020. In some markets it was even higher, with new car EV penetration topping 30% in both China and the European market in December 2022.

Global EV new sales penetration



Source: BM Review, EVvolumes, Westbeck Capital

Total EV sales for the year hit just under 10.5 million units, a year on year increase of 56% (according to data from EVvolumes.com). While that growth rate was somewhat lower than the 117% rate seen in 2021, it was off a substantially higher base – in fact 2022 sales rose by 3.77 million units y/y vs 3.63 million units in 2021.

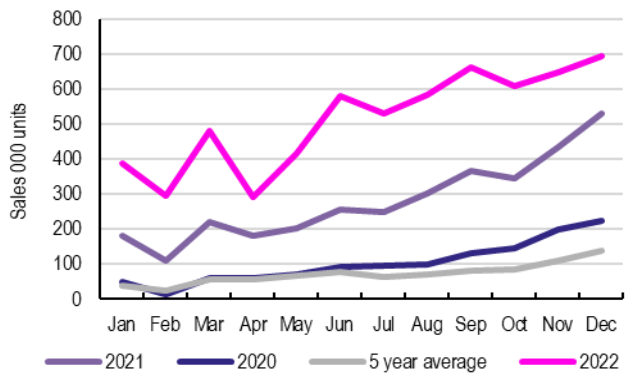
China world's largest EV market

Once again, China was the world's largest EV market in 2022, shifting just under 6.2 million vehicles, and representing 59% of the total electric vehicles sold in the world.

Sales growth slowed throughout the year and, even though many commentators are concerned about the growth outlook in 2023, we are not so concerned. EV sales penetration continues to grow, and it feels like the market is maturing in China in a way that it has yet to do in the other regional markets.

While it's difficult to say that a market that grew at 83% y/y in 2022 is a mature market, we believe it *is* fair to say that China is maturing faster than the world's other EV markets, and there are some very interesting trends emerging in that market, which we believe may very well be applicable to the world's other EV markets.

Seasonality of Chinese EV sales



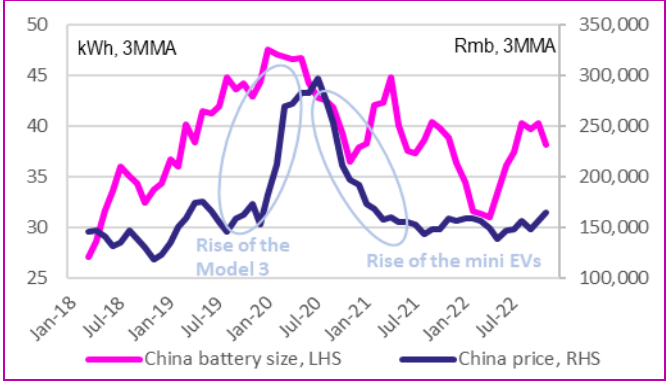
Source: BM Review, EVvolumes, Westbeck Capital

Price elasticity (battery size) becoming more important

China has become the first market in the world where ***price has mattered more than range***. In the other key EV markets in the world, EVs are generally second cars and a high proportion of sales are in the premium segment. In the premium segment, the focus has been on range and performance.

In the mass market segment, the focus is more on value for money and practicality, and in China that's pushed the focus more towards price, with range only being important insofar as consumers can be assured that their car will manage their daily or weekly commute.

Battery size and price of China's top-selling EVs



Source: BM Review, EVvolumes, Westbeck Capital

The rise of the mini EVs in 2020-21 reduced the average battery size of Chinese EVs substantially and resulted in a commensurate large drop in price. And, in our view, that has substantial implications for the juxtaposition between battery size and EV demand in other emerging EV markets.

Electric Vehicles Cont'd

To some extent we are seeing smaller EVs with shorter ranges starting to take off in the European market. Cars like the Dacia Spring and Fiat 500, both of which retail at below £20,000, are regular components of the European EV sales top ten despite neither being part of marks that regularly feature in the top ten for ICEs.

We expect that price will matter more and more over range in coming years, particularly at the mass market end of the business. Given the current juxtaposition between price and battery size, we think that means that the mass market EVs of the future will have smaller and more affordable batteries…

Tesla has best-selling models but beaten out by BYD on market share

Tesla's Model Y and Model 3 are the best-selling models globally in 2022, with the Wuling/HongGuang Mini EV rounding out the world's top 3.

Global top ten selling EV models and brands, 2022

Models	Mkt share	Brands	Mkt share
Tesla Model Y	7%	BYD	18%
Tesla Model 3	5%	Tesla Inc.	13%
Wuling HongGuang Mini	4%	VW Group	8%
BYD Song Pro/Plus PHEV	4%	GM	6%
BYD Dolphin Hb BEV	2%	Stellantis	5%
BYD Yuan Plus / Atto-3 BEV	2%	Hyundai Motor	5%
BYD Qin Plus DM-i PHEV	2%	BMW Group	4%
BYD Han BEV	1%	Geely Auto Group	3%
BYD Han PHEV	1%	Mercedes-Benz Group	3%
BYD Tang PHEV	1%	R-N-M Alliance	3%

Source: EVvolumes, Westbeck Capital

But BYD then takes the next seven spots, and this just highlights a key strategic issue for Tesla. Because, while its vehicles are undoubtedly world-class, it cannot compete against the sheer range of vehicles that the large OEMs can offer.

While Tesla is the top brand in the nascent US EV market, it is only number seven in Europe and number three in China. BYD's 23 models give it the ability to trounce Tesla in China and VW Group's 35+ models give it a similar advance in Europe.

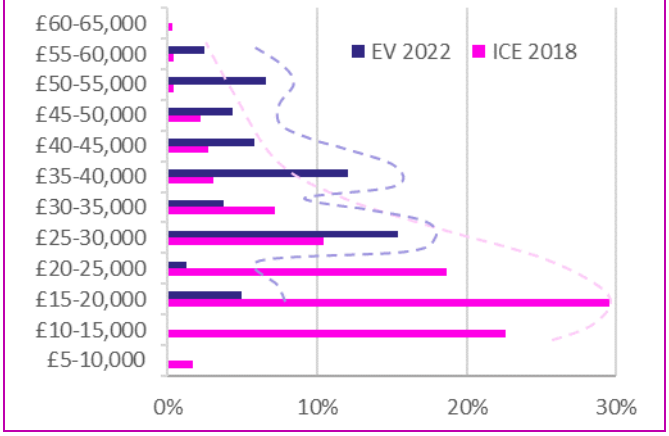
While this isn't great news for Tesla, it's potentially worse news for the small EV developers which are looking to break into the global market. How will they genuinely build market share against the existing behemoths? Can Rivian, Xpeng, Lucid and the others genuinely break out into the mass market? And, if they can't, what does the future hold for them?

Where does the EV industry go now?

In our view, the substantial improvements seen in fast charging technology in recent years remove range as a major driver of EV demand. We believe that, as result, price will be the major driver of mass market demand for EVs, as we've seen in China.

The problem is that, in the US and Europe, EVs just don't sell for mass market prices. A comparison of auto selling prices in Europe shows that the median selling price for new European autos is £15-20,000 per unit. But that's not the median selling price for EVs.

European median new car prices



Source: BM Review, EVvolumes, Westbeck Capital

No, indeed, the median selling price for EVs is closer to £25-30,000, even including subsidies. And in the US there's an even greater gap between median EV prices and mass market.

The future for EVs then has to be price. And, in this period of supernormal raw material prices, that surely means that average battery sizes must fall. Because it seems highly unlikely that greater economies of scale in manufacturing will be enough to offset further increases in battery raw materials prices. The only way to force EV prices down is to make smaller batteries, using less battery material. That will allow more cars to sell as well. That must surely be the future…

BESS: fastest-growing segment

When people think of rechargeable batteries, they probably think of electric vehicles as the fastest-growing and most important driver of demand. But, while EV demand is growing rapidly, battery energy stationary storage (BESS) is growing more rapidly (although off a lower base) and is set to be a key driver of demand for rechargeable batteries in coming years.

BESS has been on our radar for several years, but there's no getting away from the fact that it's stormed onto many other people's radar screens this year in a big way.

Whether it's long duration ESS planned to sit alongside wind and solar energy generation plants, shorter duration ESS for backup power and frequency modulation or residential storage, BESS has many demand drivers.

And generally BESS costs were falling until the middle of 2022, aided by the switch in chemistries from ternary to LFP batteries. Unfortunately, that has now stopped with BNEF's ESS cost survey finding that costs rose 27% y/y to US$324/kWh in 2022 for a four-hour duration system.

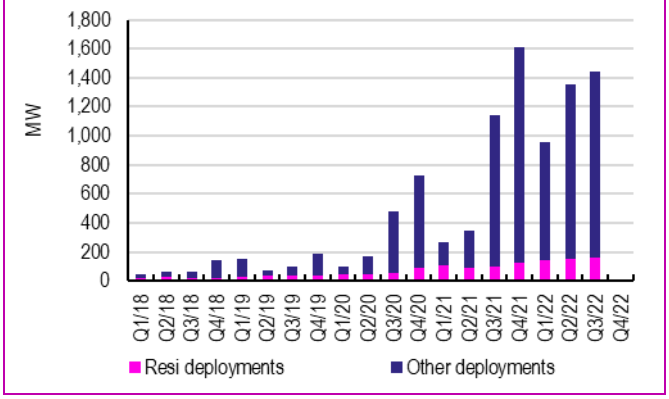
BESS costs are more expensive on a dollar per kWh basis than EV battery costs because of the substantial management systems around stationary batteries and also the cost of planning and development. Also for longer duration lithium-ion systems, some doubling up is necessary and that can inpact the economics.

The rise in costs of lithium-ion batteries should help drive demand for other long duration chemistries, such as vanadium, iron and chromium flow batteries, and potentially also sodium-ion batteries.

2022 has also seen huge acceleration in utility-scale BESS deployments, particularly in the US where the EIA suggests capacity has reached c.9GW, and in China, where there has been a substantial build out.

WoodMac reported that the US deployed over 5GWh of ESS in Q3/22, of which 4.7GWh was in the utility market. EIA expects that US BESS capacity will reach 30GW by 2025 and could go substantially higher by 2030.

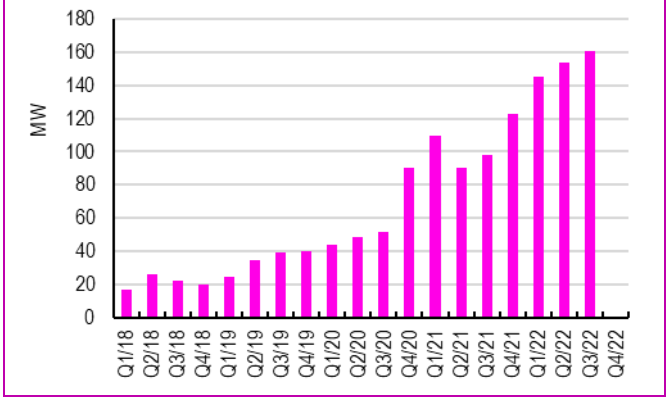
US stationary storage deployments by segment, 2018-Q3/22



Source: Wood Mackenzie, BM Review

Residential storage has also grown very rapidly in 2022, with the war in Ukraine and the subsequent disruption of European gas supplies, leading to strong demand for solar+storage solutions in Europe, previously a market which lagged the US.

US residential stationary storage deployments, 2018-Q3/22



Source: Wood Mackenzie, BM Review

Broad-scale political support has been building for ESS. The US states of New Jersey, California and New York have all introduced substantial ESS target capacities for 2030, it has been suggested that capacity in Europe needs to reach 190GW by 2030 (a huge ramp up considering only 1GW of capacity was deployed in 2021), the Australian state of Victoria set an ESS target of 6.3GW by 2035, rapidly joined by other Australian states, and several other countries have set ambitious BESS targets.

The huge growth in support for BESS led us to increase our forecasts twice during 2022.

Equities: Volatility abounds

Key index and BMR Equity basket performance, 2022

BMR Raw Materials equity baskets	2022 perf
Cobalt	-39%
Graphite	-28%
HR Lithium	-9%
Brine Lithium	-39%
Li - producers	-15%
Li - developers	-32%
Li - explorers	50%
HP Manganese developers	-40%
Nickel	-28%
Ni - explorers/developers	-24%
Vanadium	-36%
BMR Intermediate Materials equity baskets	**2022 perf**
Midstream	-29%
Recycling	-49%
BMR Downstream equity baskets	**2022 perf**
Cellmakers	-41%
EV Makers	-68%
Indices & sector ETFs	**2022 perf**
S&P Global 1200 index	-19%
S&P Global 1200 Materials index	-12%
Global X Lithium & Battery Tech ETF	-31%
Solactive Battery Value-Chain index	-14%

Source: Westbeck Capital, BM Review

Key battery material price performance, 2022

Raw Materials	2022 perf
Cobalt LME	-27%
Cobalt sulphate China (20% Del)	-56%
Graphite, China flake 190	17%
Spodumene concentrate (CIF China)	135%
Lithium carbonate China (99% del)	72%
Lithium hydroxide China (96% del)	130%
HP Manganese sulphate	-36%
Nickel, LME	43%
Nickel sulphate China (21-22.5% ExW)	3%
Vanadium pentoxide, China 98% FOB	-8%
Intermediate Materials	
NCM 523 precursor	-30%
NCM523 cathode material	28%
NCM 622 cathode material	25%
LFP precursor	54%
China SPG 99.95% 17 micron ExW	12%

Source: Westbeck Capital, BM Review

2022 was a year when equities materially underperformed the underlying battery materials, in marked contrast to 2021 when they outperformed. The only one of our equity baskets which was in positive territory for the year was our Lithium explorers basket, which managed 50% for 2022.

It was not just in battery materials where equities performed badly. The S&P Global 1200 index was down 19% and it was a torrid year for equities as a whole. The Global X Lithium & Battery Tech ETF gave up 31% and the Solactive Battery Value Chain index was down 14%.

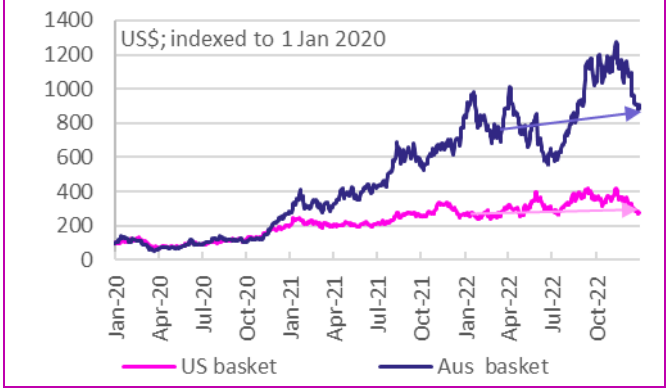
Lithium the best performer

As befits the best-performing battery material in 2022, it perhaps shouldn't be a surprise that our lithium equity baskets were the best performers. But, given that spodumene concentrate prices were up 135% for the year and lithium carbonate 72%, it is perhaps disappointing to find our hard rock equities basket down 9% and our brine equities basket down 39%.

This derating of equities vs the underlying material emphasises how difficult it has been in 2022 to attract premium valuations and to raise money.

Within the lithium space, there was again quite a substantial regional differentiation in performance, with North American-listed stocks underperforming Australian-listed stocks.

US-listed lithium basket vs Australian-listed



Source: BM Review. US:ALB, LTHM, SQM; Aus: AKE, PLS

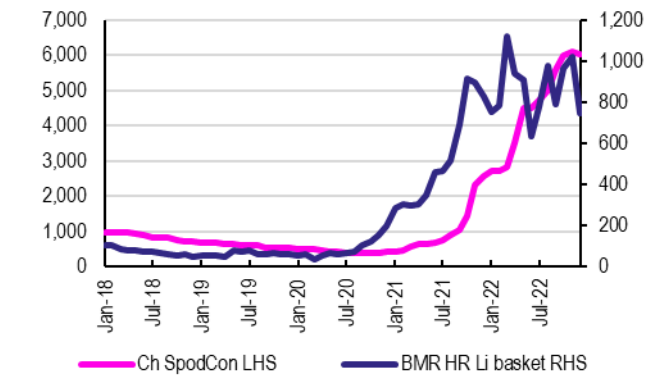
We interpret this as being down to the negativity of the US brokers on the lithium price outlook vs a number of Asian and Australian brokers who, being closer to the market, are markedly more bullish.

Equity round-up Cont'd

There was also a material difference in the performances of hard rock producer/developers vs brine producer/developers, which again is related to this regional theme. The bulk of hard rock producer/developers are Australian-based or listed, with a larger proportion of brine producers being North-American listed.

Spodumene concentrate prices didn't fall off as much at the end of the year as lithium carbonate prices but most of the stocks still gave up a lot of their performance in December.

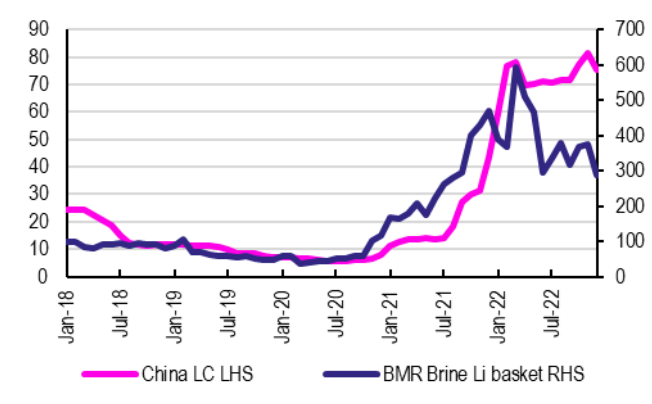
Chinese SpodCon prices vs BMR HR equity basket (US$)



Source: BM Review. HR: Hard Rock producers and developers

Despite lithium carbonate prices having a very strong quarter in CQ1/22, broker downgrades on lithium by major US brokers in CQ2/22 led to a collapse in lithium equity performance which was: 1) not commensurate with the fall in underlying material prices and; 2) never really made itself up over the rest of the year.

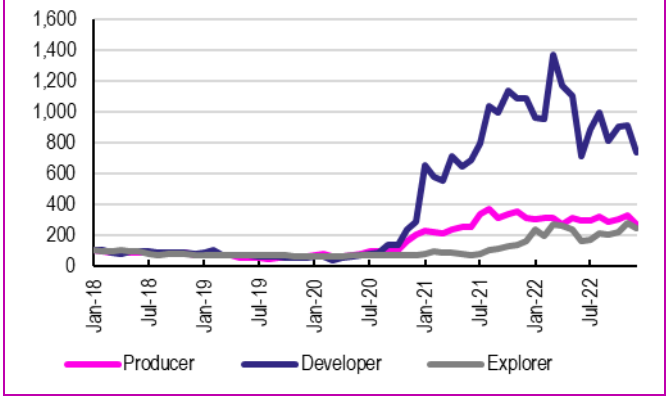
Chinese lithium carbonate price vs Brine equity basket (US$)



Source: BM Review

Over much of the year we maintained our preference for the lithium explorers in *Battery Materials Review*'s asset allocation section because of our experience that explorers perform well in periods of weak equity markets. Explorers tend to perform well during these periods because they are adding value through the drill bit and, indeed, that was very much the case in 2022.

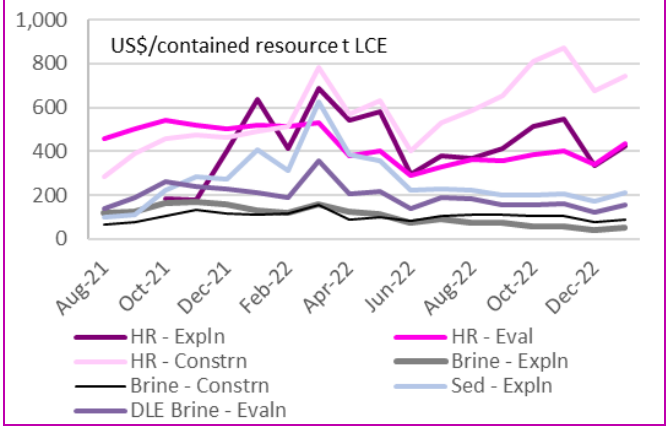
BMR lithium producer, developer and explorer baskets



Source: BM Review

We saw quite a substantial valuation re-rating of hard rock assets throughout the year. As noted above, they outperformed brine assets. Within the brine segment, the most significant de-rating was for DLE brine assets, and, outside the brine segments, sedimentary lithium developers also saw a substantial de-rating. Hard rock assets under construction were the most significant re-raters during the year.

Lithium equity valuation trends, 2021-22



Source: BM Review. EV/contained resource tonne of LCE

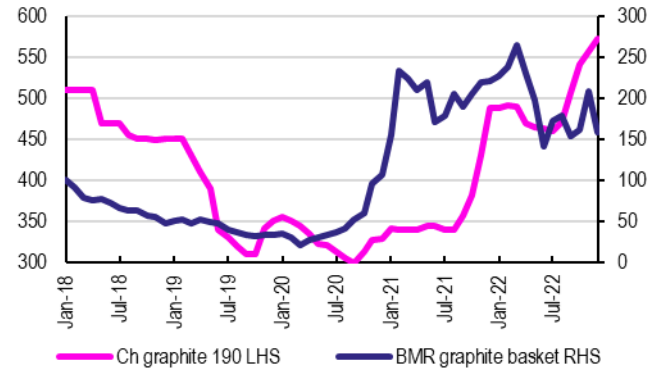
Equity round-up Cont'd

Graphite stocks down although graphite prices up

Our Graphite equity basket was down 28% in 2022 even though flake graphite prices in China rose 17% and spherical graphite prices 12%.

We have liked Graphite as a segment for some time although we note that the complexity of the segment and its relatively small size seems to have deterred institutional investors. Nevertheless, as we have noted in previous pages, we are almost as concerned about the impending "graphite gap" as we were about lithium a few years ago, and it is likely that graphite prices, particularly midstream graphite prices, may continue to run, in our view.

China flake 190 basket price vs BMR graphite basket (US$)



Source: BM Review

Whether we see Graphite equities performing will very much come down to how much institutional investment we see flowing into the sector and currently we are not seeing very much.

Part of that is down to the structure of the graphite sector, with only one stock boasting a market value exceeding US$1bn and another four with values above US$250m. It is very difficult for institutional capital to flow into companies with low trading liquidity.

This obviously makes it difficult for graphite developers to raise funds for expansion and we suggest that this segment above all others will likely be reliant on government funding, debt and stake sales to get some of these very urgently needed projects off the ground.

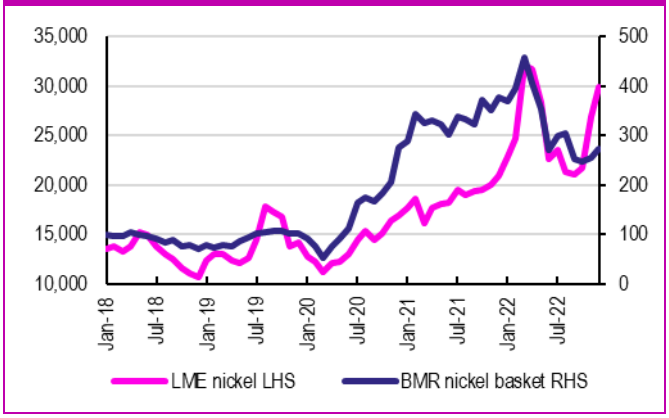
Nickel: ups and downs

2022 was an interesting year for nickel equities, with some exciting highs but some chastening lows.

The year started positively, got tighter in February after Russia's invasion of Ukraine and as the market started to speculate about what would happen to Norilsk Nickel's production, and then went from the sublime to the ridiculous with the LME debacle in March.

Ever since then nickel equities have struggled for direction as the LME becomes less and less viable as a leading indicator of nickel prices. This was strongly illustrated in December when the second LME squeeze of the year resulted in not a lot of reaction from our nickel equity basket.

LME nickel vs BMR nickel equity basket (US$)



Source: BM Review

But whichever nickel product you look at, be it LME nickel (+43% for the year) or Chinese nickel sulphate prices (+3% in US$ terms), the derating of equities vs the underlying material is profound. It seemed that equity investors just could not believe that the material prices was going up and certainly weren't prepared to follow them.

One of the big issues with nickel is the overproduction of low quality nickel (NPI) and the relative scarcity of high quality product. It seems much of the equity market is tracking the commodity end of the business, not the specialty part. Certainly the overhang of Indonesian capacity is a continued issue for equities, but we have rarely seen a dislocation of this magnitude between equities and underlying nickel prices.

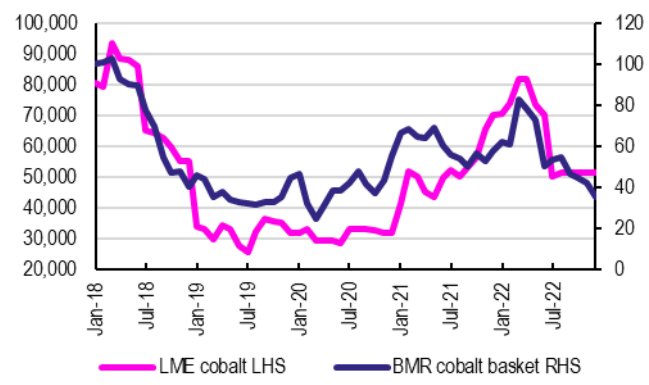
Equity round-up Cont'd

To some extent nickel has many of the same issues as graphite. The largest ex-Russia nickel producers in the world are companies like Vale, BHP and Glencore, where the nickel division is a relatively small part of the whole. The year saw another pure-play in the form of Western Areas being taken out, and now there are only a very few listed pure-play nickel producers in the world and a handful of advanced developers. That means that it's becoming increasingly difficult for equity investors to invest in the nickel thematic.

Cobalt: heading down

Our cobalt equity basket was the second-worst performer of our lithium-ion raw materials baskets, at -39% for the year. At least this was, in some way, justified with LME cobalt prices down 27% for the year and Chinese cobalt sulphate prices down 56%.

LME cobalt vs BMR cobalt equity basket (US$)



Source: BM Review

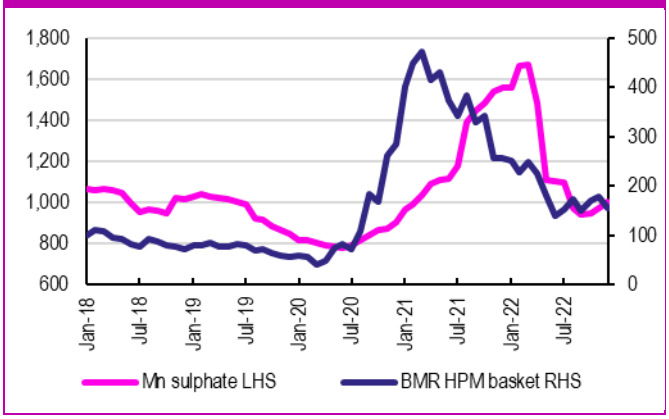
With cobalt production dominated by Chinese companies in DRC, there are relatively few ex-China producers and developers, but 2022 was not a landmark year for any of them! Probably their fingers are crossed that 2023 will be better.

HP Manganese: price opacity doesn't help equities

Our High Purity Manganese (HPM) developer equity basket struggles with the opacity of the high purity manganese market. It was our worst-performing lithium-ion raw material equity basket this year, down 40%.

We understand from our contacts in the industry that European high purity manganese prices held up relatively well, but Chinese ones (which are not selenium-free) were impacted by the downturn in the Chinese industrial complex, and were down 36%. In the absence of any other pricing indicators it seems that the equity market takes its guidance from that price series.

China Manganese sulphate price vs BMR HPM basket (US$)

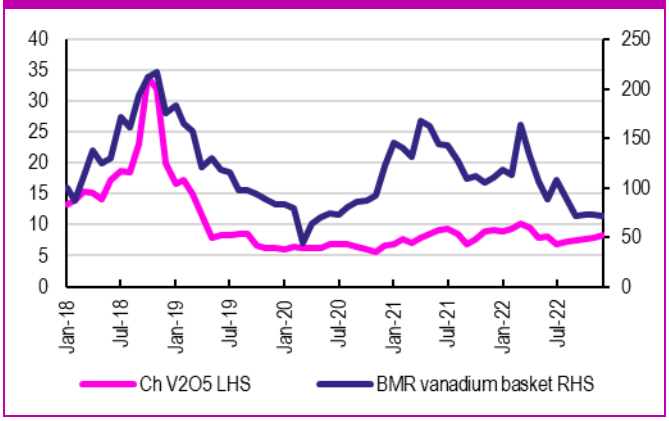


Source: BM Review

Vanadium struggles with Chinese industrial woes

Our vanadium equity basket was down 36%, while the underlying commodity gave up 8% in 2022. The weakness in the Chinese industrial complex contributed to weak steel production, a key consumer of vanadium.

China V2O5 price vs BMR vanadium equity basket (US$)



Source: BM Review

While there is quite a lot of excitement about VRFBs among equity market participants there is an understanding that they are so far lacking that Gigafactory moment to take them into large scale use. The negative movement in V2O5 prices in China during the year sapped a fair amount of momentum out of both vanadium developers and producers.

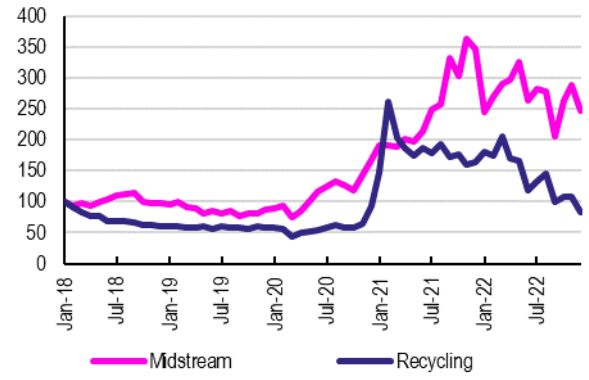
Equity round-up Cont'd

Recycling struggles; Midstream better

2022 was a difficult year for our battery recycling basket after its break out year in 2021. Our basket of battery recyclers gave up 49% after being up 77% in 2021.

To some extent this was down to recyclers being lumped in with low revenue tech stocks by factor investors, but we also believe it was due to increasing understanding that, while there is considerable government support for recycling as a theme, the actual reality of battery recycling may be more complex.

BMR Midstream and Recycling basket performance (US$)



Source: BM Review

Our Midstream basket was also weak, although it outperformed our recycling basket. It fell 29% for the year, well below last year's 107% return.

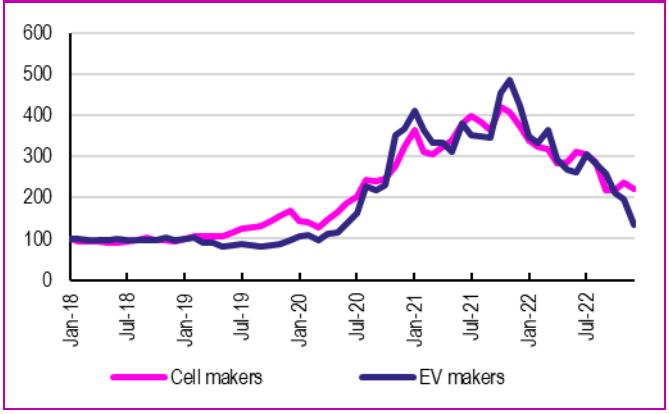
Cathode producers were the best performers in our basket, but it was a torrid year for some of the separator and foil players which experienced substantial de-ratings.

Cell makers also de-rate

Cell makers struggled with the equity market's general disdain for Tech stocks, with our basket falling 41% for the year. There was quite a lot of regional differentiation to performance, with German cell maker Varta giving up over 80% for the year and some of our Chinese cell makers also doing poorly, even though performance wasn't as negative as that.

In our view the equity market was most-concerned about the potential for raw material pass-through cost pressure and the ability of cell makers to pass that on to their clients. While margins remain at relatively low levels they didn't go negative during the year for most cell makers, so it is possible that the market's concerns were overdone.

BMR Cell and EV makers equity basket performance (US$)



Source: BM Review

EV makers the worst-performing basket

EV makers were by far the worst-performing segment in the battery value chain in 2022, with our EV manufacturers equity basket down 68% for the year.

As with cell makers, it seems that equity investors were most concerned with EV makers' ability to pass on higher raw material costs.

While the equity market saw EV makers raising prices to try to pass through costs to consumers, it worried that perhaps that wasn't a great strategy given that EV prices are already well above mass market and that any demand destruction would impact producers' bottom lines.

Once again EV makers and developers showed that rolling out new models is more complex than many expect and the litany of developers coming back to the market for more working capital during the year also led to investors moving away from the sector.

With some concern about the strength of the Western World consumer and potential for car sales growth to turn negative and EV sales growth to slow substantially, it also wasn't a great second half of the year for EV makers. Eyes are now focused on China to see whether the removal of subsidies in 2023 slows EV sales growth substantially.