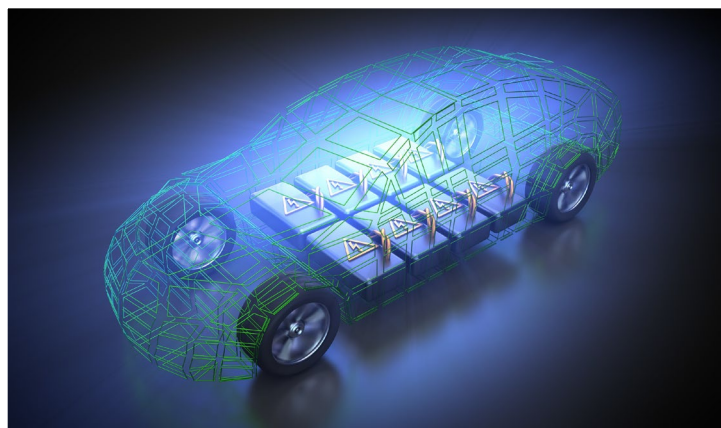
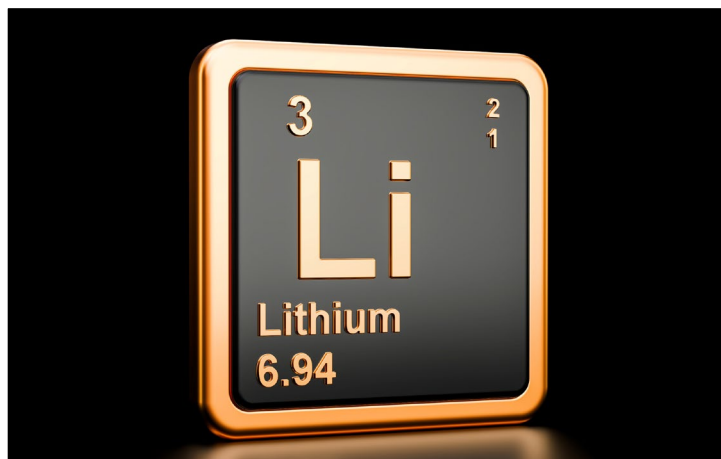


Investing in Battery Materials



How to invest in Hard Rock Lithium

Lithium is one of the most important components of the current generation of rechargeable batteries used in the Electric Vehicle (EV) revolution. Lithium prices have risen nearly tenfold in recent years and lithium equities have performed fantastically.

There are two primary forms of lithium extraction; from brine and from hard rock. This report focuses on the hard rock segment, given that it is the most rapidly-growing.

But hard rock lithium is a complex industry with many differences from the general mining industry. There have been a number of project failures over the years that have cost investors plenty.

In this guide, we help investors understand the industry, the exploration and development cycle, when to invest to generate highest returns, factors to consider when trading stocks and what sort of questions to ask management teams to avoid being tripped up.

The guide is aimed at both professional and non-professional investors.

About the author

Matt Fernley is Editor of Battery Materials Review and has been an equity analyst and investor for over twenty years. He has previously written a number of well-received introductory guides to various sectors, including in the Paper, Mining, Iron Ore and Graphite sectors. In this report he passes on the hard-won tricks and perspectives from his twenty years of investment and analytical experience.

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Thanks to Ken and Charles for the pre-reads and useful feedback.

Introduction

The Electric Vehicle (EV) revolution is a core component of the transition away from carbon-intensive energy. But it will succeed or fail according to the amount of capital that can be attracted to the supply chain. While more than sufficient capital has been attracted to cell and EV manufacturing, the upstream (mineral extraction) part of the industry has been sorely neglected, which has led to an imbalance between supply and demand in many materials.

Lithium is one of the most important components of the current generation of rechargeable batteries used in EVs. But lithium demand is growing off an ultra-low base and, up to now, the industry has been substantially under-invested, which has led to a spike in prices for the key lithium chemical intermediate products.

While there are a number of funds specialising in battery materials in existence, realistically it will be important to attract generalist capital to the space. But generalist investors will not come into a space that they do not understand and that's why *Battery Materials Review* is developing this series of introductory reports on how to invest in battery materials.

There are two primary forms of lithium extraction; from **brine** and from **hard rock**. This report focuses on the hard rock segment, given that it is the most rapidly-growing.

Different types of lithium deposit in operation and development

	Brine	Other	Hard Rock
In BG commercial production	High grade salar	N/A	Spodumene-rich Lepidolite-rich (China)
Unproven for BG commercial production	Low grade salar (DLE) Geothermal (DLE) Other low grade (DLE)	Sedimentary	Zinnwaldite Jadarite

*Source: BM Review. Note petalite and lepidolites also used for lithium production in the past; not battery grade. BG=**Battery Grade**.*

In this report, we explain to investors what the key focuses are for explorer, developer and production stage stocks, and highlight the questions that they should be asking of management teams.

We explain the mining cycle and help investors to understand the risk levels at each stage of the mining cycle.

We consider how investors can best trade these stocks and how to maximise their return potential.

We discuss those factors which often trip up investors and give insights into key valuation methodologies for stocks at all stages of development.

The report is aimed at both professional and non-professional investors.

The Basics

So, before we get into the nitty gritty of technical issues, let's get started at the beginning.

Why are we here?

Well, I assume in basic terms *you're* reading this because you believe in the rechargeable battery event, and you want to find a way to make money off it. You've done a bit of research and you think that lithium is one of the most interesting battery materials and, within that, that hard rock projects look exciting, and you want to understand more about them so that you can invest your hard-won cash into making more of it.

I'm writing this because I'm a big supporter of this sector but I'm realistic enough to know that battery materials stocks succeed or fail in terms of the number of non-specialist investors they can attract. If they can attract a lot then they, and the sector as a whole, can be successful. If they cannot, then they will fail.

But, most investors won't put a lot of money into a sector they don't understand, so it behoves those of us who do understand the intricacies of the sector to explain it to those who don't.

On top of that if investors lose money in a sector because they invested in stocks that fail then the chances are that they won't come back to that sector. In this report I hope to give investors the information they need so that they can ask the right questions and minimise the number of investment failures they have.

I say *minimise* because I'm a professional investor with over twenty years of experience and I still have investment failures, and everybody I know that invests in equities also has investment failures. The trick, of course, is to invest in more stocks that succeed than that fail!

What are we looking for?

That is the big question. I guess most of us would say that at the end of the day we're looking for a ten bagger, ie a stock that goes up ten times while you hold it! But let's be realistic, you're only likely to get ten baggers early on in the cycle and in very specific situations after that time. And there's lots of opportunity to make significant amounts of money in these stocks at all times in the cycle, so let's investigate that.

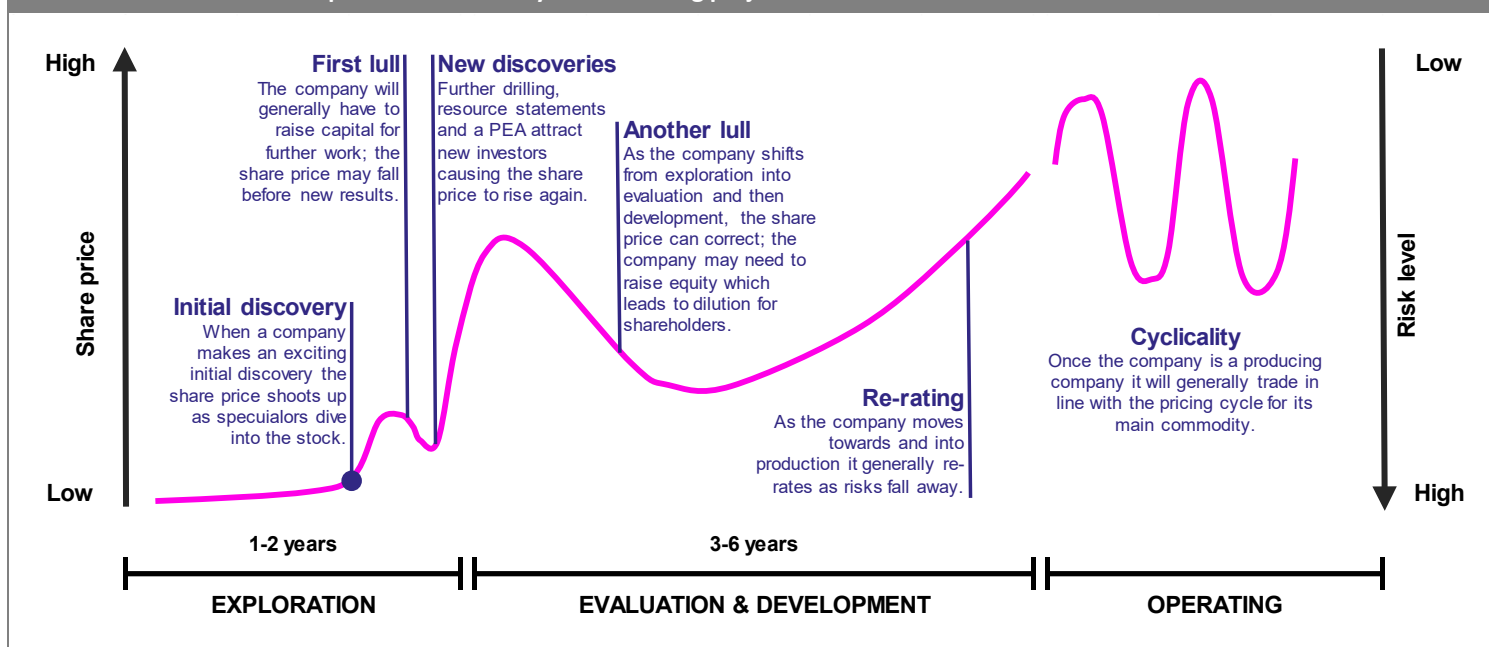
The life cycle of a mining project

Before investing in a mining stock (because that's effectively what battery raw materials stocks are), it's important to understand at what stage it is in the mining cycle. Stocks trade at different valuations according to what stage they are at in the mining cycle and they also have different amounts of upside (and downside) potential, and risk.

Early-stage stocks (pre-discovery or just after the initial discovery) have the most upside and, realistically, this is where you're most likely to find your ten bagger. BUT they also have the most risks. Just because you or the management team think they've made a great discovery, doesn't mean that that project will ever get anywhere near production. I talk about some of the factors that can prevent a project from getting into production in the next section so I won't labour the point here, apart from saying that for every ten exploration stocks that an investor buys, he/she is doing well if two or three of them actually make it into production.

That's not to say that there's not a lot of money to be made in exploration stocks, *because there is*. But an investor has to understand when to cut and run – that is the biggest lesson for investors. Don't ride a stock all the way up and all the way down. It's a horrible feeling. I know, because I've done it on a number of occasions!

Illustration of a stock's share price over the life cycle of a mining project



Source: BM Review

If you look at the illustration above, it's really important if you're to be a successful investor that you understand where the stock you're looking at is at in its life cycle. You don't want to be the investor who buys at the top of the cycle just as the company is transitioning into evaluation, or just as they do a major capital raise ahead of development. Otherwise it could take as long as several years to make your money back.

If you want to invest in exploration stocks you have to understand that there's likely to be *dilution risk*. Dilution occurs where a company raises money to finance more exploration (or potentially evaluation) which may occur at a share price below the one you got in at. When a company raises money, often it will do so at a discount to the prevailing price. That means that while its' market value may increase (because of the money it raised), the per share value of its stock may be lower in the near-term because its value is diluted by the greater number of shares in issue.

Investors also need to be aware of the "Development Lull". Depending on the timing on the global economic cycle, as well as the stock's particular cycle, some stocks may give up as much as 80-90% in the "Development Lull" and because of the fall in the company's value it may then not be able to raise equity for development, which can further prolong the duration of the lull.

Most companies will re-rate towards production, but that re-rating may be a lot more lumpy than what I've shown on the chart. Beware of a company going into production, particularly in battery materials. Those that have gone into production have almost all experienced delays and cost over-runs, which often lead to a substantial share price correction.

Once in production, a company generally trades in line with the pricing cycle of its key material. The only times this relationship is likely to break down are:

- On the upside, if it adds to capacity; and
- On the downside, if it experiences an operating accident or a geopolitical shock.

Risk appetite

An investor's risk appetite is a key consideration in any investment. Please think about what your tolerance is for risk before looking at any mining sector investment, particularly in battery materials. For starters, this is what we call a high beta sector, which means it's very volatile. Producer stocks in this sector, which are generally the least volatile of all the stocks, can still move $\pm 10\%$ in one day. Exploration stocks can often move $\pm 30\%$...and bear in mind – that might not always be in the right direction!

So it's very important that you as an investor understand what your risk appetite is. The Mining Life Cycle will help you to allocate funds to the right segments of the industry:

- If you have a high risk tolerance then the Exploration and Development segment may work for you. There is certainly multi-bagger potential in that segment, but there's also the potential to lose a substantial amount of your investment.
- If you have a low risk tolerance then you probably will want to stick to the Producer segment and, if you have a very low risk tolerance, you might want to find another sector to invest in!

The stage of the life cycle is one factor to bear in mind when considering risk. Another is the location of the asset.

Location, location, location

Location is one of the key factors that I often see investors getting wrong when evaluating investments. There are two key factors to consider when thinking about location:

- 1) What country the project is in; and
- 2) What part of the country the project is in.

Countries

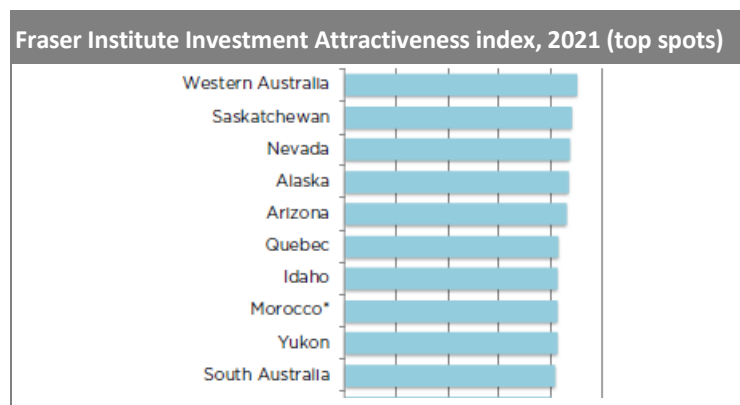
Let's talk about countries first. Not all countries are created equal when it comes to developing mining projects. And, as a result of that, an investor has to understand and factor in the risks of investing in any one country.

The **Fraser Institute**, an independent think tank, produces an annual survey on the ease of doing business for mining companies in different jurisdictions around the world. If you've never seen the survey, it's well worth a look and can provide a really good framework for understanding the risks of a company operating in a particular country.

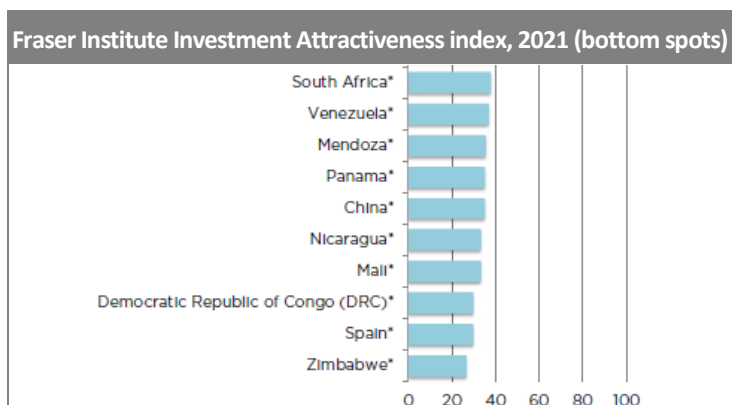
One generally finds that Australia (particularly Western Australia) and Canada come out as the best (easiest) regions for miners to operate in. As could be expected, many Emerging Countries and particularly African countries do badly. But, actually, Spain came out in the bottom two in 2021. That may be a surprise to you, but it's not a surprise to me given the number of Spanish projects I've covered over my career!

In my experience, there are countries that I would simply not invest in projects in. This is based on experience built up over 20 years as a mining analyst and investor. Sometimes

these countries do not have a strong rule of law and, even though a management team may be convinced they own an asset, they may very well find that they don't. The DRC and Russia are particularly bad for this. Other times it's to do with bureaucracy or difficult planning pathways.



Source: Fraser Institute



Source: Fraser Institute

Investors also need to be cognisant of the potential for fiscal conditions to change; the potential for royalties to rise and fixed term periods for tax breaks not to be so fixed term. Argentina is particularly bad for changing such rules on a regular basis. This can impact the returns, and hence valuation, of a company materially.

If an investor is looking for a through the cycle (ie long-term) investment on an exploration or development project, then they need to understand the impact that local planning regulations can have on development timelines. Countries and regions that have been quite outspoken on their needs to build their own supply chains often haven't backed this up by making planning of mining projects easy. The US and Europe are two such regions where investors can expect extended development timelines, at least as things sit currently (2022). Extended timelines often mean an absence of newsflow which can lead to the derating of a stock. By the way, when I talk about extended timelines, I'm talking of 10+ years compared to normal timelines of 3-7 years...

Location within a country

OK, now that I've got that rant out of the way, let's talk about locations *within* a country. Hard Rock lithium is on the edge of being classified as a bulk material. A small hard rock lithium mine might produce at a rate of 100,000 tonnes per annum (100Ktpa in our nomenclature). A large one might produce at a rate of over a million tonnes per annum (1Mtpa). That's a lot of material that needs to be moved from the mine either to the coast or wherever it's being processed inland.

That makes the location of a project key for an investor. Projects located close to a deep-water port are likely to trade at a premium to projects located in central Africa thousands of kilometres from a port. The cost of transportation of a bulk material can be up to 25% of operating costs for a project located far inland.

Power infrastructure and population centres are also important. Power because hard rock lithium needs to be crushed before its concentrated and this tends to be power-intensive. Projects close to existing power lines are preferred. Population centres are also important. Several of the mines in the Pilbara region of Western Australia are fly-in/fly-out, but this requires higher upfront costs in terms of building a camp for the employees to stay at, and has higher operating costs for employee transport and for compensation

of employees for staying at a camp in the middle of nowhere. If a project is close to a population centre where workers can be sourced from that's an advantage. Of course, being too close to a population centre isn't great either – generally people don't like living next door to mines and there tend to be more stringent planning hoops to jump through closer to population centres.

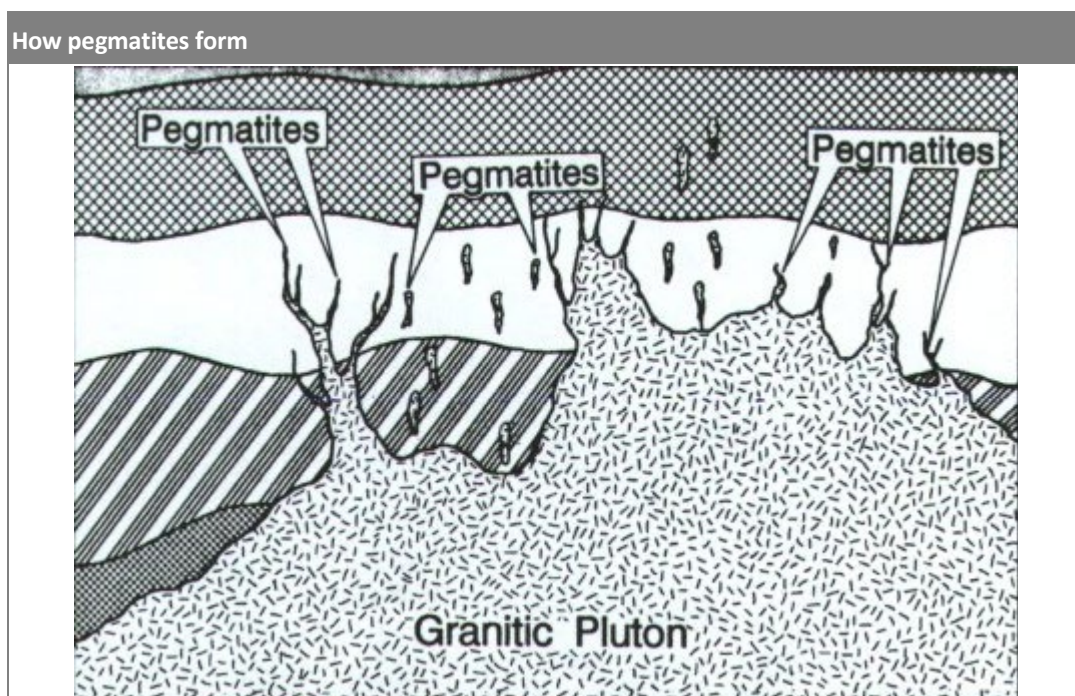
Increasingly the source of power is important. For battery materials investments, low carbon power is preferred by many ESG-type investors. Projects that utilise dirty power sources (and have no plans for sourcing renewable power) could well find themselves struggling to source debt or institutional investment.

Mineralogy

Hard rock lithium is actually an umbrella term for extraction focusing on a number of lithium-containing minerals. What type of mineralogy is dominant in a deposit can substantially impact the processing pathways, the carbon intensity, and the amount of waste produced by the project. And it can also impact investor interest and the valuation of a deposit.

When we talk about hard rock lithium, most projects are based on a material known as **pegmatite**. Without going into too much geology, pegmatite is what we call an igneous intrusive rock in so far as it forms in high temperature environments.

Often a large body of very hot rock or magma (called a batholith) comes up into the Earth's crust. Magma is extremely hot – commonly between 700-1300°C. At these temperatures most elements dissolve in waters circulating throughout the system and these waters can be pushed out from the intrusion (often at high pressures) into the surrounding rock. Pegmatites can occur in small pockets along the margins of an intrusive body and also in fractures along its margins.



Source: Northern.Edu

As they come into contact with the cooler country rock, the waters cool, forcing minerals to precipitate and crystallise.

PAK lithium-bearing pegmatite outcrop in Ontario, Canada



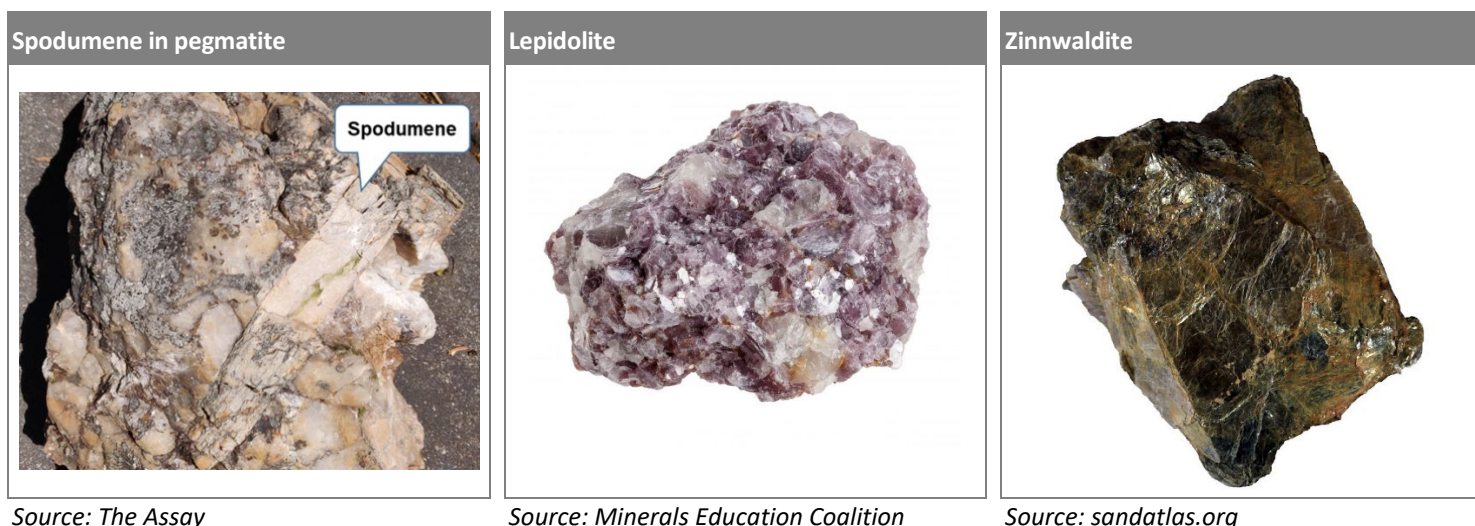
Source: Frontier Lithium

Depending on the make-up of the chemicals in the fluids, different minerals can form (and they are often zoned, with lighter minerals, like lithium, precipitating at some distance from the batholith and heavier minerals closer to it). The most common non-ore minerals in pegmatites are quartz and feldspar (which can often make useful by-products for lithium mines) while the most important lithium minerals are:

- **Spodumene:** Spodumene-rich deposits make up the bulk of currently-mined hard rock lithium deposits. It is a lithium aluminium silicate mineral which often forms in coarse-grained crystals in pegmatites.
- **Petalite:** Petalite is a lithium aluminium silicate mineral which is often a minor mineral in pegmatite systems. It is generally lower in iron than spodumene and is preferred for ceramics applications.
- **Lepidolite:** Lepidolite is a mineral in the mica family which has a complex chemical formula containing various concentrations of potassium, lithium, aluminium and silica. It can contain fluorine, high concentrations of which are generally a negative in lithium processing.
- **Zinnwaldite:** Zinnwaldite is another mica mineral which, as well as potassium, lithium, aluminium and silica, also contains iron. It may also contain fluorine.

Spodumene has the highest theoretical Li_2O (lithium oxide) content, at 8%, and hence is the most-preferred ore for processing. As a general rule of thumb, resource grades for economic hard rock spodumene projects are generally 1-2% Li_2O . However, with current elevated prices, some lower grade (sub 1% Li_2O) deposits are now being considered for development.

For lepidolite and zinnwaldite deposits, because the ore is processed via a different method, lower grades are often considered. Most Western World projects will still have in-situ resource grades in excess of 0.5% Li_2O , although some Chinese occurrences are being mined at lower grades than that.



As I noted, 90% of existing hard rock lithium production is from spodumene-rich material. Lepidolite has been successfully mined and processed in China although recoveries are not great (particularly to battery grade material) and it tends to generate a lot of waste. Petalite is mined for the ceramics industry but has so far not been used for the battery industry, and the same is true for zinnwaldite although processing methods are under development.

When looking at an orebody, mixed lithium mineralogies (ie 50% spodumene and 50% lepidolite) are not preferred because they require different processing techniques, which would make a processing operation more complex and more expensive to build. Most operations would prefer to see greater than 80% of a particular mineral to maximise lithium recovery.

Note that in the context of this report, **sedimentary** (clay) projects and brine projects are not counted as hard rock projects, so are not discussed.

Formulae and lithia contents of key lithium minerals

Name	Formula	Theoretical Li content	Theoretical Li ₂ O content
Spodumene	LiAlSi ₂ O ₆	3.7%	8.0%
Petalite	LiAlSi ₄ O ₁₀	2.3%	4.9%
Lepidolite	KLi ₂ AlSi ₃ O ₁₀ (OH,F) ₂	3.8%	8.2%
Zinnwaldite	KLiFeAl ₂ Si ₃ O ₁₀ (F,OH) ₂	1.6%	3.4%

Source: BM Review. Note Li is lithium metal content and Li₂O (Li₂O) is lithium oxide. Lithium in hard rock lithium assets and concentrates is quoted in Li₂O terms.

Exploration stage

Pre-drilling exploration

Let's be realistic here. If I as an investor am going to get an idea of the value of an *underground* orebody, drilling is what I'm going to focus on. From the point of view of an investor, however much of a fuss the management team makes about it, pre-drilling exploration is like watching the warm-up act before a concert. It might be quite fun, but it's nothing like the real thing!

The fact is that pre-drilling exploration is probably even less helpful to investors in hard rock lithium than in other types of orebody. [But by the way, it can be very helpful to a geologist and a mining company MD]. If I'm looking for a deep copper or nickel mine then there may be almost no evidence at the surface and I'm going to rely on geochemistry and geophysics, but for bulk materials like hard rock lithium I need to see surface evidence because I don't really want to go deep underground to mine for the mineral.

In hard rock lithium, management teams are likely to carry out field mapping (where geologists stroll around the licence area (us geologists call it field mapping!) and try to understand the underground structure of the country rocks). They *may* carry out soil **geochemistry** and spot **assays** on surface samples and they *may* carry out regional **geophysics**. Generally in geophysics you're looking for the most dense rocks which contain base metals and gold; in lithium you're looking for the least dense areas within heavier rocks, which will indicate pegmatites.

In some cases, management teams may carry out trenching studies where they dig down to a depth of 1-2 metres and chemically analyse material along an axis of 10-15 metres. Normally in a "hot" market a management team will go straight to drilling though because it'll give more answers in more dimensions than trenching.

All of these methodologies are aimed at helping the geologist figure out where to drill to get the most bang for his or her buck. It's just that from an investor point of view they don't tell you a hell of a lot!

Type of drilling

OK, so if drilling is apparently so important, let's talk about it then. Before we talk about results, let's first talk about methods. There are four main types of drilling in use in the lithium sector at the moment. They are:

Truck-mounted auger drilling rig



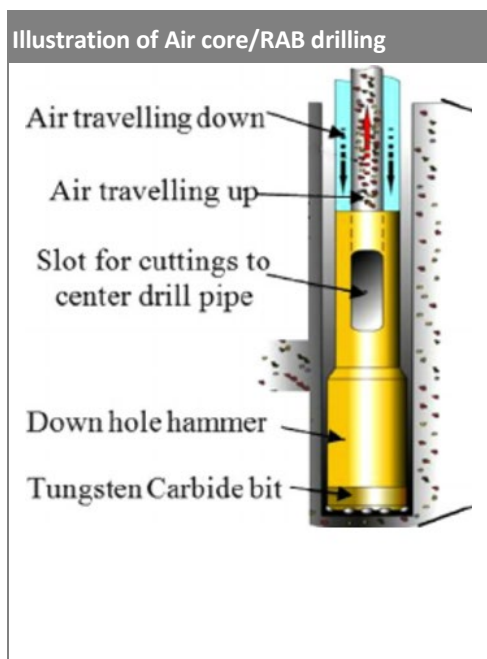
Source: Kula Gold

Auger drilling: This is a low-cost method of near-surface drilling which uses a large helix-shaped screw to extract the material from the ground. It's effective up to about 25m depth. It's best used on soft, weathered or unconsolidated material. Which isn't actually that great for hard rock lithium deposits, which are generally quite crystalline (hard). Weathered material is very much less preferred once you get into processing for lithium, so the use (and suitability) of auger drilling may raise some flags for the investor.

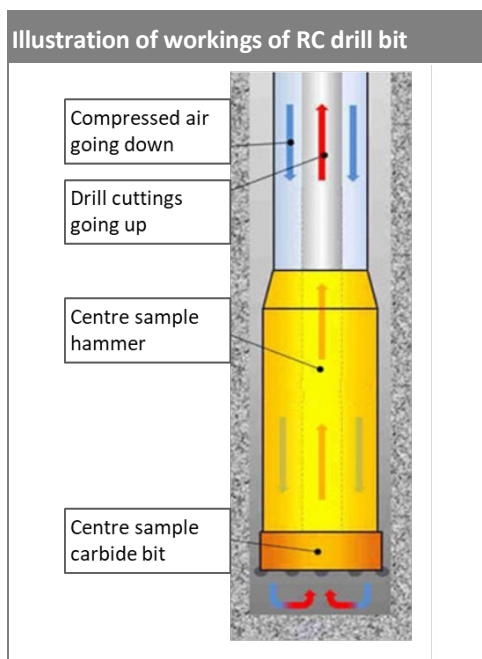
Air core/RAB drilling: Percussion Rotary Air Blast (RAB) drilling uses a pneumatic piston-driven hammer to drive a heavy drill bit into rock. It's more expensive than auger drilling, but less expensive than other methods, but again there is a depth limitation; it's generally only viable down to 150m. The drill bit (which rotates) is hollow steel and has c.20mm tungsten rods protruding from the sides which form the cutting face of the drill bit. The cuttings from the rock are blown upwards along the outside of the rods by blasts

of air (and sometimes foam) and are then collected at surface for assay. By nature of this approach there can sometimes be contamination of the chips.

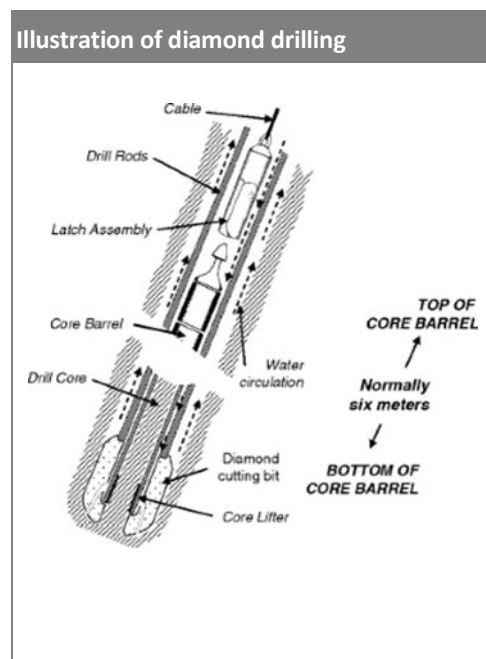
Reverse Circulation (RC) drilling: This approach is used extensively in Australia and is less common elsewhere in the world. It's more expensive than the first two (by nature of the fact that it utilises a much larger rig), but a lot cheaper than diamond drilling. The drill utilises a pneumatic reciprocating piston (hammer) which drives a tungsten-steel drill bit. Depths of as much as 500m can be achieved. RC drilling produces dry rock chips which are then brought to the surface and collected by geologists for testing. While it provides a good balance between cost and practicality, it doesn't provide the sort of structural data that a diamond drill rig can provide. The quality of the sample, however, is a differentiating factor; it's not contaminated by the wall rock in the hole and therefore provides an accurate sample for the interval in question.



Source: Hashemi et al (2013)



Source: after JC Drill



Source: after Marjoribanks (2010)

Diamond drilling: Diamond drilling is very much the Rolls Royce of drilling. And like a Rolls Royce, a diamond drill rig is big, clunky and difficult to move around! This, and the fact that it's slower than RC and other approaches, means that – like a Rolls Royce – it's really expensive to operate!



Source: Dando

A diamond rig uses a ring-shaped diamond-impregnated drill bit attached to hollow drill rods to cut a cylindrical core of solid rock. Water must be used to keep the bit cool which further adds to the list of requirements for a diamond rig. Matrix hardness, diamond size and dosing can be varied according to the rock which must be cut through. Holes within the bit allow water to be delivered to the cutting face for lubrication, cooling and removal of the drill cuttings. The drill core is then pulled up to the surface for processing.

Diamond drill rigs can get down to levels of 1200-1800m and can be used in very hard rocks, but they need to go slowly to prolong the lives of the drill bits and rods, which are very expensive. When a diamond drill core gets to the surface it is cut in half and then one half is further cut in half. That provides a quarter of the core for immediate assay, a quarter for any follow up work needed and half a core to allow the geologist to interpret the structure and make up of the deposit at depth.

Samples from air core drilling (each pile numbered for depth)



Source: Edge Drilling

Diamond drill cores that have been logged by a geologist



Source: Kitco

Grade and by-products

At the end of the day a huge amount of assessing how attractive drill results are comes down to grades. When I'm assessing a hard rock lithium project I'm looking for drilling grades of over 1.0% Li₂O (lithium oxide) for spodumene-rich assets. Most companies present grade for hard rock assets in % Li₂O terms, but some still put it in ppm Li terms. When I see grades in ppm terms, that's always a huge turn off for me since it generally suggests that grades are quite low.

I'm looking for some juxtaposition of grades and intercept thickness. If a company has, for instance, a 200m intercept averaging 0.9% Li₂O, that definitely wouldn't be a turn off, but if they can only manage 5-10m intercepts below 1.0% then I'm not going to get too excited.

Watch for grades that are too high. Spodumene has a theoretical maximum Li₂O content of 8% but I've never seen in situ grades higher than 3% over any sort of distance. If grades *are* higher than that, it may mean that spodumene isn't the only lithium mineral and that's a red flag since it may complicate processing.

Orebody shape and orientation

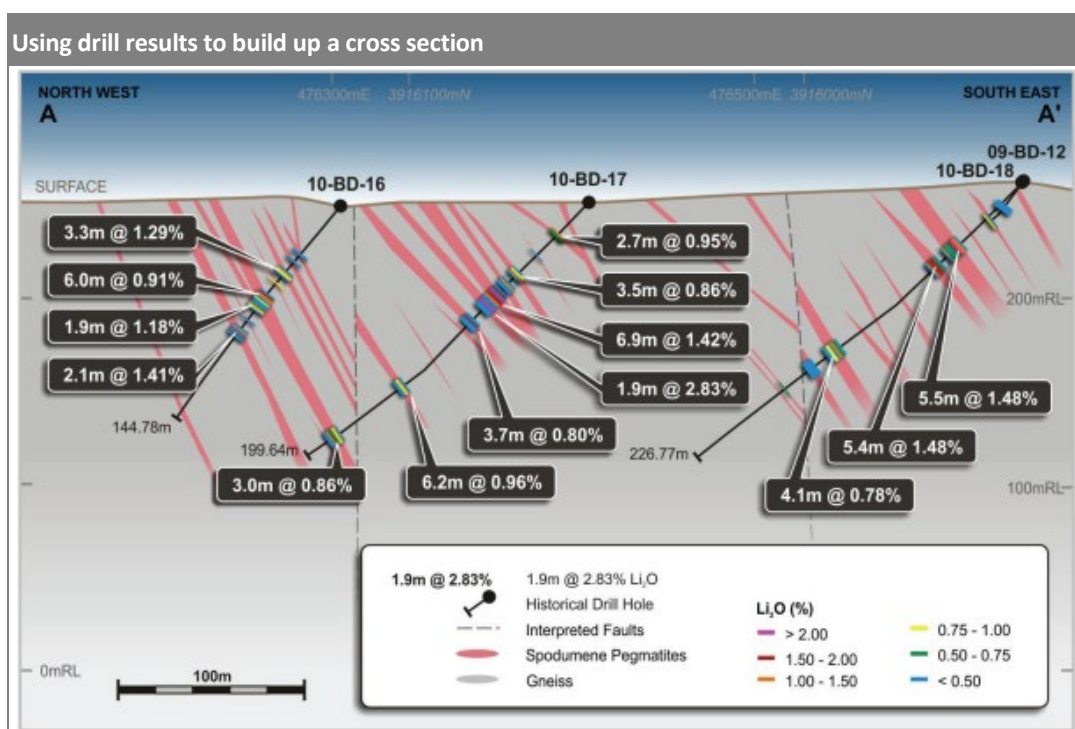
So, as a geologist, I can get a certain understanding of the structure of an area by field mapping, geophysics and geochemistry. But I *can't* understand too much about what's happening below the surface from that work. Sometimes I can make an assumption on what's happening below the surface, but most times I can't and so, to understand what's happening below the surface, I need to see drill results.

From drilling information, I can build up a genuine idea of the geological structures in the area, which might encompass rock types, mineralogies, structures and chemical makeups. So, while an investor may focus only on the lithium grade of certain intercepts, a company geologist is looking at many more factors. He or she is looking to understand if there are structural or chemical controls on the formation of deposits that can be used to identify ore in different parts of the licence area, if the presence of certain minerals indicates economic grades of lithium, and at other factors. So a company doesn't drill

just for investors and may often put in holes that don't intersect large amounts of mineralisation but are vital for the team's understanding of the deposit.

However, one of the factors that is key to understanding whether an occurrence is just geologically interesting or has the potential to be a mineable deposit is its shape and orientation, and one uses drilling to establish this. In the old days we would produce cross sections slicing up the deposit. These days we can simply feed the data into a geological modelling program which will model the orebody in 3D.

Think about the pegmatites that form the basis for the lithium mineralisation which is mined. The depth, dipping angle, spacing and thickness of those pegmatites can all be important for determining whether a deposit is mineable.



Source: Piedmont Lithium

Let's talk Mining Engineering 101. When I'm building a mine, I want to generate as little waste as possible. Waste is cost after all. And spodumene concentrate is a relatively low value material, so I want to use volume techniques for efficiency. That means that I don't want thin veins where I'm going to have to dig out a lot of waste material as well as my high grade, and I don't want to have to do a lot of pre-stripping (where I have to remove a lot of waste material above the ore before I can start mining).

Depth

All current (2022) hard rock lithium mines are open cast, although some development assets now have underground components. But they're not underground from the word go – they're surface operations that move underground. This is very much a feature of the increase in lithium prices; at US\$500/t it wasn't economic to mine hard rock lithium underground, above US\$1500/t it starts to be, so we may very well see some management teams targeting underground assets from the word "go". We will discuss the economics of this more in the *Evaluation* section.

My preference, as an investor, is to steer clear of deep-lying orebodies. While hard rock material *can* be mined via underground techniques at current SpodCon prices, it's always

going to be cheaper to build a high volume open pit operation. Open pits are generally viable down to depths of 300-500m.

Another aspect to be careful with is overburden. This is the material that needs to be removed to give me access to the orebody. Overburden removal is an upfront capital cost, so large amounts of overburden mean large amounts of pre-cashflow cost. Many pegmatite orebodies outcrop at surface so overburden removal might not be such a chore, but it's always something to consider.

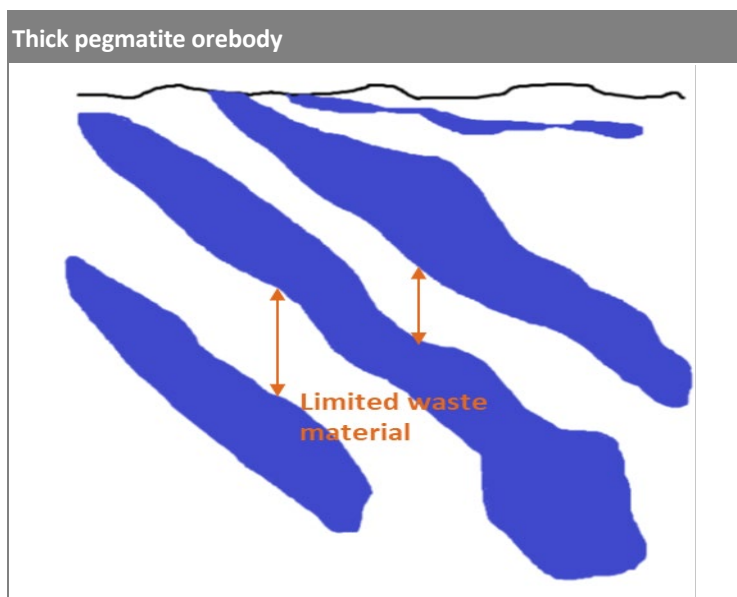
One of the things that we do need to be aware of when it comes to depths is weathering. The depth of weathering in an orebody will depend on where the orebody is located in the world. Very dry regions don't experience too much surface weathering, but wet regions can. Generally you find that weathering can extend to anywhere between five to fifteen metres in depth. Weathered material contains more clay minerals than fresh ore and therefore doesn't react as well to beneficiation; lithium recoveries in weathered (shallow) material can therefore be lower than in the main part of the orebody and investors should be aware of this when it comes to modelling the orebody.

Bearing all that in mind, once I, as an investor, have established that I'm happy with the depths of the intercepts I can then move onto the shape of the orebody.

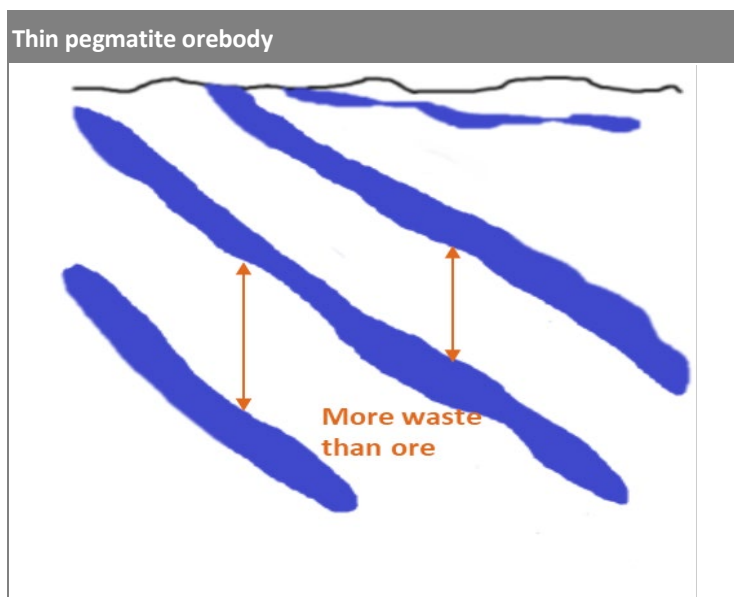
Shape and occurrence

So, let's talk about shape and occurrence of the orebody. Depending on the structural and chemical controls on mineralisation, orebodies can occur in wildly different ways. They can be massive, they can be lenticular (lots of different lenses of mineralisation) and, particularly in the context of pegmatites, they can be composed of lots of small stringer systems.

Pegmatites are formed by very hot fluids which break out from a central location and push through the country rocks. Some pegmatites are very thick, but some can be small and stringy, with waste material interspersed with ore material. Pegmatites also tend to have irregular thicknesses, pinching in and out along their length.



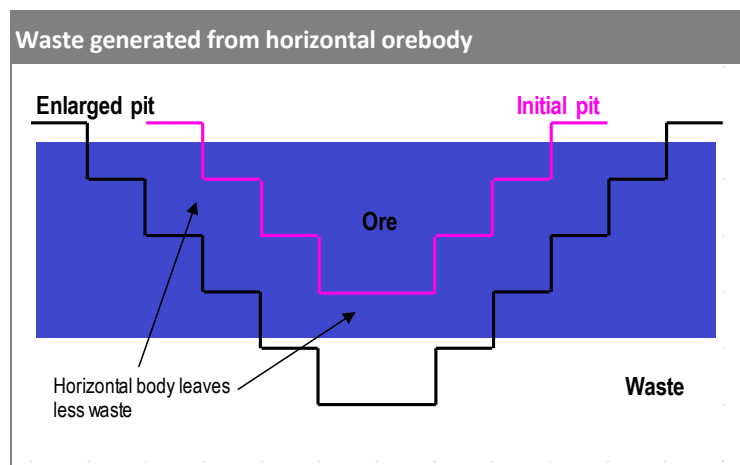
Source: BM Review



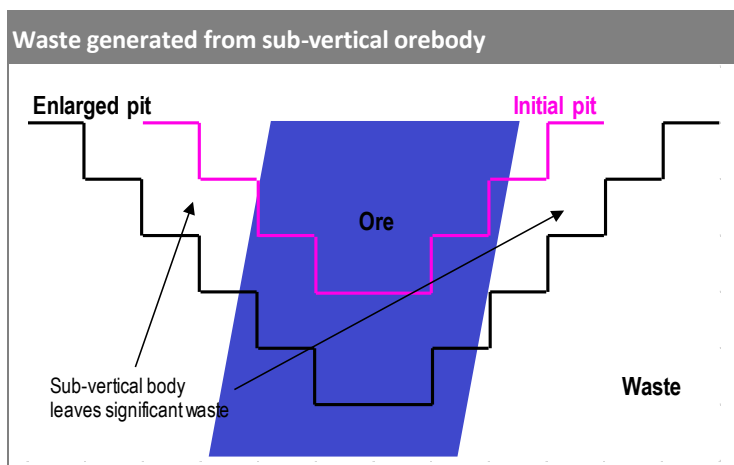
Source: BM Review

Their orientation can also vary, and this can have important impacts on the cost of mining. A flat-lying or sub-horizontal orebody will have significantly less waste material

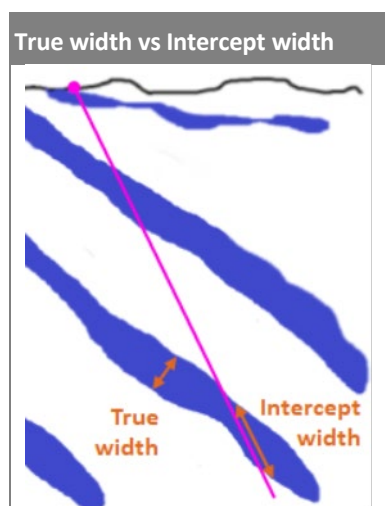
than a vertical or sub-vertical orebody. When I'm picking out projects to back, thick pegmatites that are sub-horizontal are top of my list. Note that thin pegmatites make mining more difficult as well. More wall rock in mined ore likely means lower concentrate grades, more deleterious elements and lesser recoveries.



Source: BM Review



Source: BM Review



Source: BM Review

While we're on this subject, let's quickly discuss the issue of width vs true width. This bears some similarities to the Directors' hole debate (as discussed later) but is not entirely comparable.

When you're looking at results of drilling into a sub-vertical or sub-horizontal tabular orebody it can often be difficult to appreciate what the thickness of the orebody is (particularly in the early stages of drilling). For instance, if I drill an inclined hole which intercepts with an orebody which is dipping in the same direction as my hole is inclined then, if I just look at the assay results, I may get the idea that the orebody is thicker than it actually is.

It's only by actually looking at the diamond drill cores and plotting the structural layout of the orebody that a geologist can understand what the true width of the mineralisation is. Many companies will disclose true width in their releases but some won't, so always make sure you check the cross section in the release so you can understand whether the drill hole has gone in perpendicular to the orebody or not.

Orebody size and number of pegmatites

OK, so the company I'm looking at has found what looks to be a nice orebody – it's pretty shallow, it's high grade and it's got a good orientation. Why isn't the market getting excited about it? Well, it could be about the size of the orebody.

As with all things, size matters! In mining it's doubly so. The size of the orebody governs the time that it can be mined for and the rate that it can be mined at. Nobody is going to drop a couple of hundred million dollars of capex into an orebody that doesn't have at least a ten year and preferably a 20-year mine life. And to maximise the shareholder return and balance out the fixed cost component, an orebody needs to be mined at a certain rate (and more about that later).

Which is simply to say that small orebodies, while they might be geologically interesting, won't make a company. We say as a rule of thumb that a hard rock mine needs a resource of at least 20Mt at over 1% Li₂O. If the deposit that you're looking at doesn't look like it's going to make that, you probably need to go onto the next stock.

One element to look out for is that many projects actually contain several pegmatites. So, for example, **Core Lithium**'s Finniss project in Australia's Northern Territory is composed of (at time of writing) four different pegmatites. Each occurrence boasts 1-2.5Mt of reserve and Core can simply add on new pegmatites as and when it discovers them (pegmatites are often found in swarms). Compare that with **AVZ Minerals**' Manono project in DRC where the single Roche Dure pegmatite (one of four on the licence area) boasts a resource of 400Mt @ 1.65% Li₂O. We'll discuss the impacts on economics of the different types of business model in a later section.

The Directors' hole and other common ramping methods

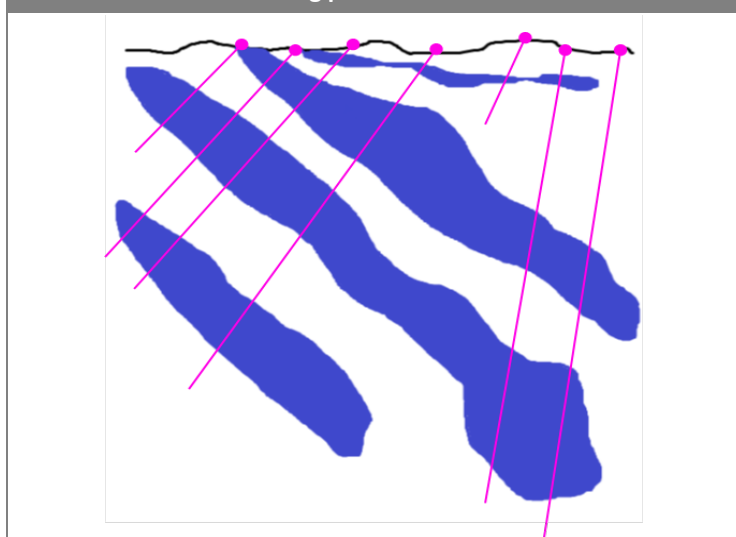
One important tip for potential investors. **Beware the "the Directors' hole"!** What's that, you may ask? That's when the geologist aims a drill down the guts of the deposit aiming to create an intercept that's so long and so good that everybody takes notice. It's an intercept that's likely to see the Directors' share options go up in value!

How can you tell if an intercept is a "Directors' hole" or not? You have to look at a cross section, and this is one of the interesting issues about drill results. You should never just look at the intercept itself. You need to look at the orientation and positioning of the intercept as well.

As best practice, all press releases showing drill intercepts should include a cross section of what the geological team thinks the deposit looks like under the surface. Sometimes this will be in three dimensions, but 2D is good enough for our requirements.

Generally, drill holes go in perpendicular to the orebody to test thickness and orientation. In very occasional cases an early hole may go through the guts of the orebody before the geological team has a handle on what's happening underground. When a hole goes through the guts of an orebody at a later stage of drilling, that's often a Directors' hole, intended to ramp the price of the stock.

Illustration of normal drilling pattern



Source: BM Review

Normal drilling pattern with a Directors' hole



Source: BM Review

Something else that investors should be aware of when a company is drilling is the issue of ramping drillholes. This is primarily an issue for ASX-listed stocks and is becoming increasingly commonplace now. It happens when a management team issues a release to say they intercepted XYZ metres of mineralised material in their hole.

For me, this is non-news. For the primary reason that the presence of pyrrhotite in a copper deposit, or spodumene in a lithium deposit, doesn't mean that there are high grades of copper or lithium. It just means that the mineralogy to support the presence of metal is in place. There may be no trace of the target metal, there may be lots of it, but the presence of those minerals doesn't mean that there is high grade mineralisation.

It's become more and more common recently for management teams to make releases about hand-held **XRF** tests on drill core. Again, this is irrelevant to me as an investor. I've lost count of the number of times I've seen a seemingly indicative XRF test that didn't yield the expected high grade assay results in a professional lab.

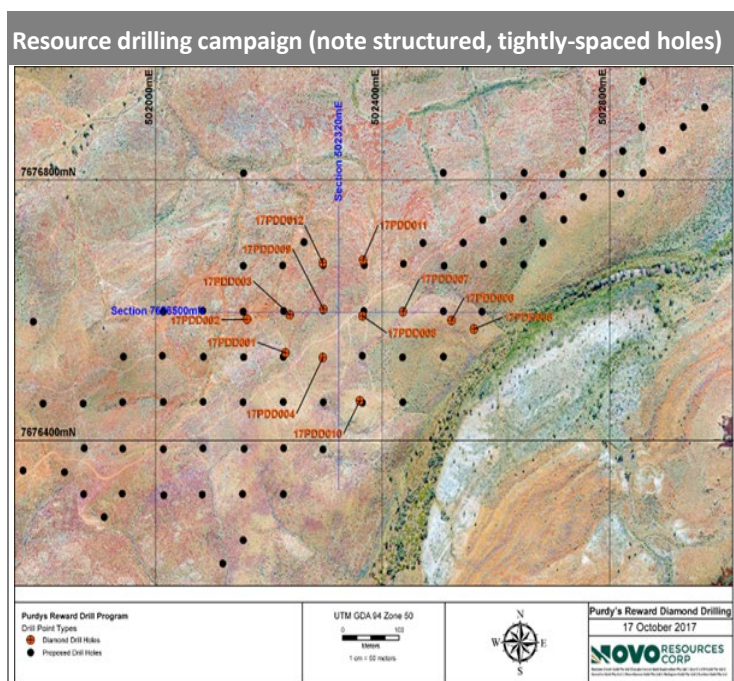
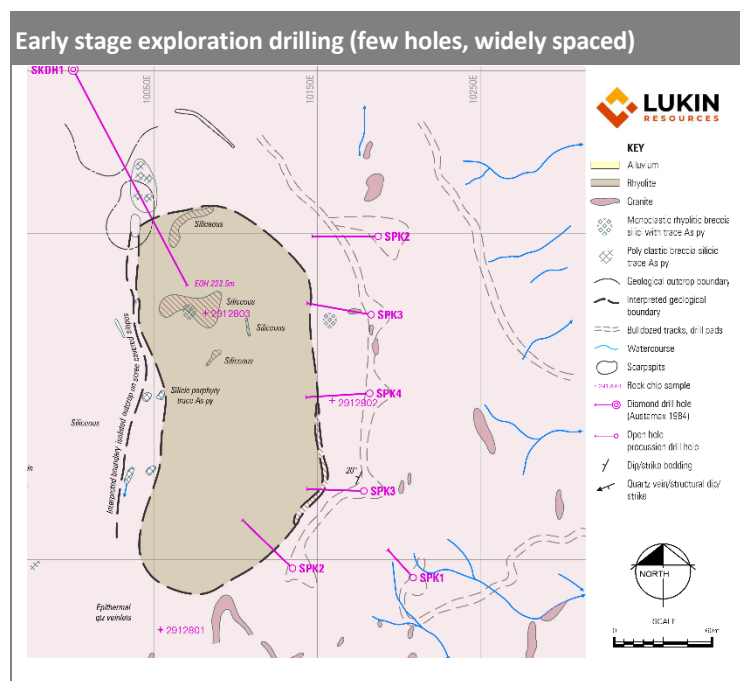
These sort of releases are just aimed at making noise in the market and should be ignored by investors, in my view.

Finally, beware of little words like 'aggregated' and 'compounded' in drilling releases. Sometimes, where an ore deposit has multiple small intercepts, management teams will present an aggregated or compound intercept where they add all the little intercepts together. This sort of nomenclature is banned on some exchanges like the TSX and ASX, but still occasionally crops up on less-regulated exchanges.

No reaction? Check for words like infill, twinning etc

So a company that you're following put out what you think is a great release and the stock hardly reacted. Why? Well, the first thing you should do is look for the words 'twinning' and 'infill' in the release.

Twinning is where a company looks to mimic the results of a historic drill hole. This might be where the core from that drill hole is lost and a company needs to check the assay results, or for some other reason. But the fact is that however good the results are, the company probably already knew them, so the market didn't get excited about them.



The other key word to look out for is Infill. There are different stages of drilling out a mineral deposit. When a company initially drills into a target, it might drop four or five

holes into a target. These are known as “scout” holes. At the early stages of drilling, holes are likely to be quite far apart as the company tries to understand how big its deposit is.

A company may be able to calculate an Inferred mineral resource off its early-stage drilling but, as it evaluates a deposit further, it will want to have a much higher level of certainty of the physical structure of the orebody and its chemical makeup. Hence it will need to carry out drilling on a tighter spacing to calculate an Indicated or Measured (tighter still) resource. This may be known as “infill drilling”. At the infill stage, the company (and investors) largely know what’s there. So, unless drilling intercepts zones that weren’t previously known, infill holes are likely to be a big yawn fest for the market.

What constitutes a three-chilli hole?

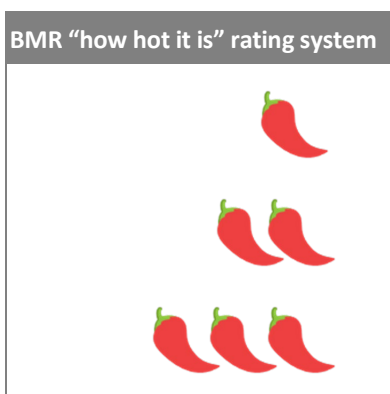
In *Battery Materials Review* we rank all the monthly drill results according to how hot they are. Three chillies for the best holes, down to two chillies, one chilli and no chillies at all for also ran holes. So, what makes a hole into a three chilli hole?

Well, at the end of the day, we’re looking for some sort of juxtaposition of the points above. Good grades (+1% Li₂O) over long (true width) intercepts (100m+), sub horizontal or very thick if they are more vertical, at shallow depth with not much overburden. If you’re seeing that in the release, then you’re probably onto a winner!

Note that the thickness of the pegmatite is really important. Experience in Western Australia has shown that material at the contact zone (where the pegmatite is in contact with the country rock) has lower metallurgical recovery. Pegmatite true thicknesses of 8-10m are a minimum in order to maximise recoveries and, of course, for a three chilli hole, we’re looking for 100+m intercepts. But, even for a one chilli hole, a 5-6m intercept at 2.0% Li₂O doesn’t get a chilli because of the aforementioned recovery issues.

One also has to bear in mind size of the deposit and strike length. It’s less common in lithium but in nickel deposits in particular you might end up with very small, very high-grade occurrences. In hard rock lithium, which is more of a bulk material, we’re looking for size and scale. So a three chilli hole from a geological point of view may very well be downgraded to a two chilli hole if we don’t interpret the deposit as being of a sufficient size. As I noted before, size matters, even in mining!

Once you’ve found a winner at the exploration stage, you then need to start to understand whether your occurrence of geological interest can be developed into an actual mine.



Source: BM Review

Evaluation stage

So, once you've found a good exploration stock, the issue then is whether that ore deposit is good enough so that it can be developed into a mine. While in the past, and in different commodities, management might do several rounds of exploration before they move into the evaluation stage, in this sort of bull market it's in a management team's best interest to push into the evaluation stage as soon as possible when they're confident that there's enough material to justify building a mine.

At the end of the day, whether a mine can be built doesn't come down to the existence of mineralised material. What governs whether a mine can be built is the existence of *sufficient quantity and quality of material that can generate a positive return for the capital required to fund an operation*. That is what the evaluation stage seeks to determine.

The importance of different exchanges

How a company manages and communicates information in its evaluation stage is very important to investors. Unfortunately, in all hot industries there will be management teams that are looking to put one over on the market. There have been a number of mining scams over the past 30 years which have cost investors a lot of money.

It has fallen to exchanges to develop rules on what companies should disclose and how they disclose it. Some exchanges have stringent rules and some not so much. From an investor's view, there are two exchanges which are out in front when it comes to the level of disclosure they insist on – the TSX and TSX Venture Exchange (TSX/TSXV) in Canada and the Australian Stock Exchange (ASX). However, even within this, it's fair to say that they each have their own strengths and weaknesses.

Comparison of disclosure requirements on different exchanges

	TSX/TSXV	ASX	AIM (UK)	US exchanges
Resource updates	Disclosure & tech. report; to NI43-101 standard	Disclosure; to JORC 2012 standard	Disclosure; to JORC2012 standard	No disclosure required
PEA	Technical report required	Some aspects disclosed	Some aspects disclosed	NA
PFS/FS	Technical report required	Some aspects disclosed	Some aspects disclosed	NA
Production reporting	Quarterly results	Quarterly production and financial statements	Interims only	Quarterly financial results
Conclusion (BMR view)	Best for developers	Best for producers		

Source: BM Review

For instance, in my view, the TSX is better for development stage companies. It requires companies to produce and publish an independent technical report which is available in its entirety to investors. The ASX requires companies to publish *highlights* from such reports but does not require the publication of the report in its entirety. This means that it's often difficult to glean all the information an analyst or investor may need when trying to build a model for a stock.

However, the ASX's requirement for quarterly reporting is much more investor-friendly for producing companies than other exchanges, in my view.

Disclosure requirements on other exchanges are not so good. Often companies will publish useful information, but they don't *have* to. I've followed companies on London's AIM and the LSE which haven't released enough information to build a model. Similarly bottom-up stock modelling for a number of US-listed lithium producers is practically impossible because they're not required to publish production or cost information, or even reserves and resources.

So, which exchange a company is listed on is important and can have very substantial implications for understanding and valuing individual stocks and projects.

PEA/Scoping study

The first stage of evaluation of a mineral deposit is normally a desktop study called a Preliminary Economic Assessment (PEA) or Scoping Study. A company's management team may conduct this themselves, or appoint an outside company to carry it out.

A PEA can be as detailed or lacking in detail as a management team wants. It's not an official requirement for progressing. I've seen PEAs carried out to Pre-Feasibility Study (PFS) standard and I've seen PEAs that may as well have been written on the back of a napkin!

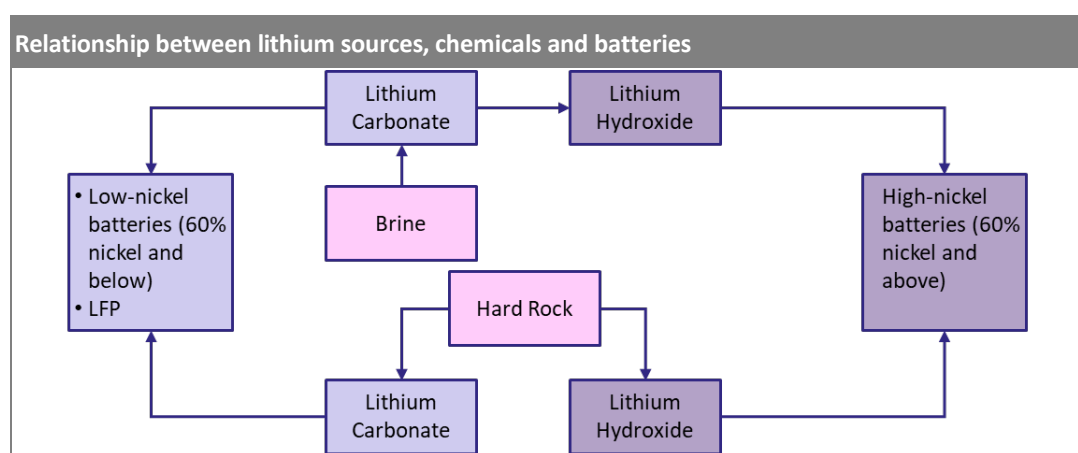
Because it's so early in a project's life there may not be large resources or detailed metallurgical testwork, so a PEA will use a series of assumptions. It will make assumptions on the likely size of the resource, production potential, the capital costs and the operating costs. And it will seek to calculate whether it will be viable to build a project based on this orebody.

From an investor or analyst point of view, the PEA allows you to start hanging some numbers on the project. From the management's point of view it helps them do that and it also shows the direction they're moving in.

Preferred output?

One of the key decisions for a management team to make is whether they want to only produce lithium concentrate or whether they want to integrate their operation and add a chemical plant on the end to upgrade their output to lithium carbonate or lithium hydroxide?

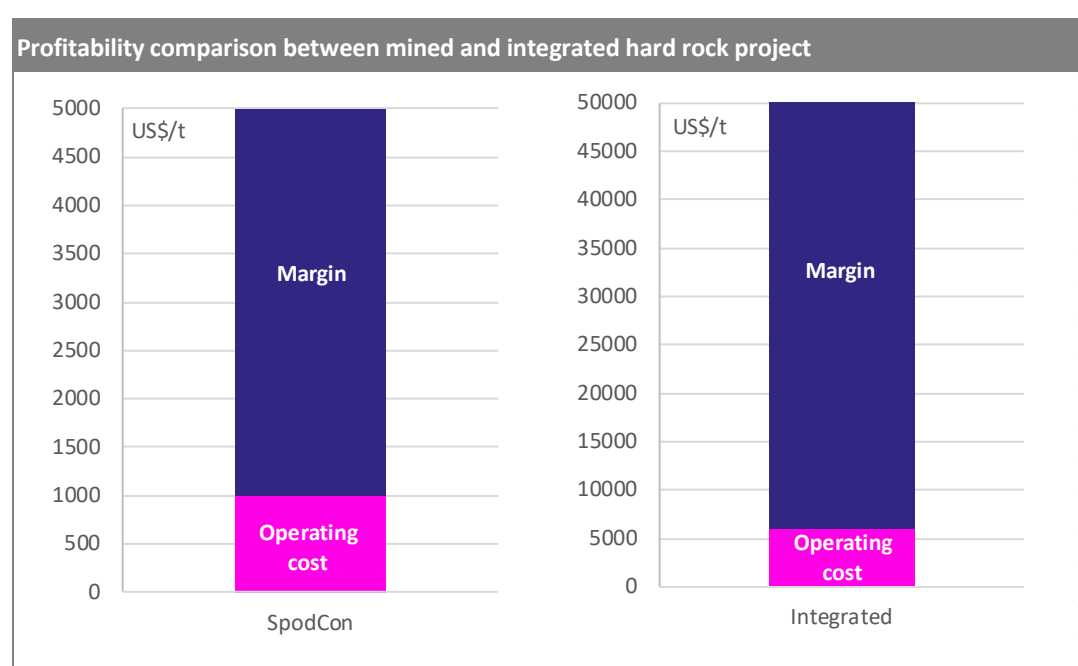
Lithium carbonate and lithium hydroxide are the primary lithium chemicals from which **cathodes** are made (the cathode being one of the key electrodes which is used in a lithium-ion battery).



Source: BM Review

Historically, lithium carbonate was the major chemical used in the battery industry, but the emergence of high-nickel batteries in recent years has led to strong demand for lithium hydroxide. **Ternary** batteries (those with a nickel-cobalt-manganese cathode or a nickel-cobalt-aluminium one) with more than 60% nickel generally need lithium hydroxide as their raw material rather than lithium carbonate. **LFP** (lithium-iron-phosphate batteries) generally use lithium carbonate. Lithium hydroxide can be used for other formulations, but its reactivity and physical properties make it difficult to use (it has a short shelf life of generally 6-8 weeks before it starts deteriorating and it forms a viscous sludge in processing which is complex to manage).

It's an important trade-off for the management team because if they decide not to integrate then they're looking at lower capex and opex, lower technical risk **but lower selling prices**. Whereas if they do go into the midstream (lithium chemicals) they'll have higher upfront and operating costs (and technical risk) but should be able to realise a much higher percentage of the value-add when it comes to pricing.



Source: BM Review

In some cases, companies are looking at hybrid products like lithium sulphate which are semi-upgraded (lower cost to transport) but don't have the technical requirements of lithium hydroxide.

There's no right or wrong answer about whether a company should go **Midstream** or not. But, since midstream processing of SpodCon is power-intensive, it's important that if they do decide to go Midstream they have access to power and, increasingly importantly in these days of focus on ESG, low-carbon power.

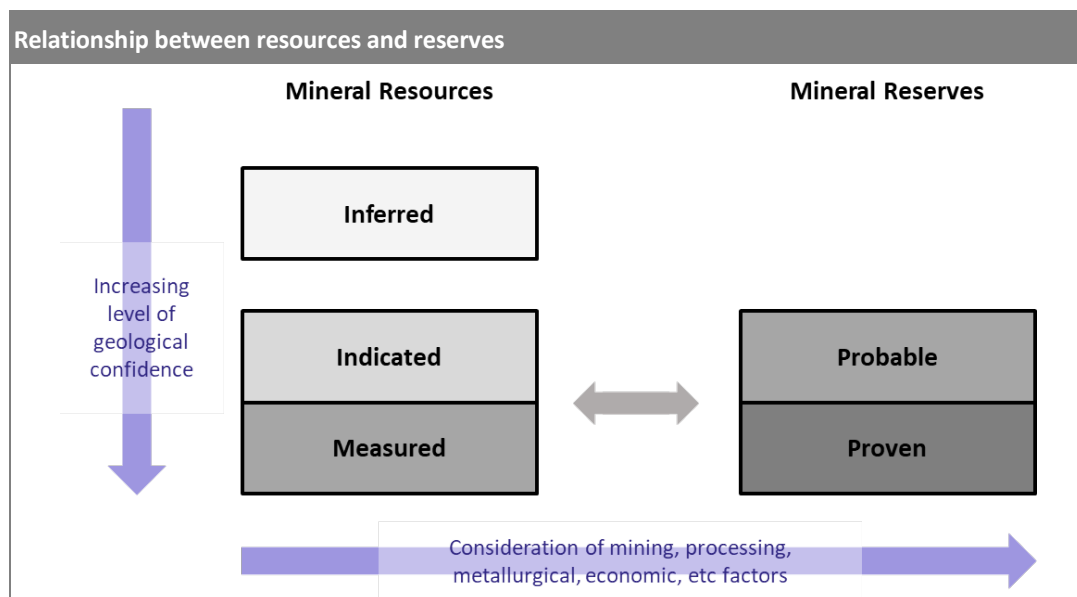
Exploration targets, resources and reserves

Let's talk about these, because the size or potential size of a deposit is very important to its eventual valuation. The size, ie the amount of the contained lithium in the deposit, determines the life of the operation and the annual production capacity of an operation.

In this context exploration targets, resources and reserves represent increasing certainty:

- An **exploration target** is the least certain estimate. It's not actually based on anything apart from a management team's early-stage estimate of what's in the ground. I believe that investors should be a bit wary about exploration targets. While some management teams are just publishing them as an indication of what they expect to find, others are clearly using them for ramping, while at the same time actually scrimping on investing in drilling. That's not the best look in my view.
- **Resources** are based on something. As noted in the previous section, they're based on actual drilling. The geological team will drill out a grid square system and then use a geostatistical program to estimate the grades in between the drill holes. This allows them to build up a 3D picture of the resource and, utilising density information, calculate the tonnage of a resource. There are three classifications of resources, Measured, Indicated and Inferred. Measured are most certain, and Inferred are least certain.

ASX-listed companies can only use Measured & Indicated resources to calculate mine life in their Pre-Feasibility and Feasibility studies; Inferred resources are so uncertain that they can't be used, but they do give an indication of potential upside and many analysts will still use them in their models. The difference between Measured and Inferred resources is the gap between drill holes. Closer spaced drill holes give higher certainty Measured resources and more widely-spaced holes push certainty down to Indicated and then to Inferred. The standards for resource reporting are defined using NI43-101 (Canada) and JORC (rest of the world). In my view, investors should be wary about resources not reported to JORC 2012 or NI43-101 standards; they may not be investment grade.



Source: BM Review

- **Reserves.** Many people from outside the industry think that reserves are just a higher certainty form of resources. *This is totally incorrect.* The difference between reserves and resources is not about certainty, it's about economics and other factors. Reserves are the part of a project's resource that is *economically extractable* at a given price. Proven & Probable reserves (again defined by JORC or NI43-101) may generally correspond quite well with Measured & Indicated resources, but they will only be the parts of the M&I resources that are defined

as economically extractable. Reserves cannot be defined until a company has produced a Pre-Feasibility study or Feasibility study to understand what proportion of the resource is economically extractable. They are the part of the resource which sits within the defined mining area (be that open pit or underground) for the project.

Pre-Feasibility Study

Once a company has a PEA which indicates that a project is viable for development, it will proceed to a Pre-Feasibility Study (PFS). There are industry-wide standards for how a PFS must be carried out and it should use independent contractors to ensure that reasonable assumptions are used.

A PFS will study all aspects of the economics of a project to make sure its is viable for development and it will make sure that it understands all of the project risk factors. It includes detailed works on:

- **The property:** Its location, mineral title and history, encumbrances, royalties;
- **Accessibility and infrastructure:** Including aspects like climate and operating season as well as water, power infrastructure, human resources and supplies;
- **Geological setting:** Both regional and local, mineralisation and geochemistry of the minerals;
- **Exploration:** Work that's already been carried out including an audit of the drilling, work on hydrogeology (water flow), geotechnical testing (how competent the country rock is to support an open pit or underground mine), discussion of exploration targets;
- **Sample preparation and data verification:** Making sure that sample management is to international standards and that data work is also to standard;
- **Mineral resource estimates:** How they're modelled and key assumptions used, and how that compares to international standards.
- **Mineral reserve estimates:** If they are given (they may not be calculated until the FS);
- **Mining methods:** Recommendations for how the orebody should be mined, what equipment will be necessary;
- **Processing and recovery methods:** Detailed processing spreadsheet and description of what equipment is needed;
- **Project infrastructure:** Focus on general site infrastructure, waste management and disposal infrastructure and site buildings;
- **Market studies and contracts:** In depth analysis of the industry that the mine is selling into, how prices are set and where the operation sits within the industry as well as a discussion on what sort of price the operation can hope to attain;
- **Environmental studies, permitting and social/community factors:** Studies on the environmental, social and community impact of all parts of the operation;
- **Capital and operating cost estimates;**
- **Economic analysis:** Detailed model of the costs and revenue potential of the operation over the entire life of the mine, including closure costs. This information is used to allow analysts to forecast cash flows and hence calculate a present value for a project;
- **Other factors** which may be relevant;
- **Recommendations and conclusions.**

A PFS will normally run to in excess of 150 pages and could easily be over 200 pages in length. It contains all of the information that an analyst or investor should need to build a model for a project.

As an analyst, I'm always a bit wary about the cost estimates and assumptions included in a PFS. Remember, these are not definite numbers and a management team will still need to refine them over the next few years. Most management teams will include a contingency estimate in their capital cost forecasts. This may be anywhere from 10-20% of costs.

Given that capital costs, and particularly working capital costs, are the most-often underestimated factors in a project, I generally chuck on another 20%+ into my estimates for what costs will/may be. I also generally inflate operating cost estimates as well.

While many non-expert investors may be tempted to look at the calculated NPV in a PFS or FS and get excited about a project, often in comparison to another one, I wouldn't. A management team's assumptions for one project may be totally different to a separate management team's assumptions for a different project. Comparing published NPVs is a dangerous undertaking. That's why analysts and professional investors prefer to build their own models, so that they are in control of the inputs.

For instance, I as an analyst may utilise a different long-term price to a company, I may believe that the country they are operating in is riskier and use a higher discount rate and I may believe that they've underestimated the working capital requirement and/or their cost of borrowing estimate should be higher.

One issue to be aware of for investors. In a bull market, which lithium is very much in at the moment, some management teams may be tempted to fast-track projects. Sometimes, this means proceeding to construction with just a PFS (not completing a FS or FEED study). While this may be viable for open pit mining of bulk commodities like iron or coal, in my view it is not suitable for development of specialty chemical products like lithium where extensive testing of the orebody is needed. I'm sure we will see more fast-track developments in this cycle, but for me it always increases the risk levels and I count on the fingers of one hand the number of projects I've covered that have gone into production off just a PFS that have been successful...

Increasing level of certainty in different project studies

	PEA/Scoping	PFS	DFS	BFS
Stage	1	2	3	4
Information	Low	Moderate	High	High
Confidence	Faithful	Optimistic	Near-certainty	Certain
Key question	Should studies go further?	Could this project be successful?	How can this project be successful within these engineering parameters?	How profitable is this project and how much capital is needed?

Source: BM Review. After Star Investing.

Feasibility Study

A feasibility study is a more-detailed version of a PFS. It will use the bulk of the same section titles, but will have more detailed work. While a PFS may contain various different scenarios for production capacity (perhaps in different stages), a FS will be practically definitive.

A FS will contain more-detailed mineral processing work and it will contain much more definitive assumptions on costs.

Which is not to say that all the assumptions in a FS will be correct! I still generally apply an additional contingency addition to capital costs, in particular.

Note that there are different types of feasibility studies. The Rolls Royce of FS's is the Definitive Feasibility Study or DFS. As its name suggests, it's pretty definitive! But it mostly focuses on technical or engineering parameters. There's also the Bankable Feasibility Study (BFS) which looks into the financing parameters of the project in more detail.

FEED or Engineering study

FEED stands for Front-End-Engineering-Design. A FEED study is an exceedingly detailed study which prices up the equipment which will be needed to build an operation.

Some management teams do not carry out a FEED study, preferring to proceed directly from the FS stage (or before). Some project teams will do a soft FEED study alongside the FS.

For a bog-standard hard rock mining project, I'm not too concerned if a management team does a FEED study – the bulk of the mining and concentration equipment is off the shelf. But if the management team is targeting an Integrated project (ie mining, concentration and then processing to lithium chemicals) it's a much more complex pathway and then I would prefer to see a FEED.

Exploration into development and the importance of management

One factor that investors should watch out for as a company moves from an exploration stance into an evaluation stance and thence into a construction stance, is the management team.

In my experience as an analyst, it's very rare to find a good exploration CEO who's also a good development and production CEO. You either need to see the CEO change as the company moves through its development lifecycle or you need to see a build out of the management team.

The issue is this – exploration is rather a top-down kind of business. It's as much an art as a science. Development is a different kettle of fish altogether. It's very definitive, it's complex and it requires a different mindset. Generally, geologists run exploration companies and mining and processing engineers run development companies. That's because engineers are much more detail-orientated.

Which is not to say that the same CEO can't take a project from exploration into production, but they must not be averse to building out their management team. As an investor I like to see a COO (with some sort of engineering background) appointed to build a project. Projects with small management teams that try to do everything themselves tend to come a cropper, in my experience.

Factors for investors to watch for

While I've spoken about a few of the features of studies, resource and reserve statements that investors need to watch out for, there are also very specific factors with regards to hard rock lithium projects that investors need to keep an eye on, and I've listed them below.

Infrastructure and transportation

As I've noted before, hard rock lithium is a semi-bulk product and that means that transportation of the concentrate product can make up a substantial bulk of operating costs.

So, location is very important. If a company is going to produce a concentrate product then it needs to be within easy transportation distance of either a deep water port or a processing plant. There currently are a number of projects at the evaluation and development stage in central Africa, thousands of kilometres away from the coast. While it may very well be economic to transport the concentrate at prices of US\$5000/t or more for **SC6**, how viable might it be to transport the product at long-term prices of US\$1000-2000/t and potentially at higher oil prices?

There also has to be a reasonable transportation solution, and investors need to cast a critical eye over a management team's suggested transport solution. I shy away from overly complex transportation solutions because they always end up costing a lot more than they should. When a company describes trucking, rail and barging, I always get the screaming heebeegeebees! The cheapest transportation solution for bulk materials is barges, followed by rail, followed by trucks. The easiest transportation solution is trucking. But management teams often forget that there is a cost of trans-shipping material from one solution to another, particularly if it's a bulk material, not in containers. It's necessary to establish a loading and unloading point and then there are transfer losses and transfers take time...

Container trucking of spodumene concentrate



Source: Altura Mining

Truck for transport of bulk concentrate



Source: Qube

And another factor is how wide the roads are; the trucks that transport bulk materials are big. The bigger they are, the cheaper they are per kilometre. The bigger they are, the bigger the roads need to be to accommodate them. If a company plans to ship bulk material down a single-track road with no bypasses around towns, that's a risk factor from my point of view... If a company wants to barge material down a river, I need to know how shallow the river is during the dry season and whether the barges can traverse

it. If they want to use a railway I need to know if capacity is available and, if so, how much capacity is available?

Underground or open cast

Once I'm happy with the transportation solution (and other infrastructure such as water and power availability and sources), I want to have a close look at the mining approach.

Traditionally, hard rock lithium projects have been open cast mines. Increasingly now, with high prices, we are seeing some companies pursue underground mining. In my view, hard rock lithium is right on the edge of material that can be economically mined using underground methods.

As a bulk material, the underground infrastructure for extraction and transportation needs to be significant. And that means capex will be high. With underground operations, operating costs rise as the mining area moves away from the decline entrance (this material is too bulky for a shaft approach). And also note the comment I made before about the risk of dilution, lower grade concentrates and lower recoveries where dilution takes place. This is a major concern in underground mines. While I'm pretty happy that prices will be high enough for the next 5-6 years to justify underground mining, I'm not convinced that they will be high enough for the following 20 years.

That makes me wary about projects pursuing the underground route and, as an investor, you should ensure that you're happy that the economics of the operation justify going down the underground route.

Beneficiation route

When it comes to concentrating spodumene-rich ores, there are two primary approaches – **DMS** (dense media separation), and **flotation**.

Both require the ore to be crushed, but to different degrees. DMS requires a relatively coarser crush (millimetres) while flotation requires material to be crushed to the size of hundreds of microns. Given that pegmatites are quite a hard material, it requires a lot more power (and therefore cost) to crush and grind down to the micron scale.

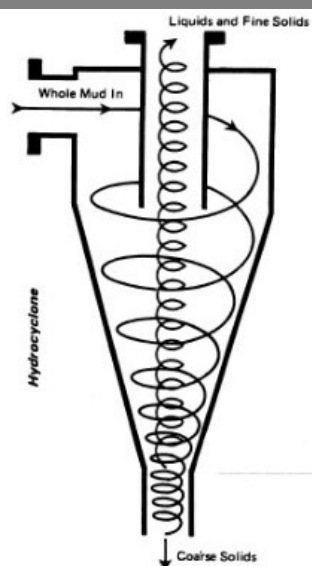
Dense Media Separation may utilise any or many different approaches compounded together but it will generally involve pushing the ore around in a circle with the heavier material settling to the bottom or the middle and the lighter material staying at the top or the sides. Often, magnetic separation (particularly Wet High Intensity Magnetic Separation (WHIMS)) will also be used to separate the non-magnetic spodumene from other magnetic materials.

Flotation again utilises different mineral densities; heavy or dense minerals fall to the bottom of a flotation tank while lighter material is adsorbed onto the bubbles.

A beneficiation operation will utilise a bank of DMS, WHIMS or flotation cells all connected in series so that a specific segment of the orebody can be extracted.

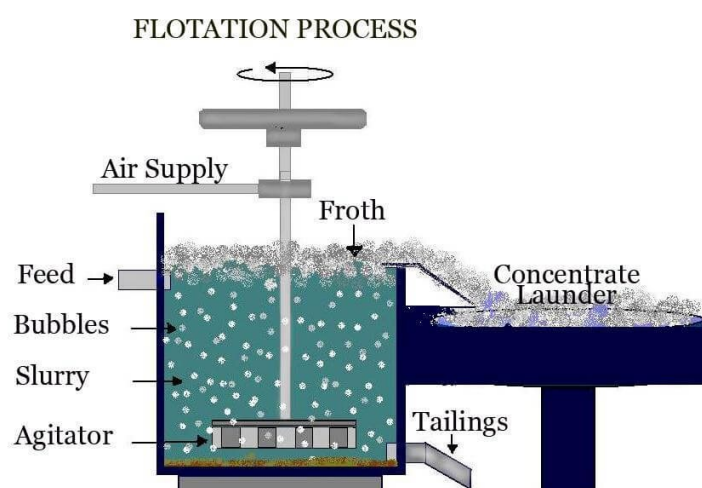
It has also been found that lithium converters prefer coarser grained material, so material beneficiated using DMS can trade at a premium. Fine grained material blows off the surface of the converter during heating, lowering recoveries. Fines may also behave in a less stable manner with regards to heat distribution during **calcining**, which causes production losses. While there are steps which may be taken to agglomerate finer grained material, they have a cost.

Illustration of hydrocyclone working principal



Source: 911 Metallurgist

Illustration of flotation cell



Source: 911 Metallurgist

Ores which can be processed using DMS-only therefore tend to be more sought-after. If a company is going down the flotation route then the source of the water used for flotation is also very important. Very saline waters don't froth up very well with frothing agents like fatty acids and, as such, recoveries are lower.

Upstream or Integrated?

The decision of whether to stick with an upstream product (**SpodCon**) or build an integrated plant (to go to lithium hydroxide or carbonate) is quite an important one for management teams. As I noted earlier there are important economic trade-offs to understand, but there are also requirements for an integrated plant which may not be present in the area where the material is mined.

The processing of lithium ores generally takes place at high temperature, which requires power availability. You're also generating a lot of waste material so there needs to be somewhere to store that waste and, in addition to that, you're also using a fair amount of other reagents which need to be transported to the plant.

Often you will find that even if a company decides to build an integrated project, that the chemical plant and the mine may not be situated in the same place. An example is **Mineral Resources** and **Albemarle's** Wodgina hard rock mine which was designed to supply material to the Kemerton hydroxide plant. It's 1700km between Wodgina and Kemerton. In northern Canada, where there are a number of projects, it's realistic that processing plants will be situated further south, closer to population and infrastructure.

Chemical testing and qualification

One of the most important factors to consider when looking at battery materials projects is qualification. Because the purity requirements for battery materials have become increasingly stringent in recent years, users of battery raw materials have to ensure that the material they buy adheres to extremely tight chemical specifications.

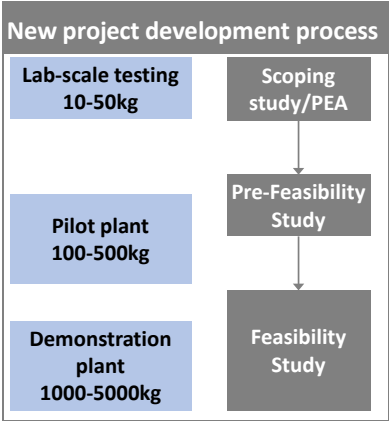
To ensure this is possible, all battery raw materials projects need to pass through a process called qualification with potential clients (and sometimes, even their clients).

Qualification is not a new process for raw material projects, but the degree of adherence to the specifications makes the qualification process extremely onerous for new projects.

When thinking about qualification, it’s important to understand how lithium is used in **batteries**. Lithium is part of the cathode, which is the positive electrode in a **cell**. In a LFP battery, lithium carbonate raw material is generally combined with iron phosphate, and in a ternary battery lithium hydroxide is generally used for the increasingly popular high nickel formulations (lithium carbonate can be used for cells below 60% nickel). In ternary batteries in particular, purity (to the ten part per million (ppm) level) is a key requirement.

Many management teams coming from a mining background can be pretty blasé about qualification and this is always a red flag to me that they perhaps haven’t done enough research on the industry into which they are heading. As an investor there are things that you should check to make sure that a management team has done enough chemical testing to ensure that their material is suitable for the battery supply chain.

Note that initial qualification can take up to TWO YEARS to complete and, even when a mine or processing plant is in production, qualification is an ongoing process.

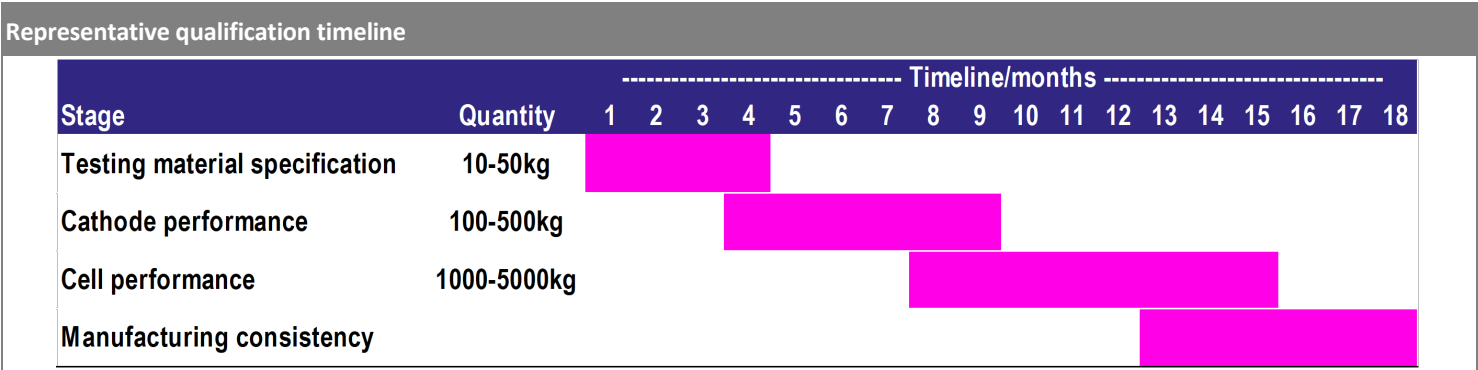


Source: BM Review

Qualification work needs to start very early on in a project’s life. For a hard rock project, drill samples can be used for lab-scale testing to ensure that the project is amenable for battery usage. By the PEA stage up to 50kg of material needs to go for lab scale testing. This material will be used to design the beneficiation plant but, importantly, it also needs to go right through the value chain all the way to cathode production and cell production. Some management teams just determine that the material can be used to make SC6, and that’s not enough in my view.

Around the PFS further testing is necessary. It’s really important that material is taken from the whole deposit, not just from one particular area. By the time that the PFS is completed c.500kg of material should have been tested.

By the time the FS is completed another 1-5 tonnes (1000-5000kg) of material should have been tested. If management is serious about the project being used for battery applications then it will have provided material to a number of cathode and cell manufacturing companies so that they can carry out testing on the material.



Source: BM Review

For integrated plants, management teams should consider a Pilot plant (small scale) and Demonstration plant (larger scale) to show that the project can produce high grade material on a consistent basis. Failure of a management team to do sufficient chemical and qualification testing should be a red flag to investors, in my view.

Indicators that investors should watch

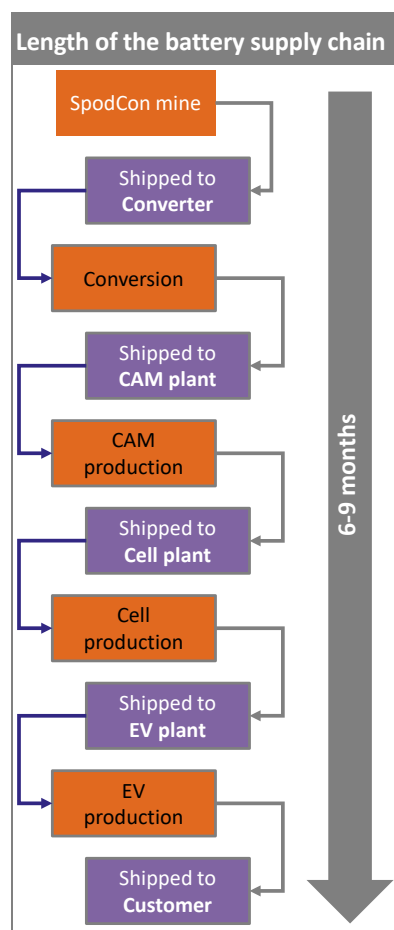
Lithium stocks (hard rock or other) go into and out of vogue according to a number of factors (indicators). One of the most important of these is lithium prices, but there are a number of factors that either cause prices to go up or down or can be leading indicators of inflection points in prices.

We keep track of all of these factors on a monthly basis in *Battery Materials Review*. It's difficult to get hold of data for many of them on a no-cost basis.

End markets

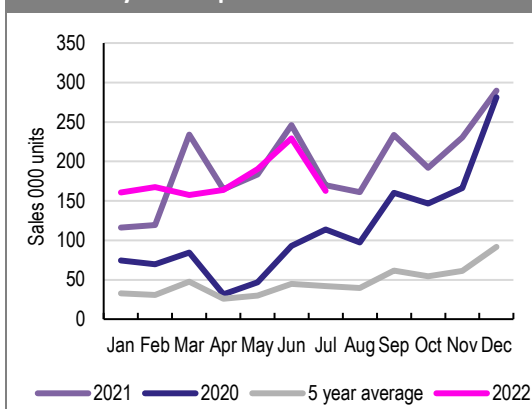
Let's talk about end markets. The biggest end market for lithium is rechargeable batteries and the market with the largest share of that is now electric vehicles. I say now, because even up to the past two years, it was consumer product batteries.

When I track **EV sales**, I look at three regional markets in particular – China, the world's largest EV market currently, Europe, its second-largest, and the US, which I expect to be a major market going forward (it isn't quite yet). I also track global EV sales (although, at the moment, that's not a lot more than the sum of the markets above).



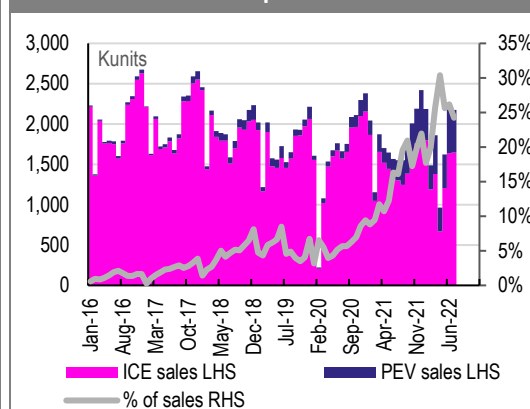
Source: BM Review

Seasonality of European PEV sales



Source: BM Review, EVvolumes.com

Chinese PEV new sales penetration



Source: BM Review, EVvolumes.com

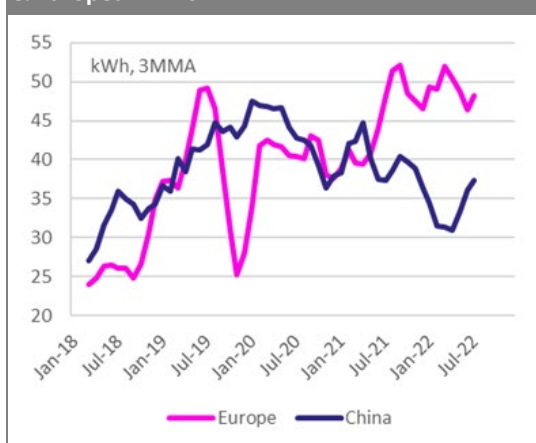
When I look at EV sales, I'm primarily looking at year on year (y/y) and month on month (m/m) growth rates, although I'll also look at year to date (YTD) growth and market penetration (the amount of EVs sold as a percentage of total new car sales in a given market). All of these things give me an idea of the health of the EV market.

While EV sales can help me to understand the overall health of the market for batteries, there are other things that I'm looking for in EV sales data that are really important to lithium demand.

One of the things that I keep a very close eye on is average battery size of the EVs in different markets. Larger batteries translate into increased lithium demand, smaller batteries into less. By tracking which models are selling best and knowing their battery size I can get an important cross section into what trends are likely to be like for lithium demand.

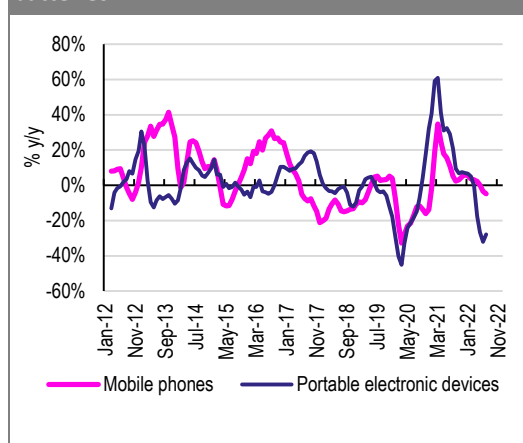
I'm also looking at whether the cars that are selling are utilising **NCM** (ternary) batteries or LFP batteries. That shows whether they're made using lithium carbonate or lithium hydroxide and has knock on impacts for spodumene concentrate demand (which is the primary raw material for lithium hydroxide).

Weighted average battery size of top 10 Chinese & European PEVs



Source: BM Review, EVvolumes.com

Chinese output growth for key users of small batteries



Source: China NBS, BM Review

I also look at **consumer products** demand and **ESS demand**, but it's not so easy to get data for these segments and it's based much more on primary research.

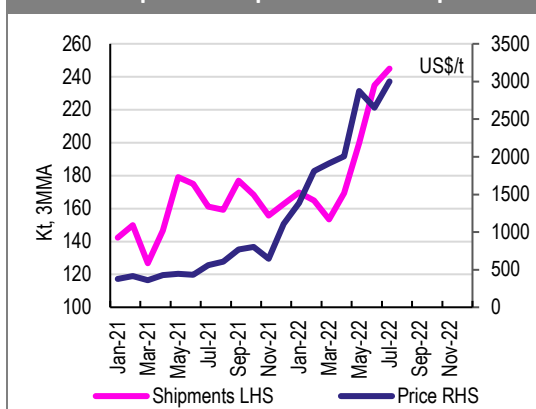
One thing to be aware of when looking at end markets as an indicator of lithium demand is that the supply chain is pretty long. Much longer than you would think. If you think about the fact that mines, **converters** and **pCAM/cathode/cell/EV** production can be in different countries, you can perhaps understand why it takes so long for EV demand trends to affect lithium demand and pricing. It can easily take of the order of 9-12 months for demand and pricing trends to flow up and down the supply chain.

Lithium trade trends

Another way to understand what's going on in the lithium industry is to track trade trends. It's possible to analyse export data for major lithium production countries such as Chile and Australia (though it's more difficult for Argentina) and to track import data for lithium consumers such as China and Korea.

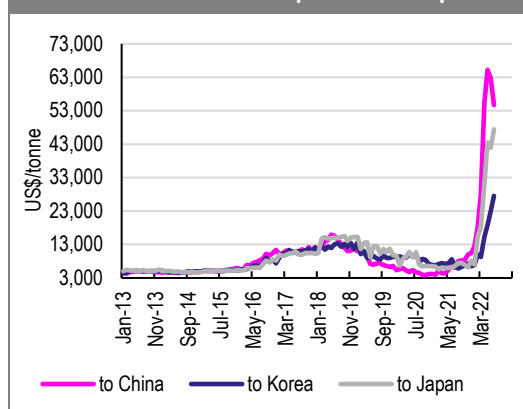
We track this data on a monthly basis in *Battery Materials Review* and it helps us to understand demand trends and also what's going on with prices, because we can calculate realised prices of lithium trade.

Australian SpodCon exports vs realised price



Source: BM Review, GlobalTradeTracker

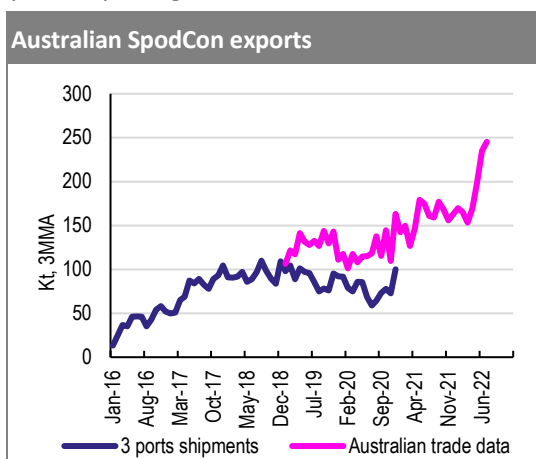
Chile lithium carbonate export realised prices



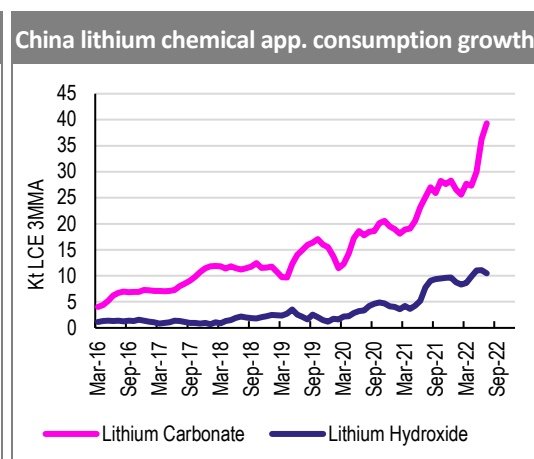
Source: BM Review, GlobalTradeTracker

Of course, when it comes to hard rock, Australia is currently the world's primary exporting region and China is the world's primary lithium chemicals production region.

For China we can calculate apparent consumption, which is very important to be able to predict pricing directions.



Source: BM Review, GlobalTradeTracker



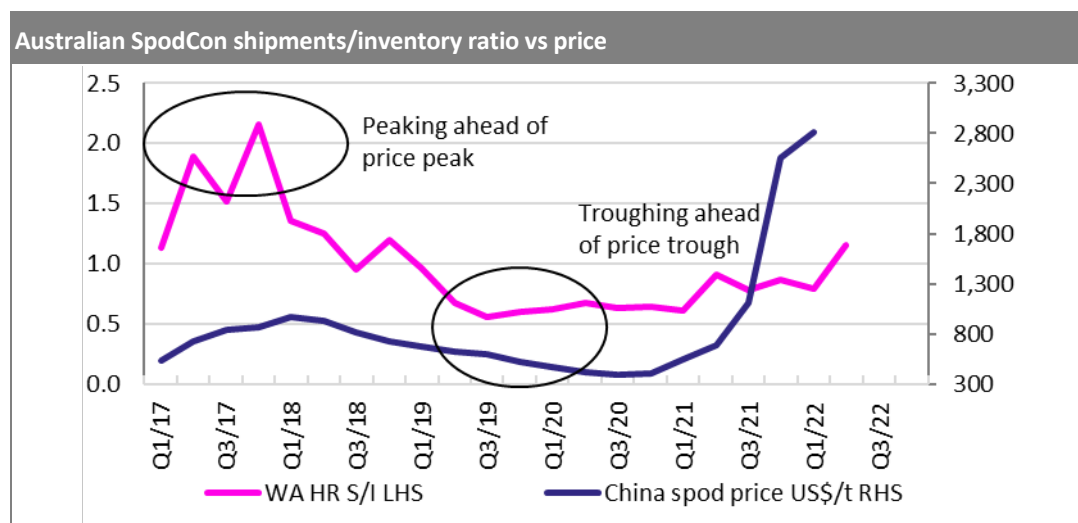
Source: BM Review, GlobalTradeTracker, ICCSino

Company data

I find that there are two types of company data which are useful indicators for lithium demand; that from Mining and Cell Manufacturing companies.

When I look at **Mining** company data, my focus is on production and sales. Most mining companies release quarterly production data which provides a snapshot of the industry and this is particularly useful for the Western Australian hard rock producers.

In fact, by following inventory trends and plotting the shipment to inventory ratio for Australian hard rock lithium producers, I was able to spot a point of inflection just before the lithium price turned up in 2020.



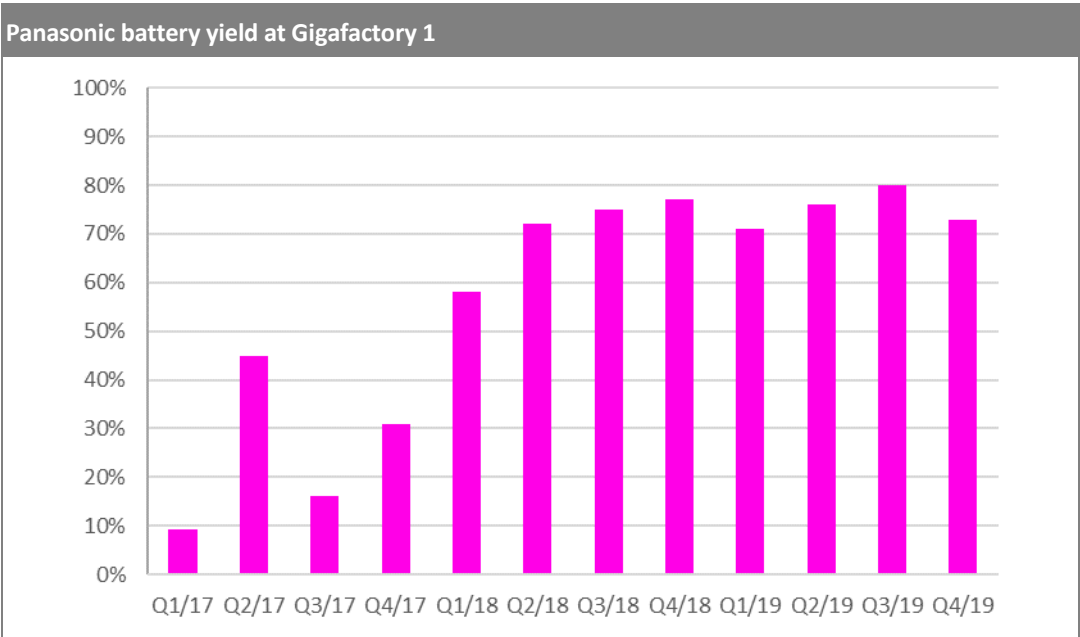
Source: Company data, BM Review

Shipments/Inventory (S/I) ratio is a common indicator used by materials and industrial analysts. The S/I ratio rises when demand is growing (shipments increase and inventories decrease) and falls when demand is weakening (lower shipments, higher inventories).

Inventories are a core indicator for the health of any industry and it was anecdotal reports of falling lithium inventories in China which convinced me to go overweight lithium in Q3/20.

Cell manufacturing companies provide less consistent data, but sometimes it can be very helpful. Battery yield is a key consideration in terms of lithium demand. Battery yield illustrates the amount of rejected cells produced in cell factories. **Panasonic** used to release a useful data series on battery yield at Gigafactory 1, which showed that most cell factories have very low yields when they start up. This improves over time but may not increase over 80-85%.

If a cell factory has a low yield, then lots of its raw materials are wasted and need to be recycled. Battery yield is therefore a key component of supply/demand models – for every cell produced by a plant, a certain number are rejected, hence demand for lithium is higher than it looks from simple cell production numbers. [Note that some major investment banks use the term ‘battery yield’ in a different way].



Source: Panasonic

It’s worth noting here that LFP cell plants generally have higher yield than high-nickel ternary plants. This is because lithium carbonate is less-reactive and has less-stringent purity specifications than lithium hydroxide.

Prices

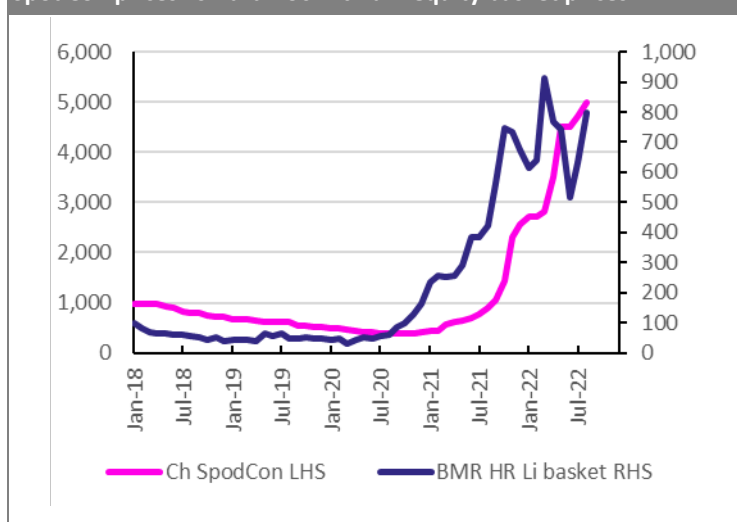
While the indicators I’ve listed above are focused on allowing you as an investor to be able to predict lithium prices, at the end of the day stock performance is actually most-closely correlated to prices and you may not want to go through all the hassle of predicting prices in advance and instead just choose to keep an eye on them as an indicator as to how you can predict what equities are likely to do.

The problem is – that’s not always that easy. Lithium is such an immature industry that it’s often very difficult for investors (particularly private ones) to track prices. Although, increasingly now, prices for lithium carbonate and lithium hydroxide are available on a daily basis from a number of websites, prices for Spodumene Concentrate, the primary product of non-integrated hard rock lithium producers, may only be available to institutional or professional investors and industry participants on a regular basis.

There are a few routes open to non-professional investors to track or predict SpodCon price performance, and these are:

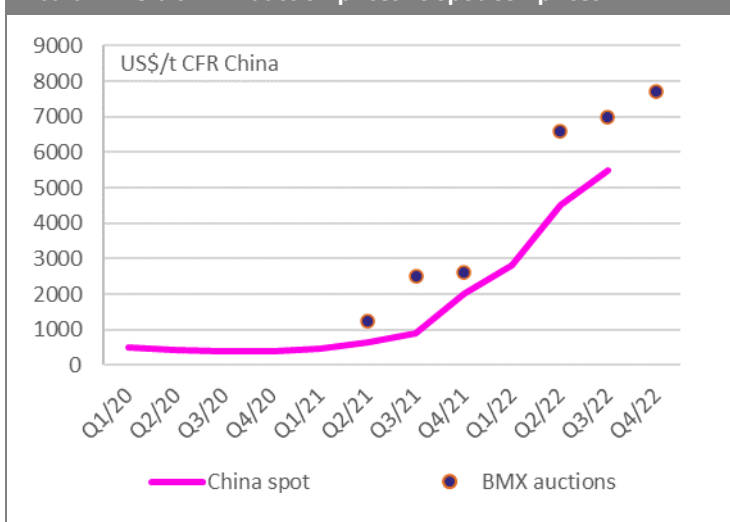
- Some companies will predict what their realised SpodCon prices will be for the next quarter. **Allkem** is one such company. It's worth looking at their quarterly activity report;
- **Pilbara Minerals** conducts ad-hoc auctions of small batches of SpodCon via its BMX auctions. It will make an investor release to confirm what prices it achieved. While, so far, these prices have been above market prices, they give a good idea of where prices may be heading;
- We track SpodCon prices in *Battery Materials Review* on a monthly basis;
- If all else fails, keep an eye on lithium hydroxide prices. Lithium hydroxide is mostly made from SpodCon so the direction of LHM prices will inform to some extent on demand in the hard rock lithium market.

SpodCon prices vs Hard Rock lithium equity basket prices



Source: BM Review

Pilbara Minerals BMX auction prices vs SpodCon prices



Source: Pilbara Minerals, BM Review

Valuing stocks

While some investors are happy playing momentum trends in the market, the chances are that at some time or another you'll wonder if the stocks you've invested in have gone high enough and might be looking overvalued.

The key to successful investing, after all, is knowing when to take profits on your positions. There's nothing more annoying than buying a stock at the bottom, seeing it go up by multiples and then seeing it go down by multiples!

While lithium prices can be used to show when a cycle is turning over, we often find that equities move in advance of materials prices cycles so, if you want to lock in maximum profits, it's important that you are able to value stocks.

There are different ways to value stocks at different stages of development and we discuss those below.

EV/resource multiples (early stage projects)

When a stock is in the early stage of development it's very difficult to value it because there just isn't a lot of data.

For stocks at the drilling stage it's practically impossible to value them. It's only after a company discloses its maiden resources that it becomes possible to effectively start to value it.

Analysts look at **multiples** for stocks and compare those to other exploration and/or development stocks in the same sector to determine whether stocks look expensive or cheap.

Most non-professional investors will look at multiples on a market capitalisation (market value) basis, but most analysts will use an *enterprise value* multiple. Enterprise value is defined as market value less net cash (or in some cases market value plus net debt). This correction is important because if a stock has a lot of cash, then it's not likely to come back to the market in the near future to raise money.

When stocks raise money in the equity market they have to issue shares, which means that the shares of existing shareholders may be worth less, particularly if the raising takes place at a discount to the existing share price.

So, from the multiple point of view, we're lowering the numerator which will make the multiple smaller, and lower multiples mean that a stock looks cheaper.

When defining the resource, many analysts only use Measured & Indicated Resources, but I always prefer to use **total resource** because it allows one to compare earlier-stage companies which may not have yet defined Measured & Indicated Resources. In my view, the bigger the range of companies used, the better the average.

I always use contained resource (resource tonnage x grade) because grades are important in terms of whether a project development is to go ahead or not.

For later stage projects some analysts like to add intended capex onto the Enterprise Value to provide an understanding of the dilution impact of this capex

In *Battery Materials Review* we disclose both the capex-adjusted and normal EV/resource multiples.

Calculating EV/resource multiples	
Share price (US\$)	100
x	
No. of shares in issue (m)	1,000,000
=	
Market value (US\$m)	100
Market value (US\$m)	100
+	
Net Debt (US\$m)	10
=	
Enterprise value (US\$m)	110
Total resource (Mt)	10
Grade (% Li ₂ O)	1%
Contained resource (Mt)	0.1
EV/resource (US\$/t)	1100

Source: BM Review

When calculating these sorts of multiples it's important to correct for what is called the **equity share** that a company owns in an asset. Most commonly a company will own 100% of an asset, but in some jurisdictions there is government free carry and, in some instances, companies joint venture (JV) to get project development financed. It is therefore important that when you are considering the company's market value or enterprise value that you compare it only against the company's share of the asset. You may also need to make a manual correction on the capex calculation as well. If a government has a free carry interest then the company will need to finance all the capex but if it's a JV, normally the company will only finance its share of the capex.

Once you have the EV/resource multiple for an individual project you can then compare that with similar projects. One normally finds that high grade projects and projects in existing production areas trade at a premium. Large low-grade projects often trade at a discount as do projects that are landlocked or in difficult to operate regions like central Africa.

Once you've developed average multiples it's possible to determine whether the project that you're looking at looks cheap or expensive vs the rest of the sector.

Representative EV/resource multiple valuation

Stock	Region	Stage	Equity share	Mkt cap US\$m	Net debt US\$m	EV US\$m	Total resource* Mt	Grade % Li2O	Contained Li2O Mt	EV/contained Li2O resource US\$/t
Early stage										
Company A	Australia	MRE	100%	52	-1.7	50	5.2	1.1%	0.06	879
Company B	Australia	PEA	100%	82	0.2	82	8.9	1.2%	0.11	770
Company C	Australia	NRE	100%	107	-10.3	97	12.0	1.3%	0.16	620
Australia average										1,2 756
Company D	Americas	MRE	100%	101	-5.2	96	7.5	1.2%	0.09	1064
Company E	Americas	PEA	100%	216	8.3	224	22.3	1.2%	0.27	838
Company F	Africa	PEA	75%	78	-1.2	77	35.1	1.4%	0.49	1 156
Company G	Europe	PEA	85%	92	-3.7	88	12.6	1.1%	0.14	637
Ex-Australia average										1 674
Evaluation										
Company H	Australia	PFS	100%	521	-2.9	518	42.1	1.2%	0.51	1026
Company I	Australia	DFS	100%	879	-12	867	79.8	1.1%	0.88	988
Company J	Australia	Construction	100%	1,200	125	1,325	25.9	1.3%	0.34	3935
Company K	Australia	DFS	100%	612	-23.2	589	52.3	1.2%	0.63	938
Australia average										2 1722
Company L	Americas	FS	100%	1,298	-42.9	1,255	41.7	1.5%	0.63	2007
Company M	Africa	DFS	70%	679	-23.7	655	120.3	1.2%	1.44	454
Company N	Europe	FS	100%	821	52.9	874	25.6	1.1%	0.28	3103
Company O	Africa	FS	85%	568	-29.6	538	68.1	1.3%	0.89	608
Ex-Australia average										1543
Production										
Company P	Various	Production	NA	5,693	-568	5,125	179.3	1.1%	1.97	2598
Company Q	Australia	Production	100%	7,198	-735	6,463	228.0	1.2%	2.74	2362
Company R	Various	Production	NA	20,067	4570	24,637	428.2	1.4%	5.99	4110
Company S	Various	Production	NA	12,568	1285	13,853	112.6	1.2%	1.35	10252
Producer average										2 4831

*Equity share

Source: BM Review

Notes: 1) Different regions trade at different valuations, and Emerging Markets will often trade at a discount; 2) Later-stage developers and producers will generally trade at a premium to earlier-stage ones.

DCF (mid/late-stage projects)

A DCF or Discounted Cash Flow model is what professional investors use to value mining projects. A DCF enables an analyst to forecast revenue and costs for a project, as well as other factors, and hence derive what the cash flows are likely to be over a forecast period. They then use something called a discount rate to discount those cash flows back to what they would be worth in the present day, and then they can be added together to generate a valuation for the project.

DCF's are quite complex analyses with lots of moving parts, so it's necessary to have a spreadsheet program at the very least to calculate a DCF. I use the NPV function in Excel to calculate mine once I've established what my cash flow forecasts are.

I'm not going to go through all of the assumptions needed to utilise a DCF because that would be a book in itself! I am going to go through a couple of the assumptions which are the most relevant within the context of hard rock lithium projects.

Recovery

Recovery is the percentage of the targeted material that can be extracted in the processing plant. For hard rock lithium projects so far, recovery has been one of the key targets of feasibility studies which management teams have struggled to attain. It has been much harder at the commercial level to hit the kind of recovery targets that laboratory level work suggested would be possible. Many of the Western Australian hard rock projects targeted recoveries of 80+%, but have only managed to get operating recoveries of around the 70+% percent level.

If a project's recovery is below target, then costs will be higher because you need to put a larger amount of material through the plant to get to the targeted output. Experience has taught that, as an analyst, it's better to assume lower than targeted recoveries (and therefore higher than targeted costs) for the first 18-24 months of plant life.

Costs

Whether it's been down to recoveries or other factors, costs have been much higher across the board than expected in new projects so far. Particularly in the early stages of development. In my view that's going to persist as an issue over the next 5-6 years because of high structural inflation. As an analyst I always take cost estimates (even those from the feasibility study) with a pinch of salt. I tend to add a contingency for operating costs; they very rarely come in at the level expected, particularly in the early quarters of ramp up.

Bear in mind that these hard rock lithium projects (in fact all mining projects) have a high fixed cost component. If production is depressed, as it normally is in ramp up, unit costs

The ramp up conundrum – impact of fixed cost base

	Unit	Life of Mine	Start up
C1 costs	US\$m	100	70
Fixed costs	US\$m	50	50
Variable costs	US\$m	50	25
Production	Kt	100	50
Fixed cost per tonne	US\$/t	500	1000
Variable cost per tonne	US\$/t	500	500
Total cost per tonne	US\$/t	1000	1500

Source: BM Review

of production can come in at multiples of their targeted level.

Beware if a company is using contract miners or overland transporters, because if that is the case, they may be contracted for a certain production structure, even if that hasn't been attained that yet.

Longer than expected ramp up/working capital impact

Whether it's because of recovery or other factors (qualification requirements can be an issue as well), these hard rock projects tend to take substantially longer to ramp up to targeted production than other mining projects you may have studied. An integrated lithium hydroxide refinery could easily take 9-15 months to hit targeted recoveries and specifications. During that period, the project is incurring costs but not making any money. That means there is a substantial requirement for working capital and this requirement is something management teams often underestimate. Don't be surprised to see an emergency fundraising.

Even in plain vanilla hard rock projects it can take several quarters to hit specs. Note that if the buyer rejects the material due to chemical impurity issues, they will not pay for it. This is a risk to be aware of when investing in battery raw materials projects.

Discount rate

The discount rate that one applies in the DCF for a project is very important. The discount rate reflects many factors but at the heart of the matter it is supposed to account for the funding cost of a project. Funding costs are a factor of the interest rate on debt and also the cost of equity. If you turn that around, they're effectively reflecting the amount of return an investor would be looking for by investing in the project, which will be a factor of the risk of a project.

Many mining investors use fixed discount rates for everything. I'm not a fan of that approach. I believe that the discount rate needs to reflect the location of a project (stable jurisdiction or not so stable) and level of development of a project (early, mid or late stage). All of these factors bring different combinations of risk and, for me, these need to be reflected in the discount rate. A higher risk project will discount the cash flows back using a higher discount factor, whereas a lower risk one will apply a lower factor (and hence have a higher valuation).

Matrix for assigning discount rates and risk discounts for Hard Rock Lithium projects

Development stage	----- Discount rate -----		Risk discount
	Developing Country	Developed Country	
Development*	16-18%	12-14%	75%
Construction*	12-14%	10-12%	50%
Production*	10-12%	8-10%	0-25%

Source: BM Review. *Higher discount rate for non-vanilla technology.

The table above shows the sort of discount rates I would apply for hard rock projects in different regions. The non-spodumene projects would have higher discount rates because they're not yet as proven at the commercial level.

Risk discount

So, you built your DCF and you're happy with your assumptions and a valuation drops out at the end. Is that the number that you should apply for your price target? In my view, it's not.

There are lots of corrections that you'll need to make to your model first.

First up, how have you dealt with the funding requirement? Some analysts just assume 50% equity and 50% debt and just bung that into the cash flow. But if you've assumed an

equity component then you need to correct for the number of shares that will need to be issued to cater for that equity (dilution). There are two ways to do this:

1. Calculate the number of shares at the current share price (or a three month average of it) and calculate a fully diluted price target (the number of shares currently in issue plus the number of shares needed to raise equity, and also make sure you include outstanding warrants, options and convertible debt); or
2. Apply a haircut to your NPV to account for future dilution. With early-stage projects I prefer to apply a haircut because the share price today should (hopefully) bear no relation to what the share price will be when the company carries out its fundraising.

I will apply a 75%, 50% or 25% hair cut to my NPV depending on the development level of the project. I will often maintain the risk discount until commercial production to account for the risk of emergency fundraisings or construction delays.

Earnings-based multiples (production stocks)

While one can easily use a DCF to value a production stock, they tend to be less flexible with regards to market behaviour and short-term materials price action and earnings. Once a stock goes into production, the market looks much more at earnings-based multiples to determine the direction of travel of the share price.

The earnings-based multiple approach is much easier than a DCF because it requires substantially fewer assumptions to forecast one to two years of earnings.

The two most commonly used earnings-based multiples are PE (price earnings ratio) and EV/EBITDA. I personally prefer EV/EBITDA because mining is a global industry and EPS (on which PE is based) is (1) dependent on what the local corporate tax rate is; and (2) may contain non-operating items which can mess up your comparisons.

As with EV/resources multiples, normally one compares earnings-based multiples with a sector average, but one can also compare the current multiple with through the cycle multiples if the stock has enough history.

Example valuation table for production stocks

	EV/Sales			EV/EBITDA			PE		
	2021	2022E	2023E	2021	2022E	2023E	2021	2022E	2023E
Company 1	1 2.2	2.0	1.8	6.1	5.9	5.7	25.3	3 23.2	21.4
Company 2	4.5	4.7	4.9	11.8	2 12.2	12.6	30.2	31.6	32.8
Company 3	4 NA	6.2	2.8	NA	NA	14.6	NA	NA	NA
Company 4	1.3	1.2	1.4	5 5.2	5.0	5.1	19.2	19.0	19.4
Company 5	2.4	2.2	2.8	5.6	5.2	4.8	18.0	16.8	15.6
Average	2.6	3.3	2.7	7.2	7.1	8.6	23.2	22.7	22.3

Source: BM Review

Notes

1. In a rising market, multiples should fall over future periods;
2. If multiples do not fall then sales/earnings are falling. Why?
3. Companies 1 & 2 are trading at a big premium to the rest. Why? The premium may be justified if they are higher margin or higher growth companies; if not then they look overvalued;
4. Company 3 is just coming into production; as such its multiples should not be used as a comparison until it reaches steady state production;
5. Company 4 is trading at a discount to the sector; if its margin and growth profile look good, it's undervalued.

Some people look at current year multiples (ie 2022 EBITDA forecasts in 2022), but I prefer one year forward (ie 2023 EBITDA in 2022) because the stock market is generally forward-looking.

In general terms lower earnings-based multiples (which indicate that the market value or enterprise value is not correctly valuing in the expected cash flows or earnings) indicate that a stock is cheap, higher multiples that it's expensive. But be aware that there may be reasons why a stock is cheap or expensive.

For instance, stocks with operations in Emerging Markets often trade at a discount, as do stocks which are ex-growth. Rapidly growing stocks, which are adding capacity, often trade at a premium, as do those with high profitability and/or that are well-managed.

Calculating a target price

When we calculate a target share price for a stock, we need to add together the calculated value of the stock's operations and projects (on a risk-adjusted basis) and its net cash (debt) position (ie if it's net cash you add, if it's net debt you subtract).

You then need to divide that total by the number of shares in issue to arrive at the target share price. But there's an important "but". Many stocks have large amounts of options and warrants that they issue to the management team and directors. It's really important to factor those in. While they may not be in the money at current share prices, they may very well be in the money at your price target and, if that's the case, then they need to be included in your calculations. There are sometimes also convertible bond instruments that need to be factored in.

How to calculate dilution

Granted	Expiry	Exercise price US\$	No. of shares m	In the money shares m
Convertible loans				
12-Jan-21	12-Jan-25	2.00	125.0	125
Performance rights				
31-Dec-20	31-May-23	1.80	1.0	1.0
31-Dec-20	31-May-23	2.00	2.0	2.0
31-Dec-20	31-Dec-24	2.20	2.0	2.0
31-Dec-20	31-Dec-24	2.40	1.0	-
Options				
31-Dec-21	31-Dec-25	1.60	1.0	1.0
31-Dec-21	31-Dec-26	2.00	5.0	5.0
31-Dec-21	31-Dec-27	2.40	6.0	-
31-Dec-21	31-Dec-28	2.80	4.0	-
Warrants				
12-Sep-20	12-Mar-23	1.20	1.5	1.5
17-Jun-22	17-Jun-24	1.40	1.5	1.5
Total			150.0	139.0 A
Current share price		2.26		
Current shares in issue		1240	B	
Fully diluted shares		1379	C=A+B	

Source: BM Review

As I noted above, it's important to factor in fundraisings. If you included an equity component in your project cash flow, then you need to add the shares that would need

to be issued to your fully diluted target share price. A fully diluted share price target can therefore be substantially lower than a non-diluted one.

Construction timelines and emergency fundraisings

My experience as an analyst has always been to take management's construction timeline forecasts with a pinch of salt. Over my 20+ years in the industry, out of the hundreds of projects I've covered, only one – yes, that's ONE – has come into production on time and on budget!

Management teams often underestimate how much working capital they'll need for development, and this is particularly prevalent in battery materials where it may take somewhat longer for projects to hit the required chemical specification than in other materials.

I would always counsel analysts and investors to assume that 6-12 months of working capital will be required, and it is quite likely that an emergency fundraising may be needed, since management teams try to dilute as little as possible at low valuations and raise as little as they can in early fundraisings.

Analysts and investors should keep an eye out for that emergency fundraising which can come any time from six months before commercial production to 12 months after, in my experience.

It's important not to assume that, just because a project has come into production, that it's safe. In my experience, a good 50% of projects that require an emergency fundraising carry it out after first production has been declared...



Other factors to pay attention to

OK, so we've discussed key mining and development factors that investors should look to understand if they want to make money from investing in hard rock lithium stocks. But there are other more general factors to do with investing in stocks (particularly smaller exploration-type stocks) that people should bear in mind as well. The below list isn't exhaustive by any means, but it does cover many of the key "eureka" moments of my past 20+ years of investing experience.

Management should have skin in the game but not too much...

When I look at stocks I always find the best-run companies are the ones where management has a reasonable holding of stock in the company. The best way to incentivise people to do a good job is if they stand to benefit from it. I like to see management teams with a good share of the company so that they benefit if the share price goes up and their wealth suffers if the stock doesn't perform well.

But on the flip side of that I don't like to see companies where management (and the board) have too much exposure to the stock. When they own too many shares they can get too fat and happy and often companies turn into what analysts call "lifestyle companies" where the owners of the company can block any attempts by minority shareholders to make changes.

In a small cap exploration stock, I like to see board and management owning 15-20% of equity and being incentivised with options and warrants. Obviously in development and production companies it's reasonable for board and management to have been diluted by financing rounds, so they may not own so much.

...but beware of family companies

One of the big things which raises red flags for me is so-called family companies, where a single shareholder or a block of closely-related shareholders might own 50+% of the stock of a company.

In some, but not all cases, the CEO of the company may be the holder or the son/daughter/other relation of the major shareholder.

In these companies you will often find a reluctance to spend money on exploration, development or expansion for fear of diluting the family's holding by having to raise equity capital from outside shareholders. This will often mean that family companies will move very slowly in their development because they don't want to dilute their holdings at low share prices. Often they will try to bodge low quality development strategies for a small amount of capital to generate cash flow to then be able to afford more incremental expansions.

In a bull market it's my experience that one needs to expand rapidly if you have a viable project. If that means raising a lot of capital then so be it. I'm not talking about wasting money needlessly, but a situation whereby a management team looks to save money by not raising for expansion isn't a great look either. Family companies often commit to ludicrous debt instruments and stupidly high debt/equity ratios (again to avoid dilution). I always go with the maxim that it's better to own 10% of a US\$1bn company than 50% of a US\$100m company. Unfortunately, many owners of "family companies" don't see it that way...



Lifestyle companies?

Watch out for liquidity traps

Liquidity in stocks is key if you're an investor. Liquidity is the amount of volume/value that trades in a stock every day. Liquid stocks attract large, institutional investors, while illiquid ones don't. As an investor you should be wary of a stock that doesn't trade more than US\$100,000 per day, unless it's a very early-stage project.

It's all very well if you see a stock very early in its exploration cycle and you think it's going to develop into a well-traded stock. But if it doesn't, you should probably think about getting out. Note that lots of family stocks aren't great traders because the family insists on keeping such a big chunk of the stock that there's not enough free float to trade.

It is important for a stock's development that institutional investors can trade it. If there isn't enough liquidity to trade it, then at some point a stock will run out of steam very rapidly.

Promoters are good...but also bad

A common theme in the mining space is promoters. There are a number of well-known mining entrepreneurs that own or have shares in multiple companies in multiple segments and push those companies to their base of followers.

Now the good thing about mining promoters is that they have a wide base of followers and if you get in early in a stock that they're promoting, the chances are that you'll make money out of it.

The bad thing about mining promoters is that they often push unsuitable projects very hard and in the end those companies fail. If you as an investor are in late and the project fails then you're going to lose a lot of money. Make sure you follow the tips on evaluating a project in the front part of this report before getting carried away on a stock promotion. If the stock doesn't pass on the things I've covered previously then maybe think about investing in something else!

Note that CEOs chosen by mining promoters (and some mining promoters themselves) are some of the best salesman I've ever come across. They'll have answers to all your concerns. But just sit back, think about it logically and if your gut tells you not to invest, then don't.

Decide what your aim is and stick to it

Make sure you decide what you want to do with an investment before you go in. Are you looking to milk some near-term performance from drill results? Do you think the project's going to get built and you're willing to park your money for five years? Do you think the lithium price is going up and you want some leverage to that move?

It's all right to change your mind while you're in a stock. For example, you might have gone in for the drill results but realise this could be a great project and decide to stick it out.

But, if the investment is not doing what you want it to do, you should cut and run. If the drill results were lousy, take your hit and go. If the lithium price doesn't rise, don't wait for it. There's nothing worse than following a stock down because you didn't have the guts to admit you made a mistake. Cut and run if you need to. There will always be another opportunity out there.



Take profit when you can...

There's nothing worse in my view than riding a stock all the way up to the top and then riding it right back down again! And I've done it several times in several different cycles!

The best advice I can give you is take profits when you can. Particularly in the exploration side you will often have the opportunity of a down week or month to add holdings back if you want to. All stocks have down times and there's nothing worse than not taking your profits when you could. My advice – don't get too greedy. If you've done well, take some money out. You don't have to take all of it out, and I would recommend against doing so, unless you think the driver that you invested for has been completed, but you should take small amounts out when you've seen a big profit.

Remember that mining and mining exploration are risky businesses. And they're cyclical. Sometimes things can happen that are within a management team's control, like an accident at the mine site. Sometimes things can happen that are totally outside a management team's control, like an electricity outage, a war, a global pandemic or a global financial crisis. All of these things have impacted my personal and/or work equity performance at one time or another.

...but don't trade too much

Similarly, don't get conned into trading too much. I understand this is a fine line. In small cap land stocks are volatile. Much more volatile than large multi-billion dollar stocks. If you're trading every few days/weeks in small caps the chances are you're trading too much. Back test what you're doing and see if you're actually making money. If you are, disregard what I said – obviously I have no idea what I'm talking about! But if you're not, step back a bit. Hold onto positions for a little while longer.

The skill set for trading large cap production stocks and small cap exploration & development stocks is different. I know a lot of fund managers, traders and analysts that use technical analysis for large caps. It works for them. There are a number of common indicators used, as well as actual technical analysis of charts. It's not uncommon to hear analysts and Portfolio Managers talking about double tops, inverted flag patterns and island reversals! Most of that is Double Dutch to me and probably will be to most people! Having said that, I do find that technical analysis is helpful in trading large cap mining equities.

Common technical indicators used for mining stocks

Moving average	30,50 Day	Useful for short-term trading calls
	200 Day	Tells you if a stock is in bull or bear market territory
RSI, MACD	-	Tells you if a stock is overbought or oversold
Bollinger bands	-	Tells you if a stock is overbought or oversold

Source: BM Review

But you can't use technical analysis for small caps, because there generally isn't enough liquidity. I'm more likely to hold onto small caps for longer. You've also got to think about why you're investing in small caps. Because let's face it – it's riskier than investing in large caps. I invest in small caps for a multi bagger opportunity. You can't get a multi bagger if you're trading in and out all the time.

A highly successful Fund Manager I know at a major fund once told me that even though he'd done OK on investing in small cap mining stocks, he would have done better if he hadn't traded around so much.

Keep an eye on catalysts and position in mining cycle

Keep an eye on your stock's level of development and its position in the mining cycle. Is it transitioning? ie going from exploration to development, or development to production? This is important to bear in mind because, at the end of the day, a stock performs because of catalysts that the management team delivers.

Whether these catalysts are positive drilling updates, resource estimates or development studies, they're all catalysts.

When catalysts are delivered close together, a stock tends to outperform. When a stock stops delivering regular catalysts, it tends not to perform as well or, indeed, badly.

As an investor, you need to understand whether catalysts that a management team is looking to deliver are important or not. Sometimes promoters will deliver "catalysts" that aren't important at all, and the stock doesn't move. Or it falls back.

An understanding of catalysts is key to investors. If a stock is regularly delivering drill results then the market will get behind that. If it stops drilling and doesn't have any catalysts in the near-term, that might be a time when an investor might consider taking profits.

As a stock goes from the exploration to the evaluation stage, catalysts become fewer. That's why stocks often fall back when they go into the evaluation stage. As they go into construction they become fewer still. It's a challenge for management teams to keep delivering catalysts during these periods.

Operating leverage

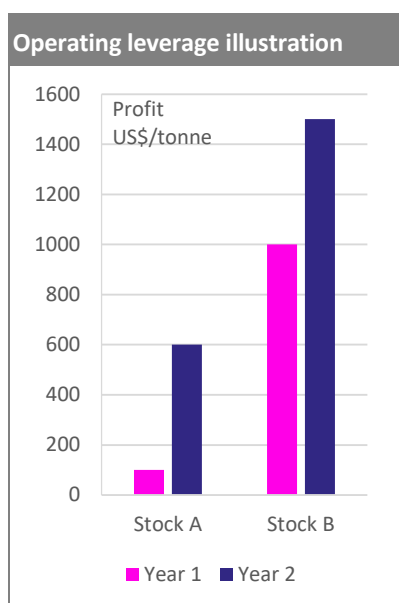
The final factor I want to talk about in this section is operating leverage. Let's say that you're convinced that the lithium price is about to top out. Which stock would you short or sell? Well, the worst quality and highest-cost producer because its profits will go down the fastest.

But say you're convinced that the lithium price is going to rise. Which stock would you buy? Many people would suggest to buy the highest quality and lowest-cost producer. They're WRONG. In a pricing upcycle, buy the highest cost or most financially-challenged producer out there. Why? Because it should outperform everything else. The reason?

Operating leverage.

Let's think about stock A and stock B. In year 1 let's say the SpodCon price is US\$5000/t and stock A, the high-cost producer has a cost of US\$4900/t so it will make US\$100/t in profit. The low-cost producer, stock B, has a cost of US\$4000/t so it makes US\$1000/t in profit.

However, in year 2 the SpodCon price rises to US\$5500/t and costs remain unchanged. Now stock A's profit is US\$600/t and stock B's is US\$1500/t. Now, stock B still has a higher profit, but its profit only rose by 50% while stock A's rose by six times. Given that stocks are normally valued on earnings multiples, I'm sure you can see that stock A's share price will rise faster. It has more operating leverage to higher prices than stock B.



Source: BM Review

Closing thoughts

So hopefully you enjoyed this report and found it useful. It's impossible to put all of my 20 years of experience as an analyst and investor into a 52-page report, but I've tried to put the important things in, and now it's time for a few closing thoughts.

During my career there have been periods when I've made a lot of money, and periods when I've lost a lot. I haven't necessarily changed my approach; so much of successful investing is, after all, about luck. But it's also about **timing**.

You can make great returns if you get into a stock early and hold as it rises. But you can make big losses on the same stock if you get sucked into buying too late and are holding the stock when it noses over. The best piece of advice I can give is not to buy just because everyone else is buying. Do a bit of research for yourself and determine whether it's the right time to buy – how many more catalysts are due in the near-term, where is the stock in the mining cycle? If you identify upside, then go for it. But, if you can't, then just leave it. Write that one off and go onto the next one.

My other big piece of advice is to cut if the stock starts moving in a way you don't understand. **Don't get wedded to your positions**. If a stock is going down but you think it's the best thing since sliced bread, there's probably a reason for that fall. It might be something that you're not aware of. The best thing you can do then is sell and live to fight another day. If you know the reason and you disagree with it, then fair play, but if you don't know the reason and the stock is moving against your expectations over a period of time, then it's probably time to go.

The number of times that I've rode a stock up and then rode it down is unreal. And it's a horrible feeling. Better to cut and then go onto the next one.

Check out the **super trend**. I used to be quite dismissive of technical analysis, with the view that I was a fundamental analyst. But there are some enormously useful things that I've come across in my investing career, and the super trend, or the 200-day moving average (200DMA), is one of them.

Basically, if a stock or index is above the 200DMA then it's in bull territory, if it's below then it's in bear territory. If you are long a stock that's just cut materially down through the 200DMA then consider selling. Similarly, if you want to go long you need to be really convinced that something's going to change. It might be that you're making a call on the lithium price, or the company just made an acquisition and that's fine, but if the stock is on a bear run then, in my view, there's no point in taking a major long position unless you're just in for a trading (short term) buy.

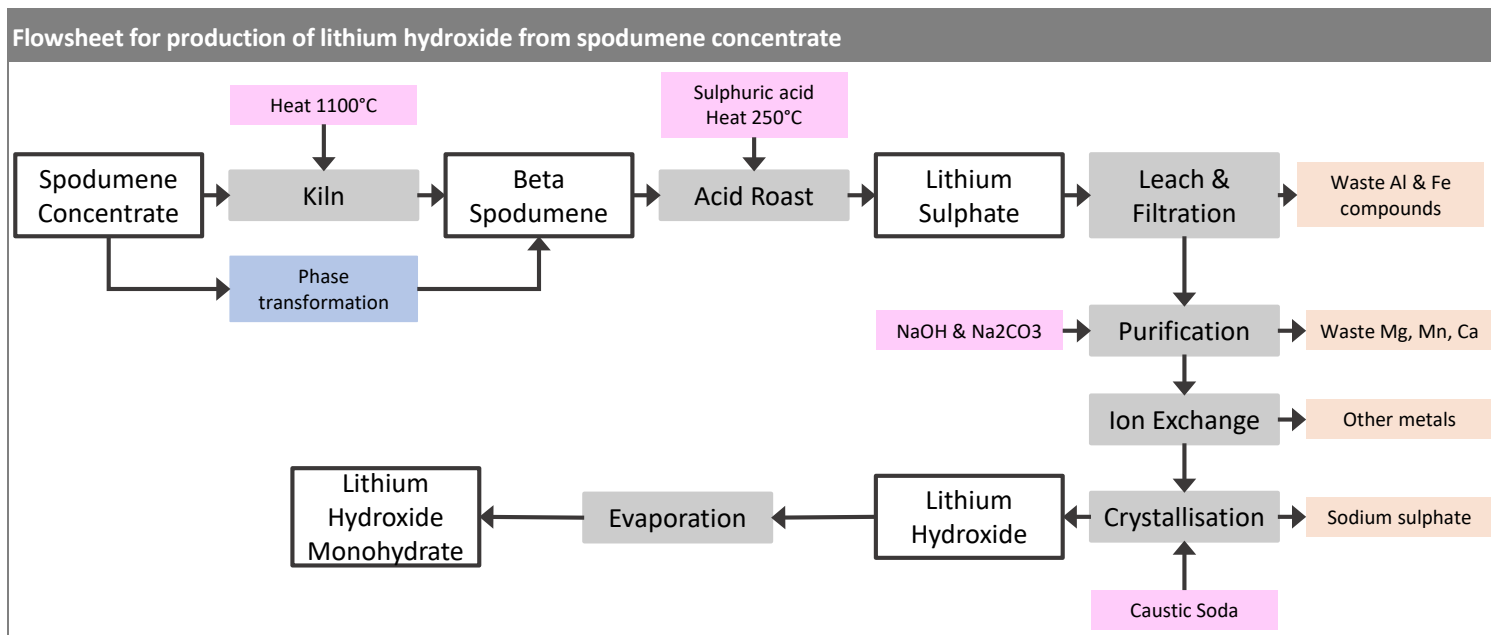
Don't be a bull or a bear in company. Stock markets work because people are willing to be on both sides of a trade. They obviously have different opinions. If people (or analysts) have different opinions to you on a stock, then that's not necessarily a bad thing. If everybody and every analyst is positive on a stock, where is the marginal buyer going to come from to push it further up? Don't be the last buyer who comes in just before a stock starts to turn over.

Always do your own research on a stock you want to buy or sell. Don't rely on what the herd is doing; they're often wrong.

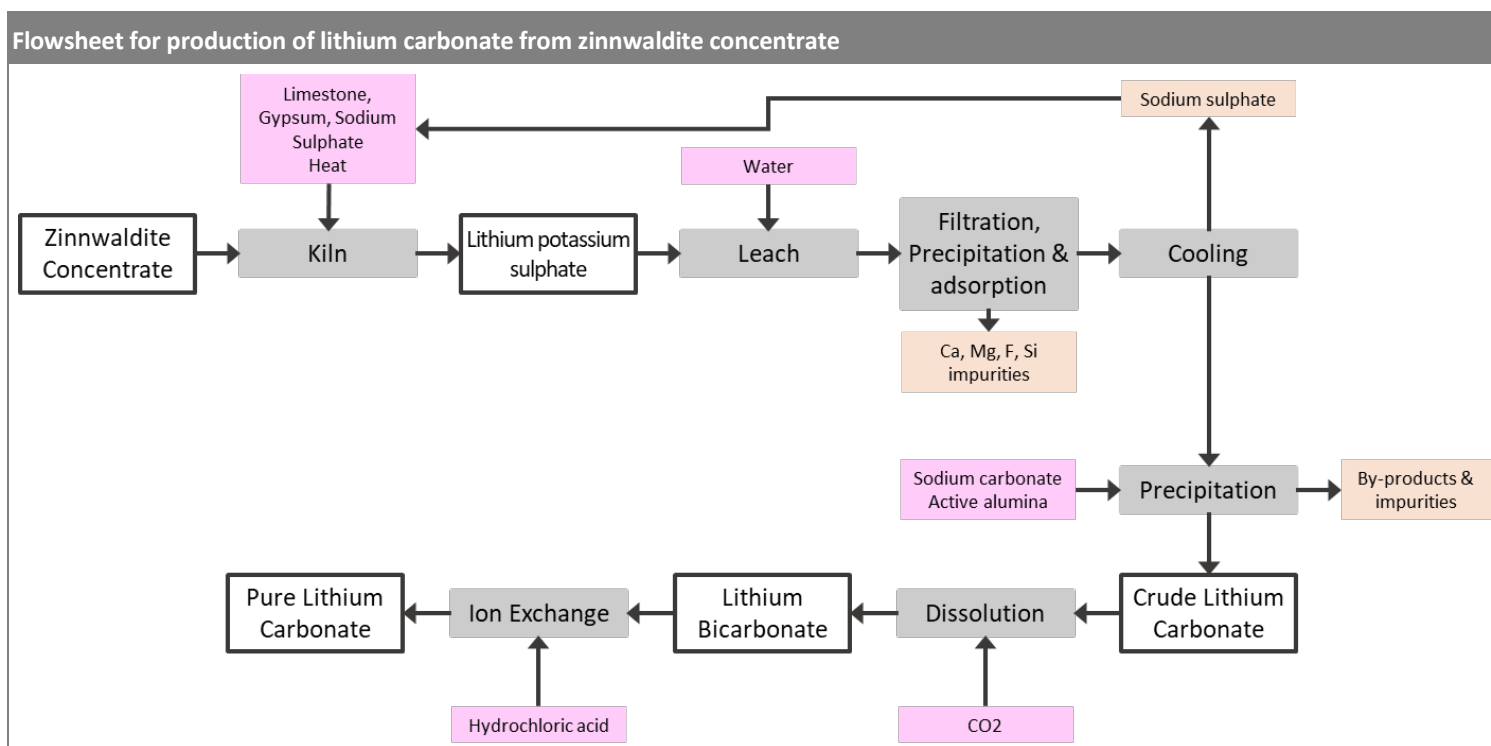
Good luck!

Appendix 1: Processing methods for key lithium chemicals

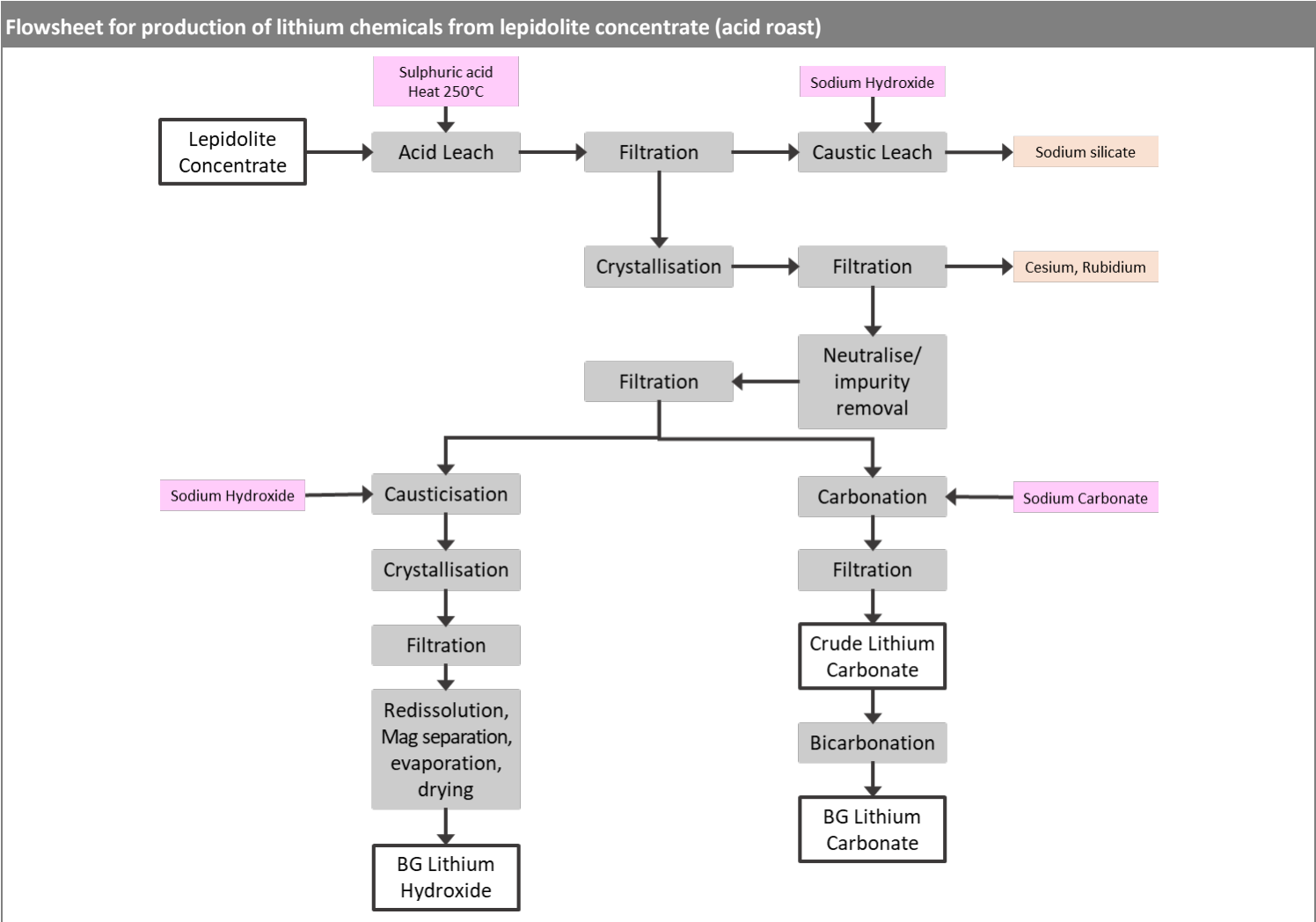
To effectively evaluate the technical risks that you as an investor may be taking on by investing in an integrated project compared to a non-integrated one, I have presented below flow sheets for common production methods for lithium chemicals from concentrated spodumene, lepidolite and zinnwaldite. Which is not to say that there are no other flowsheets in existence, it's just that these easily summarise common existing processing methodologies.



Source: BM Review



Source: BM Review



Source: BM Review

Appendix 2: Technical specifications for lithium chemicals

Below are some technical specification sheets for lithium carbonate and lithium hydroxide. Note that Lithium hydroxide technical specifications tend to be much more stringent; while you can find some 100+ppm (parts per million) levels for carbonate specs, that's not viable for lithium hydroxide products.

Representative lithium hydroxide technical specifications

Parameter	Units	Supplier 1	Supplier 2	Supplier 3
LiOH	wt% min	56.5	56.5	56.5
LiOH.H ₂ O	wt% min	99	-	-
CO ₂	wt% max	0.35	0.3	0.35
Cl	wt% max	0.002	0.0012	0.005
SO ₄	wt% max	0.01	0.002	0.005
Ca	ppm max	15	10	10
Fe	ppm max	5	3	5
Na	ppm max	20	15	50
Al	ppm max	10	2	5
Cr	ppm max	5	-	5
Cu	ppm max	5	2	5
K	ppm max	10	5	10
Mg	ppm max	-	2	-
Mn	ppm max	-	3	-
Ni	ppm max	10	3	5
Pb	ppm max	-	2	5
Si	ppm max	30	15	30
Zn	ppm max	10	2	5
CO ₃	wt% max	-	-	-
Insolubles	wt% max	-	-	-
Heavy metals as Pb	ppm max	10	-	-
Acid insolubles	wt% max	0.01	0.005	0.01

Source: Company data, BM Review

Representative lithium carbonate technical specifications

Parameter	Units	Supplier 1	Supplier 2	Supplier 3
LC	wt% min	99.6	99.8	99.5
Al	ppm max	4	-	5
Ca	ppm max	80	160	30
Fe	ppm max	2	10	5
K	ppm max	10	10	3
Mg	ppm max	80	70	10
Na	ppm max	400	650	150
Pb	ppm max	1	-	1
Zn	ppm max	1	-	1
Cl	ppm max	150	150	30
SO ₄	ppm max	150	500	150
Water	wt% max	0.4	0.35	0.25

Source: Company data, BM Review

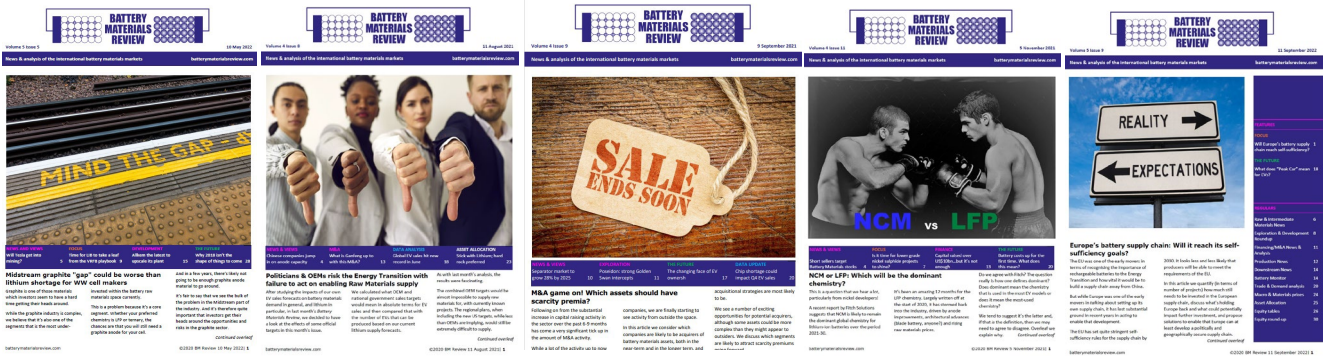
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