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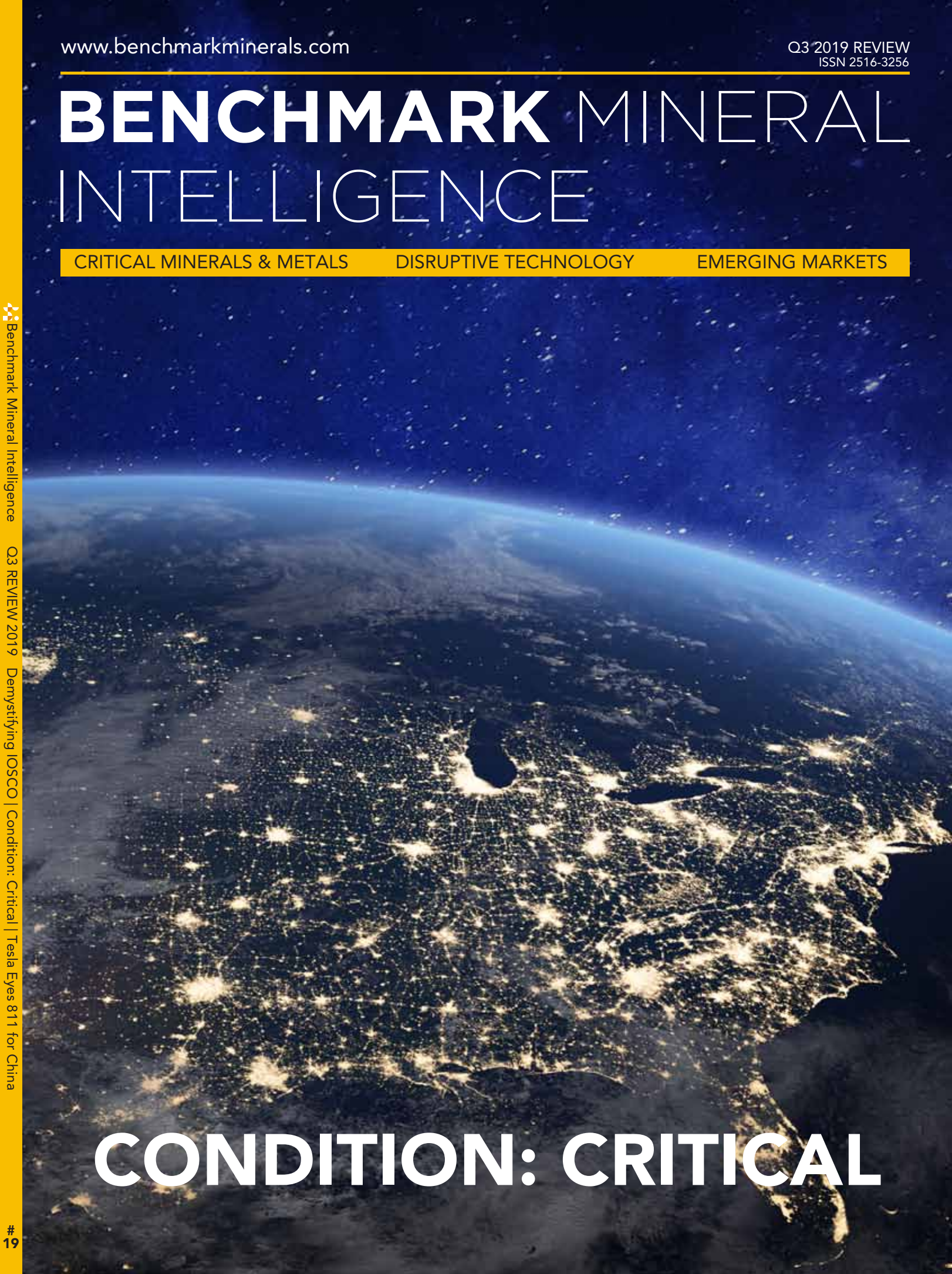
BENCHMARK MINERAL INTELLIGENCE

CRITICAL MINERALS & METALS | DISRUPTIVE TECHNOLOGY | EMERGING MARKETS



CONDITION: CRITICAL

BENCHMARK WORLD TOUR 2020

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The Benchmark World Tour is the original and world's leading series of investment seminars for the lithium ion battery to electric vehicle (EV) supply chain.

Starting in 2015 and anchored by Benchmark Minerals' expert analysts and original data, **The Benchmark World Tour** pioneered the global discussion of what has become one of most significant mega trends of the 21st Century, the Energy Storage Revolution.

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The Setup

Each city on the Benchmark World Tour offers a different style of seminar set up and networking and we have adapted our sponsorship offering to reflect this.

Email Ben Ash on bash@benchmarkminerals.com for more specific information closer to your city.

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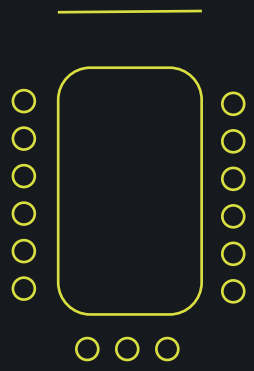

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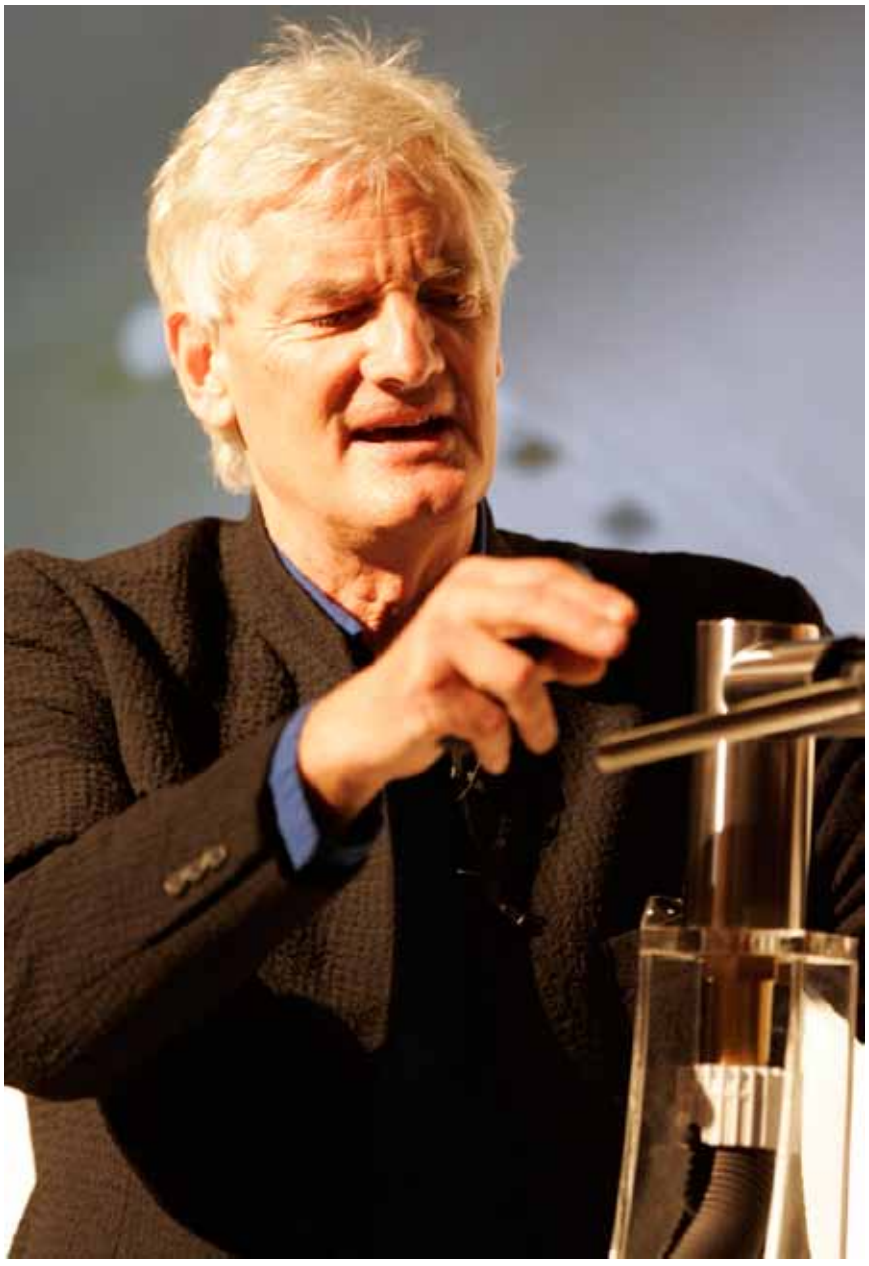


Sir James Dyson (pictured) has said Dyson will continue to invest in and research solid state batteries despite the end of its electric vehicle venture

SOLID STATE

DYSON OPTS FOR BATTERY TECHNOLOGY

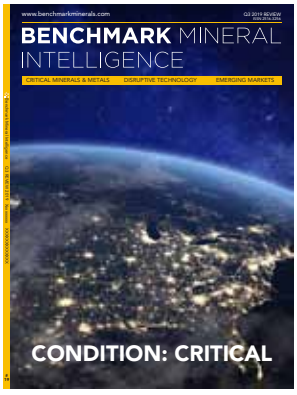
Dyson's dreams of electric vehicle production end, but it's sticking with solid state battery technology

Page 26

CONDITION: CRITICAL

Critical raw material supply is back on the agenda in the USA as Lisa Murkowski introduced the American Mineral Security Act bill. **Paul Harris** explores the history and recent developments in mineral security in the USA.

ON THE COVER



Condition: Critical — The USA has begun to take a serious look at its critical mineral supply

BENCHMARK | COMMENT

NEWS ANALYSIS

53 CHINA'S POST-SUBSIDY ELECTRIC VEHICLE MARKET

With a dramatic decrease in subsidies for electric vehicles in China **Adam Panayi**, Managing Director of Rho Motion, analyses what is happening and what the latest changes mean for the market.

Credit: Rennett Stowe

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Demystifying IOSCO

BY SIMON MOORES

IOSCO was a term most in the lithium industry had not heard of until 18 months ago.

It is something, however, that publishing companies now use as a marketing tool to make people believe they have superior prices and to add credence to their role as a Price Reporting Agency (PRA).

Becoming a PRA is the next step in the evolution of industry publications that, most likely, have their origins as monthly magazines.

Since the lithium price spike of 2017, there has been a rush in publishing to join **Benchmark Mineral Intelligence** in the lithium space.

Larger publishing companies - some from oil and gas, others from commodities as far reaching as grain and iron ore - did not want to miss out on what Goldman Sachs then called the New Oil.

And there is nothing more effective than big headlines to make big publishing houses react.

Yet, the lithium industry - a specialist industry in flux - was wise to the lack of specialism with new entrants.

This gap in the market and a need for a trustworthy, knowledgeable pricing source was identified and acted upon by our team at **Benchmark Minerals** over three years prior to this 2017 price surge.

It's why, as a company, we grew so quickly and organically with no outside investment.

Then along came IOSCO, a term that created confusion in a lithium industry that did not feel it was yet ready for financial regulations more akin to commodities.

It was borne, however, from past sins of larger publishers or "PRAs" rather than any demand from the lithium space.

The International Organisation of Securities Commissions (very Wolf of Wall Street, not very lithium) has established a set of principles, the Ten Commandments if you will, for PRAs to operate by.

They were designed for oil price reporting agencies to follow after a series of market manipulation allegations that saw the offices of Platts raided.

As a result, with big publishers keen to show regulatory adherence, it has become a marketing battle ground: big PRAs trying to outdo other big PRAs to demonstrate compliance with a set of principles designed for industries they (in many cases) don't even cover.

While PRAs tried to use their compliance as a proxy for expertise, the fundamental way in which these companies operated was unchanged: large expansive companies covering a vast array of commodities.

At the same time, **Benchmark Minerals** grew by hiring targeted team members from publishers like Fastmarkets, Wood Mackenzie and Argus Media and from the industry: Tesla, Albemarle, and SQM.

This was a driven by our founding principle at **Benchmark Minerals** that industry experience is central to professionally assessing lithium prices in an accurate and precise way.

It is crucial to first understand the industry you are reporting on, and the industry needs to trust the people and the price collection process.

It is why **Benchmark Minerals** has excelled from startup company to number one in our field.

Benchmark Minerals Lithium Price Assessments are IOSCO-regulated to the highest standard, Type 1 Reasonable Assurance.

This was something we achieved in a short space of time in Q2 2019. Having EY conduct the process added a more robust nature to the way we handle sensitive price data internally.

But what does this actually mean for lithium?

In short, not much.

IOSCO regulates the way the PRAs handle data internally. It does not assess the quality, accuracy or even the number of data points a publisher collects to assess a price.

It is in place to ensure the PRA is doing what it promises in its methodology, not that the methodology is the best fit for a specific industry.

For us this has always sat uncomfortably.

The only way to ensure quality lithium prices that are accurate and precise is to hire trustworthy people from both lithium and publishing worlds.

This creates a brand that is known and trusted by the entire EV supply chain.

It has been at the core of what we have done since the company was founded in 2014: it is a blueprint that is imbedded today and is how we became the lithium industry's reference and benchmark price.

We could not have achieved our success if it was not for the superb support from all customers that now sit within the EV supply chain (resource developers, miners, chemical producers, battery makers and automotive OEMs) and outside of the active industry (government departments, financial institutions, institutional investors, and oil and gas majors).

We are proud to be in this position today and will continue to invest to expand and strength what we do.

Thank you all for your support.

Simon Moores, Managing Director, Benchmark Mineral Intelligence

DEVELOPING INDUSTRIAL MINERALS + ADVANCED MATERIALS PROJECTS THAT'S OUR BUSINESS

Neometals

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DELIVERING CONSISTENT, SUBSTANTIAL SHAREHOLDER RETURNS

Neometals innovatively develops opportunities in minerals and advanced materials essential for a sustainable future. Our strategy focuses on de-risking and developing long life projects with strong partners and integrating down the value chain to increase margins and return value to shareholders.

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CAPTIVE WORLD-CLASS RESOURCES

- Strong balance sheet A$116M* plus $10M investments, no debt
- Strong board and management team, collectively the largest shareholders
- History of de-risking development with strong operating and offtake partners
- History of disciplined capital allocation, value realisation and sharing with shareholders

OPPORTUNITY

UNLOCKING VALUE AT EVERY OPPORTUNITY

- Advanced portfolio of minerals and materials required for a sustainable future
- Innovative value-enhancement and risk-mitigating business models
- Clear growth strategy – unique approach
- MCAP discrepancy – value crystallisation as already mature projects secure validation catalysts

OUR THREE CORE PROJECTS

LITHIUM-ION BATTERY RECYCLING

A proprietary process for recovering cobalt and other valuable materials from spent lithium batteries. Pilot plant testing currently underway with commercial development decision to follow.

LITHIUM REFINERY PROJECT

Progressing plans for a lithium refinery development to supply lithium hydroxide to the battery cathode industry, underpinned by binding life of mine annual offtake option from Mt Marion.

BARRAMBIE TITANIUM AND VANADIUM PROJECT

The value of an end-of-life strategy for lithium-ion batteries

BY HANS ERIC MELIN

Lithium-ion batteries have become increasingly important in a number of industries. The most obvious segment is electric cars which is now driving lithium-ion battery demand. But the growth rate, in relation to the technologies the battery replaces, is in fact higher in several other industries. Buses, fork lifts, energy storage, backup power, recreational and utility vehicles, e-bikes and scooters are applications where the lithium-ion battery is already outperforming the former alternatives both in terms of cost of ownership and operational performance.

With the increased adoption, a question that eventually reaches the management's attention is how to deal with the batteries when they reach end-of-life.

Many times this is described as the Achilles heel of lithium-ion. Inefficient and expensive recycling, or even lack thereof, makes companies realise they might build up liabilities although they are hard to quantify. Often the problem is taken care of when it arises, with hope of less expensive alternatives in the future.

In a way, this make a lot of sense. After all lithium-ion batteries are still fairly new and most of the attention is still needed on sourcing, design and manufacturing. But there are significant costs that could have been saved with a more active end-of-life strategy. And there are huge opportunities to be seized.

The findings in our research, confirmed on a daily basis in our contacts with players in the lithium-ion value chain, shows that already with an end-of-life volume of 50 kWh per year the difference between the worst and best case scenario exceeds $20,000 (USD).

For example, 50 kWh per year is what a larger golf court company might expect to deal with when their carts use lithium-ion batteries. The difference between the best and, the more common, worst case scenario could in fact finance 2-3 new golf carts a year.

The biggest difference is found between what we call an active end-of-life strategy and an active second life strategy. If only the golf court company wants to arrange for a more efficient recycling, instead of calling the nearest waste hauler, their savings will amount to $3,000. It's when they actively start to arrange for different second life solutions the difference starts to become significant.

Most likely a user of batteries with such a limited volume will not engage directly with second life solutions although they might very well host the batteries in their own energy storage system. Hence some of the revenues will be lost to contractors and specialists.

Still the potential of making money instead of losing it is still attractive for anyone.

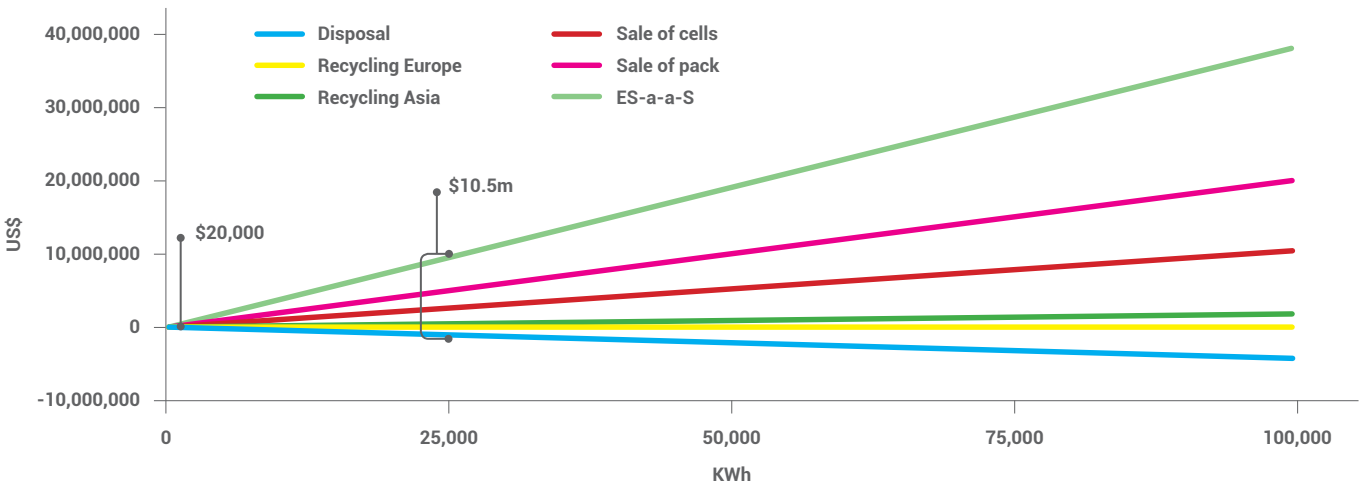
The numbers obviously increase by volume, and their significance to an organisation varies. For battery manufacturers or car makers the difference only between the best and worse recycling scenarios sum up to amounts that simply can't be ignored. With an annual end-of-life volume of 25 MWh the difference is $1.5M – a cost of $1M or revenues of $500,000. The potential earnings from second life is more than $9M!

The move from costly disposal to a profitable energy storage business is not easy. It requires a deep understanding of the market – and determination. A strong involvement already in the product development and willingness to invest is essential for obtaining sustainable margins in a new field, outside a company's core business. However, there are many intermediary steps that can be taken through partnerships or adjustment in the company's business model.

Whether end-of-life batteries represent a cost or a revenue is not something that is determined externally by the market. It's a choice. A cost is always somebody else's revenue. With a good understanding of the market you can decide what it will be for your company.

Hans Eric Melin, Founder and Consultant at Circular Energy Storage

GROSS PROFIT OR LOSS: DIFFERENT END-OF-LIFE STRATEGIES FOR LITHIUM ION BATTERIES



Source: Circular Energy Storage

More than just a lithium data point

BENCHMARK MINERAL INTELLIGENCE

To accurately and precisely assess lithium prices takes expertise, specialism and resource. Benchmark Minerals is proud to be the industry's reference price and have its data used to negotiate supply chain contracts

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Expertise
Benchmark Minerals' analysts have extensive lithium experience. Knowing your industry is crucial to assessing accurate prices

Reputation
Benchmark Minerals' sets the lithium industry's reference price and benchmark indices. Reputation is everything when you are specialising in lithium and we are proud to be trusted in contracts and in investment decisions

Resource
We have the world's most extensive team covering the lithium to EV supply chain

Location
We have team members based in London, Shanghai, San Francisco, Tokyo, Fort Lauderdale, and Santiago. To have a global perspective you need to actually be global

Regulation
Benchmark Minerals'lithium prices are assessed to an IOSCO compliant, industry specific methodology

News Analysis

IN THIS SECTION:

Credit: S. Ken

Thailand's Energy Absolute enter the Benchmark Megafactory tracker as new markets open up to battery megafactory development

COBALT SHOCKWAVES

August 2019 saw Glencore announce that it would close its Mutanda mine in the DRC, while China's Huayou Cobalt's announced plans to pull out of a deal to invest in a DRC cobalt operation. Here we look at the seismic developments that have shifted the cobalt market

BY CASPAR RAWLES & ROBERT COLBOURN

The pressures of the 15-month price slump on cobalt producers was cited by Glencore as one of the driving forces for its decision to place the world's biggest cobalt mine by production – its Mutanda operation, responsible for 20% of global supply – on care and maintenance from 2020 as it effectively suspends cobalt production from the site.

The company's 2019 half-year report stated that "at Mutanda, we are planning to transition the operation to temporary care and maintenance by year end, reflecting its reduced economic viability in the current market environment, primarily in response to low cobalt prices."

There had been warning signs that a closure of the Mutanda mine was on the cards during the first half of 2019. In February, Glencore announced a cut of 2,000 expatriate workers from the mine which had prompted fears of falling cobalt volumes from the copper-cobalt operation.

Benchmark Minerals also understands that oxide ores at the mine had been depleting earlier than expected. To continue long-term production at the mine would have required Glencore to invest in new sulphide processing facilities to transition from its oxide operation.

The new facilities would have needed significant investment and in an environment of depressed cobalt prices, increased DRC royalty payments and DRC political uncertainty will have weighed heavily on any decision made.

Glencore hasn't entirely closed the door on transitioning from oxide deposits, stating that it continues "to progress studies on the sulphide project, having the potential to extend operations for many years" with the company anticipating it will provide an update in December.

With the decision to place Mutanda on care and maintenance Glencore's Katanga asset will become the company's main producing cobalt operation. However, the project has delayed exports due to elevated levels of uranium and revised annual production guidance for 2019 a number of times, initially down from 34,000 tonnes to 26,000 and finally 14,000 tonnes in their latest report.

As we have noted before, **Benchmark Minerals** does not expect large volumes of material to be exported to market until 2020 when the new ion exchange processing circuit is commissioned.

Glencore had originally stated the new equipment would be operational at the end of 2019 but in their most recent announcement the company gave a timeline of commissioning in mid-2020.

With the planned suspension of operations at Mutanda this would suggest that the company will use up stockpiles held from the Mutanda operation for the first half of 2020.

Huayou Cobalt's announcement that it would pull out of a deal to invest in a DRC-based cobalt development will not have the seismic effect on the industry of Glencore's Mutanda decision, but it shows the consequences of cobalt's recent downturn.

In a Shanghai Stock Exchange filing Huayou announced that it was terminating its 51% investment in Lucky Resources, which holds 100% of New Minerals Investment – the company responsible for the project.

Huayou Cobalt explained that "the market environment has undergone major changes, the price of cobalt products has fallen sharply, and the profitability has fallen sharply." The company's profits have been hit dramatically by the cobalt slump as its year-on-year profits at the end of Q1 2019 were down 98%.

The DRC project was at an early stage but it highlights the challenges faced by cobalt producers. It also shows the issues that a low-price environment creates for bringing new supply to the market, especially to meet demand in the early 2020s and beyond.

SUPPLY AND PRICES

Right now, the supply-side remains unaffected as the closure of the Mutanda mine does not come into effect until 2020.

Looking at Glencore's other cobalt operation, Katanga Mining, production figures are lower than previously forecast. This, however, is not a surprise as Glencore had warned it was going to

Glencore's Katanga mine is now the company's main producing cobalt operation

Credit: Glencore

reduce the guidance in its last quarterly update. Aside from this, the material was not expected to reach the market until 2020 due to the uranium issue outlined above.

Prior to the Mutanda news, the cobalt market was widely forecast to be in oversupply until 2022 or beyond, which had weighed heavily on prices, in part driving the downward trend for the previous 12-18 months.

Removal of such significant tonnage from the market could see structural undersupply by as soon as 2020, although stockpiles accumulating in Africa will help balance the market until 2021 and possibly further.

Looking to 2020, continued production and stockpiles accumulated since early 2018 should provide enough feedstock to supply the market over the course of the year. Depending on the speed at which other operators ramp up supply, something that maybe accelerated in in response to the Mutanda closure, the market could see shortages in 2021.

The Mutanda announcement has caused an immediate and notable effect on prices. Prior to the news, prices had been falling for 15 months and saw the **Benchmark Minerals**' cobalt hydroxide, cobalt sulphate and cobalt metal prices fall 79%, 76% and 71% respectively between April 2018 and July 2019.

But Glencore's announcement saw cobalt price rises across the board with cobalt hydroxide up 17.3%, sulphate up 21.2% and metal rising 16.7% over the course of August and continued increases during September.

In percentage terms these price increases seem significant but it should be noted that these price increases have come from very low levels back to within historic average ranges, which represents a healthier market.

Whether this news is enough to sustain higher prices to the end of the year is yet to be seen, but the announcement has changed sentiment within the supply chain and has moved the looming cobalt deficit closer.

There will of course be consequences for cathode, battery and electric vehicle producers further down the supply chain but these will not come to fruition immediately. With the increased uncertainty regarding supply, we might see increased efforts to secure material directly at the mine level from cathode producers, which is something larger producers have already been undertaking.

This latest news is another knock to cobalt's image. The challenges of securing sustainable sources of cobalt remain firmly on battery and automakers agendas but this is no simple task and we continue to see efforts from manufacturers to reduce the amount of cobalt used in next generation batteries.

GLENCORE MOVE SPARKS COBALT FEARS

Glencore's revamped deal with GEM could leave electric vehicle makers short of sustainable cobalt. Benchmark looks at what this deal means to the market

BY CASPAR RAWLES

In October Glencore announced a revamped deal with the world's largest precursor producer, GEM Co Ltd, for cobalt hydroxide that equates to 61,200 tonnes of contained cobalt for a five-year period between 2020 and 2024.

Benchmark Mineral Intelligence estimates that the deal is for 25% of Glencore's forecasted cobalt hydroxide production in the contracted time period, and it comes on the back of the commodity group's closure of one of its Democratic Republic of Congo (DRC) mines, Mutanda, amid a depressed cobalt price environment.

This renewed deal trumps the previous contract that China-based GEM walked away from in 2018 and rekindles the long-term strategic relationship between the two groups.

As with any deal of significance in the EV supply chain, understanding the context is key.

Here, **Benchmark Minerals presents** the most critical implications of this latest Glencore and GEM deal for the cobalt industry.

INDUSTRY SHORTAGES

Benchmark Minerals estimates that the deal will account for 25% of Glencore's total cobalt hydroxide output in that time frame locking up a significant portion of 'sustainable' or traceable cobalt that is not at risk of association with artisanal or illegal sources within the DRC.

Glencore is the world's largest cobalt producer and we forecast that it will account for 31% of total supply in 2019.

Having such a large proportion of its supply base being used by one customer will get the attention of those battery and automakers that are not locked into the Glencore-GEM supply chain.

Glencore's Mutanda and Katanga Mining operations in the DRC are expected to produce 37,000 tonnes of cobalt hydroxide in 2019. In recent years, the cobalt industry has put much emphasis on having sustainable supply chains to give automakers confidence that its cobalt is not linked to child labour in the DRC.

Despite child labour-linked cobalt affecting fractions of actual cobalt supply, the reputation is particularly damaging to automakers EV brands.

This is compounded by the fact that Umicore – which is set to be the new owner of the Kokkola cobalt refinery in Finland after the acquisition from Freeport Cobalt completes later this year – will receive up to 12,000 tonnes a year of this material, **Benchmark Minerals** estimates.

This means over 50% of Glencore's cobalt production is tied up in long-term contracts with two major customers.

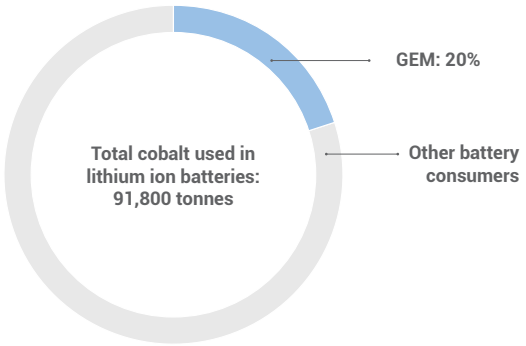
GEM'S 20% DOMINANCE

The 61,200 tonne cobalt deal will run over a 5 year period and in 2020 **Benchmark Minerals** expects GEM could handle up to 20% of all cobalt consumed in lithium ion batteries in 2020. **Benchmark Minerals** forecasts cobalt demand in lithium ion batteries to increase from 75,000 tonnes in 2019 to 152,000 tonnes in 2024, with a total market size for all end uses of 213,000 tonnes. As a result of rapidly changing supply and demand dynamics in the cobalt to EV supply chain, **Benchmark Minerals** publishes its Cobalt Forecast each quarter.

While the industry has watched with curiosity how Glencore closed its Mutanda cobalt mine

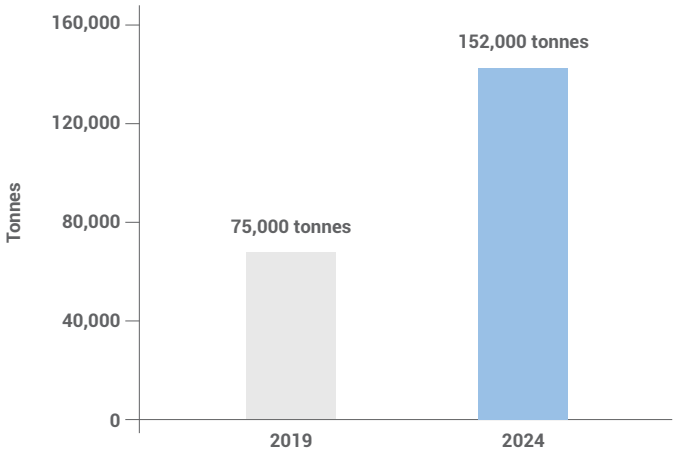
BATTERY BREAKDOWN

Potential end-users for cobalt in lithium ion batteries by end-2020 shows GEM's dominancein the pipeline



Source: Benchmark Mineral Intelligence

CO IN LITHIUM ION CELLS SET TO DOUBLE BY 2024



Source: Benchmark Mineral Intelligence, Cobalt Forecast, Q3 2019

GLENCORE'S NUMERICAL ADVANTAGE

37,000 tonnes

The amount of cobalt hydroxide Glencore is expected to produce by 2019

43%

Proportion of the world's cobalt hydroxide supply that Glencore is responsible for in 2019

$24,175

Cobalt Hydroxide's value according to Benchmark Minerals CIF Asia Assessed Price in September

37%

The amount cobalt hydroxide's price has increased since Glencore closed its Mutanda Mine

61,200 tonnes

The amount of contained cobalt GEM will buy from Glencore over a five-year period between 2020-2024

Sources: Benchmark Mineral Intelligence, Glencore 2019

in August only to then sign the new GEM deal, the reality is that Glencore is by far still the most influential factor in the cobalt industry, at least until EV demand and battery technology enters a new gear in the mid-2020s.

The announcement of the Mutanda closure caused a upward price reaction and saw the **Benchmark Minerals**' Cobalt Hydroxide CIF Asia Assessed Price increase by 17% in August and a further 20% in September.

Mid-point cobalt hydroxide prices as of July 2019 rose from $17,050/tonne to $24,175 in September, a significant increase after 15 straight months of declining prices.

It also had a significant impact on **Benchmark Minerals**' Cobalt Forecast, shifting the market into structural undersupply by as early as 2020, three years sooner than expected such is the size of the Mutanda operation

Over the past 18 months, however, **Benchmark Minerals** has seen significant cobalt stockpiles grow in the DRC and elsewhere in Africa which will be sufficient to feed the market in 2020 and soften the short term blow. Doubts still remain over whether cobalt's ex-Glencore supply base can or is willing to expand supply in time for 2021 onwards, especially considering how difficult the industry finds predicting the leading producer's strategy.

LONG-TERM CONTRACTS ARE KING

This development also continues the trend of large long-term contracts in the cobalt industry as the precursor, cathode and lithium ion battery cell manufacturers ramp up significantly to supply Auto OEMs.

The structure of these contracts and relationships becomes even more critical as volumes increase and purchasers have limited financial instruments to hedge their exposure.

Present-day financial instruments such the London Metal Exchange (LME) physical cobalt contract have not gained any liquidity within cobalt and the EV supply chain continues to look to other mechanisms and exchanges for options.

Understanding the nuances of each link in this supply chain is key to forecasting.

Considering it takes 12-15 months to extract cobalt out of the ground and make its way into an electric vehicle, understanding the stock-in-process (cobalt locked up within the supply chain) and the consumer ramp up is crucial to our forecasting services at **Benchmark Minerals**.

There is little doubt that in times of a tight market, Glencore will look more favourable towards long term contracted customers than the smaller volume spot market.

TESLA EYES 811 FOR CHINA-MADE EVS

Benchmark understands Tesla is considering using LG Chem's NCM 811 cells in its Shanghai Gigafactory suggesting a future diversification in suppliers and cells

BY SIMON MOORES

In an evolution in the long-standing partnership between Tesla and Panasonic, **Benchmark Mineral Intelligence** understands that LG Chem will be the 2170 lithium ion battery cell supplier for Model 3 and Model Y vehicles made at the Gigafactory 3 in Shanghai, China.

Although not officially confirmed by either company, **Benchmark Mineral Intelligence** believes that the widespread reports in Q3 2019 are accurate and that LG Chem will be supplying Tesla from its battery megafactory in Nanjing, China, which is expected to have a capacity of 28GWh of cells in 2019, a 40% increase on 2018.

Most critically, for the upstream of the supply chain, Tesla vehicles will now be powered by Nickel-Cobalt-Manganese (NCM) chemistry which **Benchmark Minerals** believes will be the high capacity 811 ratio. However, LG Chem also produces 523 and 622 cells which could also make its way into the Tesla supply chain.

This agreement marks a major development in Tesla's supply chain as the company had previously only sourced cells from Japan's Panasonic. Panasonic's cells are produced both in Suminoe in Japan for the original 18650s used in Model S and Model X and Gigafactory 1 in the Nevada, US, which developed the new 2170/21700 format.

South Korea's LG Chem is one of the few tier 1 suppliers that **Benchmark Minerals** estimates has sufficient active capacity in China to fulfil Tesla's needs at Gigafactory 3.

The choice to including LG Chem as a supplier to its electric vehicle (EV) business may also highlight a diversification away from the exclusive use of NCA cathode by Tesla for two main reasons:

■ LG Chem is limited with NCA but experienced with NCM

LG Chem has limited experience with NCA but has significant experience in the use of NCM cathode, including higher nickel variants with the company already producing 622 for passenger EVs in large format pouch cells and 811 for use in e-buses and portable applications in cylindrical format.

US-based e-bus pioneer, Proterra, has also been using LG Chem's 811 cells in its California-made vehicles.

"NCM 811 is not as elusive a unicorn as it is often been portrayed," Dustin Grace, Proterra's Vice President of Technology explained.

"Proterra has been collaborating with LG Chem on this awesome chemistry since early 2016. Series production began in April 2017, and we have produced over 200MWh of NCM 811 HV battery packs since," he added.

Grace also explained that Proterra's first generation of battery packs are over 150Wh/kg and the module us over 200Wh/kg.

■ Diversifying sources is a sensible strategic move for Tesla

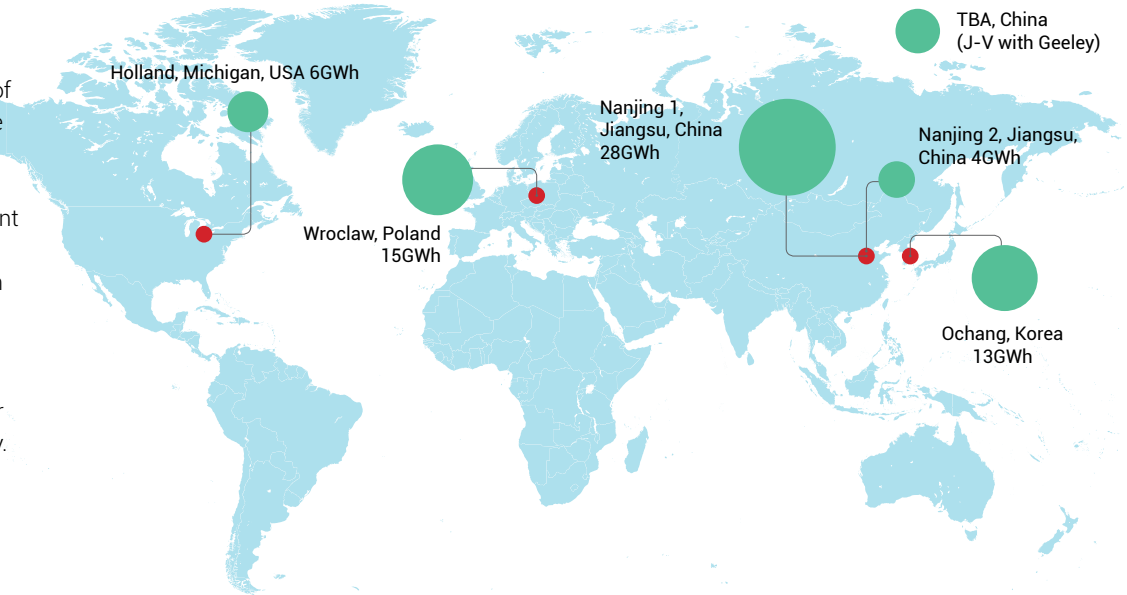
Tesla had previously sourced much of its cathode material from Sumitomo Metal Mining (SMM) in Japan via Panasonic.

In 2018, SMM outlined plans to focus its

LG CHEM'S GLOBAL EV BATTERY FOOTPRINT (GWh CAPACITY BY END-2019)

LG Chem has been the most aggressive tier 1 battery producer in terms of expanding both cumulative capacity and the location of that capacity. It now has five sites under development for either expansion or a new battery cell production facility. The cell producer's global approach to battery making is creating a new, more localised direction for the electric vehicle industry.

Total 2019 Capacity: 66GWh



Source: Benchmark Mineral Intelligence – Lithium ion Battery Megafactory Assessment

cathode production on two main clients: Panasonic and Toyota. With LG Chem supplying cells for Gigafactory 3 the cathode material used will be sourced from a new supplier.

The production of NCA cathode in China is very limited and experience lies within NCM production, therefore a move to NCM 811 may be the natural choice for Tesla, which is one of the few EV producers that has deployed cylindrical format cells, for which NCM 811 is suited, in its pack design.

NCM 811 and NCA provide similar performance characteristics and the transition should allow Tesla to continue to offer comparable driving ranges between the two cathode types.

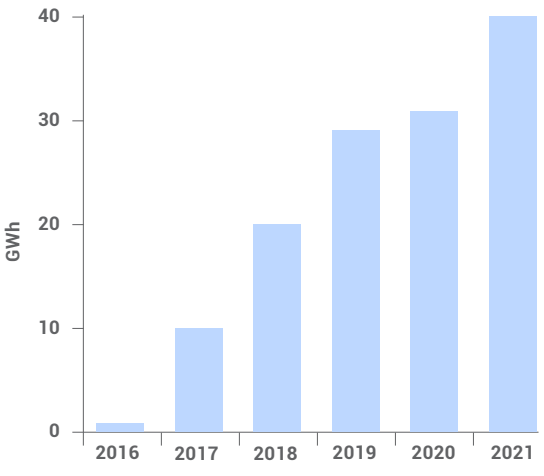
It is expected that vehicle production at Gigafactory 3 will commence in late 2019 following a rapid build of the plant that only began in January 2019.

Benchmark Minerals believes initially, during early production, that some of the cells will be supplied by both LG Chem and from Gigafactory 1 in the US before entirely transitioning to cells produced in China.

Despite this new supply partnership **Benchmark Minerals** still expects cells to be produced at Gigafactory 3 in the longer-term. This will follow the successful production of vehicles at the plant, although domestic cell production is not expected on-site until 2022.

It still remains unclear if Tesla intends to produce the cells itself, or if the company will choose a technology partnership as it has with Panasonic at Gigafactory 1.

LG CHEM'S INCREASING CHINA FOOTPRINT



Since 2014, LG Chem has been planning a significant lithium ion battery cell expansion in China in the form of a Nanjing-based manufacturing facility, in Jiangsu province located 300km west of Shanghai.

Since launching operations in 2016, this first Nanjing cell facility has ramped up from 2GWh capacity to an estimated 28GWh by end-2019, according to Benchmark Minerals' Battery Megafactory Assessment monthly subscription service.

Source: Benchmark Mineral Intelligence – Lithium ion Battery Megafactory Assessment

For those that do produce their own cells, navigating the volatile waters of raw material prices will be a core challenge.

As the automotive industry pushes towards lower cost electric vehicles to break into the mass market, producers are increasingly reliant on driving the average cost of automotive grade lithium ion battery cells down below $100/kWh.

However, as this manufacturing cost of cells decreases, the proportionate value of the raw materials that make up the battery increases.

For example, all the mineral, metal and chemical components of the BOM (Bill of Materials) back in 2015 would have been on average 60% of the manufacturing cost.

Today, this average is closer to 80% for the Tesla 2170 NCA chemistry that is used in its US-made vehicles. So, as the cost of the battery cell and battery pack is the decisive factor in the success or failure of EVs, the cost price of the raw materials will become the decisive factor in the success or failure of lithium ion batteries.

The availability and price of raw materials is also rarely a factor that is discussed when considering emerging battery chemistries, yet it is the defining factor of whether a battery becomes commercially viable for the mass market or a niche technology.

HARD ROCK HEADACHE

Falling spodumene prices through 2019 force spodumene ramp ups to stall

BY ANDREW MILLER & ROBERT COLBOURN

Further spodumene price decreases through Q3 2019 led to a number of new suppliers revising their ramp up schedules, with Alita Resources forced to appoint administrators after the company's offtakers pushed for reduced pricing.

Prices across the industry came under considerable pressures during the quarter, with **Benchmark Minerals**' Spodumene 6% (FOB Australia) price falling to new lows of between $560-$525/tonne with the slow consumption of new material and a slump in downstream lithium chemical prices.

These low costs could put pressures on new projects that are still operating above target production costs. Lower than anticipated chemical capacities also contributed to shipment delays during the quarter, with Galaxy Resources and Pilbara Minerals delaying shipments in early-Q3 to ease mounting stockpiles.

Pressures on new producers saw Alita Resources, which owns the Bald Hill lithium mine in Western Australia, appoint administrators at the end of August having halted trading in the middle of the month, the latest sign of the strain being felt by hard rock producers – particularly non-integrated operations.

Alita's Bald Hill mine – the first of 2018's new generation of spodumene mines to enter production – accounted for 3,000 tonnes of lithium carbonate equivalent supply (LCE) last year, according to the **Benchmark Minerals**' Lithium Forecast model.

News of the company's financial difficulties means production is expected to cease until there is a notable uptick in pricing.

In August, Galaxy Resources announced that it had acquired the senior secured loan facility provided to Alita Resources, in which it holds equity. Galaxy's Chief Executive Officer, Simon Hay, said of the deal, "acquisition of the facility provides Galaxy with the flexibility of being the secured lender to Alita as well as being the largest equity holder. As the senior, secured creditor Galaxy can work directly with all stakeholders to examine the best possible reorganization options."

With fears of oversupply shared across Australia's hard rock producers, Galaxy had announced in June 2019 that it would delay one of its shipments of 15,000 dmt to July. Galaxy reported 98,334 dmt production for H1 of its financial year, up 7% yoy, with sales volumes of only 44,630 dmt. As a result, revenue from operations were US$28 million for H1 2019, down from $88.4 million for the same period in 2018, with their average selling prices down 36% from H2 2018.

TABLE 1: ALTURA MINING'S OFFTAKE AGREEMENTS

Altura Mining announced two new offtake agreements with Shandong Ruifi and Guangdong Weihua during the quarter.

Offtake partner	Tonnage	Contract Expiry
Lionergy	65,000 dmt	September 2023
Ganfeng	70,000 dmt	December 2021
Shandong Ruifu	35,000 dmt	June 2024
Guangdong Weihua	50,000 dmt	December 2024

Source: Altura Mining Limited

DOWNSTREAM INTEREST

Despite the negative sentiment surrounding the market, the longer-term demand picture for spodumene showed positive signs during the quarter. For instance, Altura Mining – having begun production in H2 2018 – announced two new offtake agreements during the quarter, reflecting the continued long-term demand from downstream consumers.

The first of these was the binding offtake agreement with lithium producer Shandong Ruifi. The 5-year deal will see Altura supply 35,000 tpa of spodumene concentrate. At the same time Altura announced that it had agreed to terminate an existing 50,000tpa offtake agreement with Shaanxi J&R Optimum Energy (JRO).

Following this, at the start of August Altura announced a 50,000 tpa offtake agreement with

Western Australia, home to much of the world's hard-rock lithium supply

Credit: Stefan Jürgensen

Guangdong Weihua Corporation. Altura agreed a minimum price of US$585 dmt and a maximum price of US $695 (both CIF basis) for the first contract period with Weihua. The second and subsequent years are structured as a minimum price of $550 (FOB) and maximum of $950 based on 6% Li20.

Altura also announced that another offtake partner Lionergy, would reduce the tonnage agreed in its offtake agreement from 100,000 to 65,000 dmt.

Altura now has four offtake agreements in place totaling 220,000 dmt per annum, equaling its production capacity. See table 1 for a list of Altura's current offtake agreements.

Evidently, downstream interest in terms of securing supply through long-term offtake agreements continues. The quarter also saw notable downstream investments in the Australian hard-rock scene.

Ningbo Shanshan increased its equity interest in Altura to 19.4% with a AUS $22million placement as a further vote of confidence from downstream consumers.

Battery giant CATL's investment in Pilbara Minerals was amongst the biggest moves of the quarter. CATL took an 8.5% position in Pilbara, raising AUS$ 55 million for the Australian miner, as the Chinese lithium ion producer looks to make more inroads into the supply chain as it attempts to move into the battery industry's top tier. See page 22 for a deep-dive into CATL's ambitions.

ALBEMARLE DOWNGRADES

In August, Albemarle downgraded its expansion plans for the coming 5 years, confirming it would reduce its planned capital expenditure by $1.5bn over the next five years and downgrade its capacity expansion by 125,000 tpa to 225,000 tpa.

Albemarle's Kemerton project – which will use spodumene ore from the Talison Greenbushes mine – was targeting 40-50,000 tpa LCE for its wave one and two capacity plans in previously disclosed plans, however, with their latest amendments it is now targeting 30,000 tpa LCE.

The hard-rock Greenbushes Mine operated by Talison through a joint venture between Albemarle (49%) and China's Tianqi (51%) is estimated by **Benchmark Minerals** to have produced 85,000 tonnes of LCE in 2018, which equates to approximately a quarter of global lithium supply.

Albemarle has also decided not to follow through with its Kemerton wave three to five plans which would have extended capacity by a further 75,000 tonnes LCE.

These announcements follow the adjustment of the company's joint venture with Mineral Resources, which increases Albemarle's interest in the Wodgina Lithium Project to 60% and will see the companies form a 60:40 joint venture to operate the mine and associated lithium hydroxide facilities.

Albemarle's continued interest in the Wodgina project may suggest the company is not confident that the Talison mine expansion will be enough in the long-term.

Elsewhere, Tianqi made progress developing its processing facilities for its Australian feedstock over the quarter as it began production at its Kwinana project. The lithium hydroxide facility is targeting 24,000 tpa in stage one, gradually ramping up as we move in to 2020.

However, Tianqi's stage two expansion plans were put on hold. Stage two plans would have increased output to 48,000 tonnes per year at a cost of AUS $300 million. The Chinese producer is feeling the impact of falling lithium prices as it reported its H1 2019 net profit was down 85.2% compared with the same period last year.

Despite these challenges Tianqi secured two new long-term supply deals during the quarter having agreed supply deals with LG Chem and Northvolt.

Australia's hard rock lithium scene is clearly facing a number of headwinds, but there are positive signs as supply deals continue to be sought and companies to continue to invest. It's been notable that investment from outside the sector has been lacking, however, Wesfarmers' acquisition of Kidman Resources has now been confirmed (see page 34), which could be a sign this is changing.

To subscribe to Benchmark Mineral Intelligence's Lithium Price Assessment contact: amiller@benchmarkminerals.com.

CATL NEARING TIER ONE

CATL took a stake in Pilbara Minerals in September as the Chinese battery maker makes inroads across the supply chain. Here we take a deeper look at CATL's rise to being on the cusp of attaining tier-one battery manufacturer status

BY ROBERT COLBOURN

September saw a flurry of activity from battery cell manufacturer Contemporary Amperex Technology Co., Limited (CATL) as it secured an 8.5% stake in Pilbara Minerals, agreed to develop batteries in collaboration with Bosch, reached an agreement to supply Daimler's trucks and buses and launched a new recycling joint venture (JV) with its subsidiary Brunp. In Q3 2019 alone, CATL announced deals seven deals covering the full supply chain – with OEMs, cathode producers and raw material suppliers.

Since being founded in 2011 the company has grown to be one of the biggest names in the lithium ion cell space. Outside of China it has offices, manufacturing facilities and R&D centres in the USA, Canada, France, Germany and Japan.

It has also been one of the most active battery manufacturers in the supply chain in terms of supply agreements and joint ventures during that time period, and particularly over the past two years. We've listed some of key agreements the company has entered into in the timeline shown on page 23 to 24.

RAW MATERIALS

Looking at recent activity, amongst the biggest news in relation to CATL and the lithium ion supply chain was arguably its purchase of a stake in Australian spodumene miner Pilbara Minerals in Q3 2019. The equity raising saw CATL pay AUS $55 million to Pilbara Minerals, to be paid in two tranches, for an 8.5% stake in the Australian lithium miner.

Pilbara's Managing Director, Ken Brinsden, said of the deal: "while there has been commentary talking down the current state of lithium markets, it has belied the significant interest we have continued to see from the strategic players in the lithium ion supply chain and their focus on lithium raw material supply."

Pilbara will use the capital raised from the CATL deal to strengthen its balance sheets and working capital, while supporting the ramp-up of the company's Pilgangoora Project to its stage one nameplate capacity production of 330,000 tonnes per annum (tpa) of spodumene concentrate.

Pilbara also made downstream processing progress during the quarter Pilbara as it agreed to a 21% stake in a POSCO JV, which plans to build and operate a 40ktpa primary lithium hydroxide processing chemical processing facility in South Korea.

Aware of the relatively weak lithium market and particularly the pressures facing spodumene producers, CATL took the opportunity to invest in Pilbara. As lithium market sentiment moves from fears of oversupply to fears of structural undersupply – which could be expected in the next couple of years – we will see how well this deal plays out.

This isn't CATL's first move in lithium, for instance it took a controlling stake in Canadian lithium producer North American Lithium back in March 2018. However, operations were suspended in February 2019 as the producer came under pressure from falling spodumene prices and in September 2019 there were reports of other companies bidding for North American Lithium's assets.

Daimler's eCascadi uses a 550 kWh battery pack. CATL recently agreed to supply the company with its cells

Credit: Daimler Trucks & Buses

Closer to home CATL also recently took a 15% position in a JV with Canmax. The proposed JV will establish a lithium processing plant which is expected to produce 20,000 tpa of lithium carbonate equivalent (LCE) in phase one, ramping up to 40,000 tpa in phase two.

Cobalt is on all battery-makers radars, and in 2017 it was reported that CATL had struck a deal to source cobalt 20,000 tonnes of cobalt from Glencore, with Volkswagen ultimately agreeing to purchase batteries produced by CATL to support the deal.

CATL, like other battery manufacturers, has announced it is moving towards higher-nickel cathodes at the expense of cobalt. Earlier this year, the company's chairman announced that the company was mass producing NCM 811 (eight parts nickel, one part cobalt, one part manganese). However, 811 production remains in its early stages and securing cobalt supply will still be an important goal on CATL's radar today and looking forward into the early 2020s.

In April 2018 CATL took a 25% share in Canada-based North American Nickel. The company is at an early stage of development, which also reflects the timing of moves to higher nickel cathodes such as NCM 811.

CATL has also made strides elsewhere in the nickel market. Last year a JV was announced that saw CATL take a 25% stake in a bold battery-grade nickel project in Morowali, Indonesia. The JV sees CATL collaborating with Chinese stainless-steel manufacturer Tsingshan and battery materials producer GEM to establish a nickel processing plant using high pressure acid leaching (HPAL).

However, the route to battery grade nickel sulphate from laterite ores using HPAL is energy intensive and uses chemical heavy processing. The timelines and costs proposed for the Morowali plant have received a sceptical response from the nickel industry and there have been reports of cost overruns.

In a move to expand its source of raw materials, September 2019 also saw CATL establish a new recycling JV with its subsidiary Brunp. The JV – Ningbo Brunp CATL New Energy – based in Ningbo, Zhejiang. This forward-looking move will provide CATL with another potential source of raw materials for production, which will become particularly relevant when we see end-of life taking more of a prominent role in the supply chain.

OEMS

While CATL has been executing its raw material strategy it has been forming closer ties with its ultimate customers: OEMS.

In the past two years CATL has agreed supply deals with some of the auto industry's key players including Daimler, Toyota, Honda, BMW, Volkswagen and Nissan-Renault. In addition, CATL has numbers joint ventures with Chinese automakers for cell production including SAIC, GAC, FAW and Dongfeng Motors.

However, despite these deals CATL remains a tier 2 battery producer on the **Benchmark Minerals'** Lithium Ion Battery Megafactory Assessment. Whilst the company possesses the significant scale needed to secure large automotive cell contracts the company has struggled to match the quality of its fierce Korean and Japanese rivals.

For CATL to reach tier 1 status the company needs to finalise qualification to supply multi-national electric vehicle producers outside of China.

Benchmark Minerals believe this critical qualification step is just around the corner for CATL, and once received it will see the company reach the upper echelon of cell suppliers globally.

CATL already has nine battery megafactories in the pipeline in **Benchmark Minerals'** Lithium Ion Megafactory Assessment, three producing facilities in 2018 with the remainder expected to be in production by 2023. Looking forward to 2028, CATL has over 300 GWh of production capacity forecasted, which accounts for just over 15% of the pipeline globally.

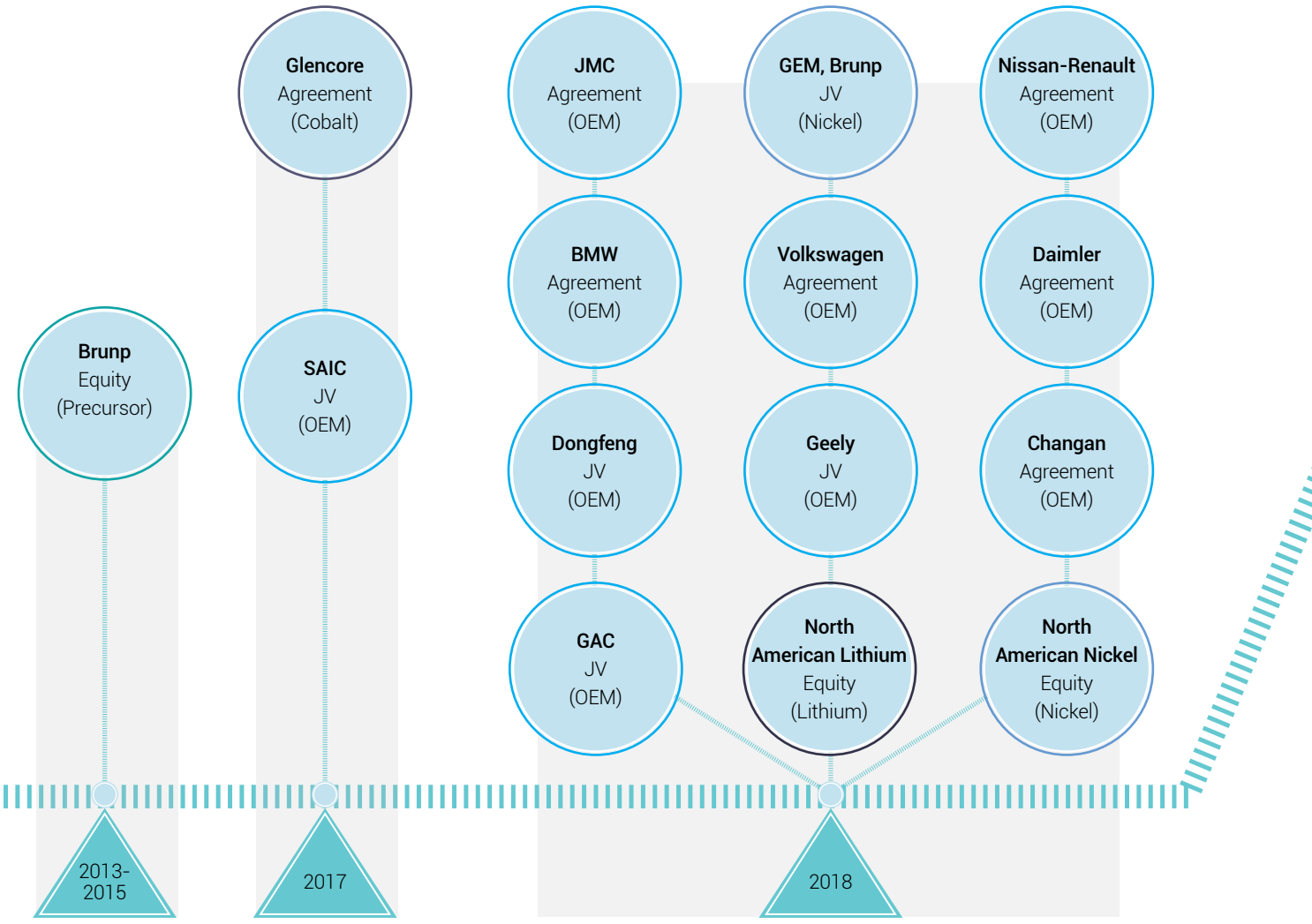
Despite this activity, expansions have largely been domestically focussed with eight of nine of the megafactories located in China.

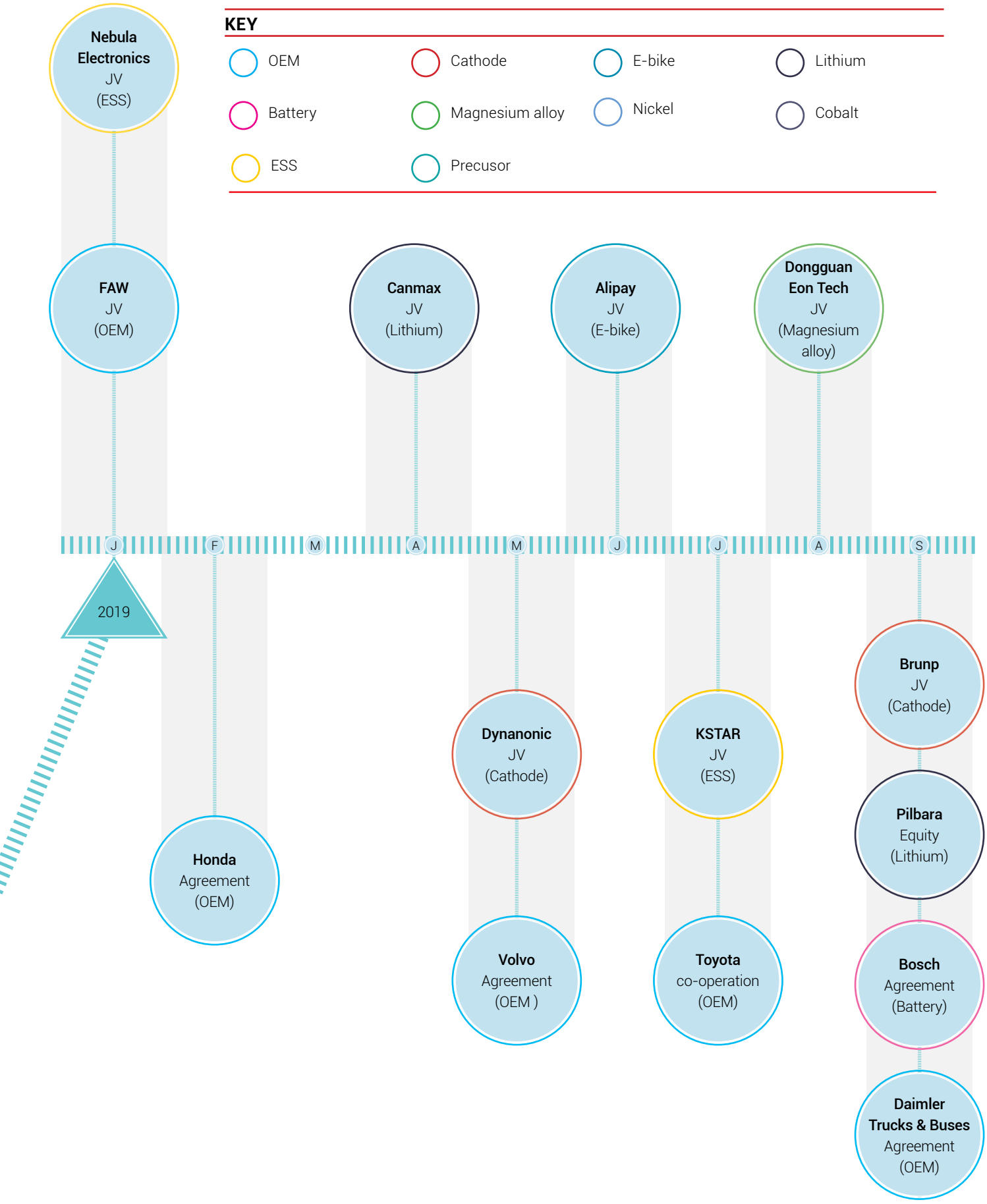
However, with its growing base of Western OEM clients, the company may soon add further capacity outside of China, with the company reportedly eyeing North America for the next expansion.

CATL is homing in on tier 1 battery production and Western OEMs qualify and use its batteries in global markets, we will soon see it mixing with incumbents in the battery industry's top-tier.

TIMELINE OF CATL'S DEALS

Since being founded in 2011 CATL has grown to being one of the world's biggest lithium ion battery manufacturers. In the past two years the company has become increasingly active in the supply chain. The timeline below outlines some of the key deals CATL has entered into

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Brunp JV (Cathode)
Pilbara Equity (Lithium)
Volvo Agreement (OEM)
Toyota co-operation (OEM)
Bosch Agreement (Battery)
Daimler Trucks & Buses Agreement (OEM)

DYSON OPTS FOR BATTERY TECHNOLOGY

Dyson announced that it would be exiting the electric vehicle race. But with this news there are signs it is pivoting to focus on solid state batteries

BY SIMON MOORES & ROBERT COLBOURN

Dyson's high profile exit from its electric vehicle (EV) development in early-October was met with a good amount of press coverage as a harbinger of things to come for those seeking to brave 21st century automotive production.

For many years now, the automotive space has warned new entrants that it is a high volume, low margin business and that anyone making new vehicles would be crazy to attempt such a feat. The essence of an automotive OEM is to drive the cost of each and every component of a car down each year, buying each of their items for under market price and therefore dominating the supply chain.

There is a culture within the automotive industry which views supply chains as there to serve the OEM. The school of thought from new developers is that successful EV production is about developing intellectual property (IP) first - through chemistry, electrical engineering and software - and supply chain second.

Of course, the answer is that this nascent stage for EVs lies somewhere in the middle.

And this is where Dyson, the UK's most high-profile technology-focus company famous for reinventing the vacuum cleaner and expanding into a vast array of electrical appliances including air purifiers and hand dryers, has found itself.

After spending three years developing a prototype that many believed was going to be the revival of the UK car sector, the reality set in that Dyson's developers could not yet make good enough margins.

"Though we have tried very hard throughout the development process, we simply cannot make it commercially viable," Founder James Dyson explained.

"We have been through a serious process to find a buyer for the project which has, unfortunately, been unsuccessful so far," he added.

The reality is that Dyson would have been a niche producer of high end vehicles with the market expecting a full production run of 10,000 vehicles per year.

Following the announcement Matthew Oliver, Engineering Lead (Automotive) at Dyson, who had worked on the project, gave his take on the decision: "a vehicle is rightfully influenced by the external rules and regulations that protect the consumers from harm…and thus, the solution tends toward the same answer – as it does in the Aerospace industry. Not to forget a business needs to make money from the products it sells."

He continued "it's a shame, but quite probably, when the dust settles, it will be seen as the right decision."

In summary, after three years of development Dyson truly worked out where the margins were in the complex EV supply chain - and that wasn't in the vehicle itself, certainly for a low volume producer.

And this is where the most telling part of Dyson's announcement lay:

"We will also concentrate on the formidable task of manufacturing solid state batteries and other fundamental technologies which we have identified: sensing technologies, vision systems, robotics, machine learning, and AI offer us significant opportunities which we must grab with both hands," Dyson said.

"Our battery will benefit Dyson in a profound way and take us in exciting new directions. In summary, our investment appetite is undiminished and we will continue to deepen our roots in both the UK and Singapore," he added.

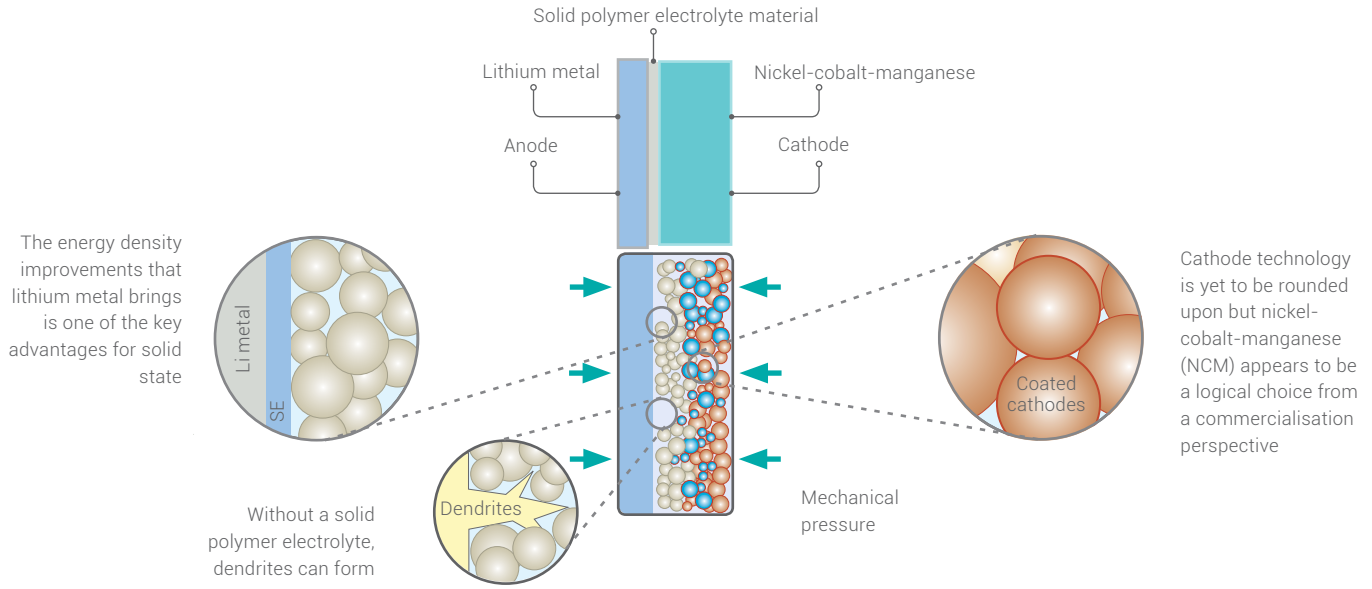
Dyson's failure to speed up the industry's commercialisation of solid state batteries lay at the core of its EV backtrack.

To enter the EV space you either need to be first - and that ship has sailed - or you need to be special, something Dyson was targeting.

Solid state batteries - a lithium ion battery that

SOLID STATE UP CLOSE

The key advantages that solid state batteries hold over lithium ion is increasing energy density through the use of a lithium metal anode and a solid electrolyte interface, dispensing with the liquid version used in lithium ion cells.



Benchmark Mineral Intelligence, adapted from Nature Energy

is great in energy density that present NCM and NCA technology and offers a number of benefits including fast charging - was Dyson's pathway to becoming a unique EV producer.

However, Dyson's foray into the solid state space started badly with its controversial purchase of US-solid state battery developer Satki3 for $90 million in 2015. Dyson, one of the world's most innovative and technology savvy companies, said it was going to build a multi-billion-dollar battery plant on the back of Sakti3's patents as the centre piece to its manufacturing of EVs.

Many in the battery industry believed that the Dyson-Sakti3 deal was underpinned by over-promotion from founder, Ann Marie Sastry, leaving the company with more work than expected on the new battery technology.

Within two years of the acquisition Dyson had written off £46 million against Satki3. The mistakes in this project ultimately filtered through to its EV business.

"When you look at Dyon's acquisition [of Satki3] it didn't demonstrate a good understanding of the solid state space," said Emily Hersh Managing Partner of DCDB group and fellow at the Payne Institute at the Colorado School of Mines.

Despite the failures of the Satki3, solid state is the great hope of many in the battery space but huge obstacles remain. Dyson's continued investment into solid state research while abandoning its EV pursuit shows it clearly has faith that these obstacles can be overcome.

The industry is yet to see any major developments in the solid state space at a commercial level and where these developments will come from remains unclear. Hersh explained that "there are a number of areas solid state developments could come from: start-ups, technology companies, and in-house from large manufacturers."

"I expect to see more advances in solid state coming from large and experienced manufacturers with considerable resources, capable of funding a big in-house team. The experience and knowledge of these companies will be critical as the manufacturing challenges in developing solid state batteries are considerable," she added.

The manufacturing challenges are multi-layered as Andy Leyland, Head of Supply Chain Strategy at **Benchmark Mineral Intelligence** explained: "for solid state, what's needed is an economic way to manufacture, transport and attach a 20-micron thickness lithium metal film for the anode – without it cracking."

Questions also remain surrounding the raw material costs facing solid state manufacturers. "At the core of the economics is lithium metal - this has to be significantly cheaper, which isn't just about economies of scale, it means reducing the amount of energy used to produce the metal, and new manufacturing techniques to achieve this besides today's electrolysis method. You also have the problem that putting a fragile and volatile lithium metal anode in one of the harshest and unpredictable environments possible for a sustained period of time," he said.

"These are big hurdles to overcome before you see a solid state powered car that is less than $100,000," said Leyland.

However, Hersh does not expect to see electric vehicles to be the first solid state applications, "the first places we would see solid state technology deployed would be in military, drone or small-scale aviation applications. The necessity for energy density in these applications would justify the high cost," she explained.

"Once we see solid state used in these areas then we are more likely to see meaningful developments in the electric vehicle space," she added.

After a number of years exploring both the solid state and electric vehicle spaces Dyson has learned the cold hard realities of the supply chain.

"What they've realised, and to be honest, what they should have realised ages ago, is that the automotive business is about vehicle assembly efficiency, scale and low margins," Leyland said.

"It's actually not an attractive sector to get into compared to some of the other technologies Dyson are developing," Leyland concluded.

SYRAH SCALES BACK PRODUCTION

The outlook for flake graphite supply was curtailed in September with news that Syrah Resources would reduce output from its Balama project moving into Q4

Syrah Resources announced in early-September that it would conduct an orderly reduction in its flake graphite output for the remainder of the year, with total 2019 supply from Balama now expected to be around 150,000 tonnes.

Syrah produced 49,000 tonnes of natural flake graphite in Q1 2019, 44,000 tonnes in Q2 2019 and recently announced production volumes of approximately 45,000 in Q3.

In its 10 September market update the company announced it would be conducting a reduction in production volume through the end of Q3 and to significantly reduce production volumes in Q4. The company had initially been targeting production volumes of 250,000 tonnes for the year but oversupply fears have forced the company's hand.

Syrah's Managing Director Shaun Verner said of Syrah's decision, "in response to the sudden and material decrease in spot graphite prices impacting price negotiations and contract renewals, we have taken immediate action to reduce our production volumes in Q4 2019 to levels sufficient to maintain operations and continue our production optimisation activities. During this period, we will focus on further increases to product grade and consistency to drive our product differentiation. Although a difficult decision, we believe that this action is in the best interests of shareholders to preserve long term value."

He added, "Balama hosts the world's most significant graphite ore body with a mine life of over 50 years. Our available liquidity and cost reduction initiatives allow for flexibility to manage our near-term production volumes in line with demand growth, and to ensure that price premiums reflect Syrah's long-term supply of high quality graphite."

The downgrade comes following reports of a material decrease in pricing from the company's sales into China, with further pressures expected moving into Q4. Syrah has come under significant pricing pressures through the year. It reported its Q3 2019 weighted average price to have unexpectedly reduced to approximately US$400 per tonne, down from US$457 in Q2 2019 and $469 per tonne in Q1.

There is no doubt that high inventories within the flake graphite industries, aided by slower Chinese battery and EV space than in 2018, has led to the price declines seen both with Syrah and the industry in general.

In September, the **Benchmark Flake Graphite Price Index** fell to 125.0 – falling -5.8% for the month and -12.6% for the year, led by pressures across finer flake grades – as excess supplies mounted amid slow industrial demand.

Slow demand growth from traditional end-markets along with oversupply mean further decreases are expected before the end of the year, however, the cost structure of the majority of producers in the market should prevent prices slumping too far.

China's evolving flake graphite trade balance is being advanced by structural changes in the country's domestic market, which were demonstrated in September as state-owned Minmetals Group stepped up its flake graphite planning following the allocation of Luobei's Yunshun mine in August.

While it is unclear how Minmetals will adjust production or allocation from the mine, it is expected to target increased value-added output in line with China's wider graphite approach.

While this change in control could have significant implications for Heilongjiang's longer-term flake graphite production potential (particularly for spherical graphite feedstock), the market will remain oversupplied given ongoing expansions of new operations in Africa and continued output from China's established mines to support greater value-added output.

Despite some relief in price reductions, industry sources in China remain wary of a growing supply surplus, intensified by the ramp up of projects in Africa which had exported a total of 125,178 tonnes into China by the end of July, almost double what China had exported to other regions.

This stark transformation in the country's trade balance is creating an increasingly competitive environment in China's flake graphite mining sector and we could see domestic prices reach new lows by the end of the year.

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NICKEL SUPPLY SHOCK

The nickel market was shocked by Indonesia's announcement of an earlier than expected nickel ore export ban. Here, Benchmark looks at the key points and the implications for the battery market

BY GREG MILLER & ROBERT COLBOURN

Indonesia shocked the market in September 2019 as it brought forward its plan to ban exports of nickel ore to January 2020 - two years earlier than it had previously announced - in its drive to promote more downstream domestic processing.

The nickel market is dominated by stainless steel production and much of nickel ore produced in Indonesia is bound for China's stainless-steel industry. Last year exports from Indonesia accounted for approximately a third of nickel entering China and 11% of global supply. Indonesia's share of global supply was forecast to increase significantly out to the 2020s, however, the latest news is likely to curtail these capacity increases.

Luhut Pandjaitan, a coordinating minister overseeing mining, said of the government's decision, "now (exports) may be at $7.8 billion, in 2020 they will reach $12 billion and in 2024 they may exceed $30 billion, including exports of lithium batteries" highlighting how the country hopes to cement a downstream role in the electric vehicle supply chain.

Although the decision to bring the ban forward is a shock, Indonesia's recent history illustrates that shock decisions related to its mining industry are not a new phenomenon. Only ten years ago Indonesia passed the Mining Law, which led to a 2014 ore export ban mandating that companies must process ore before exporting it.

Similar to the latest export ban, the government is looking to restructure the economy and develop the downstream industries associated with mining and processing. The original policy seemed to be having positive effects as processed nickel exports were on the rise, however, to the surprise of many the ban was short-lived and by Q1 2017 it had been overturned. It only took three years and another shock for the decision to be effectively reversed again.

The effects of the ore ban were potentially compounded with the news that a mining operation based in the Philippines' southern Tawi-Tawi province was set to cease operations soon as its ore resources have almost depleted. The two countries are a hub of nickel production, thus a drop in supply from the two could have far reaching effects.

Elsewhere in Southeast Asia, it was reported that a nickel processing plant owned by the Metallurgical Corporation of China (MCC) could face closure following the spillage of mine waste in Papua New Guinea. How mining operations manage waste is already under more scrutiny

NICKEL IN NUMBERS

2.4 mt
Nickel market's approximate size in 2018

27%
Indonesia's share of mined supply in 2018

32%
Indonesia's accounted for 32% of nickel entering China in 2018

Source: Benchmark Mineral Intelligence

Indonesian's president Joko Widodo has bold plans for the country's downstream industry

CREDIT: IMO

following the recent Vale disaster in Brazil. MCC could face a range of punishments for the incident at its Ramu mine, ranging from compensation, legal action and ultimately to mine closure. The outcome of this decision is yet to be seen but if the operation were to close it would act as a further supply shock.

With lithium ion batteries using ever higher nickel content nickel's role in the electric vehicle supply chain is set to grow exponentially. However, demand for battery grade nickel sulphate from the lithium ion battery industry currently represents a small proportion of the wider nickel market which is dominated by stainless-steel production.

HOW DO THE LATEST CHANGES AFFECT THE BATTERY MARKET?

Within the nickel market, "class 1" nickel has typically been used in the battery sector, either produced directly as a sulphate or converted from a metal product. Indonesian ore usually follows the "class 2" route, ultimately producing nickel pig iron (NPI) destined for the stainless-steel sector.

While the supply shock does not directly affect the supply of class 1 nickel, it's likely that we will see a greater share of class 1 nickel consumed by the stainless-steel industry in 2020. Much of the ore exported from Indonesia and the Philippines is smelted into NPI for stainless steel and some of this supply will have to come from elsewhere.

While Indonesian nickel exporters will be feeling the burn from the export-ban, producers with downstream projects in the country will have a head start and add further incentive to ramp up operations and bring them online.

One of the boldest downstream Indonesian projects is led by Chinese stainless-steel manufacturer Tsingshan, in partnership with GEM and CATL. The processing plant was announced in Q3 2018 with capex costs of $700 million. The operation is being developed to use a high-pressure acid leaching (HPAL) process and will reportedly target 131,000 tonnes per annum of nickel sulphate. Production is expected to begin in 2021 and operations are expected to ramp up to capacity in 2022.

However, there has been much scepticism within the industry surrounding both the proposed capex and timelines to production. There were even reports over the quarter that the total costs of the project could more than double to $1.5 billion, although this was denied by GEM.

The route to battery grade nickel sulphate from laterite ores using HPAL is energy intensive and uses chemical heavy processing. HPAL projects are also typically capital intensive and the space is littered with a number of projects failing to meet their nameplate capacity. The consortium backing the Morowali project hopes it can set a new standard for the electric vehicle supply chain looking to meet growing nickel sulphate demand from battery producers, however, it looks like its initial goals were too optimistic.

The Indonesian government hopes their nickel export ban will spur the development of its nascent downstream industry. The immediate consequence of the decision has been an uptick in nickel pricing. With Indonesia's history of reversing decisions there is no certainty that this policy will prevail in the long-term but as the nickel market transforms with the ascendancy of the battery supply chain Indonesia will continue to play a role regardless of its position in the value chain.

THAILAND ENTERS MEGAFACTORY SCENE

Thailand entered Benchmark's Lithium Ion Battery Megafactory Tracker in Q3 2018 as megafactory in the pipeline exceeds 100 for the first time. Here we look at the development of megafactories in emerging markets

Benchmark Minerals' Lithium Ion Battery Megafactory tracker added its first Thailand-based battery factory in Q3 as Thai energy company Energy Absolute (EA) reaffirmed plans to enter the scene with a $3 billion investment in domestic battery production.

EA plans to build a 50 GWh megafactory in Chachoengsao, Thailand, approximately 50 miles east of the capital Bangkok.

EA will begin with a phase one capacity of 1GWh, which it expects to come online in 2020. However, the company has already delayed in beginning its commercial operations as it had initially targeted phase one production in H1 2019 and phase two to begin in 2021.

It is targeting to ramp up to 50GWh of capacity in 2022. This is an optimistic timeline for a company with limited cell production experience and **Benchmark** would expect further delays or for the project to fall short of its capacity targets in the proposed time frame.

To achieve its ambitions EA is drawing on the knowledge of Amita Technologies, in which it took a 77% stake in 2018. Amita was founded in 2000 and has an estimated production capacity of 500MWh in cell production. It produces nickel-cobalt-manganese (NCM) cells and it is therefore likely that this technology will be used in EA's Thailand-based megafactory.

Battery production is EA's latest pursuit in a decade focusing on energy supply. In 2009 the company entered the biodiesel market and expanded in solar power and wind power in 2011 and 2015 respectively.

The company's latest move does not end with battery cell production. It also has plans to move into the energy storage, the electric vehicle (EV) market and provide charging networks. It has already launched its first EV for the Thai market: the SPA1.

The vehicle has a limited range of 124 miles (200 km) but is designed for use in urban centres and has already won an order of 3,500 vehicles by one of the city's main taxi operators.

Making use of subsidies offered by the Thai government and low tax placed on domestically produced vehicles, Mine Mobility's first EV offering is priced at THB 1.2m ($39,000).

Mine Mobility has a big economic advantage over foreign imports which can accrue import taxes of between 20-80%, compared to 0% on Mine Mobility EVs and a reduced excise tax of just 2% compared with 8% for foreign imports.

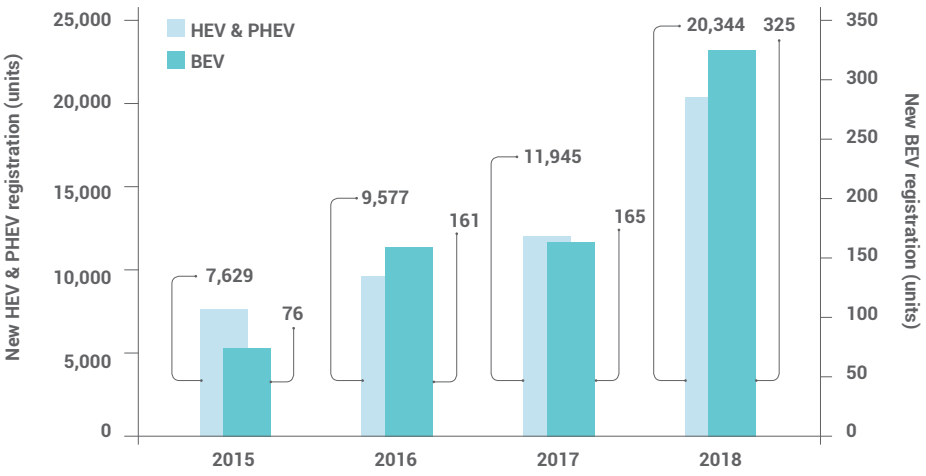
NEW JURISDICTIONS

As the number of battery megafactories in the pipeline has now broken the 100-mark we can expect to see new countries announce realistic plans to build megafactory production, which offers battery cell manufacturers new jurisdictions

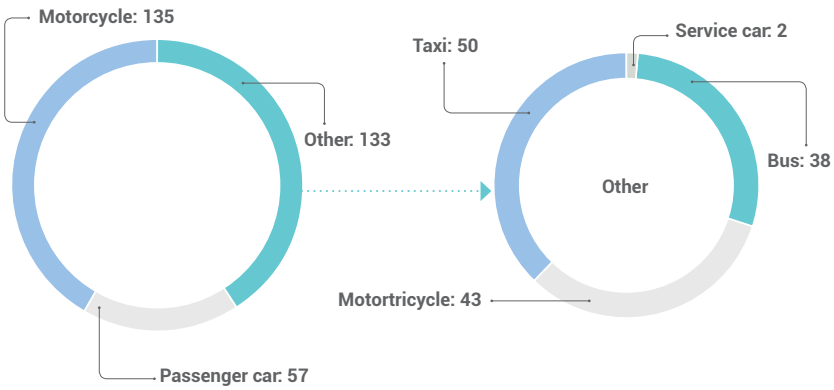
ELECTRIC VEHICLE REGISTRATIONS IN THAILAND

Sales of pure electric vehicles in Thailand are coming from a very low base, with sales figures currently dominated by hybrid electric vehicle and plug-in hybrid electric vehicles. However, EV sales notably jumped in 2018 and with recent developments in the Thai EV market 2019's figures could be even more positive. The proportion of sales in Thailand's EV market attributed to passenger cars is very low, representing a very different market from that of it Chinese and Western counterparts.

Number of new xEV registration (as of 31 Dec 2018)



New BEV registration by vehicle type (as of 31 Dec 2018)



Source: EV Association of Thailand

and markets to operate in.

Right now, we have megafactories in the pipeline or in production in the following continents and countries:

- Asia/Pacific: China, Japan, Korea, Thailand, Australia
- Europe: UK, Germany, Sweden, Poland, Czech Republic, Hungary,
- North America: USA

The current pipeline mirrors current and prospective electric vehicle (EV) markets – thus China's domination. But as electric vehicle adoption becomes more widespread we can expect to see representation from new markets as battery manufacturers look to produce locally to service different markets.

So, where can we expect to see emerging market megafactory developments going forward? There have also been promising signs coming out of India and Indonesia of late.

In July, India's Finance Minister Nirmala Sitharaman announced two new policies, which target increased electric vehicle adoption. The first will provide an income-tax deduction of INR150,000 on interest paid on loans to purchase EVs. The second will lower the goods and service tax on EVs and chargers from 12% to 5%. The government is also accelerating the tightening of emission regulations, using the country's emissions standards.

India's electric vehicles will differ greatly from those in the West and will be led by 2-wheelers and 3-wheelers, which account for 85% of the domestic auto market and 99% of electric vehicles produced in the last 12 months. In the world's fourth largest auto market there is undoubtedly pent up demand for electric vehicles.

State-owned Bharat Heavy Electricals Limited and Libcoin - a consortium which includes Magnis Energy (which has plans for cell plants in the US and Australia) - are also looking to bring cell production capacity to India.

Efforts in India are not limited to government, there are already plans afoot from the country's private sector to gain footholds in the supply chain asTata Group is finalising plans to build a lithium ion battery facility in the Dholera Special Investment Region in Gujarat. Meanwhile,

While we do not track any battery megafactories in our assessment, it seems only a matter of time until India makes formal steps to announce viable battery megafactory production.

Indonesia is Southeast Asia's biggest economy and one of the most populous countries on earth. It also has a big pollution problem in its major cities and the government wants to change this.

August saw Indonesian President Joko Widodo push and enact a new piece of regulation focusing on the acceleration of a domestic battery electric vehicle program. The regulation will use a mixture of incentives, environmental protections and requirements for domestic production to increase EV adoption and attempt to establish itself within the lithium ion value chain. See page 30 for a look at the Indonesian government's latest steps to establish its own nickel processing capabilities as part of its wider plans for its role in the supply chain.

Away from government regulation, Indonesia's domestic EV market received a vote of confidence from Toyota earlier this year as it announced it would invest $2 billion in the development of EVs from now until 2023. Toyota's president, Akio Toyoda, said of the move: "because the Indonesian government already has an electric vehicle development map, Toyota considers Indonesia a prime EV investment destination."

WESFARMERS COMPLETES KIDMAN ACQUISITION

Here, Benchmark Minerals outlines the key details of Wesfarmers' acquisition of Kidman and its potential impact on the lithium market

Australia's largest company by revenue, Wesfarmers, completed its AUS$1.5 billion deal to acquire lithium developer Kidman Resources in September.

The purchase by the multibillion-dollar conglomerate, which has major interests in chemicals, coal and fertilisers, could have wide repercussions for the global lithium market and the wider Australian resources sector.

On completion of the deal, Wesfarmers' Managing Director Rob Scott said, "this acquisition and our planned future investment is an attractive opportunity to participate in the development of a large-scale, long-life and high-grade lithium hydroxide project in Western Australia in partnership with a global leader in the lithium industry".

He continued, "it leverages and builds on the existing strengths and chemical processing capabilities within our chemicals, energy and fertilisers business, while supporting Western Australia's ambition to become a global hub for downstream lithium processing."

As the largest Australian company by revenue, Wesfarmers adds a major stamp of approval to Kidman Resources and the lithium growth tailwind. In a period where the lithium prices are under pressure and the lithium industry is struggling to attract investment from outside of the sector this is a vote of confidence in lithium's long-term prospects.

By choosing to pursue opportunities in lithium via M&A instead of bolstering its large specialty chemicals or coal portfolio, Wesfarmers could be the first in a wave of large diversified conglomerates that contemplate serious plays in the battery metals space.

It also represents the migration of capital towards the energy storage supply chain, from companies that typically operate in larger, established commodity markets.

Wesfarmers has likely had the opportunity to study Kidman's supply agreements with Tesla, Mitsui, and LG Chem. The deal would indicate that the offtake contracts are serious and bankable enough for a solid investment justification to shareholders.

This lends further credibility to the involvement of automotive OEMs and major battery producers' in the development of new projects.

With a strong asset portfolio and balance sheet, Wesfarmers is likely in a better position to execute the construction and ramp up of a battery-grade lithium chemicals facility.

Furthermore, based on the structure of the Mt Holland 50:50 joint venture with SQM, we believe SQM would have been party to discussions with Wesfarmers about their ability to complete this project together.

The acquisition moving ahead indicates that SQM has likely given a stamp of approval for Wesfarmers as a credible JV partner. As such, this event could foreshadow a wave of similar partnerships forming across industry players in the future.

LITHIUM ION'S PIONEERS SCOOP NOBEL

The lithium ion batteries' developers are recognised for the development of a critical 21st century technology

As the **Benchmark Quarterly Review** was going to press it was announced that the Nobel Prize in chemistry for 2019 was to be awarded "for the development of lithium-ion batteries."

This year's award went to Stanley Whittingham, professor at Binghamton University; John Goodenough, Cockrell Chair in Engineering at the University of Texas; and Akira Yoshino, professor at Meijo University.

Stanley Whittingham first developed the lithium ion battery in the 1970s. Speaking as the guest of honour at **Benchmark Minerals**' Cathodes 2017 event he said: "This field started not with an electronics company but with a little company called that was then called Esso [Exxon]. We came up with some ideas on electrical storage based on lithium. I spent 15 minutes in New York city with a committee of their board of directors. The next day they said they were going to invest in it and build an R&D project. Those days research was just like drilling oil wells – 'we put the money in, hopefully 10% make some money.'"

Whittingham added, "all is not bad with resource companies, they pushed it hard and in fact went commercial for a short period." The oil crisis of the 1970s gave oil companies the impetus to invest in research and development projects outside of traditional fossil fuels.

Following on from Whittingham's work in the 1970s, John B. Goodenough demonstrated in 1980 that a metal oxide would provide the lithium ion's cathode greater potential than metal sulphide, using a cobalt oxide. Using this new cathode material, his battery was capable of producing twice the power of Whittingham's at four volts.

Credit: The Nobel Prize

John B. Goodenough (left), M. Stanley Whittingham (centre), Akira Yoshino (right)

Goodenough continued the work of Whittingham, producing the rechargeable lithium ion battery, having established that the batteries could be charged after manufacturer.

As the interest in lithium ion batteries waned, Japanese electronic companies were looking for ways to produce commercially viable, lightweight, rechargeable batteries: in steps Akira Yoshino.

Yoshino successfully used Goodenough's cobalt oxide cathode along with a petroleum coke anode material – instead of a lithium material used previously in the anode.

Finally, in 1991, 174 years after lithium was first discovered, the rechargeable lithium ion battery became truly commercially available.

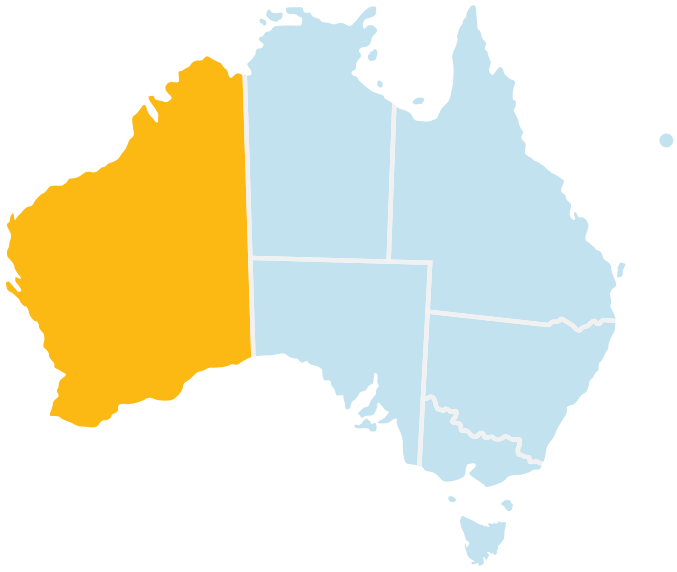
Japan's Prime Minister, Shinzo Abe, reportedly telephoned Yoshino on receipt of the award, saying: "As a Japanese, I'm proud of you for developing something that has changed people's lives," Abe continued, "it is a very good message to the world that a Nobel laureate has been selected from Japan."

The achievements of these three pioneers have had and will continue to have a profound impact on the trajectory of human development. The Nobel Prize Committee summed up the importance of this achievement, saying "lithium-ion batteries have revolutionised our lives since they first entered the market in 1991. They have laid the foundation of a wireless, fossil fuel-free society, and are of the greatest benefit to humankind."

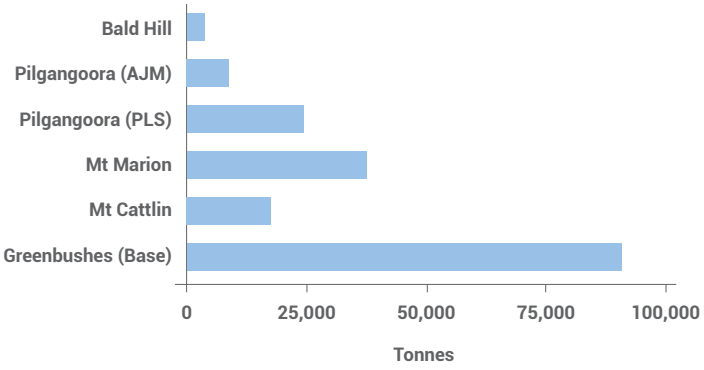
BENCHMARK MINERALS' FORECASTING HIGHLIGHTS OF THE QUARTER

Australia

Australia has been at the forefront of lithium feedstock expansions since 2015, with the number of operating spodumene operations rising to 6 by HI 2019. Recent price decreases have forced Alita Resources to appoint administrators and will likely limit volumes from Bald Hill in the medium term. Pilbara Minerals and Altura Mining have continued their ramp ups, however demand is slowing from Chinese converters.

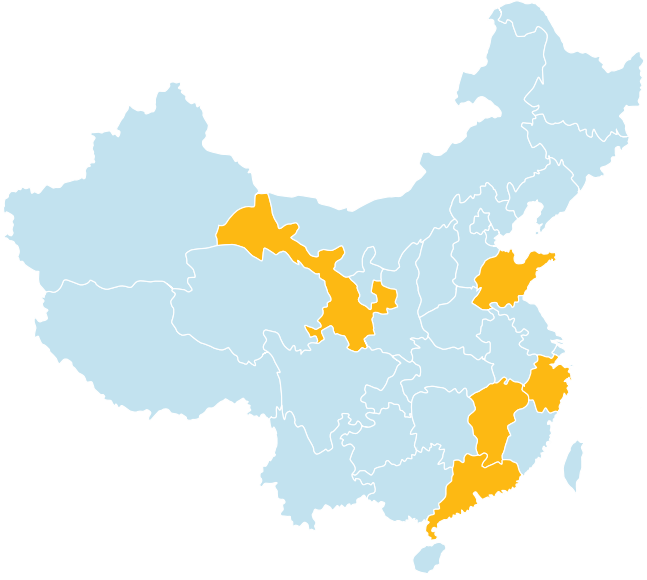


Australia's hard rock lithium forecast 2019 production

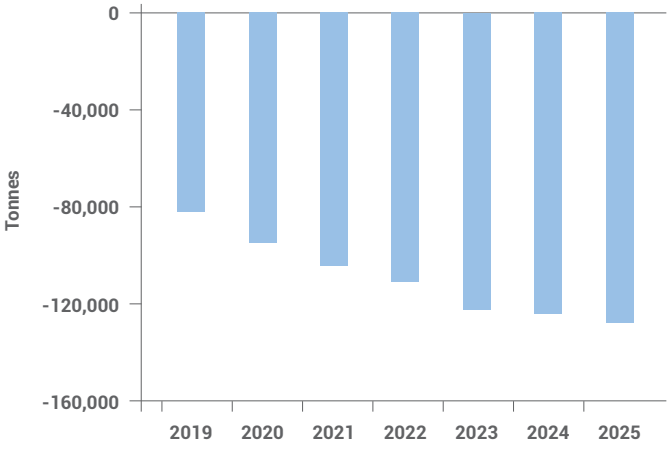


China

China has a dominant position in cobalt refining capacity, accounting for over 67% of global refined output in 2019. However, China has a growing feedstock deficit with little domestic capacity of its own, relying heavily on imports from the DRC for its cobalt refining.



China's growing cobalt feedstock deficit



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LITHIUM ION'S NEW FRONTIER

Eric. M Leslie, Managing Director, TRION Energy Solutions

The use of silicon in lithium ion battery anodes promises to provide a step-change in battery density. However, there are a number of hurdles to achieve this. Here, **Benchmark Minerals** talks with **Eric M. Leslie**, Managing Director of **TRION Energy Solutions**, about the use of silicon in batteries and TRION's plans for the industry

Benchmark: Could you let our readers know about the history of TRION Energy Solutions as well as why TRION was set up and what the company aims to achieve?

Eric. M Leslie: Back in June of 2013, a business associate called me and asked me if my advisory firm had any bandwidth to take on a new client. When I heard that the potential client was convinced that he had figured out a way to make batteries last 10 times longer, not light on fire and charge in minutes, I quickly arranged an introductory call. I vividly remember that conversation as what was going through my mind was - Maybe, just maybe, this individual might be able to cure not only me, but hundreds of millions of others around the world that suffer daily, from LBA - Low Battery Anxiety!

Two months later we incorporated the company with the goal to commercialise a solid-state battery that would revolutionise the battery world within a few years, which turned out to be an unrealistic goal that was nowhere near remotely achievable.

Fast forward a little over six years and the world is still suffering from LBA.

There is however a bright light on the horizon, as back in 2014, we were able to have the foresight to pivot away from the original solid-state idea and channel our R&D efforts into figuring out how to deliver about a 35% step-change improvement to energy density in lithium ion batteries by improving the anode, which to date has been the choke point in delivering higher energy density in lithium ion batteries.

We are now on the cusp of commercialising our patented advanced Silicon Modified Graphite (SiMoGraph) anode materials that have the potential to deliver, as a drop-in, low cost solution, the better performance metrics which the lithium ion battery industry has been striving to achieve for decades.

Benchmark: What are the main benefits of using silicon in anodes?

EL: Lithium ion batteries play an essential role as the energy source for products in multiple different market verticals including electric vehicles (EV) and consumer electronic devices, to name but a few.

The energy density of lithium ion batteries has been remarkably increased since its first commercialisation in the 1980s due to both improved material chemistry and industrial manufacturing processes. The primary challenge now being faced is that lithium ion batteries are reaching the theoretical limit of their energy density, based on the materials currently being used.

As a result, battery cell manufacturers are exploring the use of alternative material chemistries other than those used in conventional lithium ion battery systems (i.e., lithium transition-metal oxides as the cathode and graphite particles as the anode) to increase energy density, thereby extending battery life and/or increasing device functionality between charges, as well as decreasing cost, in terms of $/kWh.

Among all types of alternative anode materials, silicon has attracted the most amount of attention because of its high gravimetric capacity compared to conventional graphite (3,580 mAh/g for silicon and 372 mA/g for graphite).

The low working voltage of silicon makes it more advantageous with regard to energy density enhancement, compared to other potential anode materials with high gravimetric capacities but higher working voltages, such as different types of transition metal oxides. The abundance of silicon also makes it attractive, due to its relatively low price.

Benchmark: Despite the energy density benefits offered by silicon use in anodes there are a number of obstacles. Can you run us through the challenges of using silicon in anodes?

EL: There are several challenges that need to be overcome before commercial application of silicon in lithium ion batteries can be realised. One of the major challenges of silicon is its huge volume change which is greater than 300% expansion and contraction during alloying and de-alloying with lithium, which occurs during charge-discharge cycling. This leads to several issues, including particle pulverisation and anode cracking, continuous solid-electrolyte interface (SEI) growth and associated increases in ion transport resistance, and even peeling of the active material from the copper current collector.

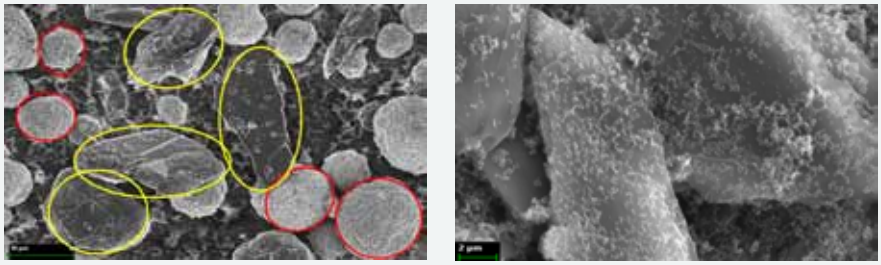
Another problem is the poor electrical conductivity of silicon, which requires the silicon particles to be robustly connected to a network of electrically conductive material throughout the lifetime of the battery. Without sufficiently strong attachment between the silicon and the electrically conducting material, the expansion and contraction of the silicon particles tends to disrupt the network, resulting in electrical isolation of the silicon and severe degradation of anode performance.

To address these issues associated with silicon, numerous efforts have been devoted to investigating the electrochemical and mechanical behaviour of novel silicon or silicon-based anode architectures. The use of nano-structured silicon, such as nanowires, nanotubes, and void-containing structures like yolk-shell architectures, have achieved significant enhancement in specific capacity and cyclability. However, while technically creative and scientifically sound, most of these approaches cannot be applied commercially because the fabrication processes are expensive and hard to scale-up.

Furthermore, the advantageous cell

FIGURE 1: SILICON AGGLOMERATION ISSUES

The image on the left shows a silicon/graphite anode material produced by current, state-of-the-art, mixing techniques. It is evident that nano-sized silicon agglomerates form ~10 micrometre spheres. The agglomerated silicon expands dramatically during cycling which leads to failure of the anode. The image on the right shows the results using TRION's silicon modified graphite (SiMoGraph)

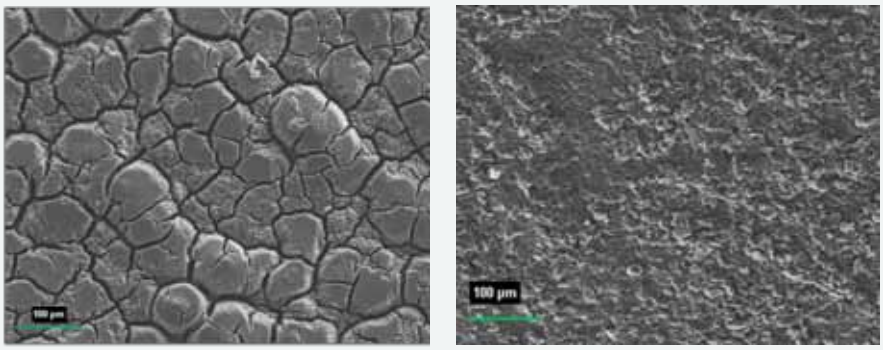


CREDIT: TRION Energy Solutions

> Among all types of alternative anode materials, silicon has attracted the most amount of attention because of its high gravimetric capacity compared to conventional graphite
>
> Eric M. Leslie, TRION Energy Solutions

FIGURE 2: ANODE CRACKING ISSUES

Traditional mixing silicon/graphite anode after 40 cycles (left) versus silicon modified graphite (SiMoGraph) after 100 cycles (right).



CREDIT: TRION Energy Solutions

performance of silicon anode solutions reported in the literature frequently relies on electrode fabrication and cell cycling conditions being far outside commercial requirements. These include mass loadings and electrode densities (areal capacity) that are too low, and low active material fraction (due to too much binder and/or conductive additives being in the binder).

Instead of pursuing complex and expensive nano-architecture strategies to accommodate silicon in the anode, a common approach has been to simply mix silicon with buffering agents which can be used to alleviate the volume change issue. The buffering agents can be electrochemically active or non-active, but certain carbon-based materials which are both electrically conductive and electrochemically active are advantageous, compared to non-active buffering agents, in terms of anode battery performance enhancement.

Since graphite (natural or synthetic) is the current state-of-the-art anode material for commercial lithium ion batteries, with performance near graphite's theoretical capacity of 372 mAh/g, the primary commercial approach has been to blend graphite with small amounts of silicon, or more commonly with silicon oxide (SiOx), which has about half the capacity of elemental silicon but is a little easier to work with.

However, existing technologies do not result in stable performance if the addition of the silicon material exceeds about 5% by weight. A major cause of this limitation is the lack of uniform distribution of the silicon in graphite/silicon (or graphite/SiOx) blends, resulting in severe agglomeration of the silicon particles, especially with respect to preferred nano-sized silicon particles, which do not fracture on expansion. The capacity of a graphite/silicon anode with agglomerated silicon will fade quickly due to the mechanical failure of the anode. Even distribution of nano-silicon on graphite remains one of the bottle necks for commercial utilisation of silicon.

> Existing technologies do not result in stable performance if the addition of the silicon material exceeds about 5% by weight
>
> Eric M. Leslie, TRION Energy Solutions

In addition, the well-distributed silicon must be robustly attached to the graphite, so that the silicon particles do not detach from the graphite during charge/discharge cycling (involving the large volume expansion and contraction at every cycle) and disrupt the electrical connectivity.

Finally, all anodes comprising silicon face the problem of parasitic reactions with the electrolyte, which can result in premature electrolyte degradation and cell failure. Tackling this problem may involve applying protective coatings to the silicon and/or formulation of the electrolyte to diminish unwanted chemical reactions.

Benchmark: What is TRION's approach to using silicon and what benefits does this offer?

EL: TRION has a growing portfolio of patents, centred on a "self-assembly" technology that permits layer by layer engineering of particle functionality. Of central importance to the lithium ion battery application, is that this proprietary technology enables silicon particles to be attached uniformly and robustly on the surface of graphite particles (via non-covalent and/or covalent interactions) by means of a controllable, easy-to-scale, low-cost process. In addition to nano-silicon, other high-capacity electrochemically active materials, such as tin nanoparticles, can be attached on graphite with uniform distribution, offering further opportunity to engineer the anodes performance.

The amount of silicon that can be uniformly attached in a single deposition depends only on the surface area of the graphite. For battery grade graphite, the surface area is usually less than 5 m2/g which can hold about 15% by wt of 50 nm silicon without

agglomeration, and with room for particle expansion. With TRION's process, this results in a highly dispersed deposition of the particles across the graphite surfaces.

TRION's Generation I anode materials, with 15% by wt silicon added in a proprietary way to graphite, provide an increase in full cell volumetric energy density of about 35%. Although it can be calculated that the addition of further amounts of silicon will lead to diminishing returns in increased energy density for any graphite/silicon system, TRION's Generation II SiMoGraph technology does nevertheless permit higher silicon loadings by self-assembling a multi-layer structure in which the primary silicon layer on the graphite core is followed by successive graphene/silicon layers. The silicon loading level can thereby be designed to meet a range of even higher battery performance requirements.

Benchmark: Can you share some of the results from TRION's testing?

EL: TRION's proprietary process of achieving uniform distribution of silicon, which is in intimate contact with the graphite, has overcome the cracking issues that occur when silicon is added to graphite using traditional mixing methods. When disassembled after only 40 charge/discharge cycles, as shown in Figure 2, an anode prepared by traditional mixing methods shows severe cracking, resulting in rapid degradation of anode capacity. The SiMoGraph anode, on the other hand, shows no indications of cracking when disassembled after 100 cycles. Consequently, the SiMoGraph anode retains a constant capacity in excess of 500 mAh/g for over 500 cycles at an aggressive 1C cycling rate.

Dimensional change due to the electrode expansion and gassing is another important factor that requires attention. For commercial applications, the battery must generally not exceed a 10% thickness increase during cycling of the cell, especially for portable electronics which are only designed to accommodate a small volume expansion of the battery. Therefore, the thickness of a pouch-type full cell containing SiMoGraph (with 15% wt Si) was monitored during cycling. The results showed approximately a 2.3% anode thickness increase, corresponding to approximately a 0.8 % increase in full cell thickness, which is well within the required limit.

> One of the major challenges of silicon is its huge volume change which is greater than 300% expansion and contraction during alloying and de-alloying with lithium
>
> Eric M. Leslie, TRION Energy Solutions

In order to maximise full cell cycling longevity, TRION's current focus involves application of proprietary approaches to optimizing the SEI formation and reducing, or eliminating, parasitic electrolyte reactions. Unlike a number of silicon based architectures, the structure of SiMoGraph materials is well suited to precise application of low-cost, state-of-the-art coating technologies that address these issues.

Benchmark: What is TRION's approach to commercialisation ? Are you targeting specific batteries and applications?

EL: TRION will be pursuing a licensing approach to the commercialization of SiMoGraph.

We are currently focused on pursuing applications that will benefit the most from increases in energy density such as consumer electronic devices and EVs, not so much from increases in power. We are confident that, over time with a larger scientific team in place, we will be able to deliver next generation anodes that significantly reduce Low Battery Anxiety across a broad spectrum of energy and power applications.

Benchmark: What type of interest are you receiving from downstream OEM, cell manufacturers, material companies?

EL: Although we have only recently begun down the path of transitioning out of conducting R&D in stealth mode, we have been pleasantly surprised at the reception that we have been receiving from multiple different large companies about starting their due diligence process to potentially participate in our Series B round and or becoming a strategic partner.

Benchmark: Anode manufacturers are predominantly based in Asia and the sector is dominated by large companies. Where do you see the market going in the future?

EL: That's a great question and a tough one to answer. In light of the fact that our Generation I SiMoGraph anode materials are made with 85% synthetic graphite and 15% by weight silicon our materials could be manufactured anywhere in the world. Only time will tell how this plays out.

Benchmark: If you were to have a crystal ball, what does the future hold for TRION?

EL: We believe that with the performance data that we are currently achieving, which we are happy to share with interested parties, we will be able to attract one or more strategic investors into our Series B round of funding that will accelerate bringing our low cost, proprietary SiMoGraph anode materials to the market. We further believe that once the battery world and consumers understand just how large a step-change in energy density our SiMoGraph anode materials can deliver, our anode materials will become the "Gold Standard" specified to be used in the production of billions of lithium ion batteries annually.

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Ford
ARGO
SELF-DRIVING TEST VEHICLE

VOLKSWAGEN JOINS FORD WITH INVESTMENT IN AUTONOMOUS VEHICLE COMPANY ARGO AI

Volkswagen's foray into new automobile markets continued in Q3 2019 as it invested $2.6 billion in autonomous vehicle startup Argo AI.

The German auto major joins its US counterpart Ford – which previously invested $1 billion in February 2017 – in partnership with Argo, valuing the US-based company at $7billion. Both Ford and Volkswagen hold an equal share in Argo.

As part of the Argo AI deal Volkswagen has committed $1billion in funding and is contributing its $1.6 billion Autonomous Intelligent Driving company.

This announcement expands on the existing alliance between Ford and Volkswagen as the companies combine forces to deal with the existential threats facing the auto industry's incumbents.

This year Volkswagen announced plans for its own battery megafactory with Northvolt and agreed supply deals with raw material producers to manage the supply chain risks associated with battery cell production.

Volkswagen also made its Modular Electric Toolkit (MEB) available to the wider auto market, which Ford has announced it will use in electric vehicle production. Ford is expecting to deliver 600,000 European vehicles using Volkswagen's MED over the next six years.

Ford's CEO Jim Hackett said of the Volkswagen-Argo announcement, "while Ford and Volkswagen remain independent and fiercely competitive in the marketplace, teaming up and working with Argo AI on this important technology allows us to deliver unmatched capability, scale and geographic reach." Hackett continued. "Unlocking the synergies across a range of areas allows us to showcase the power of our global alliance in this era of smart vehicles for a smart world."

Source: ARGO AI

CONDITION: CRITICAL

Critical raw material supply is back on the agenda in the US as Lisa Murkowski introduced the American Mineral Security Act bill this year. Here, **Paul Harris** looks at the history and latest developments in US raw material security

In May 2019, US Republican senator Lisa Murkowski introduced the American Mineral Security Act bill, which aims to rebuild a domestic mineral supply chain, particularly for battery minerals such as lithium, graphite and cobalt to reduce US reliance on foreign sources. With lithium-ion batteries seen as a key element in the future of transportation and energy storage, there is a feeling the US has been caught napping while China acquired a leading position over global materials supply.

"Unless we take significant steps, we're at risk of ceding major economic drivers to other countries," said senator Murkowski, chair of the US Senate Committee of Energy and Natural Resources. "Our nation's mineral security is a significant, urgent and often ignored challenge…our reliance on China and other nations for critical minerals costs us jobs…and leaves us at a geopolitical disadvantage," she said.

Other observers agree. "The challenge… is ensuring that the US does not exchange a dependence on OPEC's oil for a dependence on China's batteries and critical minerals," said Robbie Diamond of Securing America's Future Energy.

Benchmark Minerals assisted in the genesis of the bill by highlighting the realities of material supply in the battery space. Speaking at the US senate this year, **Benchmark Minerals**' Managing Director Simon Moores said "the US produces 1% of global lithium supply and 7% of refined lithium chemical supply, while China produces 51%. For cobalt, the US has zero mining or chemicals capacity whilst China controls 80% of this second stage. For graphite, the US has no flake graphite mining or anode production compared to China's 51% and 100% of the world's total, and the situation for nickel sulphate is similar.

"We are in the midst of a global battery arms race that is intensifying. Lithium, graphite, cobalt and nickel are the key enablers of the lithium ion battery and, in turn, the lithium ion battery is the key enabler of the energy storage revolution. … The US has been a bystander in building domestic supply chain capacity. … These supply chains are the oil pipelines of tomorrow. The lithium ion battery is to the 21st century is what the oil barrel was to the 20th century," said Moores.

Credit: Artic Circle

Senator Lisa Murkowski introduced the American Mineral Security Act bill in May 2019

The bill comes within a zeitgeist which sees US president Donald Trump forge an increasingly nationalist agenda focusing on US interests and reeling-in decades of Internationalism which the US formerly spearheaded. "The future does not belong to globalists. The future belongs to patriots," he said during a speech to the United Nations on September 24th. In-sourcing of jobs and industry is part of Trump's agenda, and minerals production is within that. In June 2019, president Trump signed an Executive Order to push this along. A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals tasked the US Secretaries of Interior and Defense to prepare a list of critical minerals and develop a strategy for reducing foreign dependence on metals and minerals deemed critical. This followed the December 2017 Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply US Geological Survey report which listed 23 metals and minerals—including cobalt and graphite—critical to the US national economy and national security.

How did we get here?

A focus on strategic minerals represents a return to the past. The 1939 Strategic and Critical Materials Stock Piling Act which sought to "provide for common defense by acquiring stocks of strategic and critical materials essential to the needs of industry for the manufacture of supplies for the armed forces and the civilian population in time of a national emergency, and to encourage, as far as possible, the further development of strategic and critical materials within the United States for common defense." This saw the Defense Logistics Agency (DLA) manage the National Defense Stockpile of various metals and minerals.

"The strategic stockpile never worked as a concept until the late 1940s after Russia detonated a hydrogen bomb. In 1956, the stockpile had a value of $10.3 billion. At the end of the George Bush administration in 1993 it was worth $1.2 billion. After the fall of the Soviet Union in 1989 the US Department of Defense decided it had no existential threat from Communism anymore and therefore no threat of having mineral dependence cut off, and so it started selling down the stockpile," Micky Fulp of MercenaryGeologist.com told **Benchmark Minerals**.

The post-Soviet world of free trade agreements saw mineral-rich China emerge as a market economy and saw the production of many minerals in the US cease because it was easier and cheaper to buy them

elsewhere as global trade barriers fell. Thirty years after the Cold War ended, China and Russia are increasingly seen as military and economic threats to the Western world, a context in which global supply chains that supply the exotic mineral elements our digital world requires present strategic vulnerabilities. "Technology is changing, materials science is changing, innovation is changing but the laws are what they were. This is going to have a drag on the economy, on technology development and defence platforms. Law and permitting regimes have to catch up to where we need them to be with innovation and technologies," said McGroarty.

Supply chains

What is critical: the raw mineral, the refined mineral or the final technology? President Trump wants US businesses to onshore production, but does this make sense if inputs are sourced overseas? "Is an iPhone made in China or California? Is it necessary to have greater domestic lithium and cobalt supplies if we buy an iPhone from China? How much end-to-end supply chain will be in the US if the mineral supply is there and will manufacturing shift back because of this?" asked Denis Laviolette, president and CEO Goldspot Discoveries.

Rather than the minerals themselves per se, the debate is centred on supply chains, according to Patrick Highsmith, former president and CEO of Pure Energy Minerals. "China doesn't control the lithium resources, but it has converters who buy it. Once lithium arrives in China and is converted, will it come out again? The conversion technology in Japan and South Korea is better than in China while the US is on the side-lines of this part of the value chain. What is being done to encourage the development of a lithium supply chain in the US? This is not a government issue but a business issue," he told **Benchmark Minerals**.

Government has the tools to stimulate a domestic minerals industry, but under what conditions is it prepared to use them? The evidence is mixed.

The US Department of Commerce (DOC) investigated the effects of uranium imports on US national security under Section 232 of the 1962 Trade Expansion Act after Energy Fuels and Ur-Energy argued the loss of a viable US uranium mining industry would have a detrimental impact on the country's national, energy and economic security and its ability to sustain an independent nuclear fuel cycle. They sought a quota to limit imports to effectively reserve 25% of the market for domestic production and a buy American policy for federal entities. But although the US imports 93% of its uranium, president Trump declined to countenance this even though Russia and former Soviet states represent the bulk of world production. "At this time, I do not concur with the Secretary's finding that uranium imports threaten to impair the national security of the United States," he said in a statement.

Credit: The White House

Critical mineral security is now firmly on the USA's agenda. Particularly in the face of Chinese supply chain dominance

While president Trump backed away from assisting the uranium industry, he adopted a more supportive stance for rare earth elements (REE). In July, he triggered a Defense Title III action under section 303 of the 1950 Defense Production Act. "I hereby determine … that the domestic production capability for rare earth metals and alloys is essential to the national defense. Without presidential action under section 303 of the Act, US industry cannot reasonably be expected to provide the production capability for rare earth metals and alloys adequately and in a timely manner. Further, purchases, purchase commitments or other action pursuant to section 303 of the Act are the most cost-effective, expedient and practical alternative method for meeting the need for this critical capability," he stated.

This means, in effect, that the domestic production of REEs are eligible for defence support. "Defence Title III allows for federal investment in the material identified which means the material can be bought for the National Defence Stockpile, the government can enter into purchase commitment (off-take) agreements, it could finance the facilities related to producing more of the material and invest in facilities to improve the processes to improve the material. This puts the full weight of the Pentagon purchasing power behind it," said McGroarty.

What is there?

Forcing the Pentagon to buy local is one thing but this assumes there are minerals for it to buy. Determining this is one of the aims of the Murkowski bill. Section 5 requires a quantitative and qualitative assessment of undiscovered critical mineral resources throughout the US, including, "probability estimates of tonnage and grade, using all available public and private information and datasets, including exploration histories." For Jonathan Evans, president and CEO of Lithium Americas, "the government is focused on having robust supply chains and understanding where the resources are and how they work. The nature of supply chains is not lost on the government anymore and

they want stable supply chains for the supply of critical industries," he told **Benchmark Minerals**.

Compiling information within the US to have a greater understanding of the country's minerals potential is no mean feat given that the pertinent information in many states is in private hands. "One of the barriers to this is that in certain states such as Nevada, Arizona and Idaho a lot of the data is privately held and the owners do not need to provide it to the government," said Laviolette.

Where there is a data vacuum, government could step in to generate information using cutting edge exploration tools. "There is innovation in ways of generating information that could bypass [information held privately] such as generating multi-spectral data over an entire state. An explorer cannot fly over land held by another company, but the government can. States or government could generate new data rather than trying to piece together historical data, and this could be made publicly available to attract exploration investment," said Laviolette.

The drive for better information is not limited to the national territory and is arguably one of the rare moments of the Trump administration engaging in Internationalism. Secretary of State Mike Pompeo met with foreign ministers from nine countries (Australia, Botswana, Peru, Argentina, Brazil, Democratic Republic of the Congo, Namibia, the Philippines and Zambia) which joined the Energy Resource Governance Initiative (ERGI) to help discover and develop minerals used to make EVs on the side-lines of the United Nations General Assembly in New York in September. ERGI is a US Department of State, Bureau of Energy Resources (ENR)-led effort to promote sound mining sector governance and resilient energy mineral supply chains.

Financing

The key challenge for mineral explorers and developers will always be access to capital. Many companies in this space are publicly traded and rely on capital markets to raise funds. The cyclical nature of mineral and capital markets sees funding windows open and close as minerals oscillates, which is of little use for a government seeking to advance on strategic goals. Prevailing market conditions have a huge impact on mineral

Benchmark Minerals' gave testimony at the US Senate Committee of Energy and Natural Resources earlier this year

markets as the stultification of the copper price this year due to the US-China trade dispute shows, even though the copper market is heading towards a structural supply deficit. Lithium, cobalt and other battery minerals are in the same boat.

Three years ago, investor interest in lithium rocketed and it was relatively easy for lithium explorers to raise equity. Lithium prices have since plunged on the back of a flood of new mines coming into production and it is almost impossible for lithium juniors to raise equity. Most cobalt is produced as a by-product of nickel and with nickel prices near all-time lows, much capacity has been mothballed. When nickel prices increase, by-product cobalt will come back into the market and weaken the pricing primary cobalt projects require to develop and sustain their operations. "The problem is the long-term viability of a small market. The lithium price fell from $19,500/t to under $12,000/t. Cobalt prices skyrocketed but then fell 70% over the last year. You need a sustainable price for any mineral development," said Fulp.

For Keith Phillips, president and CEO

Credit: Benchmark

of Piedmont Lithium, this presents "an interesting dichotomy" in that lithium equities are poorly valued although there is strong hydroxide demand approaching. "There are periods when it is very hard to raise money and periods when it is easier. Now we are in a period where it is hard to raise equity and so money will have to come from Asian banks and traders," he said.

"The biggest issue is how to solve the financing question. Minerals exploration and development is a capital intensive high-risk cyclical industry. We look with envy at every dollar the government is throwing at EVs. There are no similar measures helping the industry secure miners domestically. We need to drill [our property in Idaho] and this is what costs the big dollars, so we need a stronger market to raise money," said Mell.

The fickleness of capital markets means they are unlikely to be the main source of funds to take battery minerals projects into production, with many juniors instead looking along the value chain to find funding partners among the processors, battery manufacturers and even automakers.

"When we come out with a pre-feasibility study that shows our Graphite Creek project in Alaska is economically feasible it will open the doors to companies relying on graphite from China. I see an end-user potentially stepping in to finance the end goal," said Anthony Huston, president and CEO of Graphite One, who thinks the project will need $300-400 million to build a mine and plant to produce 60,000-70,000tpy of graphite.

Direct government funding or subsidies to companies could be a possibility to increase the supply of critical minerals, but observers give the idea short shrift. "Giving subsidies or tax credits is a legitimate way to help finance this sector but backing junior explorers in this way is never going to happen," said Fulp. "The government hasn't provided loan guarantees in a long time, so I don't know if that is realistic," said Lithium Americas' Jonathan Evans.

Bernard Rowe, Managing Director of Ioneer, proposes a number of government efforts to give impetus to raw material supply, saying: "incentives could include tax abatements, income tax credits, designated opportunity zones and low-interest loans to underpin the funding required to develop domestic mines that will produce the key battery ingredients such as lithium, cobalt and nickel."

Whereas Bruce Richardson, Executive Chairman & CEO of Anson Resources, suggests the US government could create new departments, explaining "an inter-government agency should be established to establish a road map of how government can assist the development of industry with a focus on eliminating red tape and out-dated regulations reducing imports and developing export markets for mineral resources, batteries and electric vehicles."

However, Robert Mintak, CEO & Director of Standard Lithium, points out that the USA has a number of domestic political hurdles to overcome to take a more prominent role in the supply chain, "it is hard for western governments, particularly the US to look past partisanship and short-termism when it comes to creating a national strategy for a nascent and polarising industry like energy

storage - lithium-ion batteries," he said.

Beyond that, the federal and state governments could help bring entire districts into production through the development of general infrastructure such as roads and power, argues Laviolette. "Subsidies would have to be on infrastructure to open up new areas for production and there is a section of the [Murkowski] act that directly speaks to this, to open access by bringing in roads and power. Geology is very precise at a macro level, in identifying a high-potential district. You don't need to know which individual project is best in order to run infrastructure into a region," he said.

As the profile of the mineral's security issue increases, it may enable mineral companies to appeal to investors on patriotic grounds, particularly those who help fund initiatives such as mining the oceans or mining asteroids and are concerned about US mineral dependence on China and Russia. "It becomes a political, philosophical issue so you need to find people that support America First causes," said Fulp. "If this issue [strategic minerals security] is driven into the limelight, made very public and promoted properly, it will result in more retail investors making their way into the space. Retail investors look for optionality and that is exploration," said Laviolette.

Permitting

In the absence of subsidies, what can government do to create a more attractive environment for mineral investors? The government could help create greater certainty for investors by improving the line-of-sight on project permitting timelines, which both helps to reduce investment risk as well as giving a greater indication of when investors can expect to see a return on their investments. Reducing permitting red-tape to improve process times is something the Trump administration has strongly advanced and is also including in the Mineral Securities Act bill. "If legislative initiatives about critical minerals are successful in reducing permitting times, that would help the investment case for minerals projects and provide greater certainty on timelines for investors," said Phillips.

Murkowski's bill seeks to implement permitting reforms for the Department of the Interior and Department of Agriculture Forest Service to reduce delays. "Projects in the US need to be competitive, and what has slowed them down has been uncertainty related to permitting," said Evans. "Permitting processes have become more Byzantine, less transparent and less predictable, which adds a lot of time and therefore cost to minerals projects. If you don't remove the obstacles in permitting projects companies are not going to bring them into production," Dan McGroarty, Graphite One advisor and who has testified in the US House and Senate on critical minerals issue, told **Benchmark Minerals**.

> It is hard for western governments, particularly the US to look past partisanship and short-termism when it comes to creating a national strategy for a nascent and polarising industry like energy storage - lithium-ion batteries
>
> Robert Mintak, Standard Lithium

Executive Order 13807 of August 2017 Establishing discipline and accountability in the environmental review and permitting process for infrastructure projects which put timelines on NEPA (National Environmental Policy Act) to change behaviour of public agencies for permitting. "The BLM (Bureau of Land Management) used to take five years to review an EIS and now the government is looking at the process taking 12 months," said Evans.

To help this, the Trump administration relocated the BLM headquarters from Washington to Colorado along with 85 jobs, putting the administrators in the heart of the territory they have to administer, although it has also successively cut the BLM budget: the 2019 budget is US$1 billion, down from $1.1 in 2018, $1.3 in 2017 and $1.2 billion in 2016.

Miners have perceived a positive change in attitudes towards permitting. "There has been a pretty big shift of focus, but it doesn't turn on a dime. We see the field offices trying to do the right thing by the American taxpayer to make things more efficient. We are seeing improvements, but it is still important to do the right work and follow the process, so the outcome is defendable and supportable by the community," John DeCooman, VP business development and strategy at precious metals miner SSR Mining told **Benchmark Minerals**.

High up on the miners wish-list of possible changes which would have positive impacts is greater coordination between government agencies. "it is helpful having a policy of endorsement by the government that rallies public agencies around a cause. It can be tough to understand who to talk to at times because there is a lack of coordination," said Evans.

> Incentives could include tax abatements, income tax credits, designated opportunity zones and low-interest loans to underpin the funding required to develop domestic mines
>
> Bernard Rowe, Ioneer

For Fulp, the attention on mineral

US CRITICAL MINERALS LIST

In May 2018, the US Department of the Interior published a list of minerals it designates as critical. The US is import-reliant for 31 of 35 minerals in the list and completely relies on imports for 14 of the critical minerals listed

Mineral commodity	Aerospace (non-defence)	Defence	Energy	Telecommunications and electronics	Transportation (non-aerospace)	Other	Top producer	Top supplier	Notable example application
Aluminium	X	X	X	X	X	X	China	Canada	Aircraft, power transmission lines, lightweight alloys
Antimony	–	X	X	X	X	X	China	China	Lead-acid batteries
Arsenic	–	X	X	X	–	X	China	China	Microwave communications (gallium arsenide)
Barite	–	–	X	X	–	X	China	China	Oil and gas drilling fluid
Beryllium	X	X	X	X	–	X	US	Kazakhstan	Satellite communications, beryllium metal for aerospace
Bismuth	–	X	X	X	–	X	China	China	Pharmaceuticals, lead-free solders
Cesium and rubidium	X	X	X	X	–	X	Canada	Canada	Medical applications, global positioning satellites, nightvision devices
Chromium	X	X	X	X	X	X	South Africa	South Africa	Jet engines (superalloys), stainless steels
Cobalt	X	X	X	X	X	X	DRC (Kinshasa)	Norway	Jet engines (superalloys), rechargeable batteries
Fluorspar	–	–	X	X	–	X	China	Mexico	Aluminium and steel production, uranium processing
Gallium	X	X	X	X	–	X	China	China	Radar, light-emitting diodes (LEDs), cellular phones
Germanium	X	X	X	X	–	X	China	China	Infrared devices, fiber optics
Graphite (natural)	X	X	X	X	X	X	China	China	Rechargeable batteries, body armour
Helium	–	–	–	X	–	X	US	Qatar	Cryogenic (magnetic resonance imaging [MRI])
Indium	X	X	X	X	–	X	China	Canada	Flat-panel displays (indium-tin-oxide), specialty alloys
Lithium	X	X	X	X	X	X	Australia	Chile	Rechargeable batteries, aluminium-lithium alloys for aerospace
Magnesium	X	X	X	X	X	X	China	China	Incendiary countermeasures for aerospace
Manganese	X	X	X	X	X	X	China	South Africa	Aluminium and steel production, lightweight alloys
Niobium	X	X	X	X	–	X	Brazil	Brazil	High-strength steel for defence and infrastructure
Platinum group metals[1]	X	–	X	X	X	X	South Africa	South Africa	Catalysts, superalloys for jet engines
Potash	–	–	X	X	–	X	Canada	Canada	Agricultural fertiliser
Rare earth elements[2]	X	X	X	X	X	X	China	China	Aerospace guidance, lasers, fibre optics
Rhenium	X	–	X	X	–	X	Chile	Chile	Jet engines (superalloys), catalysts
Scandium	X	X	X	X	–	X	China	China	Lightweight alloys, fuel cells
Strontium	X	X	X	X	X	X	Spain	Mexico	Aluminium alloys, permanent magnets, flares
Tantalum	X	X	X	X	–	X	Rwanda	China	Capacitors in cellular phones, jet engines (superalloys)
Tellurium	–	X	X	X	–	X	China	Canada	Infrared devices (night vision), solar cells
Tin	–	X	–	X	–	X	China	Peru	Solder, flat-panel displays (indium-tin-oxide)
Titanium	X	X	X	X	–	X	China	South Africa	Jet engines (superalloys) and airframes (titanium alloys), armour
Tungsten	X	X	X	X	–	X	China	China	Cutting and drilling tools, catalysts, jet engines (superalloys)
Uranium	X	X	X	–	–	X	Kazakhstan	Canada	Nuclear applications, medical applications
Vanadium	X	X	X	X	–	X	China	South Africa	Jet engines (superalloys) and airframes (titanium alloys), high-strength steel
Zirconium and hafnium	X	X	X	X	–	X	Australia	China	Thermal barrier coating in jet engines, nuclear applications

[1]This category includes platinum, palladium, rhodium, ruthenium, iridium, and osmium. [2]This category includes yttrium and the lanthanides.

Source: USGS

Credit: Graphite One

Range Front location of Graphite Creek Deposit

security exposes the dysfunctional nature of government and lack of coordination between different agencies. "You have the Department of Defense selling the stockpiles as another part of government is putting [the stockpiled minerals] on the critical list. It makes no sense," he said.

Lack of coordination could be a barrier to the development of lithium brine projects, said Highsmith. "The water lithium is dissolved in is subject to state administration of water rights, but lithium is a federally locatable mineral, which raises the question of how do you get access to it? State law can be overruled if the state is using its statutes to regulate a federally authorised mineral. Lithium in Nevada is all about water rights and it shouldn't be," he said.

Lack of policy coordination could also stifle the development of the cobalt belt in Idaho. "The growing concern on economic or military grounds contrasts with the bureaucracy minerals developers have to deal with [with public officials] who haven't received that message and are going contrary to the executive order. The deposits in the Idaho cobalt belt are under threat as the US Forestry Service is looking to protect the area. A consultation is going on and if the White House had any idea of its implications they would be shocked," Trent Mell, president and CEO of First Cobalt, told **Benchmark Minerals**.

Curiously, coordination mechanisms exist within a similar facet of government. Title 41 of 2015's Fixing America's Surface Transportation (FAST) Act was designed to improve the timeliness, predictability and transparency of the Federal environmental review and authorisation process for infrastructure projects, and established procedures to standardise interagency consultation and coordination practices. It also codified into law the use of the permitting dashboard to track project timelines, address the project delivery process and track environmental review and permitting milestones. "FAST 41 created a dashboard where you can see where your project is and what stage it is at, but it stopped short of including mining projects," said McGroarty.

Political ping pong

The attention on minerals supply security is positive for the minerals sector but it also faces legislative threats as Democrats try to revise the 1872 Mining Law and put in large royalties.

"If Hardrock Mining Reform legislation by Chair Grijalva and senator Udall is signed into law by a Democrat president it will destroy the US mining industry. It seeks to put an oil and gas royalty regime of 12.5% on all new mining projects and an 8% royalty on existing operations," said Fulp.

While mining has taken giant strides to improve its image and environmental performance in recent years, being pro-mining is still widely perceived as being anti-environment.

While president Trump works to open more the of US to mineral exploration and exploitation, such as opening the Alaskan Arctic Reserve for oil exploration and opening some national forests, the forces opposing him are pro-environment.

A subsequent administration could remove any legislation Trump puts in place as he is doing by methodically winding back legislation his predecessor Barrack Obama put in place to protect the environment or mitigate the impacts of the climate crisis.

"The kinds of measures that Trump is putting in for the mining sector are easy to dismantle for a future president," said Laviolette.

WHAT DOES THE POST-SUBSIDY CHINA EV MARKET LOOK LIKE?

The subsidies which have supported China's world-leading electric vehicle market are being cut. Here, **Adam Panayi,** Managing Director, Rho Motion, explores the post-subsidy landscape

CHINA'S NEW ENERGY VEHICLE SUBSIDIES

Reducing to zero

Electric vehicle sales in China account for half the global market, propelled by the country's subsidy regime. However, the government subsidy is being steadily reduced and will ultimately be removed

	2019	2019 transition	2018	2018 transition	2017
BEV range (Km)	Subsidy RMB				
100≤ R <150	-	-	-	14,000	20,000
150≤ R <200	-	2,000	15,000	25,000	36,000
200≤ R <250	-	2,000	24,000	25,000	36,000
250≤ R <300	18,000	20,000	34,000	31,000	44,000
300≤ R<400	18,000	27,000	45,000	31,000	44,000
R≥400	25,000	30,000	50,000	31,000	44,000
R≥500	25,000	30,000	50,000	31,000	44,000

	2019	2018	2017
BEV Wh/kg	Subsidy RMB		
<90	-	-	-
90-105	-	-	10,000
105-120	-	6,000	10,000
120- 125	-	10,000	11,000
125- 140	8,000	10,000	11,000
140- 160	9,000	11,000	11,000
160- 180	10,000	12,000	11,000
>180	10,000	12,000	11,000

Source: Chinese Ministry of Finance

China has dominated the electric vehicle market for the majority of the period that there has been a market to speak of, the rate of market development there outstrips any other region both in terms of penetration and volumes, and this trend has not abated in 2019.

The first chart shows Battery Electric and Plug-in Hybrid Electric Vehicle (BEV & PHEV) penetration by regional market and the total volume of sales for the first 8 months of 2019, and highlights the extent of this dominance, with sales in China alone greater than the rest of the world combined.

Consequently, the market in China is monitored closely as any loss of momentum in the market would have implications for the entire electric vehicle (EV) & battery supply chain, from raw materials to charging infrastructure. As such the recent reduction is the size and scope of the government subsidy which has undoubtedly had an impact on the market since its came into effect in July, was always going to generate headlines in a market that has hitherto only seen growth. In this article, we provide our analysis of the medium and long-term impact of this change in the subsidy regime, drawing on research from our EV & Battery Quarterly Outlook, the Q4 2019 iteration of which is released at the end of October.

What happened when the subsidy was removed, and what has happened since?

Earlier this year the government announced an incremental phase-down and eventual elimination of EV subsidies in order to reduce market dependence on fiscal support. From July 2019, BEV's with a range of 400 km or more had their subsidies halved from RMB50,000 to RMB25,000, BEV's with a range less than 250 km will receive no subsidy.

The second chart shows passenger car and light duty vehicle (PC &LDV) BEV & PHEV sales in China on a monthly basis for the period 2017-2019 year-to-date. Tracking for 2019, it can be seen that there was a marked increase in June sales ahead of the subsidies removal. There was then a subsequent 50% month-on-month fall in the market in July, and a 16% rise in sales in August.

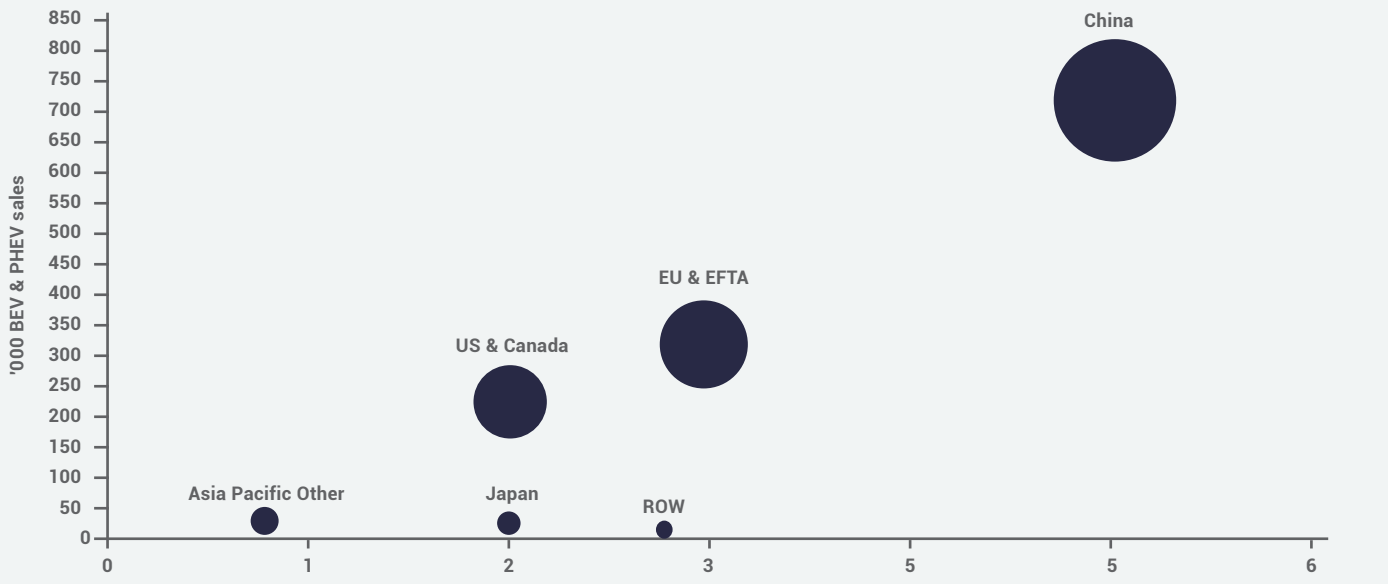
Probably the most interesting thing to note about the sales figures since the subsidy has been curtailed, is the fact that monthly sales in both July and August were lower than the respective months in 2018. In a market that has known nothing but exponential growth for several years this is quite a turnaround, but is it part of an ongoing trend? And if the market can be moved by the lack of subsidies, does it signal a shift in technological focus to fuel cell vehicles where subsidies are, for now, being preserved?

Our view is that this is unlikely on both counts. The first reason for this relates to short-term vehicle market dynamics. On a year-to-date basis for the 8 months to August, sales of BEV & PHEVs are up 38% on the same period in 2018, for PC & LDVs, so the relative slowdown since July should be viewed in the perspective of a very strong first half of the year. Further, there was clearly a strong pre-buy effect in June, which was always likely to hit sales in subsequent months. In addition, sales of all vehicles in China typically increase into the final quarter as well, as can be seen

CHART 1: EV SALES CONTINUE TO GROW, WITH CHINA ACCOUNTING FOR HALF THE MARKET

China vs the rest of the world

As with many stages of the lithium ion and electric vehicle supply chains it can be viewed as China versus the rest of the world. China dominates global BEV & PHEV sales. However, will this domination continue in the post-subsidy landscape?

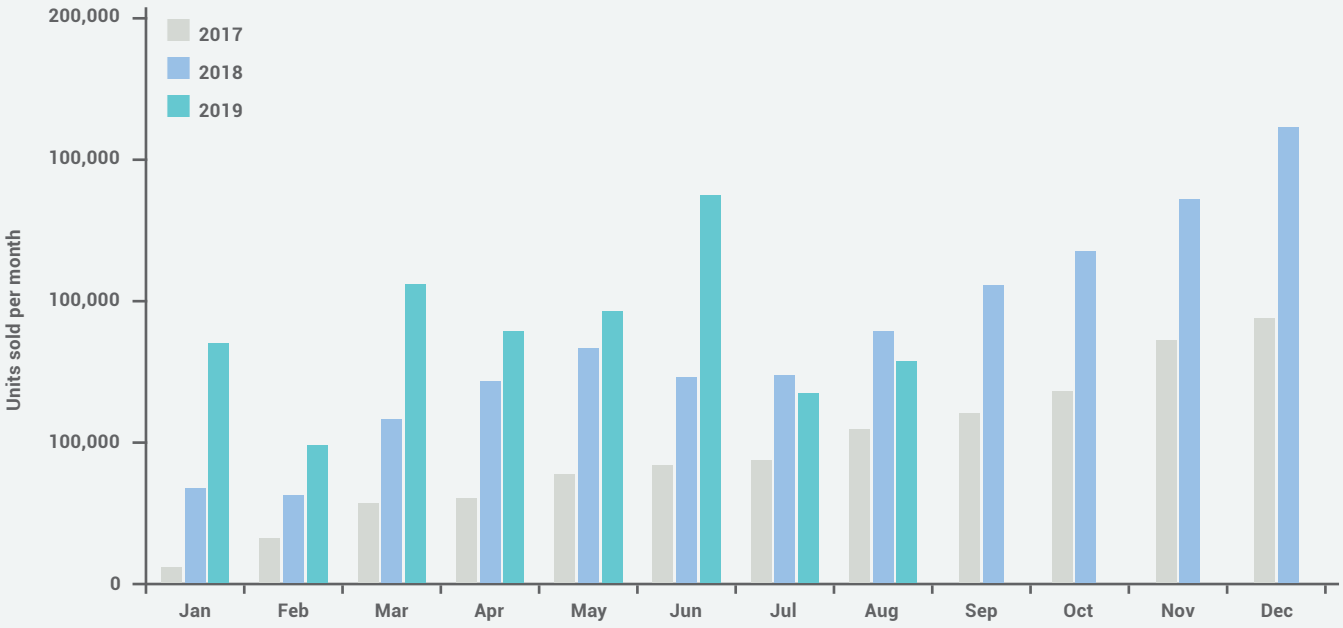


Source: Rho Motion

CHART 2: CHINA PASSENGER CAR BEV & PHEV SALES BY MONTH, 2017-2019

2017-2019 monthly sales

Comparing figures for 2017, 2018 and 2019 it's notable that June 2019's sale figures dramatically increased, which was just before the subsidy removal began. The first two months following the subsidy change saw year-on-year falls. But will this trend continue in the long term?



Source: Rho Motion

in the chart, so it is likely that the market will continue to recover as the year draws to a close.

The second reason why we do not see this as part of a major shift in the market is because of longer-term government and OEM strategies. In all markets EV adoption is essentially driven by the interaction between government intervention, in the form of either emissions legislation or subsidies and incentives, and OEM's response in terms of their model line-ups and choice of battery pack size and chemistry.

In the first instance, despite the reduction in the subsidy, the government continues to support EV adoption through more stringent emissions legislation and other incentives. At a national level on the legislation side, the introduction of China 6 (Euro 6 equivalent) legislation puts pressure on OEMs to resolve issues around an inefficient gasoline fleet in terms of fuel consumption and nitrogen oxide (NOx) emissions. These measures will only become more stringent over time, and pressure on OEMs to reduce fleet average emissions will become more intense, especially with the introduction of more rigorous Worldwide Harmonised Light Vehicle Test Procedure (WLTP) test cycles.

In addition incentives remain in place, the Ministry of Finance announced that New Energy Vehicles (NEVs) purchased from 1 January 2018 to 31 December 2020 shall remain exempt from vehicle purchase tax. At a local level, significant restrictions on the purchase of new ICE vehicles in major cities such as Beijing and Shanghai, continue to push EV adoption.

The government has policy targets for OEMs as well. The NEV mandate specifies credit targets for two years, replacing subsidies with a credit-trading system, which among other targets, specifies that a carmaker must have bought or earned NEV credits equal to 10% of its ICE sales in 2019 and 12% in 2020.

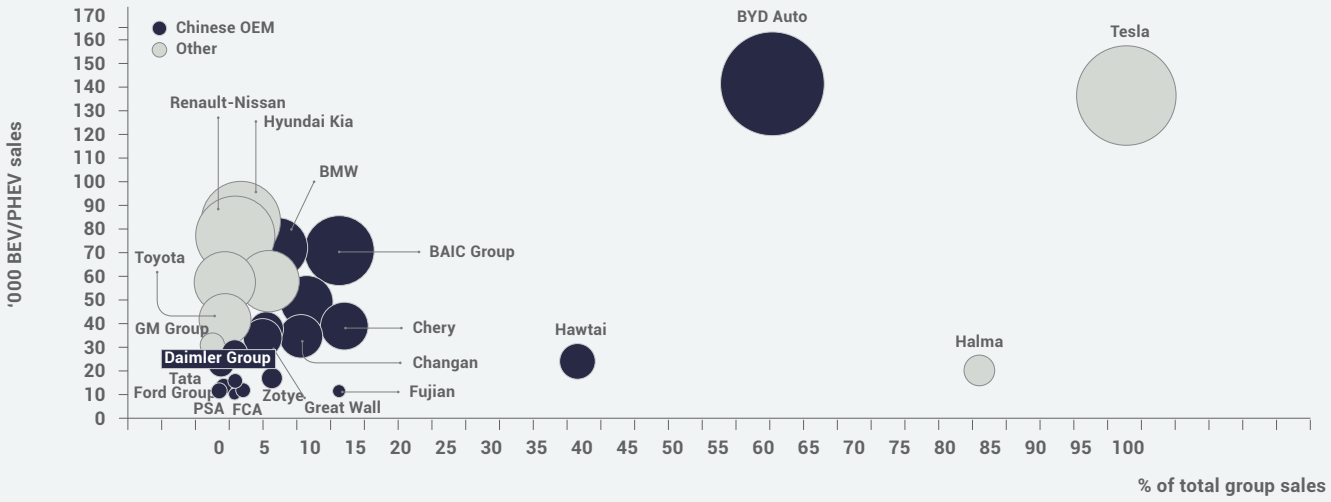
All of which means that both local and international OEMs looking to operate in China will continue to develop zero emissions vehicles as part of their overall strategy in the coming years. As it stands, Chinese OEMs are well ahead of their peers in other markets in this regard, as illustrated in the third chart, which plots EV sales volumes and penetration by OEM for the first six months of 2019. Chinese OEMs as a whole are pushing ahead more quickly towards electrification than automakers anywhere else in the world, and this shows no sign of this slowing down.

Looking at some of the larger Chinese OEMs in turn. At BYD, BEV & PHEV sales already account for well over half of its vehicles sales for the first half of this year, and as a major battery manufacturer its strategic interest is a further push towards electrification over the coming years, across all of its vehicle classes, including buses and coaches where it is by far the world's leading manufacturer. BAIC is looking towards ▶

CHART 3: MAJOR EUROPEAN OEMS PLAYING CATCH-UP ON EV DEVELOPMENT AGAINST CHINESE AUTOMAKERS

EV sales vs total sales

This chart shows OEMs' total number of BEV/PHEV sales compared with the percentage of total group sales. You can see that European OEMs have a lot of catching up to do, especially compared with their Chinese counterparts.



Source: Rho Motion

100% EV penetration by 2025, when it will end production of ICEs, Chery is aiming to produce 200,000 vehicles per year by 2020, and Geely plans to electrify 90% of its range by 2020, targeting 30 electric and hybrid models. It is also looking to develop a fuel cell vehicle by 2025.

SAIC Motor, China's largest carmaker and the local partner for Volkswagen and General Motors, has a strategy focussed on NEVs and intelligent connected cars as well as overseas expansion. SAIC Volkswagen is moving forward with new EV plant Shanghai, and is scheduled to start operation in October 2020, with an annual production capacity of 300,000 vehicles. SAIC announced it plans to install 50,000 public charging points with an investment of $3 billion by 2020.

So how will a change in the subsidy regime affect OEM strategy?

To deal with the issue of whether OEMs will now pivot towards fuel cell vehicles (FCV) owing to a continued subsidy structure for those vehicles, we make the following points. Firstly, the only reason the subsidy for FCV remains in place is because uptake, and therefore fiscal outlay, has been minimal, and it may still be removed shortly anyway.

> The curtailment of subsidies both this year, and into the future, is more a sign of EV market maturity and health over the longer-term

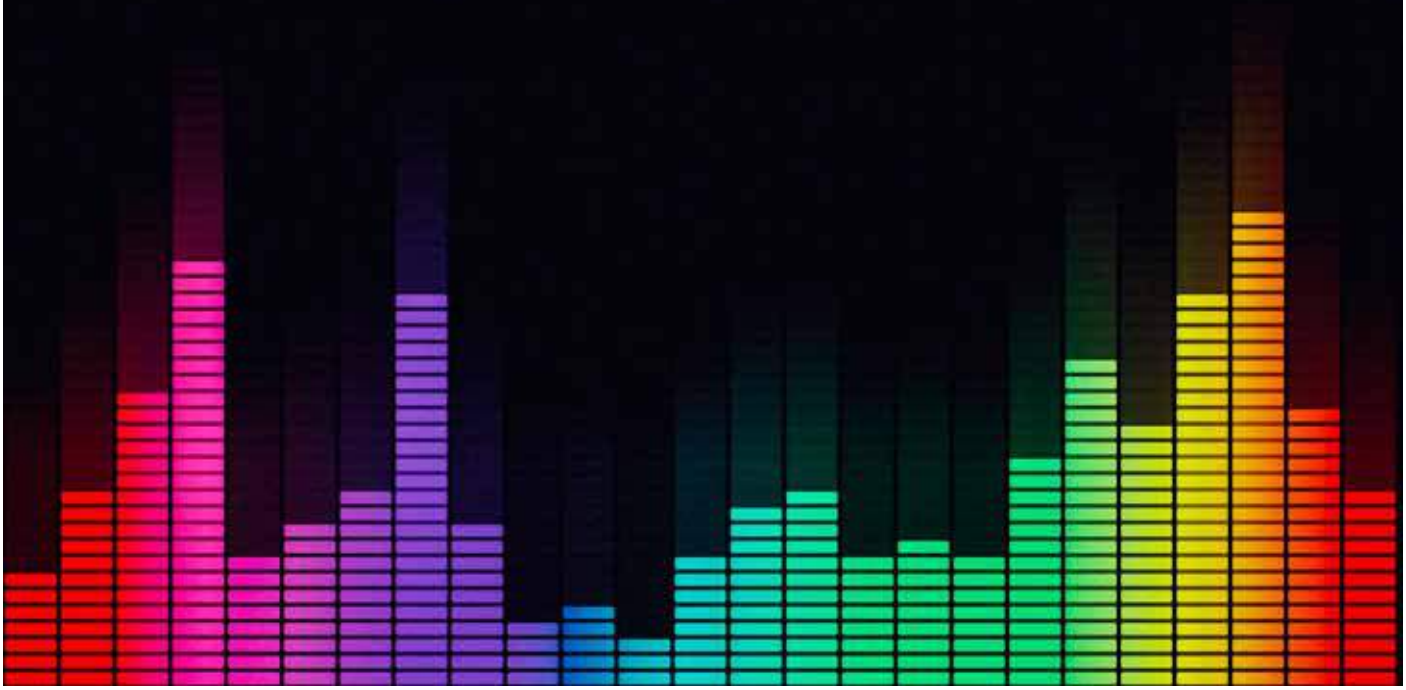
Second, it would seem imprudent for the OEMs and the government to move away from a lithium-ion battery and EV industry where they have a strategic advantage, and where significant investments have already been made, to one where neither of those things is true.

Given that subsidies have to date been range based, their removal is more likely to have an impact on both the type of vehicles coming onto the market and their battery chemistry. As there is no longer an overriding incentive to produce longer range vehicles to qualify for subsidies, we expect that there will be a move towards an increased proliferation of lower range urban focused vehicles, which will be targeted at a market where durability and cost are key, which suggests that an uptick in LFP market share in the battery mix is likely over the coming years.

As such, the curtailment of subsidies both this year, and into the future, is more a sign of EV market maturity and health over the longer-term, and a transition to an industry to one that will need to sustain itself through scale, efficiency and ongoing innovation, in this regard China is likely setting a template for other markets to follow.

CHART TOPPERS

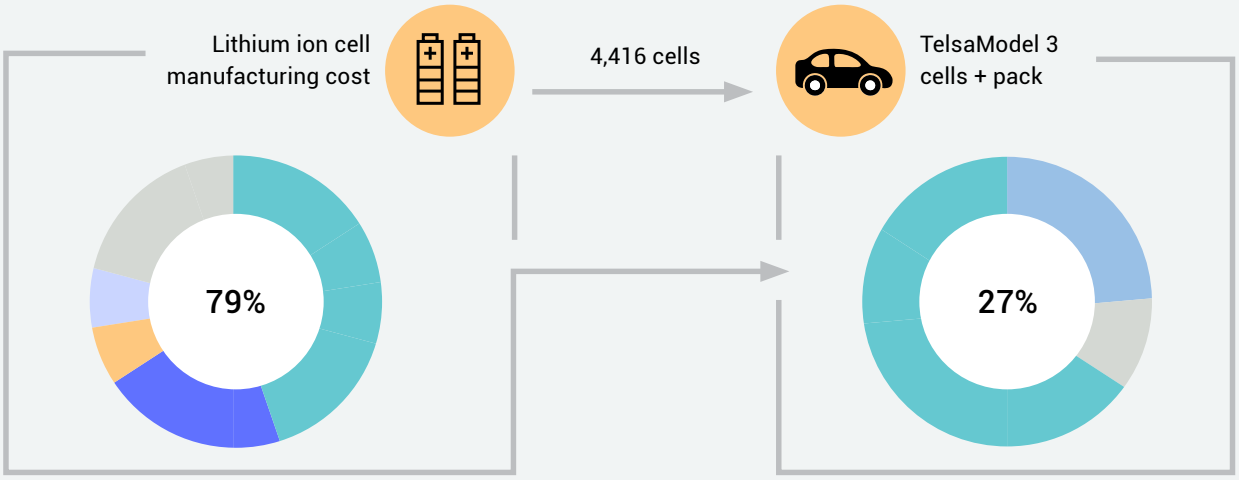
Having concluded the final leg of the **Benchmark 2019 World Tour** here we highlight some of the key charts and data we've presented during the course of this year



THE COST OF BATTERIES IS THE DECISIVE FACTOR IN THE SUCCESS OR FAILURE OF EVS

Batteries are the biggest EV cost

As Tesla is well aware and new entrants to electric vehicle production are beginning to learn, the cost of producing batteries is the decisive factor in the success or failure of electric vehicles. With a very different cost structure to internal combustion engine vehicles, the auto industry's incumbents are having to adapt fast to successfully transition to EV businesses.



Source: Benchmark Mineral Intelligence

MISCONCEPTIONS ABOUT QUALIFICATION COULD CAUSE DELAYED DELIVERY AND CASH FLOW TIMELINES DURING CONTRACT EXECUTION START-UP

Qualification misconceptions

There are a number of misconceptions surrounding the qualification process for battery raw materials. Qualification is not a box-ticking, one off exercise but can be a long-process requiring input from technical, commercial and production teams. It is critical for producers to understand these processes to successfully deliver within the expected timeframes to and with the expected cash flows.

Common misconception		Reality
1	Qualification is a one-time process for my company	■ Most intense before initial supply introduction ■ Full qualification for each new line commissioning ■ Smaller qualification exercises for major flowsheet changes ■ Ad-hoc audits if regulations change
2	The customer's qualification process is immutable	■ Process is malleable based on results ■ Legal/policy changes could occur between contract signature and production
3	Qualification is squarely on the technical team	■ Plant operating team will be heavily involved ■ Commercial team plays project management role
4	Qualification only involves the specific product, and not company processes	■ Plant operations will be discussed in depth ■ Preventative maintenance and reliability ■ Customer wants to see effective risk plan is key mitigation strategy at plants
5	Qualification will not get in the way of my contract being carried out	Kiss of death

Source: Benchmark Mineral Intelligence

QUALIFICATION IS AN ACTIONABLE TOPIC FOR DISCUSSION ACROSS THE VALUE CHAIN

Qualification relevant to all stakeholders

Qualification is a topic that the entire supply chain should discuss and consider. Whether financiers are looking to fund a project, cell producers looking to qualify raw materials or OEMs intending to source battery cells, understanding the qualification processes involved in your value chain should not be ignored. This even extends to government level as regulations or laws can affect the qualification process considerably with the potential for unintended consequences.

Financiers

- Ask management teams about their qualification discussions with major buyers
- As project nears production, the lack of a clear qualification plan agreed with potential buyers is concerning

Mining & chemicals

- Prepare a clear 1-page or 3-slide qualification plan that can be disseminated to major stakeholders
- Bring up qualification from the first customer visit
- Have technical team engaged early in the customer process
- Codify high-level qualification plan in offtake contract

Battery producer

- Be prepared to present your qualification steps to supplier as early as the initial meetings
- Codify high-level qualification plan in offtake contract
- Make sure appropriate resources can be dedicated to qualification to ensure contract execution timeline is met

Auto OEM

- Understand your cell makers' qualification plan and determine who takes ownership of qualification process
- Codify high-level qualification plan in offtake contract
- Make sure appropriate resources can be dedicated to qualification to ensure contract execution timeline is met

Government

- Before making major regulatory changes as related to manufacturing process or specific battery materials, consider the impact that such changes could have on an already intense qualification process, the impact on domestic industry's qualification timelines, and the downstream impact of that timeline delay to broader domestic supply chain

Source: Benchmark Mineral Intelligence

HOW THE SUPPLY CHAIN LOOKS FROM ITS MANY DIFFERENT STAGES

Different vantage points

The supply chain looks very different depending on where a player sits within the supply chain. These views have also changed over time, particular for automotive majors who have had a humbling experience as their perceptions of the supply chain have had to change dramatically over the past five years.

How do autos view the supply chain?

Arrogance (2016-2017)

- Commodity industries will always have supply available
- The supply chain is in place to serve us, the OEM

Realisation (2018-2019)

- These are speciality chemicals, not as straight forward as commodities
- We can't buy lithium like we buy windscreen wipers and dictate all the terms

Passive involvement (2019-2020)

- We should sign long term contracts with majors
- We should consider offtakes with junior miners

Active involvement (>2020)

- We need to invest in a new mine
- We need control of supply as a hedge and for actual supply for our EVs
- The more supply we control, the more sway we will have in the supply chain over cathode and battery makers

How do battery producers view the supply chain?

Capacity & location

- Capacity needed to fulfil major auto contracts
- Raw material worries- exposure to volatility
- Strategic locations in major auto regions are key - China, Europe, US

How do miners view the supply chain?

Capacity & location

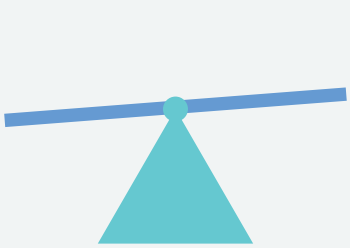
- Volume and lowest quartile key to success
- Large long life assets needed as a result
- Strategic locations - jurisdictions in key regions, much like battery makers

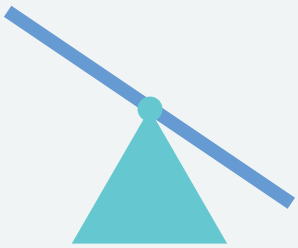
Source: Benchmark Mineral Intelligence

HOW DO SUPPLY CHAIN RELATIONSHIPS PLAY OUT IN 2019?

Balance of power now

Miners are volume/revenue focused, whereas speciality chemicals companies have specific end users, which means they tend to do business on long-term contracts. Chemical companies have to keep producing through low prices, but commodity companies can turn the tap off. The balance of power is slightly in resource company's favour. Autos are more likely to take price risk than battery companies, and could bypass them completely and control the supply chain downstream. The balance of power sits with automakers.





Miners	Chemicals	Battery	Autos
■ Volume ■ Best revenues possible at all times	■ Prices not as malleable ■ Long-term contracts - therefore relationships crucial ■ Obligations to keep supplying	■ Need to keep producing quality cells ■ Controls qualification process ■ Pass material price risk on to autos	■ Willing to take cost risk ■ As a result, wants control of the supply chain

Source: Benchmark Mineral Intelligence

HOW DO SUPPLY CHAIN RELATIONSHIPS PLAY OUT IN 2025?

What lies ahead

As commodity companies understand that battery raw materials need a chemical speciality focus they will evolve to move down the value chain and possibly merge with chemical companies. As auto's EV plans become bigger and crystallise the battery numbers required will become clearer. As autos take on more pricing risk and control more of the downstream supply chain we may see them acquire battery makers. Battery plants will become geopolitical tools – markets may allow automakers to make these acquisitions, but will politicians?

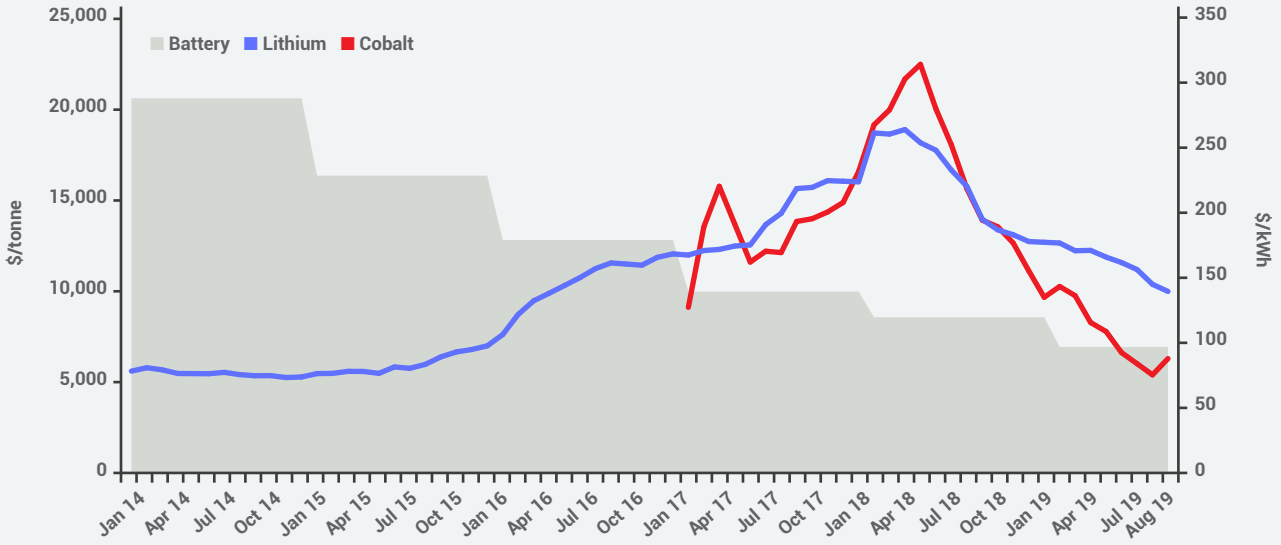
Miners	Chemicals	Battery	Autos
■ Understanding that 21st Century commodities have a speciality element ■ Evolve to move down value chain	■ Will need raw material control to stay competitive ■ Commercial IP and processing experience won't be enough	■ Will end up with 3 to 5 major auto consumers ■ Because they didn't take on material price, margins get eroded	■ Control all of downstream ■ Quality, volume and cost of batteries will define business

Source: Benchmark Mineral Intelligence

LITHIUM ION CELL COSTS HAVE CONTINUED TO TUMBLE DESPITE RAW MATERIAL COST VOLATILITY

Cell costs v raw material costs

A surge in battery raw material costs – notably for lithium and cobalt – would have led many to believe that there would be a corresponding increase in the costs of producing battery cells. In fact, the opposite has happened. As prices rose for input raw materials through 2015-2018, battery cell production fell to below $150 per kWh.

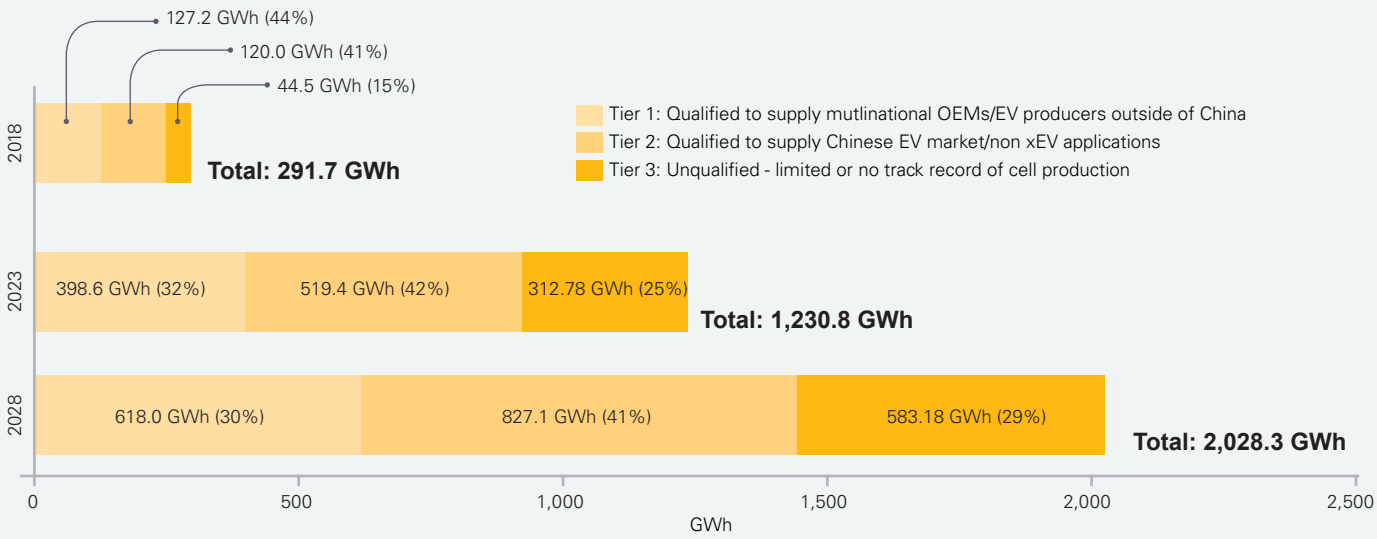


Source: Benchmark Mineral Intelligence

DESPITE BIG COMMITMENTS JUST 30% OF FUTURE CAPACITY HAS BEEN QUALIFIED BY MULTINATIONAL OEMS

The battery industry's three tiers

There are now over 100 megafactories with over 2TWh of production in the pipeline for 2028 but if you break down the numbers into the three tiers of battery cell production it paints a different picture. While in 2018 almost 44% of battery cell capacity came from tier one producers, looking forward to 2028 this figure falls below 29%. This illustrates the number of new projects coming online from relatively inexperienced cell manufacturers in China.



Source: Benchmark Mineral Intelligence Megafactory Assessment {Sept 2019}

RAW MATERIAL PRICE IMPACTS ON NCM 622 POUCH COSTS

Cell cost scenarios

This chart outlines a number of scenarios ranging from recent levels to what we've dubbed Armageddon and shows the effect of fluctuating cobalt sulphate, nickel sulphate, and lithium carbonate prices on battery cell and battery pack costs. These are rough numbers based on a 50GWh Chinese megafactory. This highlights how changing raw material costs can affect a the costs of production and ultimately a manufacturers bottom line.

	Scenario 1 Today's price	Scenario 2 Armageddon	Scenario 3 Volatility as norm	Scenario 4 Tight spot
$CoSO_4$	$6.20/kg	$22.50/kg	$9.30/kg (+50%)	$9.30/kg (+50%)
$NiSO_4$	$4.12/kg	$4.12/kg	$3.09/kg (-25%)	$5.15/kg (+25%)
$Li2CO_3$	$8.90/kg	$24.75/kg	$13.35/kg (+50%)	$13.35/kg (+50%)
Cell cost	$101.47 /kWh	$148.37 /kWh + 46%	$108.31/kWh + 7%	$117.31/kWh + 16%

65 KWh pack-cell cost

Calculations assume all other input/manufacturing costs remain the same. Cell production based on up to 50 GWh facility in China

Source: Benchmark Mineral Intelligence

RAW MATERIAL COST IMPACTS — NCM 622 VS 811 POUCH — NICKEL ANALYSIS

Nickel prices and 811 adoption

This scenario shows how an increase in the nickel sulphate price of approximately 28% can erode the economic advantages of 811. Although this is a substantial increase, the sustained lack of investment in the supply chain in recent years due to low pricing and the forecast increase in battery nickel demand shows this isn't beyond the realms of possibility. This is a basic example, ignoring margins and taxes and also fluctuations in other raw material input prices, but it highlights how sensitive cell production is to raw material costs.

	NCM 622 Today's price	NCM 811 The nickel question
$CoSO_4$	$6.20/kg	$6.20/kg
$NiSO_4$	$4.12/kg	$5.27/kg
$Li2CO_3$	$8.90/kg	$8.90/kg
Cell cost	$101.47 /kWh	$101. 72/kWh

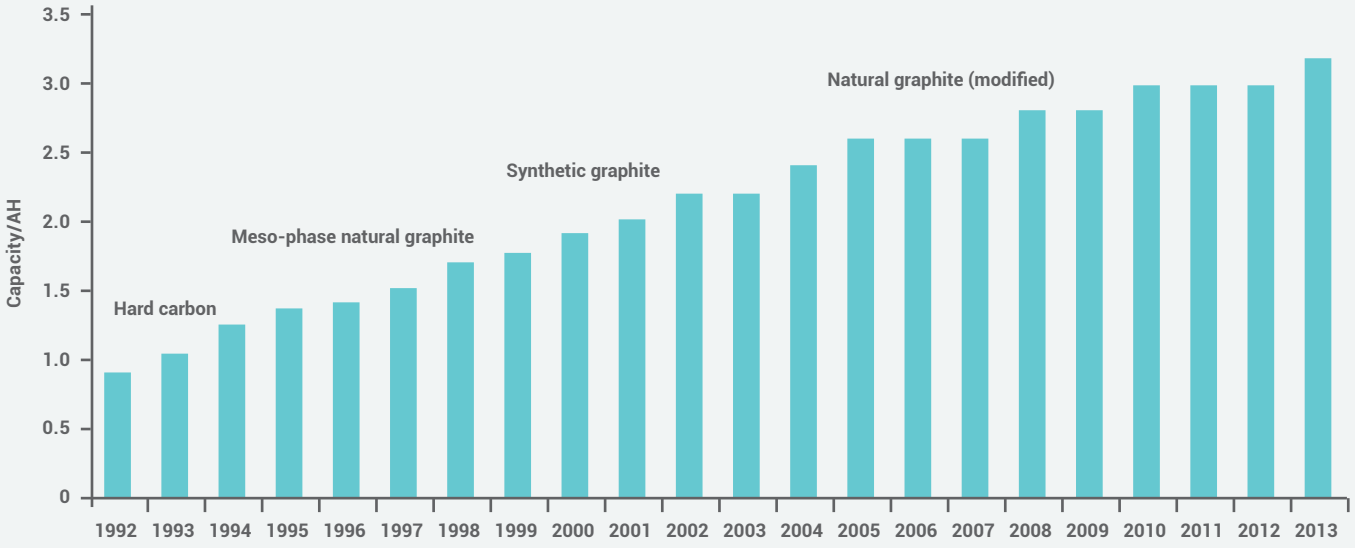
- Nickel prices at recent highs but a further +28% increase equalises NCM 622 vs 811 on raw material costs alone
- This is equal to a contained nickel price of around $23,600/tonne
- This does not mean nickel metal price needs to reach that level but nickel price + sulphate premium

Source: Benchmark Mineral Intelligence

TYPICAL 18650 HIGH ENERGY CELL— ANODE

Anode material over time

Capacity increases from synthetic graphite contributed well to increases in battery energy density after the hard carbon and meso-phase anode materials in the early days of lithium ion batteries. Since 2005, surface modified natural graphite has grown gradually and some of the anode material is blended with synthetic graphite. However, the capacity of graphite has reached a saturation point in recent years and adding silicon to the anode offers further capacity increases in the anode.

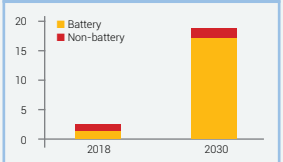
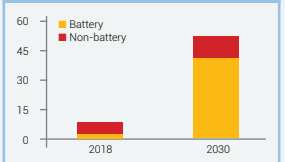
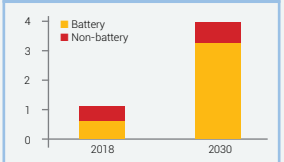
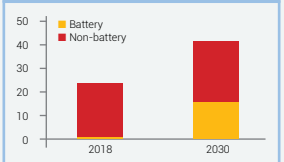


Source: ???????

LOOKING FORWARD TO 2030: BATTERY RAW MATERIAL DEMAND

Long term raw material needs

The chart below shows demand for lithium, natural flake graphite, cobalt, and primary nickel in 2018 and forecast out to 2030. Each raw material has an associated capex cost and expected growth rates, along with key challenges and primary locations. Right now, we're seeing plenty of investment downstream in battery cell and electric vehicle production but this needs to be matched with raw material supply.

	Lithium demand (LCE basis) 2018-2030 (in OOOs)	Natural flake graphite demand 2018-2030 (in OOOs)	Cobalt demand 2018-2030 (in OOOs)	Primary nickel demand 2018-2030 (in OOOs)
				
	CAGR 18.1% 2.0% (Non-battery) 21.4% (Battery)	CAGR 16.6% 5.5% (Non-battery) 25.6% (Battery)	CAGR 11.4% 2.9% (Non-battery) 15.4% (Battery)	CAGR 4.8% 1.8% (Non-battery) 29.0% (Battery)
	Total Capex required[1]: $24bn	Total Capex required[2]: $13bn	Total Capex required[3]:>$50bn combined in Cu & Ni	Total Capex required[4]: $39bn
Challenges	■ Quality & consistency of product ■ Lack of chemical experience ■ Lack of a futures price ■ Potential oversupply in medium-term	■ Substitution due to solid state battery adoption ■ Confusion over role of synthetic graphite ■ Not seen as a core battery raw material	■ Environmental concerns ■ 70% DRC raw material ■ (brand image, lack of western investors) ■ High cost/substitution ■ By-product	■ Near-term over-supply ■ Historically low price ■ Laterite challenges ■ Non-core assets ■ Recycling ■ Sulphuric acid supply
Locations	■ Latin America ■ North America ■ Australia ■ Africa ■ Europe ■ China	■ Africa ■ Brazil ■ North America ■ China	■ DRC, ■ Australia ■ North America ■ Russia	■ Indonesia ■ Australia ■ Philippines ■ PNG

1. Capex includes processing capacity to either a carbonate or hydroxide 2. Capex estimate includes processing to spherical uncoated
3. Cobalt is today, and is expected to remain in the long-term, a byproduct of nickel and copper production 4. Capex is average of Class 1 and NPI/FeNi production

Source: Benchmark Mineral Intelligence

BENCHMARK'S SIMON MOORES ON IDENTIFYING THE BULLS*&T IN BATTERY METALS ANALYSIS

Benchmark Minerals' Managing Director **Simon Moores** recently spoke to **Stockhead** about battery raw material analysis, visiting the supply chain, and what makes a good price reporting agency. Read the interview here.

For punters looking to find accurate and relevant prices and info on the lithium-ion supply chain — what qualities make a good PRA?

"For me, it's really simple. Fundamentally, all the PRAs covering this space – lithium, graphite, cobalt, nickel – collect their price data in a journalistic way.

The only differentiating factor between them is expertise in the space – are they specifically focused on [battery metals], or do they cover a wide range of minerals and metals?

Do these analysts know the lithium industry, for example? How long have they worked in the industry, and more importantly – does the industry know them?

This is very important. When you are collecting very sensitive price data you have to be sure the information you're getting is accurate.

The second thing is resources – how many people have they got working on this, specifically?

It's a balance of resources, experience and specialism. All the other PRAs are much bigger organisations covering a vast array of minerals and metals; **Benchmark** are the only guys in the space that focus solely on the lithium-ion supply chain. We do nothing else.

When I launched **Benchmark** in 2014 there was no one else specialising in the lithium-ion supply chain.

It was only when the price spike happened in 2016/2017 that all these big companies – Fastmarkets, Platts, and so on – decided that they needed to get in. It was very reactive."

How can people tell the difference between experienced/ not so experienced analysts?

"In the last four months we have hired people from Tesla [and lithium majors] Albemarle and SQM to add to the experience we already have.

That shows you where we are as a business.

But general investors or people sitting outside the actual supply chain won't know [an analyst] so it comes down to reputation. You need to be able to stand behind all the data and analysis you put out there.

This is why we do the **Benchmark World Tour**. We can stand up, honestly answer questions, and be transparent with our knowledge. It gives confidence to the market and those people outside the supply chain."

How many PRAs physically walk through factories and mine sites? Is this an important part of the data collection?

"We visit mining operations, battery plants, automotive OEMs [original equipment manufacturers] – the whole supply chain.

That is a core part of our data collection. I don't think the other guys do it, to be honest.

Our lithium price assessments, for example, cost four to five times our nearest competitor which means that it is a different product.

We publish 10 lithium chemical prices, 1 spodumene price, and an index price every month.

And it's not just about having accurate and trusted lithium prices – which we have – it's also about the context around that price.

Having that context is absolutely crucial for people making big investment decisions. How did we get that number, but more importantly – what does it mean?

They need to know the context, not just the price, and we can provide both. That is a key differentiating factor for us."

In June, the London Metals Exchange (LME) partnered with Fastmarkets instead of Benchmark on a new lithium futures contract. Was that a shock decision?

"I can honestly say that the lithium industry was shocked."

We were at a lithium conference in Santiago [Chile] at the time, and there was certainly a down and depressed feeling that we didn't get it.

But the LME is new to lithium — it doesn't define lithium.

For the LME lithium price to work it must have the trust of industry, which it doesn't. It all started very badly.

The industry still wants to smooth out volatility in lithium prices but there are other mechanisms they want to use. Benchmark is helping develop those with the industry — that's the future."

More than just a lithium data point

BENCHMARK MINERAL INTELLIGENCE

To accurately and precisely assess lithium prices takes expertise, specialism and resource. Benchmark Minerals is proud to be the industry's reference price and have its data used to negotiate supply chain contracts

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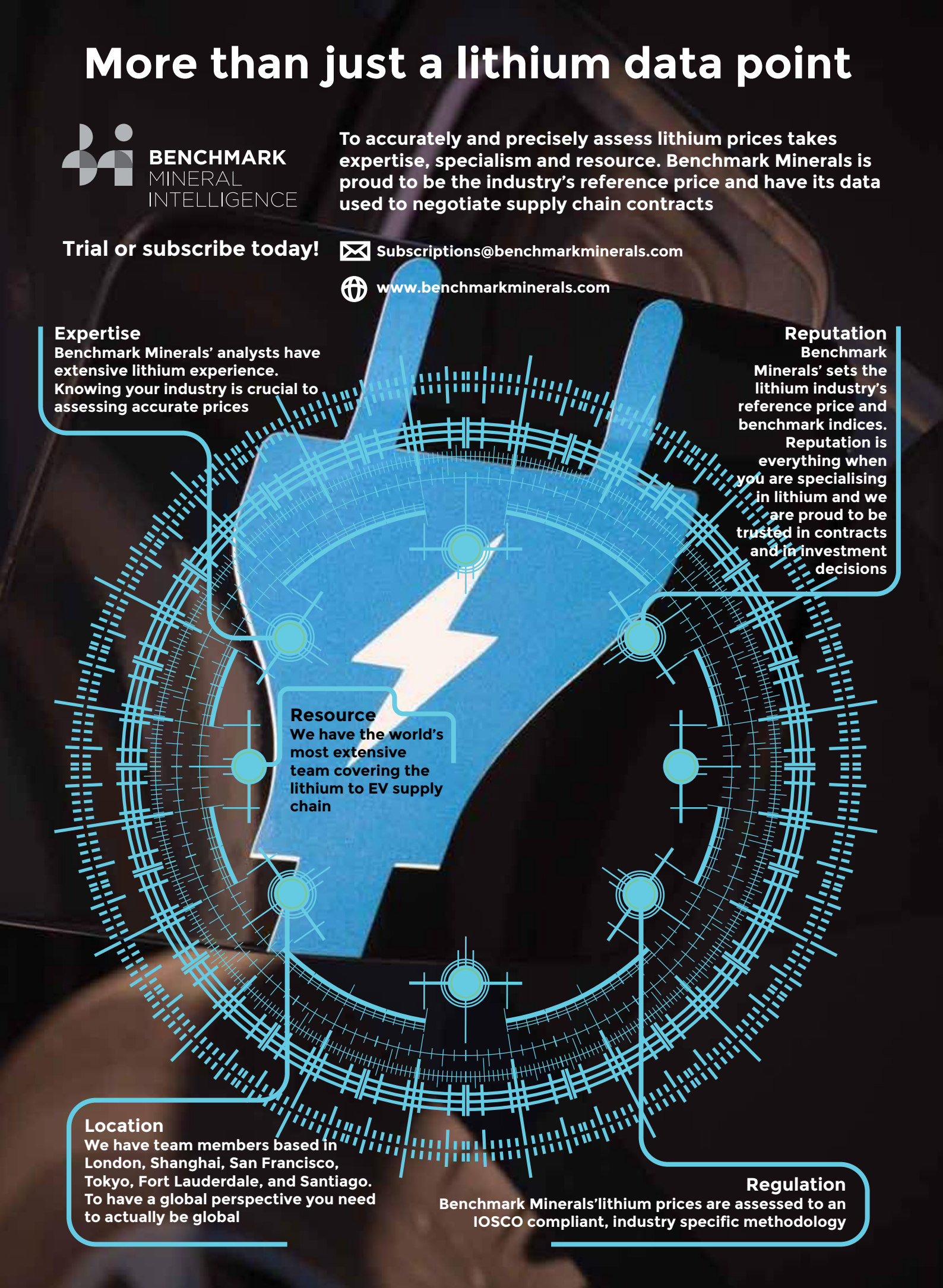

Expertise
Benchmark Minerals' analysts have extensive lithium experience. Knowing your industry is crucial to assessing accurate prices

Reputation
Benchmark Minerals' sets the lithium industry's reference price and benchmark indices. Reputation is everything when you are specialising in lithium and we are proud to be trusted in contracts and in investment decisions

Resource
We have the world's most extensive team covering the lithium to EV supply chain

Location
We have team members based in London, Shanghai, San Francisco, Tokyo, Fort Lauderdale, and Santiago. To have a global perspective you need to actually be global

Regulation
Benchmark Minerals'lithium prices are assessed to an IOSCO compliant, industry specific methodology

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*The Government of China through the State Bureau of Material Reserves' acquired the largest strategic cobalt stockpile in excess of 5,000 Mt, in 2015-2016.