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BENCHMARK MINERAL INTELLIGENCE

CRITICAL MINERALS & METALS | DISRUPTIVE TECHNOLOGY | EMERGING MARKETS

CRUDE AWAKENING

Benchmark Mineral Intelligence Q4 REVIEW 2020 Lithium Price Rises | EU Sustainable Batteries | 2020 In Review

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Apple is once again looking to enter the EV scene, as other Big Tech companies continue to circle

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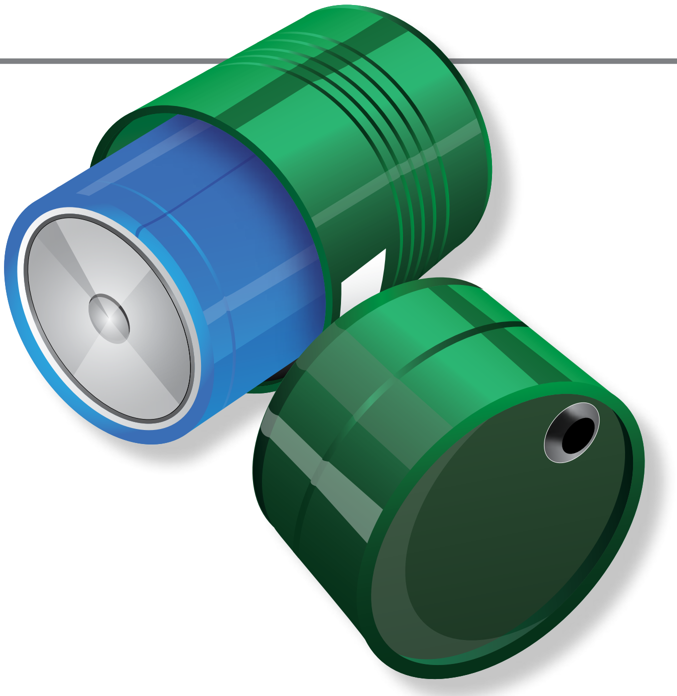

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Ahmed Mehdi, Principal Consultant, **Benchmark Mineral Intelligence**, explores the relationship between oil and lithium ion and the implications of the energy transition on both industries

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HIGH PURITY MANGANESE OPPORTUNITY SERVING THE ELECTRIC VEHICLE MARKET

PROJECT HIGHLIGHTS	
Net Present Value	C$505M (US$357M)[1] C$389M (US$275M)[2]
IRR	82.1% after[2]
Capex	C$155M (US$110M)[3]
Cash Costs	US$1,866/t HPEMM
Project Life	10 years
Production Rate	30 - 40kt per annum of contained manganese
Mining Method	Open pit, free-digging
Resource Grade	27.3% MnO

[1]Pretax [2]After tax [3]Capex

GIYANI METALS CORP. IS A HIGH PURITY MANGANESE DEVELOPMENT COMPANY WITH PROJECTS IN BOTSWANA, AFRICA

THE COMPANY'S FLAGSHIP K.HILL PROJECT IS A LOW CAPEX, LOW OPEX, NEAR-SURFACE DEPOSIT THAT IS CURRENTLY GOING THROUGH A FEASIBILITY STUDY TO PRODUCE HIGH PURITY MANGANESE

info@giyanimetals.com https://giyanimetals.com

Apple-Hyundai EV partnership the next major step of the lithium ion battery era

The start of 2021 has seen the return of yet to be confirmed reports that Apple is looking to enter the electric vehicle scene with South Korea's Hyundai.

Local Korean news reported that the two companies will sign a partnership in Q1 to develop autonomous electric vehicles and begin production by 2024.

This is not the first time Apple has flirted with the electric vehicle market – having been circling since at least 2014 with its Project Titan division.

Apple's electric vehicle ambitions were brought into the public domain in 2015 when it came to light that the company was being sued by battery producer A123 Systems for attempting to poach its staff. Apple's battery venture had at the time recruited hundreds of employees according to the Wall Street Journal.

> With the auto industry changing at a faster pace than ever, it seems it's only a matter of time before Apple and the world's largest technology companies crash the electric vehicle party

Apple ultimately settled with A123 out of court in mid-2015, and since then there have been continued rumours about Apple's electric vehicle ambitions but still nothing concrete.

ELECTRIC VEHICLES THE OBVIOUS NEXT STEP FOR APPLE & BIG TECH

In 2019, Herbet Diess, Volkswagen's Chairman, outlined the tectonic shifts facing the auto industry: "The car will become the most complex internet device we have known so far, the car will become a software product."

Existing automakers such as Volkswagen are having to balance their existing ICE (internal combustion engine) business while repositioning themselves for electric vehicle demand.

But as the quote from Diess suggests, with the changes being brought about by electric vehicles, the automotive sector is ripe for disruption from the tech sector.

Technology companies are keenly aware of this and electric vehicles have been on their for some time. Whether Apple's Project Titan, Google's development of autonomous vehicles, or Amazon's partnership with Rivian to develop a bespoke electric van, the opportunity is there although it has not been fully realised yet.

This phenomenon is not limited to the west as shown by the recent news that Baidu, China's answer to Google, just announced a partnership with Chinese EV-maker Geely to produce smart electric vehicles.

Having disrupted and reshaped the mobile phone technology market in the late 2000s and early 2010s, for Apple a move into electric vehicles makes the most sense. Central to both the success of the bulk of Apple's products – the iPhone, iPad, Macbook, Apple Watch – and electric vehicles has been the lithium ion battery.

In essence an EV is more akin to an iPhone than a car – it is an iPhone on wheels. The software that drives the car's efficiency is nearly as important as the batteries that power it. Yet EVs are the new technology entering a very well-established auto industry that, despite Tesla's best efforts, has not seen true disruption since it was founded.

With the auto industry changing at a faster pace than ever, it seems it's only a matter of time before Apple and the world's largest technology companies crash the electric vehicle party.


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News Analysis

IN THIS SECTION:

Benchmark's data shows lithium ion cell prices are closing in on $100/kWh but price falls are not guaranteed

LITHIUM SEES FIRST RISE FOR 3 YEARS

Lithium prices see their first sustained rise in 3 years. Benchmark breaks this down, explaining why this is happening, where this is happening, and what this means

Lithium prices within China, as assessed by **Benchmark Mineral Intelligence**, are beginning to rise for the first time in three years marked by rises in Chinese domestic chemical prices throughout Q4 2020, bringing an end to lithium's two-and-a-half year bear market.

Benchmark's Lithium Carbonate, EXW China Battery Grade, prices have increased by 11.7% from an average of $6,000/tonne in **Benchmark**'s October 2020 Assessment to an average of $6,700/tonne at the end of December.

Likewise, prices of **Benchmark**'s Lithium Hydroxide EXW China Battery Grade, have increased during the same period, albeit at a lower rate of 2.6%, increasing from an average of $7,750/tonne in **Benchmark**'s October Assessment to $7,950/tonne and by the end of 2020.

While prices remain low, and flat, around the rest of the world, improving sentiment across the spodumene and chemical sectors is creating positive momentum for contract negotiations from Q1 2021 onwards.

RISING PRICE ENVIRONMENT

For **Benchmark**'s **Lithium Price Assessments**, it is crucial to not only gain the granular detail (data and contextual evidence) that makes us the lithium industry's reference price, but to also be able to call any rising price data points as a prevailing trend.

Since prices began to fall in 2018 there have been periods where both lithium carbonate and hydroxide prices have shown short-term rises. But these increases were isolated and not sustained.

However, this time is proving to be different.

For the last 6 months of 2020, all major lithium chemical prices that **Benchmark** collects were essentially flatlining together in unison for the first time since lithium prices peaked in Q1 2018.

In essence, lithium prices have bottomed out after nearly two years of declining prices.

While prices have bottomed out in the rest of the world, China, as **Benchmark**'s **Lithium Price Assessment** shows, has seen consistent price rises in both lithium carbonate and hydroxide during the same period.

WHY ARE LITHIUM PRICES RISING?

The main driver behind the upward movement of lithium carbonate prices in China is the strong growth in lithium iron phosphate (LFP) cathode which is finding renewed interest in passenger EVs in addition to electric buses.

Although China's EV subsidies have been maintained, there is less incentive – particularly at current raw material pricing – to push towards the higher-nickel chemistries that fuelled the focus on NCM 811 around 2018.

In addition, the improvements that have been made in LFP cell-to-pack design mean that LFP can now compete on energy density terms with mid-nickel NCM variations.

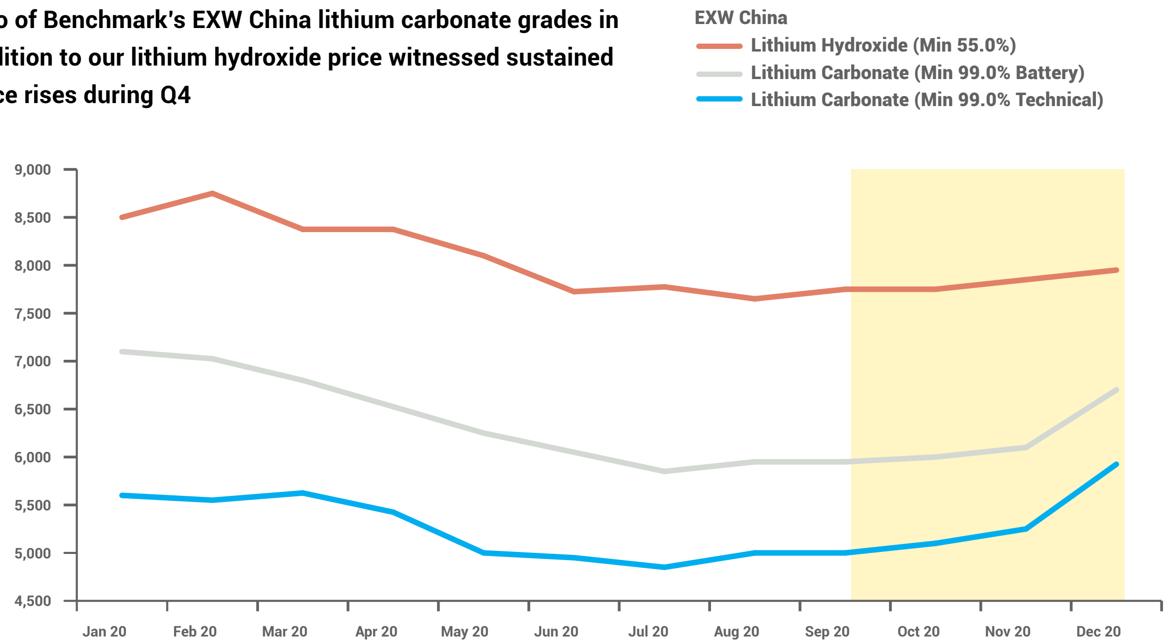
This within the context of improved battery demand sentiment moving into the new year saw a run on lithium carbonate volumes towards the end of Q4.

As was demonstrated in the industry's previous price spike, which began in late-2015, demand growth at a rate that exceeds industry expectations can have profound implications for the future growth trajectory, and China has often proven a bellwether for the direction of global prices, with greater liquidity in the domestic market making pricing more responsive to market imbalances.

While it is too early to say whether this could be replicated in 2021, a reversal in the relationship between carbonate and hydroxide in China's domestic market has often marked the peaks and troughs of lithium's price cycle. The turnaround in pricing in late-Q4 could be an indicator of more turbulence in 2021.

BENCHMARK'S CHINA LITHIUM PRICES WERE POSITIVE THROUGHOUT Q4 2020

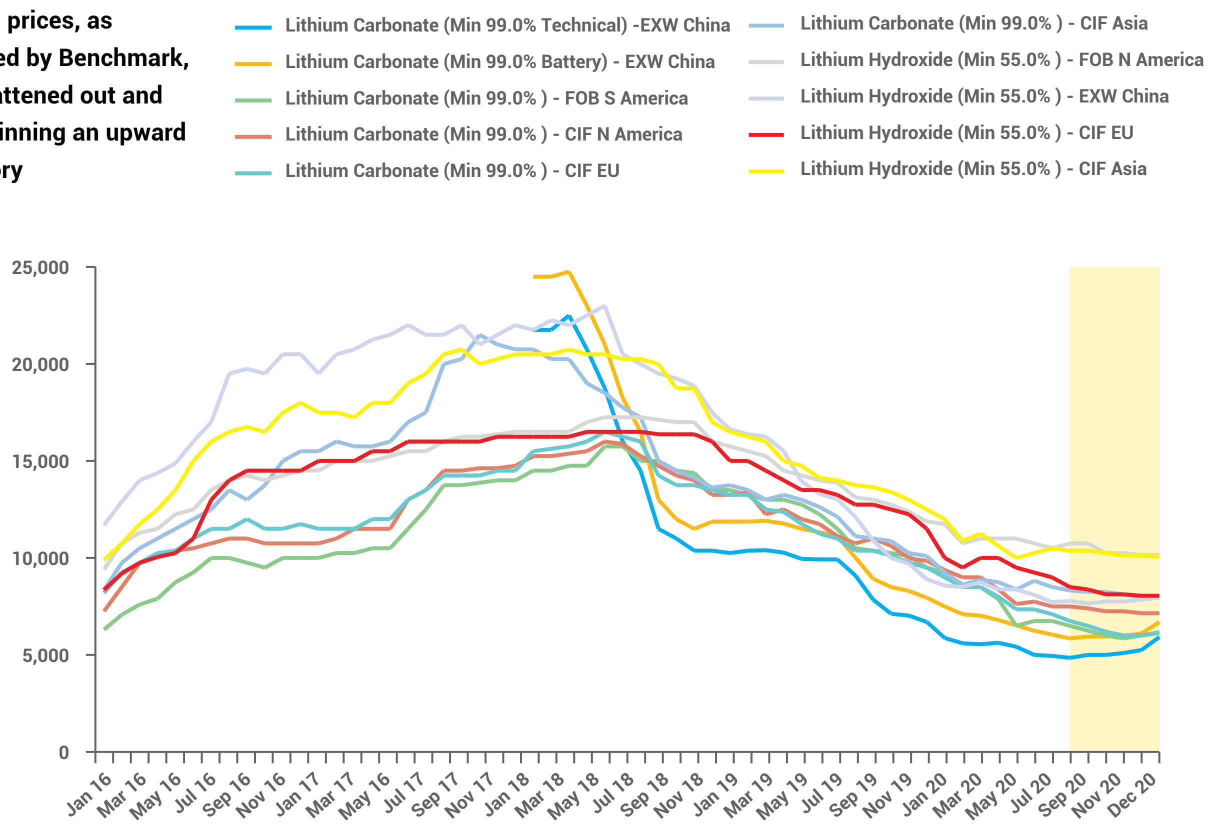
Two of Benchmark's EXW China lithium carbonate grades in addition to our lithium hydroxide price witnessed sustained price rises during Q4



Source: Benchmark's Lithium Price Assessment

WE ARE NOW ENTERING A RISING LITHIUM PRICE ENVIRONMENT

Lithium prices, as assessed by Benchmark, have flattened out and are beginning an upward trajectory



Source: Benchmark's Lithium Price Assessment

LITHIUM'S TROUBLES CONTINUE

Despite early signs of price rises, lithium's low price environment continued to put pressure on hard rock producers

While the lithium market showed consistent price rises during Q4, the consequences of lithium's long-running bear market saw casualties mount with Pilbara's purchase of Altura, Livent taking a stake in Nemaska's Whabouchi project, and Tianqi offloading a share of Greenbushes and Kwinana to IGO.

PILBARA-ALTURA

Pilbara Minerals announced that it has established a conditional agreement to acquire Altura Lithium's operation, which puts it on the path to taking control of Altura's Pilgangoora project.

Prior to Pilbara's announcement it was reported that Altura had entered receivership, having become overburdened by its debt obligations.

The total purchase price announced by Pilbara is AUS $175 million — AUS $155 million upfront, with AUS$20 million delayed, the cash for which Pilbara will source from a future equity capital raise.

As Pilbara's acquisition edges closer to completion, this could mark the start of expected consolidation in the lithium industry as larger producers are able to take advantage of difficult market conditions that see struggling producers become victims of lithium's falling prices.

Both Pilbara's and Altura's projects are located in adjoining land tenements in Pilgangoora, Western Australia. Pilbara's nameplate Stage 1 capacity is 330,000 tpa, while Altura's Stage 1 capacity is 220,000 tpa of spodumene concentrate, enabling Pilbara to significantly expand its capacity at the bottom of the lithium market.

The move to take control of a project on its doorstep will likely see a number of synergies between the operations and enable Pilbara to push down production costs on a USD per tonne basis.

IGO ENTERS LITHIUM

The quarter saw a new entrant to the lithium industry with Australia's IGO Ltd set to take a stake in Tianqi Lithium's operations, securing a 25% stake in the Greenbushes lithium mine and 49% share in the downstream lithium hydroxide Kwinana project in a US$1.4 billion deal.

This deal comes following extended negotiations between Tianqi and China's state-owned Citibank regarding a $1.8 billion loan repayment due in late November. IGO's investment would provide Tianqi with a financial reprieve at the expense of its majority share in Greenbushes and full ownership of Kwinana (now 51%).

The new Greenbushes ownership structure would see IGO holding a 24.99% interest in the operation, Tianqi 26.01% and Albemarle 49%.

However, IGO's financing for the deal, which will come from a mixture of equity raising and debt, has yet to be secured.

The investment will also need to be approved by Australia's Foreign Investment Review Board. Tianqi's knowledge of the need for Australian approval may swayed their decision in the buyer they selected for Greenbushes, knowing that further Chinese investment in such a strategic asset would have likely been rejected.

If these hurdles are overcome, IGO's investment sees it take a stake in the world's largest and lowest-cost hard rock lithium asset, which **Benchmark**'s **Lithium Forecast** shows produced 23% of global lithium supply in 2019.

The deal also sets up IGO to be a vertically integrated producer of lithium chemicals with an interest in the suspended downstream lithium hydroxide Kwinana project.

The 24,000 tpa operation was due to begin operations in H1 2020, however, this was postponed in March with Tianqi citing coronavirus issues.

Tianqi's expansions in recent years have stretched it financially. In particular the decision to purchase a 23.8% stake in Chilean lithium producer SQM for $4.1 billion in 2018, back when lithium prices were at their peak, is now haunting Tianqi.

Financially troubled and suffering under the pressures of poor market conditions, it was no

Credit:Nemaska Lithium

Livent is to take a stake in the Whabouchi project, Quebec, alongside The Pallinghurst Group and Investissement Quebec

secret that Tianqi was looking to offload a share of Greenbushes – and IGO are set to capitalise on this.

Historically, IGO has been focused on gold and copper assets but its investment in Greenbushes and Kwinana highlights the company's increased focus on the battery supply chain, with it already producing nickel, cobalt and copper through its Nova asset.

LIVENT LOOKS NORTH

Nemaska Lithium had stretched itself with capital expenditure overruns as it pursued its vertically integrated spodumene-hydroxide Whabouchi project in Quebec, which had a nameplate capacity of 37,000 tpa of lithium hydroxide. However, the company faced growing financial difficulties and filed for bankruptcy at the end of 2019, and the project ultimately changed ownership this year.

During the quarter, Livent and The Pallinghurst Group formed a joint venture to acquire assets from Nemaska Lithium, and will own 50% of the newly named project, New Nemaska. The remaining 50% will be held by Investissement Quebec.

Livent was previously set to receive material from the project, having agreed an offtake agreement with Nemaska in 2016 for 8,000 tonnes of lithium carbonate. However, at the start of 2019 Nemaska announced it had terminated this agreement and relations soured as Livent confirmed it would take legal action over the disputed supply deal.

Four years on and Livent is again set to source lithium from the Whabouchi project. But this represents a very different structure to its previous offtake agreement with Nemaska Lithium, with greater potential risks as it takes a direct stake in the hard rock operation.

Livent will bring its established hydroxide expertise to the project and, along with Pallinghurst and Investissement Quebec, will be hoping to avoid the issues that Nemaska Lithium faced in developing the project.

LITHIUM'S TURBULENT 2018-2021

Unforgiving market conditions since 2018 have put significant pressure on producers and developers alike.

Benchmark's **Lithium Forecast** shows that at the end of 2019 the lithium market had approximately 25,000-50,000 tonnes LCE of excess material carried over into 2020.

In turn, as **Benchmark**'s **Lithium Price Assessment** shows, spodumene prices continued to fall throughout the first half of 2020, reaching lows of USD $375/tonne (6% Li2O, FOB Australia) between August and October.

With a supply backlog and falling prices majors have delayed and cut expansion plans while wider investment into the sector and development stage companies has been limited.

These pressures have continued to exert themselves on hard rock players since 2018 as spodumene prices have edged lower and lower.

However, it's worth noting that were positive signs for spodumene and wider lithium prices in the second half of the year, with prices flattening in August and rising in Q4.

Not only has this sustained period of falling prices forced developers and producers out of the market, but it has failed to incentivise new production. As such, the likelihood of lithium supply bottlenecks emerging are only going to grow as new capacity fails to materialise.

Benchmark's **Lithium Forecast** shows that while the lithium market has been in surplus, it will tighten in the coming 18 months and we forecast that from 2022 the market will move into deficit. The coronavirus outbreak and the resilience of electric vehicle (EV) demand in China and Europe illustrates how many auto manufacturers have underestimated the growth prospects ahead for battery raw material demand.

TRAFIGURA & DRC IN ARTISANAL REFORM

In Q4, Trafigura and the DRC government took steps to formalise the artisanal cobalt sector and clean up DRC-cobalt's reputation

Trafigura has signed a cobalt supply deal with the Democratic Republic of Congo (DRC) state agency Entreprise Générale du Cobalt (EGC) to work towards reforming working conditions in the country's artisanal sector. Although full details of the arrangement are yet to be revealed, the move is a positive step towards formalisation of artisanal mining in the DRC.

Under the terms of the agreement, Trafigura will finance the establishment of six controlled artisanal mining zones and fund the installation of ore purchasing stations, covering costs related to the delivery of traceable cobalt hydroxide.

Production from these artisanal sites is expected to be traced using QR code technology and EGC will ensure that cobalt marketed by Trafigura complies with OECD due diligence guidelines, providing greater transparency for downstream customers.

Trafigura first piloted a controlled artisanal mining site in 2018 at the Mutoshi concession, in partnership with Chemaf. However, production has been halted since March due to the COVID-19 pandemic.

While the precise format and mechanics of the new operations are yet to be confirmed, Trafigura's enhanced involvement in the sector will help bring confidence to downstream consumers that artisanal cobalt has been mined in a sustainable manner, free from potential human rights abuses.

This also marks further effort from the DRC government to formalise the sector, but this time with the backing of an established cobalt market player.

In February this year the DRC government announced plans to grant the EGC monopoly powers to purchase cobalt mined from artisanal sources in efforts to support formalisation but also to exert greater control over prices, something which caused concern in some parts of the supply chain.

However, few details were released as to how the material would be traced and whether independent companies could audit the process. The DRC would also be unlikely to be able to fund purchase the purchases independently, hence the need to rely on external capital to support any structural changes to the sector.

DRC CAUTION EASING

As **Benchmark** has previously outlined, the changes required to rectify the issues in the DRC cobalt supply chain will not happen overnight, and it will require not only a change in process but also attitude.

There would be no electric vehicle industry without DRC cobalt – which **Benchmark**'s **Cobalt Forecast** shows produced 74% of global supply in 2019. Auto OEMs may be able to source some of their cobalt from outside of the DRC, but DRC-sourced cobalt will continue to be pivotal for the electric vehicle industry as it ramps up production through the 2020s.

As such, there is a growing acceptance in the

Credit: Amnesty International

Trafigura had previously piloted the Mutoshi concession artisanal site in partnership with Chemaf

electric vehicle industry of the need to actively engage with artisanal mining sites in the DRC to help ensure the traceability of the cobalt coming from the region and improve both the working and economic conditions of local people.

Several key stakeholders, including Tesla and Glencore, have pledged to improve working conditions at artisanal sties by joining the recently formed Fair Cobalt Alliance (FCA), a pact which aims to develop and implement a set of responsible mining practices at artisanal and small-scale mining sites in the DRC.

However, some automakers remain reluctant to source cobalt from artisanal mines. VW outlined that it does not currently accept cobalt from artisanal mines, while BMW has signed agreements to procure cobalt from non-DRC sources.

But formalisation of the sector could benefit both the artisanal miners and the auto OEMs.

Through formalisation of the sector, the active involvement of multinational corporations would reduce the influence of unaccountable independent cooperatives in the market, who have largely been able to exploit artisanal miners for their own gain unchecked. As such, artisanal and small-scale workers would be more likely to receive a better price for the cobalt they mine; ultimately improving the economic conditions of workers on the ground.

From the perspective of the EV and battery industries, as they transition ever closer towards nickel-rich (NCM 811/NCA) cathode chemistries, enhanced scrutiny and accountability over the artisanal sector would help to mitigate some of the ESG risks associated with DRC sourcing for downstream consumers, thus dampening the desire to engineer cobalt out of the battery cathode.

ARTISANAL'S ROLE

While significant attention is paid to the ethical implications of DRC cobalt and its artisanal mining sector, the majority of cobalt is procured from non-artisanal sources.

Benchmark estimates that over 90% of the DRC's 2020 cobalt production will come from non-artisanal sources, and that artisanal cobalt from the DRC will represent less than 5% of the world's supply.

This figure, however, fluctuates depending on the prevailing cobalt price. With **Benchmark**'s cobalt hydroxide prices (**Benchmark**'s **Cobalt Hydroxide** (100% Co contained basis), CIF Asia, USD/tonne) down significantly from their April 2018 peak, the share of production from artisanal sources has diminished in cobalt's low-price environment, with the sector further impacted this year by the COVID-19 pandemic. But as the cobalt market tightens and prices rise, the share of production from artisanal sources would typically increase, acting as a 'swing supply' in the market.

However, increased scrutiny and tighter regulations of mining practices at artisanal sites is likely to limit the ability of artisanal cobalt to act as quickly to provide this 'swing supply' in times of market tightness – as traditionally has been the case – and may even fuel higher price levels as the market moves into structural deficit over the coming decade.

For now, there are questions as to how quickly the EGC and Trafigura will be able to expand and ramp up the programme ahead of cobalt price rises.

Further details on the structure of the Trafigura-EGC operations will provide greater clarity on how the future shape of the artisanal sector in the DRC will affect the structure of the market.

COBALT'S SHIFT TO BATTERY-DRIVEN PRICING

Cobalt prices are down considerably from their 2018 highs, but recent price rises illustrate how pricing dynamics are increasingly driven by the battery market

While cobalt prices have shown positive signs of late, there are nuances within the market which highlight the key fundamentals that will likely decide cobalt's future price trend – which is taking its cues less and less from the industrial metal supply chain.

Cobalt metal prices (cobalt battery metal, min 99.8%, EXW Europe, USD/lb) rose 15% between the July 2020 issue of **Benchmark**'s **Cobalt Price Assessment** and the end of October 2020. While these price rises seem promising, the cobalt metal market's outlook in the medium term, at least, has mixed prospects ahead.

News that China's SRB is stockpiling cobalt metal alongside the recovery in some industrial markets has supported these price rises of late. In addition, metal purchasing by the battery supply chain for conversion to cobalt chemicals in summer, linked to hydroxide tightness, supported prices and drew down inventories of those holding stock of the correct physical form of metal suited to conversion.

However, the prospect of a second wave of coronavirus has now become a reality in many regions, with this uncertainty we are likely to continue to undergo reduced activity in the aviation industry, which is the key consumer of the metal.

Despite these uncertainties, cobalt metal has enjoyed relatively good price performance during H2 2020 to date, but what is really driving this?

Such an uncertain demand outlook is usually detrimental for metal pricing – but positive sentiment around battery demand for cobalt chemicals is now the key indicator for future price trends in the market, outweighing the bearish sentiment around metal demand from traditional markets in the near term.

The (electric vehicle) EV market's H2 2020 recovery has been strong, with China having its best quarter in over 12 months and Europe posting surging EV sales numbers, up over 101% Jan-Feb 2020 over the same period a year earlier.

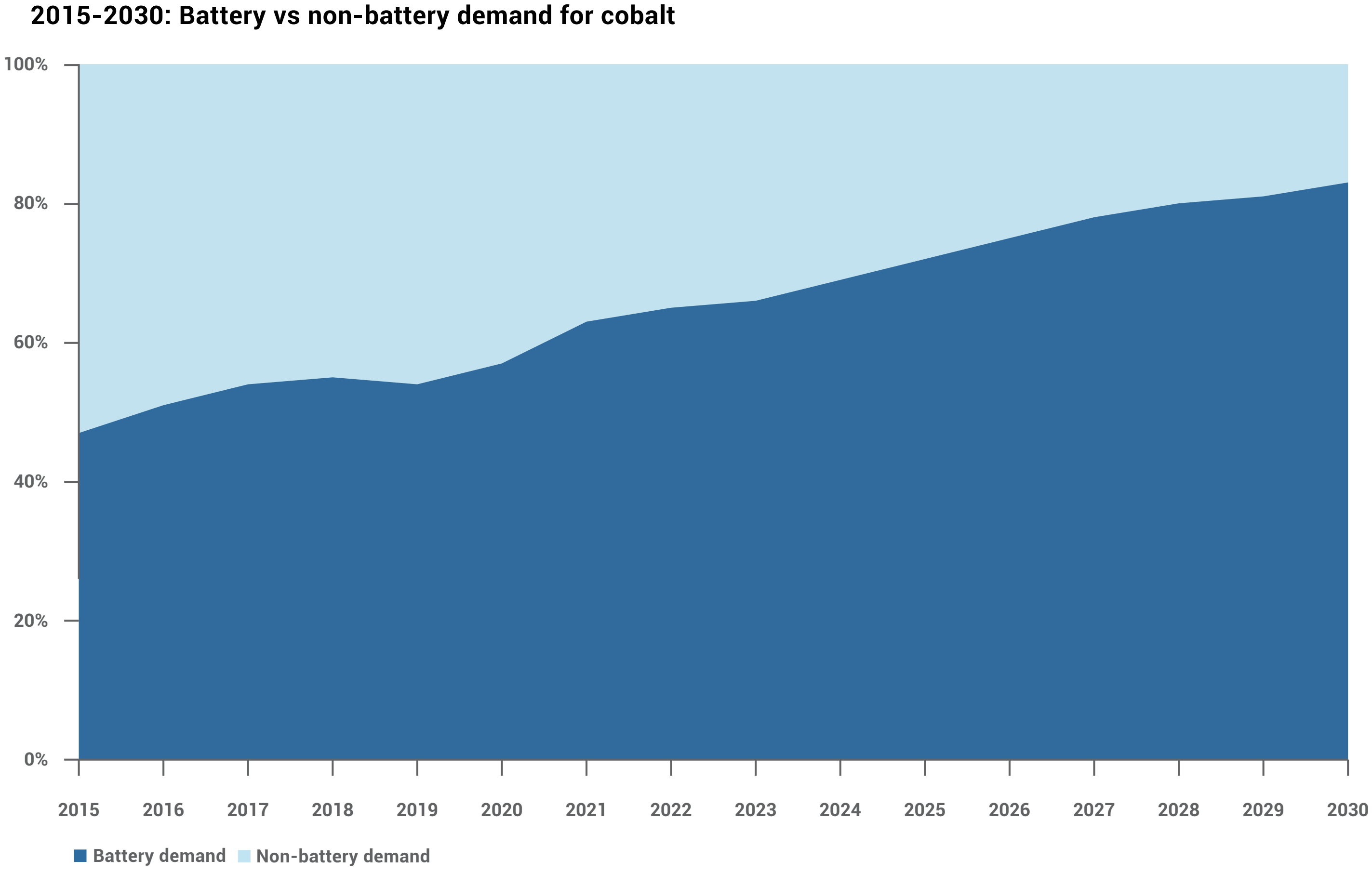
This coupled with better than expected demand for portable electronics applications, linked to home working, and mobility products such as eBikes, has seen the sentiment for the outlook for cobalt demand from the battery supply chain improve considerably from where it stood at the start of the pandemic in early 2020.

As demand from the battery sector grows, it is natural that it becomes the driving force behind prices and sentiment, as the industry is increasingly focussed on the 'new world' of cobalt hydroxide, the battery feedstock to chemical supply chain and the forecasted market balance rather than the 'old world' – cobalt metal and the industrial supply chain.

Whilst activity in the metal supply chain will always remain important to the cobalt market, and especially cobalt pricing, shifting sands are starting to see greater and greater emphasis on cobalt hydroxide, and the availability of this feedstock to the battery market.

The transition to a hydroxide dominated

COBALT'S SHIFTING DEMAND DYNAMICS



Benchmark Mineral Intelligence Cobalt Forecast

prevailing price becomes more evident when you look at the global supply outlook. With only 25% of refined products annually produced in metal form, the balance has been in favour of chemicals for some years, largely focussed on the battery market.

This is even more evident when looking at the supply of intermediate products, with cobalt hydroxide accounting for 70% of unrefined supply in 2020 according to **Benchmark**'s **Cobalt Forecast**, with the proportion set to grow in the coming years.

But this growth in market dominance is needed as demand for cobalt from the battery sector takes up an increasing portion of supply. **Benchmark**'s **Cobalt Forecast** shows that 57% of cobalt demand will come from the battery sector by the end of 2020, with this is expected to rise to 72% by 2025.

With the cobalt world continuing to evolve to meet this new battery gold rush it is demand for feedstock, cobalt hydroxide, and any perceived tightness as we move in to 2021, alongside positive demand sentiment, that have helped support cobalt prices in 2020.

Benchmark's cobalt hydroxide prices (100% Co contained basis, CIF Asia) rose from a low of $21,600/tonne in April 2020, at the peak of concern of falling demand linked to the pandemic, to $27,150/tonne as assessed at the end of October 2020, an increase of 25.7%.

Implied payables over the period increased from 63.0% to 79.3% in October, as concerns mounted over hydroxide availability. Initially, the price increase was due to short term supply tightness linked to logistics disruptions from South Africa's lockdown. But these high prices remained as the demand outlook for 2021 strengthens, and fears begin to crystalise over long term availability, particularly from industrial Democratic Republic of the Congo (DRC) producers.

But is the outlook for cobalt as rosy as it seems? Not quite.

As automakers grapple with trying to reduce the cost of EVs to appeal to a wider market, alongside improvements in the technology, cheaper lithium iron phosphate (LFP) batteries have seen a resurgence in 2020.

Whilst this LFP growth is primarily linked to EVs in the Chinese domestic market, this is now starting to bleed into the international market with Tesla recently starting to export Chinese made Model 3 vehicles to Europe which contain LFP cells supplied by CATL.

Not only is cobalt facing challenges from LFP but also reducing concentrations in cathode technology as the industry continues its march towards high nickel cathodes, primarily NCM 811. Whilst the timeline for this is far from certain, as automakers still face difficulties with deploying the technology, it is looking to be an inevitability at this stage, and will see cobalt use on a per kWh basis continue to fall.

Nonetheless, these challenges do not spell the end for rising cobalt demand, as the expected growth in sales of batteries in the coming years will outweigh falling cobalt intensities in individual cells. **Benchmark** forecasts the battery industry will require a further 100,000 tonnes of the mineral by 2025, a 150% increase over the 5 years.

GEM INCREASES STAKE IN HPAL PROJECT

Indonesian nickel remains key to EV expansions as the country looks to establish downstream battery supply chain capabilities

Leading Chinese battery cathode material producer, GEM, revealed in early January that it had signed a memorandum of understanding (MoU) to double its equity from 36% to 72% in the PT QMB New Energy Materials nickel and cobalt project in Indonesia, to take a controlling stake in the operation, which it has been developing ion partnership with China's CATL and Tsingshan, among others.

The project, located at the Morowali Industrial park in Indonesia, has a design capacity of 50,000 tpa of nickel and 4,000 tpa of cobalt, and had originally been due to begin commercial production in 2022.

However, since its announcement in 2018, the project's development has been hit by numerous setbacks, including delays related to the ongoing COVID-19 pandemic. According to the **Benchmark Nickel Forecast**, the project is set to begin operating in 2022, with an initial production capacity of 10,000 tpa of nickel before ramping close to nameplate capacity later in the decade.

GEM cited a desire to expand its 'strategic control' over nickel resources as the rationale behind the decision.

It hopes to minimise the company's exposure to risk associated with both price volatility and supply security as it ramps up its high-nickel precursor and cathode production capabilities, amid expectations of a shortage of battery suitable nickel supply later in the decade.

Despite the coronavirus-driven slowdown in nickel demand from the battery industry in 2020, GEM has moved to secure its long-term nickel supply in anticipation of robust demand growth from the battery industry and expected supply shortages of battery suitable nickel.

In September last year, GEM signed a long-term supply agreement with PT Halmahera Persada Lygend, a joint venture (JV) between China's Ningbo Lygend and Indonesia's Harita Group, nickel and cobalt sulphate produced at the JV's currently under development HPAL plant on Obi Island, Indonesia.

Starting from 2021, GEM will purchase between 74,400 and 178,560 tonnes of nickel contained in sulphate over an eight-year period - equivalent to between 9,300 and 22,320 tonnes per annum.

CATHODE DEMAND TRENDS FAVOURS NICKEL GROWTH

While nickel and cobalt free LFP (lithium iron phosphate) cathode technology has undergone a renaissance in 2020, driven in large part by cost imperatives and technological improvements, GEM's announcement is a further vote of confidence for NCM's (nickel, cobalt, manganese) future as the predominant cathode technology for automakers.

Benchmark's **Nickel Forecast** shows that the share of demand for NCM cathodes will increase from 46% of the cathode market in 2020 to 78% in 2030, during this time nickel demand from the lithium ion battery industry is set to increase almost 20x.

For cathode and battery cell producers alike, as the battery industry increasingly transitions towards nickel-rich cathode chemistries, direct upstream investment is proving critical to both ensuring a secure and reliable supply of nickel and reducing raw material costs.

BASF & ERAMET AGREEMENT

While, to date, investments in Indonesia have largely been the sphere of Chinese companies, BASF and Eramet signed an agreement to jointly assess the development of a hydrometallurgical nickel-cobalt refining complex in Indonesia in December. The complex would include an HPAL plant located in Weda Bay, to produce 42,000 tpa of nickel contained in an intermediate, and a separate Base Metals Refinery (BMR) targeting precursor and cathode material production.

Following the completion of the feasibility study, if a decision is taken to proceed with the project, the two companies are targeting a start-up of both the HPAL and BMR by the mid-2020s, providing BASF with stable access to nickel and cobalt raw materials as it ramps up high-nickel cathode production over the coming decade.

Furthermore, Indonesia has recently attracted investment from South Korea's LG Energy Solutions, LG Chem's spin-of battery business, as key stakeholders in the supply chain look to capitalise on the region's significant mineral resources. Tesla are also said to be weighing up an investment in Indonesia.

However, questions remain over environmental risks associated with nickel mining in Indonesia. In particular there are concerns relating to coal fired power plants used to power nickel operations, which is unlikely to change in the medium term, deforestation impacts, and the ongoing questions surrounding tailings at HPAL plants. Concerns of the environmental impact of HPAL nickel operations, the PT QMB project and another Huayue Nickel & Cobalt project withdrew applications to use deep-see tailings in Indonesia after strong opposition.

While there are also concerns of ambitious timelines and capital requirements for Indonesia's HPAL projects, **Benchmark** expects Indonesian HPAL to be the most dynamic source of nickel supply for the battery sector through the coming years.

INDONESIA'S DOWNSTREAM AMBITIONS

The importance of nickel to the development of the EV sector has been underlined by the interest shown by major OEMs in developing an integrated supply chain in Indonesia. The Indonesian government said recently it had discussed downstream investments in the EV supply chain within the country with LG Chem, CATL and Tesla.

There seems to be recognition that to tap into Indonesia's major reserves of laterite nickel—which can potentially yield battery-grade quality via HPAL processing—OEMs will need to engage with a government that wants at attract inward investment in both upstream and downstream sections of the EV supply chain. Indonesia has in the past banned the export of nickel ore to (successfully) encourage foreign investment in stainless steel production in the country.

In December, Indonesian government officials claimed that provisional agreements had been established by two of the world's largest cell makers by production capacity: CATL and LG Energy Solution (LG Chem's battery spinoff).

It was reported that CATL had agreed to invest $5billion in a lithium ion battery megafactory, due to start production in 2024, although at this stage there has been no official confirmation from CATL.

An Indonesian government representative also announced that a memorandum of understanding (MOU) had been agreed with LG Energy Solution to establish an integrated battery supply chain in Indonesia in a deal reportedly worth $9.8 billion.

NICKEL DEVELOPMENTS ELSEWHERE

Indonesian HPAL is set to be critical for the EV industry to ramp up at scale. But development elsewhere show that there remains the need for diversified supply.

In October, LG Chem signed an MOU with Pure Minerals for the purchase of up to 10,000 tonnes of contained nickel, both MHP and sulphate, from its TECH nickel processing refinery which is planned for Townsville, Australia. The project will source ore from New Caledonia and use the DNi Process (direct nickel process), an alternative to HPAL.

New Caledonia remains an important supply of nickel and during the quarter Vale signed a binding put option agreement for the sale of its 95% interest in Vale Nouvelle-Calédonie SAS (VNC) with Prony Resources, a consortium led by the current Vale New Caledonia management (50%) and others, including Swiss trading house Trafigura as a minority shareholder (25%)

The proposed transaction is scheduled for completion in Q1 2021 and a reserve of $500 million will be reflected on Vale's consolidated financial statements; subject to a number of conditions being met, including approval by Caledonian authorities and the French state. Vale

The transaction represents the culmination of long-running efforts by Vale to divest from VNC, due to the financial burden of operating the mine.

The company unsuccessfully looked to sell the mine in 2017, before re-igniting attempts towards disposing the asset at the end of 2019, which included a re-organisation of the operation's flowsheet from nickel oxide production to mixed hydroxide precipitate (MHP) to target growing demand from the battery market.

A proposed deal with Australia's New Century Resources fell through in September 2020 and the mine had been set to enter care and maintenance from the beginning of 2021 as a result.

Under the terms of the proposal, Trafigura is expected to have exclusive offtake rights to production at VNC, with industry contacts noting to **Benchmark** that the Swiss trading house has already started marketing MHP from the operation to potential customers in the battery supply chain.

Trafigura continues to expand its footprint in the battery supply chain, with recent investments in Terrafame's nickel sulphate project – due to commission in Q1 2020 – and November's cobalt supply deal with the Democratic Republic of Congo (DRC) state agency Entreprise Générale du Cobalt (EGC).

As one of the few active producers of MHP, news that the mine's future has been secured will ease some supply concerns heading into 2021, with demand for nickel intermediates such as MHP set to grow substantially.

MHP payables are expected to increase in 2021, due to both increased demand and growing utilisation of MHP as feedstock for nickel sulphate production, and concerns surrounding the availability of supply, which is expected to tighten amid uncertain timelines for new supply from Indonesia and the ramp-up of production from existing mines.

Furthermore, the new ownership faces a serious challenge to cut its high cash costs which have dogged the embattled asset since production began in 2010. VNC sits at the top end of the nickel cost curve (with capex coming in at an estimated $4.5bn) and unless new ownership is able to cut cash costs significantly, the operation is likely to struggle to compete with lower cost MHP produced at Chinese owned operations in Indonesia and Papua New Guinea.

However, as a non-Chinese owned asset located in French territory (and as such coming under EU jurisdiction), the mine is strategically placed to potentially benefit from rising demand for nickel and cobalt units from Europe over the coming decade.

CHINA CONTINUES GRAPHITE EXPANSIONS

China continues to expand natural flake graphite production in Heilongjiang and Inner Mongolia as the country once again becomes a net exporter

China continued to aggressively build out its domestic graphite supply chain through the quarter, which sees the country take an increasingly dominant position in the market following the COVID 19 outbreak.

Within China there is also a shift underway which is seeing new graphite production focused in the provinces of Heilongjiang, which has emerged as China's flake graphite mining hub, with production centred around Jixi and Luobei, and Inner Mongolia.

During the quarter, the Luobei local government announced plans that would see local graphite mining have no winter production halt in 2020, delaying the break into 2021, significantly shortening the length of the usual winter closure which normally lasts from November until March.

Hegang municipal government in Heilongjiang also stated aims to speed up local graphite industry construction in November, targeting a production value of RMB 40bn ($6.1bn) across a range of graphite products by 2025.

Furthermore, the government announced plans to construct two major graphite industrial parks in Hegang City and Luobei County, without specifying capacity, as the region looks to dominate the upstream graphite supply chain under backing from the central government.

Within China, market participants reported to **Benchmark** that flake producers in Luobei worked extended hours during December to reach yearly production targets and alleviate diminished inventories, following the impact of COVID-19 on production earlier this year.

Continued operation in Luobei has not only included Minmetals' operations, but also 18 local graphite processing companies aiming to return to typical inventories for larger mesh sizes, and capitalise on better pricing in part driven by a stronger RMB.

There has also been significant downstream investment in China, however, fears persist that further expansions will cause a prolonged structural surplus in global markets. This has been seen across various provinces with several local authorities and companies announcing either development parks or expansions.

CHINA REVERTS TO NET EXPORT

Since the outbreak of the COVID-19 pandemic, we have seen the reversal of China's position from a net importer to net exporter of graphite. China had only recently become a net importer of natural flake graphite originating came from African operations.

However, graphite's sustained low-price environment has forced African production to come offline with current levels of demand unable to sustain production.

With this picture emerging, China is increasingly looking inward to Heilongjiang and Inner Mongolia to support its domestic industry and growing downstream needs.

While China has again become a net exporter, the levels of exports are lower than previous periods as the country is increasingly looking inward to support its graphite supply chain.

In this context, the need for other regions globally to develop their own localised supply chain the future is critical to avoid future shortages associated with ramping up battery demand.

UK SETS NEW EV TARGET

During the quarter the UK outlined new electric vehicle targets, but to meet these ambitious goals it needs to devise a successful strategy

The UK government outlined a ten-point plan, together with £12bn, for developing domestic new energy industries which it hopes will usher in a green industrial revolution.

As many expected, electric vehicles and lithium ion batteries are a major focus of the government's efforts, bringing forward its internal combustion engine (ICE) ban.

A UK government statement said: "Following extensive consultation with car manufacturers and sellers, the Prime Minister has confirmed that the UK will end the sale of new petrol and diesel cars and vans by 2030, ten years earlier than planned."

However, Prime Minister Johnson acknowledged that the UK government would continue to allow the sale of hybrid vehicles until 2035.

The UK's new and ambitious 2030 combustion engine ban target, which is ten years earlier than originally planned, is set to make the country one of the pioneers of electric vehicle adoption, phasing out ICE vehicles much earlier than other major markets globally.

To support this accelerated roadmap the UK has announced £2.6 billion of investments for the UK's electric vehicle industry: £1.3 billion to support charging rollout, £582 million in financial incentives for zero and ultra-low emission vehicles, and £500 million to be spent on developing mass-scale production of lithium ion batteries for the EV industry.

£15BN NEEDED FOR UK CELL PRODUCTION

While the UK is a hub of battery and automotive

The UK government is speeding up its EV adoption timeline by 5 years

Sunderland is home to Envision AESC's 1.9GWh megafactory - the UK's only gigafactory scale battery plant

expertise, the country's lithium ion supply chain capabilities are currently ill prepared to meet these ambitious targets.

To meet its domestic lithium ion battery cell requirements, **Benchmark** anticipates that the UK will need to build battery cell production capacity of 175GWh, at a cost of US$20 billion (approximately £15.05 billion).

In an interview with The Telegraph newspaper, **Benchmark**'s Managing Director, Simon Moores, outlined the mismatch between the UK's ambition and its supply chain capabilities at present.

"If you're going to be a major player in electric vehicles, you need batteries at scale, at quality, and at low cost. As a result I think at least four battery gigafactories will need to be built in the next six years."

Moores explained further: "In a pre-corona world we could have been forgiven the UK being slow on building gigafactories here domestically. However, since Covid-19 the rest of the world has surged ahead while Britain has done nothing"

According to data from **Benchmark**'s **Lithium ion Battery Megafactory Assessment**, in 2020 China announced 38 new battery megafactories, Europe announced three (with SVolt confirming a new German factory this week) and two new Tesla operations were announced in the USA.

While the UK does have gigawatt hour scale production at the Envision AESC facility in Sunderland, this is inadequate to meet its own domestic cell requirements if it is to scale up production.

MISSING RAW MATERIAL STRATEGY

To support growing lithium ion cell demand, and to scale up its own domestic industry, the UK needs to establish an effective raw material and advanced material strategy.

The raw material implications of 175GWh of battery cell production would require approximately 155,000 tonnes of lithium, 210,000 tonnes of graphite anode, 18,000 tonnes of cobalt, and 140,000 tonnes of nickel.

Boris Johnson's statement, while progressive in terms of new energy ambitions, failed to acknowledge the supply chain constraints facing the battery and electric vehicle supply chains.

While **Benchmark** understands it is difficult to address these nuances, it is critical the UK government outlines its own strategy for raw material sourcing if it is to effectively meet these targets.

The UK has some potential capacity for its own domestic supply of battery raw materials, such as lithium, however the bulk of battery minerals will need to be sourced internationally.

As such, **Benchmark** would expect the government to develop its existing relationships and build new partnerships with battery raw material producing countries to guarantee an adequate supply of raw materials.

Benchmark's **Lithium**, **Cobalt**, **Graphite**, **Nickel** and **Manganese** forecasts all show a looming supply deficit, and by the mid-2020s as industry and government's ramp up electric vehicle demand, supply bottlenecks will become amplified, particularly for non-producing countries.

Although the UK is limited by geography in terms of raw material extraction, it could establish its own operations for processing, refining or manufacturing of advanced battery materials such as anode and cathode. Currently it has minimal capacity in these areas, but it would be a wise strategy for the country to develop these capabilities, which are currently concentrated in the lithium ion belt of China, South Korea and Japan.

The UK government's new target illustrates the upward trajectory of the lithium ion and electric vehicle industries. But this is where the hard work begins, and for the UK to succeed in meeting these targets it will need to get its strategy correct across the supply chain.

EV RECALLS RISK HIGH NICKEL UPTAKE

With a number of high profile electric vehicle recalls linked to batteries during 2020, Benchmark explains the significance of this to the supply chain

In Q4 BMW and Hyundai Motors were the latest auto OEMs to recall electric vehicles (EV) due to battery safety issues.

26,700 plug-in hybrid electric vehicles were affected in BMW's recall. A BMW spokesperson explained that the issue was not country specific and that it had arisen due to "impurities in the production process of the battery cells." BMW's cells are supplied by China's CATL and South Korea's Samsung SDI.

As part of Hyundai's October announcement, it planned to recall 51,000 vehicles in total across Europe, China, and North America. LG Chem, Hyundai's supplier, stated that faulty cells were not the cause of the fire, but the precise cause has not yet been established.

No auto OEMs are immune to these problems; in 2020 Ford, Mercedes-Benz, and GM all had incidents that have led to investigation or recalls. Recalls are also not new to the auto industry, and as EV demand scales up the number of recalls will likely follow.

Nonetheless, OEMs will want to avoid EV recalls which could have major repercussions for the supply chain's trajectory. EV manufacturers will be aware of the hefty financial and reputational damages they may face for a large-scale recall.

What is notable about these recent recalls are that these were in EVs using tier 1 battery cells, which are the highest quality available and in demand from leading OEMs. This illustrates how difficult it is to produce lithium ion cells at scale without quality issues, even for the industry's leaders.

BATTERIES UNDER THE MICROSCOPE

These recalls all relate to the battery. However, the battery umbrella is a broad term, with issues arising from cell contaminants, faulty battery management systems (BMS), battery modules and wiring issues.

As such there is no one size fits all approach to fix these issues. But some of these problems are easier to fix than others for auto OEMs, depending on the underlying issues. A BMS system issue, for instance, would be more easily identified and rectified than problems relating to a battery cell.

Any issues at a cell level will be of great concern to battery manufacturers and auto OEMs, due to both the costs associated with battery cells and the complexity of supply chains feeding into them. These concerns can have an impact on the uptake in technology – with OEM qualification and warranty requirements potentially affecting the future trajectory of battery cell chemistry.

Cathode chemistry is a determining factor in this, with certain chemistries more prone to thermal runaway than others, with LFP (lithium iron phosphate) cells offering greater stability and higher nickel NCM (nickel, cathode, manganese) cathodes holding greater risk.

IMPLICATIONS FOR BATTERY TECHNOLOGY

The uptake of high nickel NCM cathodes is the major expected trend for electric vehicles over the next decade, with **Benchmark**'s **Lithium** forecast showing NCM's share of the cathode market increasing from 43% in 2020 to 68% in 2025.

In particular, NCM 811 (eight parts nickel, 1 part cobalt, 1 part manganese) cathodes are expected to be the cathode of choice for Western OEMs chasing more energy dense batteries with greater range.

NCM 811 batteries use lower proportions of cobalt than other NCM variants, which offers greater energy density and also reduces the price and supply chain risks associated with cobalt. But as cobalt content is decreased there

Credit: Hyundai

Hyundai Motors were one of several leading automakers forced to undertake electric vehicle recalls in 2020

are implications for cell safety – lower cobalt NCM and NCA variants are more susceptible to life cycle difficulties and other safety issues.

Technological improvements at the cathode and electrolyte level, and effective battery cooling and BMS systems can mitigate some of the additional risks associated with NCM cathodes.

However, safety concerns from auto OEMs and battery manufacturers still linger. In May and August 2020, there were a series of incidents where GAC New Energy Vehicles' EVs caught fire in China. All three of these vehicles were using CATL's NCM 811 battery cells in their packs. While GAC New Energy Vehicles and CATL have disputed rumours that this was caused by the NCM 811 cells, it is yet to be established what the root cause was.

With these fairly high-profile incidents associated with NCM 811 cells, there is the risk of delay in adoption of the technology as cautious OEMs limit their uptake, in turn seeing battery manufacturers, fearful of being unable to meet Western OEMs' warranty requirements, push back their high nickel plans.

For OEMs, the potential consequences of battery faults are seismic. The fallout from Samsung's Galaxy Note 7 battery problems is the most obvious warning to the electric vehicle industry. Faulty battery cells led to several instances of thermal runaway and phones catching fire, which ultimately cost Samsung in excess of $5 billion – without even taking into account the reputational damages brought about by the episode.

With batteries accounting for such a high proportion of EVs costs, a large-scale product recall by an OEM would easily exceed the costs which Samsung experienced.

LITHIUM ION'S THREE TIERS

High quality materials are required to produce high quality cells, and leading Western OEMs will need battery cells from tier 1 battery suppliers to meet their qualification requirements.

While there is currently no shortage in battery production, not all battery tiers are suitable for all OEMs and **Benchmark**'s **Lithium ion Battery Database** shows that in 2020, tier 1 production is forecast to have been only 54% of global supply.

Earlier this year there were already reports of European OEMs facing battery cell supply shortages. This trend could be further exacerbated by raw material supply shortages, which are likely to develop from 2022/23 onwards.

These bottlenecks will potentially affect tier 1 battery cell production and ultimately European OEMs' abilities to meet their electrification targets. In turn, these could be further complicated by any cell safety issues related to NCM 811 cathodes.

While the uptake of NCM 811 continues, any issues with safety – and the wrangling over warranty between automaker and battery manufacturer – could delay moves to NCM 811 cathodes or even lead to changes in cathode chemistry altogether.

BATTERY CELL PRICES FALL TO $110/KWH

Benchmark's data shows ion cell prices saw dramatic falls through the 2010s, but this is not a foregone conclusion

Lithium ion battery cell prices have decreased from $290/kWh in 2014 to $110/kWh in 2020 (large contract automotive), according to **Benchmark**'s latest data, yet there is a view in the lithium ion industry that this trend will continue indefinitely.

This in turn will lower the price of electric vehicles and bring cost parity between internal combustion engine (ICE) and electric vehicles (EV) in the all-important $20,000-$30,000 mass market vehicle segment. Given the strong track record of the industry over the years you could be forgiven for thinking this is a done deal.

It is not.

What battery cost analysis often ignores is that declines have primarily been driven by two things, economies of scale and technological improvement, ignoring a third critical input to cell costs, the cost of raw materials.

Worryingly enough many automotive board members still expect battery costs to continue to decline at pace without understanding the supply chain they are at the end of. Price volatility is introduced to the automotive battery supply chain at the mineral extraction phase. Here prices are determined by the market fundamentals of supply, demand, cost and inventory level.

This is something **Benchmark Mineral Intelligence** has built a global data and advisory business on. There is little argument that demand for critical raw materials and chemicals will continue to increase.

Even in this year with its unprecedented demand shock the market has been broadly favourable for EVs, with more and more announcements on EV sales targets, cell and cathode investments.

However, the mine finance side of the market has been more akin to the slow-moving train wreck for which 2020 will be mostly remembered. In short, we are financing demand for commodities and chemicals, but not their supply.

Mines and refineries require high sunk capital, often in challenging social and political environments. They take years to find, define, licence and construct. Geology does not recognise boarders and EU and other "Green Subsides" will not, for example, finance nickel and cobalt mining in Indonesia.

All of this leads us to the ever increasing need to build more extraction capacity. There is no geological shortage of these materials, there is a planning and financing shortage.

Capital requires a return, and in some industry forecasts of cell costs falling to $60-70/KWh there is little room to pay for, let alone incentivise, all the greenfield mining projects required.

As shown in the chart below for lithium, the industry needs to double in size every 4-5 years, as do other battery raw materials.

Any industry would struggle to do this in a falling price environment, especially if it cannot service its debt. This will put a floor on how low raw material and battery costs can fall.

It is worth noting the role of recycled supply (in red), which has an approximate 12-year lag on when material was first consumed. In lithium and other raw materials recycling will play an important role, but it will not solve supply questions alone until the late 2040s or 2050s at the earliest.

RAW MATERIAL RISKS

Chart one shows what would happen to next generation NCM 811 cell costs if each of lithium, cobalt and nickel hit their highest price levels seen in the past 10 years. The result is an increase in cell costs from $87.2/kwh to $119.0/kwh. The same amount of lithium, cobalt, and nickel running along the same production line, but with a 36.5% cost increase.

These raw material price levels have happened before, and the market fundamentals show they could happen again.

When a 10% cell producer margin is included, moving from a production cost to a price, in a 70KWh battery pack this adds almost $2,500 to every vehicle.

Given raw material markets are widely forecast to see supply deficits in the coming years it would seem to be optimistic to base investment plans on historical performance.

Battery costs and prices will not continue to decline because they have declined in the past.

Larger factories, higher nickel content, increased energy density from the anode and a thousand incremental improvements will all help drive cell costs lower, but, without investment in mining and refining capacity this could be quickly reversed.

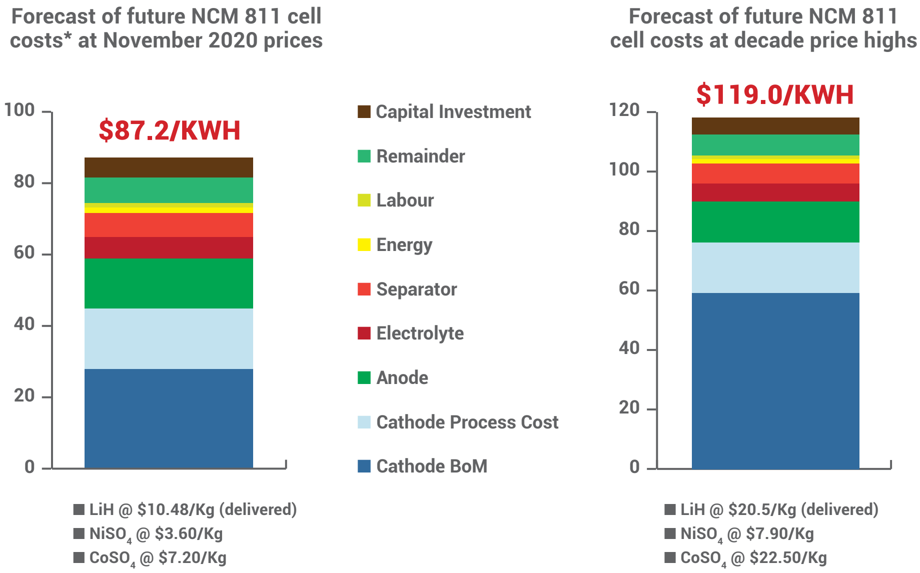
OEM'S RESPONSIBILITY

Price risk falls at the feet of the consumer, in this case the carmaker or original equipment manufacturer (OEM). Raw material prices are cost pass-through for cathode and cell producers. They may negotiate and purchase the raw materials, but it is the OEM who ultimately pays for them.

Their ability to pass on these costs to their customers is also limited given EVs are in essence a substitute product for ICE vehicles.

The answer for OEMs is more active management of supply chains. It is unsurprising that Tesla as the Western World's "Thought Leader" in all things EVs addressed this (albeit in a somewhat woolly fashion) during its Battery Day. Other OEMs should take heed and take a more active role in raw material sourcing and purchasing, or battery costs will soon reverse course.

CHART ONE: WHAT HAPPENS TO NEXT GENERATION NCM 811 LITHIUM ION BATTERY COSTS IF RAW MATERIAL SHORTAGES SEE PRICES INCREASE?



*Cell costs modelled on theoretical 10 GWh non-integrated plant in 2025, excludes producer margin, module and pack costs

Source: Benchmark Mineral Intelligence

IS THIS THE END FOR DOUBLE DIGIT DECLINES?

A long-term comparison of prices shows an impressive decline, which is a good guide on how lithium ion battery production has come of EV age.

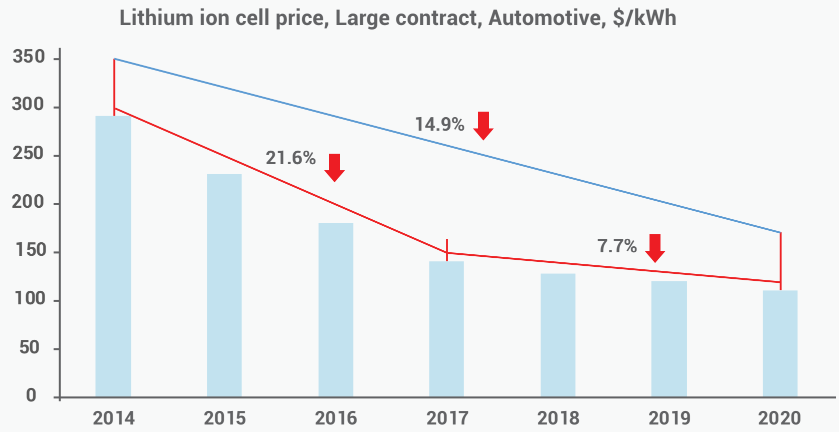
Lithium ion battery cell prices have fallen 62% since 2014 at an average of 14.9% each year.

Take that trend back to 2005 when the same average price – albeit not for automotive but large contract portable technology, the driving market at the time – was $1,300/kWh, over ten-fold today's $110/kWh, and representing a 15.2% compound average annual fall.

However, this does not tell the full story.

If you look a little closer you will see that the landscape for lithium ion battery cell price declines has changed significantly over the last three years.

CHART TWO: LITHIUM ION BATTERY CELL PRICE DECREASES HAVE SLOWED



Source: Benchmark Mineral Intelligence

From 2014 and 2017, the price of lithium ion batteries fell an average of 21.6% a year.

Yet, between 2017 and 2020 the price of lithium ion batteries fell a fraction of that pace, at 7.7% a year.

The issue with analysing the price decline trend of lithium ion batteries over a longer period of time is that it does not give a nuanced or knowledgeable enough picture.

If we analysed this price trend between 2014 and 2020, the last 6 years, it would show a significant double digit compound annual decline of 14.9%, leaving the reader to suggest that:

1 A double digit decline is occurring each year for the last 6 years and,

2 That these double digit declines that are still 'occurring' in 2020 will carry on into the future

It is the same problem with experience curves: an over simplistic, non-industry approach to forecasting lithium ion batteries may have worked for a generalist but it is not fit for purpose for an industry participant going into the 2020s.

As large contract average lithium ion battery cell prices fall ever closer to the $100/kWh mark, the proportionate cost of the Bill of Materials increases.

And what is the largest input into the Bill of Materials? Minerals, metals and chemicals such as lithium, cobalt, nickel, graphite, manganese and copper.

Therefore to properly forecast lithium ion battery cell prices you need to understand raw materials.

EU IN PUSH FOR SUSTAINABLE BATTERIES

The European Commission proposed new legislation in December, with particular focus on the sustainability aspect of the battery supply chain

The European Commission's (EC) proposal to update to its existing battery legislation, outlined in December, is set to form a part of the European Union's (EU) Green New Deal and focus on creating more sustainable batteries produced within and sold into the EU.

However, with the EU already facing an uphill climb to meet its growing electric vehicle ambitions, the extra hurdle of sustainability, which is necessary to ensure the clean energy transition remains clean, will add to the challenges of scaling up battery production on the continent.

Discussing the legislation Vice-President for Interinstitutional Relations Maroš Šefčovič said: "The Commission puts forward a new future-proof regulatory framework on batteries to ensure that only the greenest, best performing and safest batteries make it onto the EU market. This ambitious framework on transparent and ethical sourcing of raw materials, carbon-footprint of batteries, and recycling is an essential element to achieve open strategic autonomy in this critical sector and accelerate our work under the European Battery Alliance."

The proposed regulations would develop an EU framework for quantifying the carbon footprint of batteries, which would see lithium ion cells sold in the EU requiring a carbon footprint declaration from July 2024 onwards.

These regulations would then become more stringent from January 2026, with electric vehicle (EV) batteries needing to show a carbon intensity performance label and from July 2027 onwards having to comply with carbon footprint thresholds.

Anticipating the growth in EV battery cell demand this decade, which **Benchmark**'s **Lithium ion Battery Database** forecasts will increase 23x in Europe between 2020 and 2030, the legislation also proposes a formal threshold for battery recycling to come into effect at the start of the 2030s.

Beginning in January 2027, batteries in the EU will also have to declare the content of recycled cobalt, lithium and nickel. From 2030 onwards this will see minimum requirements for some recycled battery materials: 12% cobalt, 4% lithium and 4% nickel. By 2035, this would increase to increase to: 20% cobalt, 10% lithium and 12% nickel.

DEVELOPING THE EU'S SUPPLY CHAIN

The latest move to modernise the EU's battery regulations reflects the rapid changes the industry is undergoing.

It also builds on the EU's recent efforts to support the buildout of Europe's battery supply chain through efforts such as the European Battery Alliance (EBA). The EBA has already played a key role in major supply chain developments to date, such as the European Investment Bank's (EIB) €350 million funding in Northvolt's Skellefteå megafactory in Sweden.

Backing from both the French and German governments was also critical to the PSA Group and Total joint venture that established the 40GWh of capacity in the pipeline in France and

Credit: Sébastien Bertrand

The European Commission is modernising its battery cell legislation with increased focus on sustainability

Germany last year.

Needless to say, political and industrial collaborations over the past 2 years have put Europe on track to become the world's second lithium ion hub after China. Data from **Benchmark**'s **Lithium ion Battery Megafactory Assessment** shows that it has 16 megafactories in the pipeline for 2029, with 503.2 GWh of capacity set to be online in that time.

However, while investment has been flowing into Europe's cell capacity, and to a lesser extent cathode capacity, it's evident that Europe's upstream supply chain is ill prepared to meet its future cell requirements.

The continent has a number of battery raw material projects under development – but to date investment into these projects has not been sufficient to develop sustainable supply. The establishment of the European Raw Materials Alliance indicates the EU's desire to support this buildout, but this is yet to translate into significant upstream developments.

It's worth noting that even if Europe's raw material projects under development came online, the EU would still need to look outside of its borders to source its battery raw materials from the ground.

The EU's efforts to develop its own recycling capacity, while important for the sustainability of the battery supply chain, therefore also recognise the raw material risks the continent faces – something it hopes to alleviate in the future.

With its new sustainability targets, the EU is looking to incentivise the buildout of its supply chain by promoting localisation and domestic battery recycling capacity. This supports the efforts to minimise the battery supply chain's footprint while also supporting the EU's strategic effort to develop an advantage in raw material sourcing in the long-term.

By defining recycled raw material requirements and formalising the display of carbon footprints it is also outlining the future standards required of tier 1 battery producers looking to supply the EU's EV market.

However, despite its long-term thinking Europe's OEMs and governments still face near-term raw material shortages throughout the 2020s that will be critical to meet growing EV demand.

2021: 3 THINGS TO WATCH OUT FOR IN THE EV MARKET

Adam Panayi, Managing Director of Rho Motion, reviews 2020's EV market and looks forward to what we can expect in 2021

It is time once again to take a look back at what came to pass in the EV market last year, and to lay out what we can reasonably expect in 2021. This article draws on analysis from Rho Motion's EV & Battery Quarterly Outlook and our EV Battery Chemistry Monthly Assessment.

EUROPE V CHINA IN 2021

In 2020 Europe made significant gains on the previously all dominant Chinese market in terms of total EVs sold; and we expect that full year sales for total BEV & PHEV sales in each geography will be roughly equal. In 2021 we expect that we will continue to see these two largest EV markets remain relatively close in terms of overall units sold. However, it is important to note that the drivers and characteristics of this demand have been quite different in 2020, and will remain so in 2021.

In Europe, a significant part of the uptick in 2020 was due to intervention in the market by national governments, which was itself legitimised by the onset of the Covid-19. Germany for instance increased its subsidy to a maximum of €9,000 as part of its relief package, France to €7,000, and this had a strong effect on sales in the second half of the year. This was supported by the release of a number of new models, notably the VW ID-3 which had significant pre-orders.

What is most noteworthy from a battery demand point of view is that nearly half of all EV sales in Europe were PHEVs, something we predicted in our 3 things to look out for in 2020. This had a noticeable impact on pack sizes both in the region and globally. Based on model line-ups and ongoing market trends we expect that the share of PHEVs will remain very strong in Europe in 2021.

In China, government intervention has been fairly limited, the subsidy scheme was extended but remains well off 2019 levels. Alongside an economic recovery from the worst of the shutdown in Q1 2020, which has not been seen to the same extent in any other major economy, what also drove the recovery in the EV market in China is a greater availability and diversity of models at difference price points and for different use cases.

Aside from the popularity of the China made Tesla Model 3 in 2020, many smaller models that have recently been introduced into the market. The affordability of these models has made them very popular, with some BEV's, such as the Wuling Hong Guang Mini, being priced for around USD5,000.

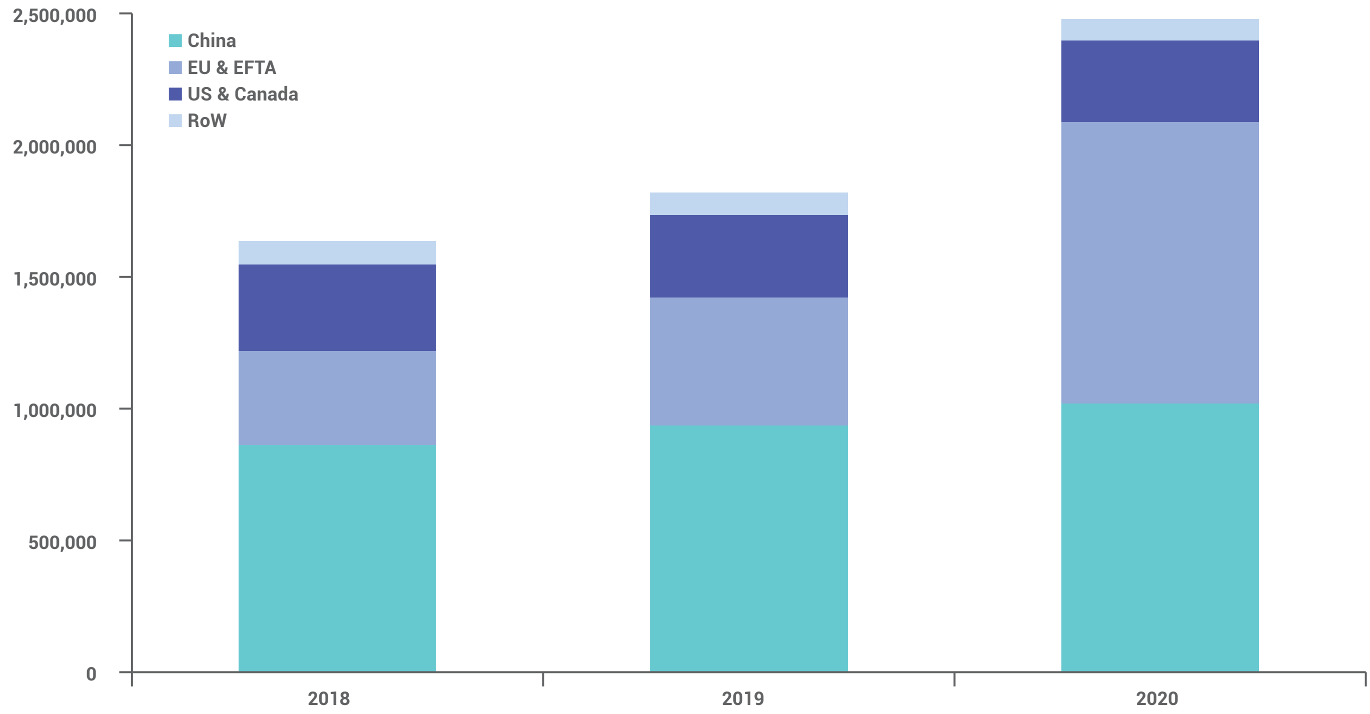
US UPLIFT

In the US the new administration could coincide with a significant uptake in the US market this year. A simple and likely highly effective policy lever the Biden Administration could pull would be to remove the volume cap that saw the phasing out of the tax credit for Tesla, and later for GM.

There is clear correlation between Tesla's sales and the stages of reduction of the credit, and a lack of stimulus to replace has seen the US market stagnate in 2020. The lack of upfront

CHINA IS NO LONGER THE LARGEST MARKET, FOR NOW, BUT STILL REMAINS THE CRUCIAL PLAYER

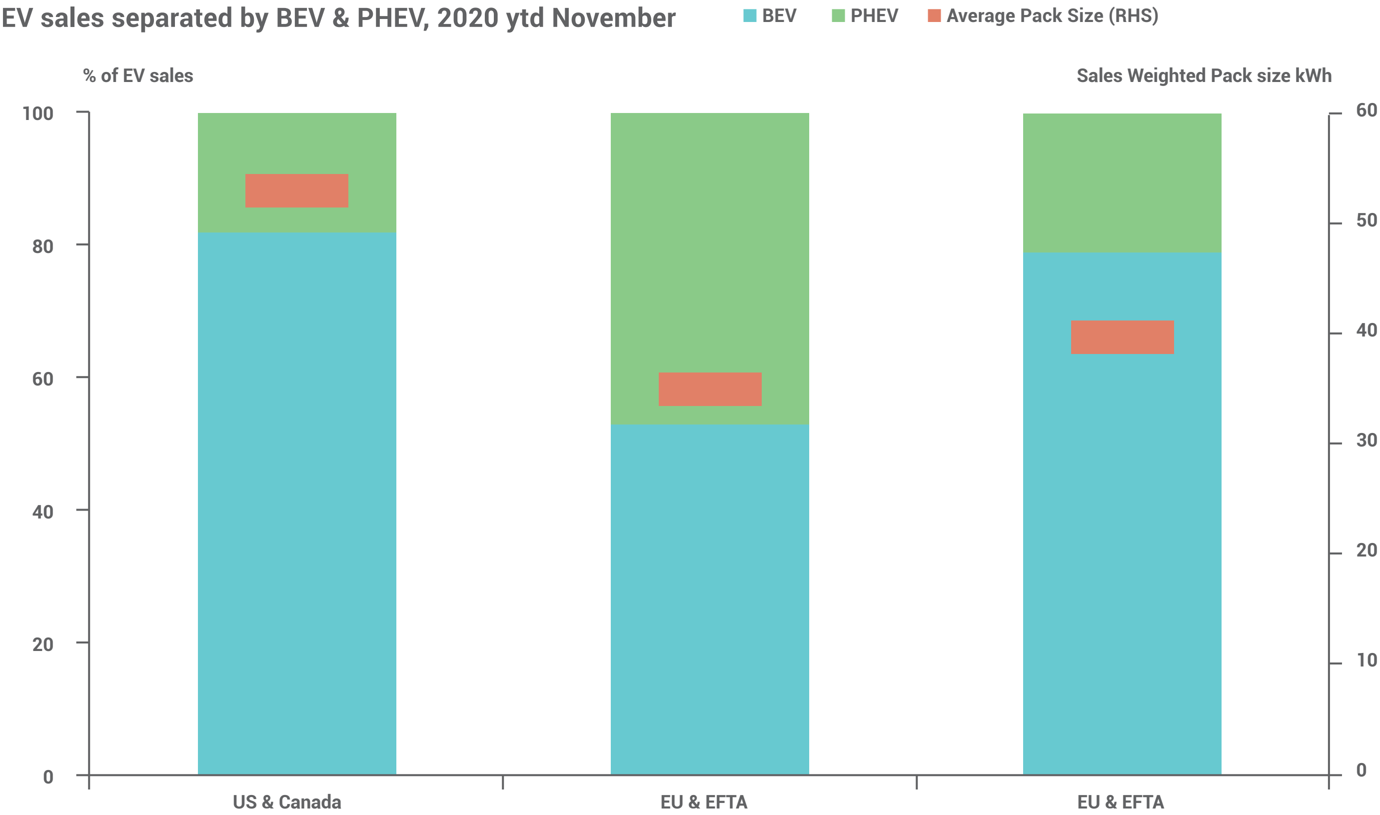
Regional passenger car BEV & PHEV Sales 2018-2020, ytd November



Source: Rho Motion

RISES IN PHEV SALES IN EUROPE WEIGHED ON PACK RISES IN 2020

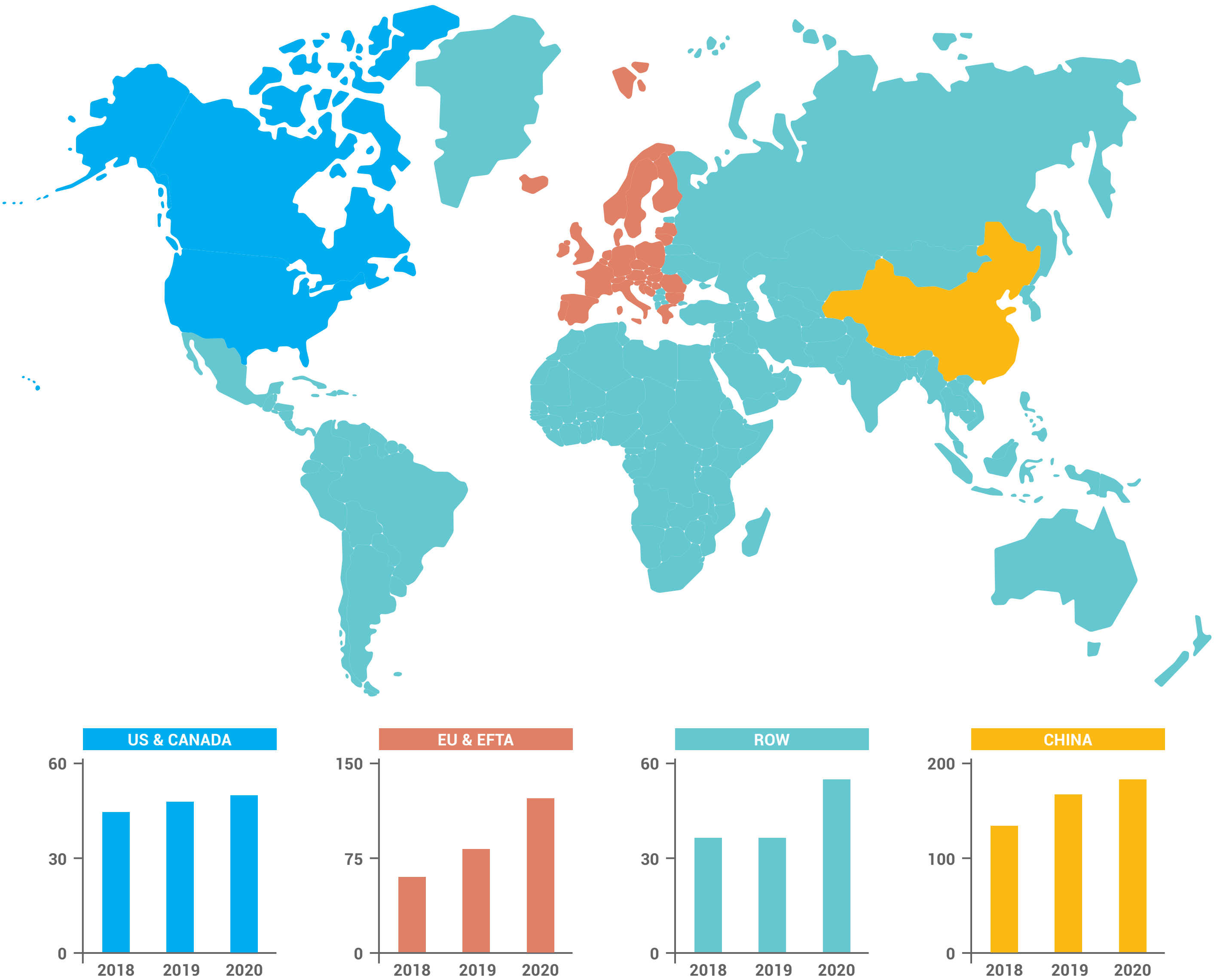
EV sales separated by BEV & PHEV, 2020 ytd November



Source: Rho Motion

CONSUMER CHOICE MATTERS, AND ITS IMPORTANCE WILL CONTINUE TO INCREASE

Number of different BEV and PHEV models sold by region, 2018-2020



Source: Rho Motion

fiscal cost to reintroduce the credit should make it an easy decision, as the foregone tax revenue for sales would be relatively marginal. We also understand that the new regime will look to introduce tougher fuel economy standards which will also give a boost to EV sales, albeit over the longer term.

GREATER DIVERSITY

Based on what we saw in 2020, and the model line ups for the year ahead, we can expect to see the further diversification of both vehicle offerings and resulting cathode chemistry in 2021. China as ever will lead the way in this regard, with a greater number of models coming into the market at a larger range of price points than in Europe or North America. Typically we can assume that BEVs with smaller battery packs, below 25kWh, are likely to be LFPs, although LFP cell-to-pack technology is finding applications in much larger pack sizes as well.

This trend will very likely come to Europe in the coming years as well. We may well also see the commercial roll out of NCMA in the second half of the year, and in Europe we have seen models introduced with NCM712 as another pathway towards higher nickel and energy dense batteries as an alternative to NCM811. Despite this, we do expect that NCM811 share will continue to build, mainly in China, where its use expanded significantly in 2020.

Looking at the anode, we expect to see an ongoing trend towards more blended natural and synthetic graphite anodes, and that at the higher end of the market a push towards greater use of silicon additives to boost density. Overall the key point here is that as the market expands, more tailored solutions to different use cases become viable, at both a vehicle and battery level, which may require a change in the way the conversation around battery chemistry takes place in the first place.

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Credit: BASF

BREAKING GROUND

H2 2020 saw BASF begin construction of its new cathode active materials plant in Schwarzheide, Germany, which the company is aiming will begin production in 2022.

But BASF is not alone and as Europe's battery cell production capacity pipeline grows, particularly in central and Eastern Europe, the continent's cathode production capacity has begun to emerge in its shadow.

In Poland, both Umicore's Nysa and Johnson Matthey's Konin cathode plants are also set to come online in 2022.

These are the first major steps towards localisation of Europe's supply chain. While European OEMs will still rely on raw materials from around the globe, these developments underline the trends in the lithium ion supply chain in the coming decade.


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TO UNDERSTAND THE FUTURE, YOU NEED RELIABLE DATA ON THE PRESENT.
The speed at which people adopt new technology is increasing.
Low carbon industries such as lithium ion batteries are becoming mainstream. Yet the supply chains that serve them are slower to react.
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PRECISION REQUIRED

Benchmark spoke to **Donald J. MacCrindle**, Business Development Director, **IntriPlex Technologies**, about the critical role lithium ion battery cell components will play in scaling up battery production to meet electric vehicle and energy storage demand

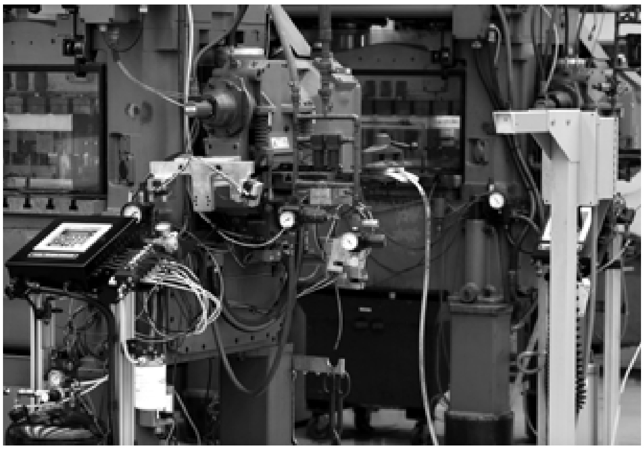
Donald J. MacCrindle, Business Development Director, IntriPlex Technologies

Benchmark: Firstly, could you give *Benchmark*'s readers an overview of IntriPlex Technologies?

Donald J. MacCrindle: IntriPlex Technologies is a global leader in high volume, precision stamping and forming technology. IntriPlex is a key business unit of MMI, a world-class component manufacturer and diverse manufacturing technology company headquartered in Singapore. MMI is a technology and solution leader, with global manufacturing capability in precision stamping, factory automation, magnetics, casting, and machining. IntriPlex is headquartered in Santa Barbara, CA, with manufacturing locations in North America and Asia. With over 30 years of experience, IntriPlex has become a dominant solution provider of precision components, in very high volumes. IntriPlex is highly regarded for providing very economical stamped and formed component solutions in applications where it was once thought only machined components would suffice. One prime example is in the computer hard drive industry where we have replaced many tens-of-billions of machined components with low-cost and superior performing precision stamped solutions. As testimony, every large cloud data centre and over 60% of personal computers built to-date use IntriPlex products. IntriPlex has developed and patented vital processes that allow us to maintain production dimensional tolerances down to ±7 microns over billions of parts produced per year.

IntriPlex supports a global customer base engaged in the manufacture of hard drives, felecom Fiberoptics, medical devices and most recently lithium ion battery cell components. IntriPlex, renowned for our capability, quality, and innovation is a key supplier and partner to many of the largest technology companies in the world.

Today, IntriPlex is highly focused on supporting the rapidly growing and evolving lithium ion batterty cell manufacturers, where



R&D Stamping Operation within the IntriPlex Innovation Center (left), and tight tolerance, high volume, IntriPlex stamped component assortment (right)
Credit: IntriPlex

high precision, high quality and consistency in high volume are paramount to support this demanding market.

Benchmark: How does IntriPlex cater to the expanding needs of lithium ion battery cell manufacturers?

DM: IntriPlex is a very innovative and flexible company. Our ability to take your ideas and turn them into producible, high quality, economical solutions, and provide them in large volumes, is what makes us unique and a highly regarded partner to cell manufacturers. IntriPlex's ever expanding global footprint allows us to maintain close ties with each cell production facility to assure the highest level of support and service. Our talented and experienced engineering team, resident in our Innovation Center, is always ready to accept new challenges developing, modeling, prototyping and testing breakthroughs in performance or manufacturability of products in full collaboration with our customers.

Benchmark: What cell types does IntriPlex support and why?

DM: IntriPlex manufactures a variety of components used predominantly in cylindrical and prismatic cell formats. The third dominant cell format, pouch type, does not typically need our components as their construction uses foil tabs as termination and very few internal components. The products we manufacture include, diaphragms, rupture disks, vents, anode/cathode collectors, sealing plates and terminations. IntriPlex uses a wide variety of materials ranging from common metals to viscoelastic polymers. Material selection is driven by our customer's ultimate design and performance requirements.

> The ultra-high volume automation machinery used today for cell production requires very consistent, tight tolerance components to assure flawless assembly without incident or down-time
>
> Donald J. MacCrindle, IntriPlex Technologies

Benchmark: Why would a lithium ion cell producer look to IntriPlex for support of their cell production?

DM: Lithium ion cell producers look to IntriPlex because of their need for a highly reliable supplier that can provide tight tolerances, significant part to part consistency, at a globally competitive price, over millions and even billions of parts produced. The ultra-high volume automation machinery used today for cell production requires very consistent, tight tolerance components to assure flawless assembly without incident or down-time. IntriPlex has proven experience and expertise providing billions of precision components for these applications. IntriPlex can provide peace of mind to the cell producer that every lot of components received is what they require to maintain the most economical production of cells.

In addition to its reliability as a high-volume precision component supplier, IntriPlex is a technology partner with its customers and is committed to investment in research and development at the component level necessary to support continuous improvement in cell manufacturability, end-use performance enhancement and product roadmaps of the cell manufacturers.

Benchmark: Which regions of the world does IntriPlex support today and what are the company's plans for the future?

DM: IntriPlex is a global manufacturing company. Our headquarters, Innovation Center and North American manufacturing are located in Santa Barbara, California. We have high volume manufacturing in Thailand, along with shared facilities with our parent MMI, in China, Singapore and Malaysia. IntriPlex has

Precision progressive stamping die, designed and built by IntriPlex (left) and various lithium ion battery components (right).

Credit: IntriPlex

strategic plans for additional facilities in North America, China, and Europe as our customers and volumes dictate.

Benchmark: With battery cell technology and format constantly evolving, for example Tesla's recent 4680 cell announcement, how do you support and keep pace with these changes?

DM: Although there are many industry standard cell sizes and formats, 18650 and 2170 cylindrical, and F3 thru F8 prismatic, most cell manufacturers have unique internal designs and terminations dependent on their customers' needs. Upcoming technologies and formats are not an issue as IntriPlex works very closely with the cell manufacturers' engineering teams to assure that innovative, cost effective designs are brought to fruition.

We are looking forward to the new cell designs such as Tesla's 4680 format or up-and-coming solid-state cells, as IntriPlex is always ready for the challenge. Historically, IntriPlex has been able to design and produce numerous component designs that competitors have deemed unproducible. IntriPlex will provide full and complete collaboration and support with new components design ideas for future cell formats. IntriPlex is renowned for our innovative product designs and processes. Today we have over 80 global patents for processes as well as product designs. IntriPlex always has an eye on how we can provide the most economical component that fulfills the customer's performance specifications, especially in the demanding battery cell market.

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> Donald J. MacCrindle, IntriPlex Technologies

Benchmark: How important is R&D and how does this support your customers' needs for innovative manufacturing solutions?

DM: While a world-class manufacturer, IntriPlex identifies itself as a technology company, developing manufacturing solutions and product innovations to benefit our customers. We established our customer-focused Innovation Center to support the growing needs of our customers and to help differentiate us from ordinary metal stampers. Through the years IntriPlex has developed cutting edge, precision stamping solutions for a variety of industries and applications. The most popular and successful efforts have been to find lower-cost ways of manufacturing precision products by stretching the bounds of stamping capability. Our Innovation Center is resident to PhDs specialising in mechanical engineering, electrical engineering, stamping technology, metallurgy, as well as a broad range of test and analysis capability, including mechanical, electrical, and thermal modeling assets. IntriPlex takes great pride in our real time collaborative partnerships with our customers. As battery cell design continually evolves, IntriPlex works with our customers to create innovative, cost effective component solutions.

Benchmark: *Benchmark* is tracking 181 battery megafactories in the pipeline, with over 3,000 GWh of capacity by 2029. With battery production set to scale up rapidly through the 2030s, what should battery cell manufacturers consider when devising their cell component strategies?

DM: The *Benchmark Megafactory* analysis and data has been invaluable to IntriPlex in identifying possible customer targets and tracking the overall progress of this important industry as it evolves globally. As battery

IntriPlex Innovation Center, Santa Barbara, California

cell producers move to increase production GWh capacities globally over the next 10 years by nearly 4X, the need for battery cell components is increasing at a similar rate. With 100s of billions of cells being produced in the coming years, it is imperative that the cell manufacturers seek component support from world-class, high quality and cost-effective partners such as IntriPlex. IntriPlex, a proven ultra-high volume manufacturer of these needed components, can assure flawless support to the cell manufacturers' global strategies.

Benchmark: Many key battery raw materials are facing looming shortages as demand scales up. Do you foresee any bottlenecks developing in the materials for lithium ion components?

DM: IntriPlex is well prepared to support the exponential growth in the battery industry, when it comes to the cell components we support. Today, the majority of raw materials required for our components are relatively common and readily available worldwide. IntriPlex maintains and manages strategic supply relationships and advance material planning strategies to assure that sufficient inventory is on-hand and our global supply chain is well maintained. The biggest capacity challenge is assuring that sufficient tool capacity is ready and available when required. Increasingly shorter lead times are continually presented by this growing market, and tooling lead times can be stressed. IntriPlex maintains significant in-house tooling resource for tool design, development and production to assure we have complete control of this important factor. IntriPlex does not foresee any material issues impacting our component supply into the future.

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>
> Donald J. MacCrindle, IntriPlex Technologies

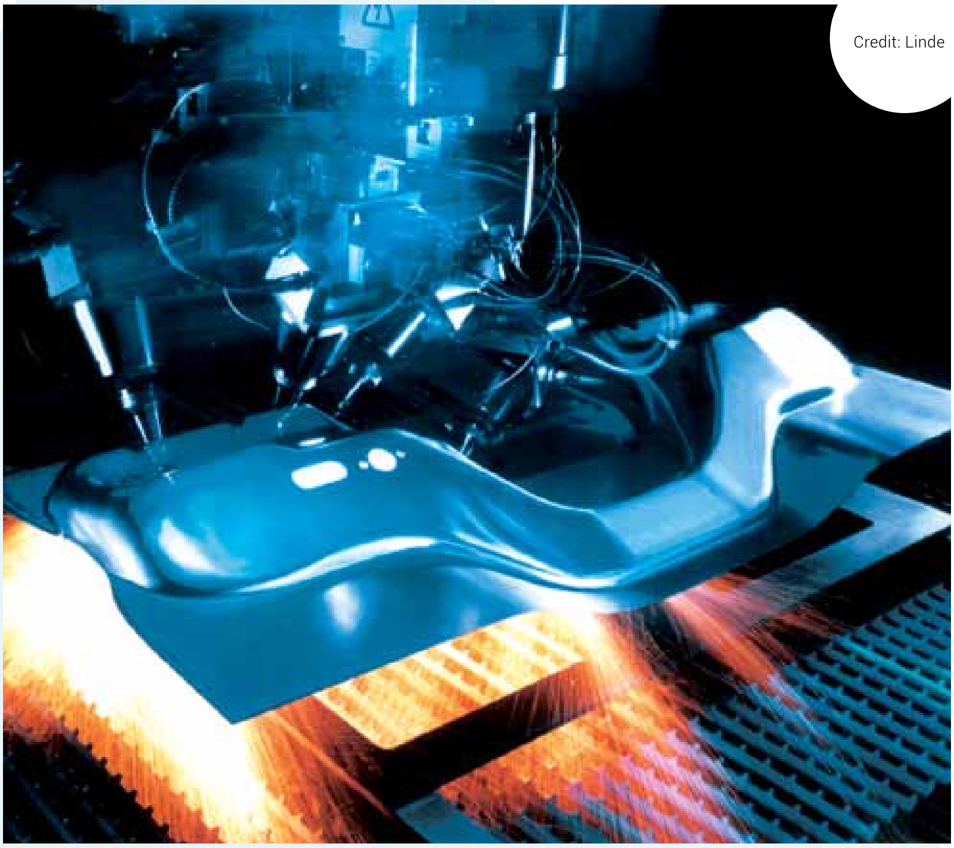
Benchmark: In closing, why is the lithium ion battery cell global production picture important to IntriPlex?

DM: IntriPlex has spent the last 30 years building a global business that specialises in ultra-high volume, precision stamped and formed components. As a significant supplier to the computer, telecom, and medical markets we are always looking for new areas of growth. As IntriPlex continued to evaluate new applications and markets that could benefit from our unique expertise and experience, it became apparent that we could make a positive impact in the exciting and rapidly growing lithium ion battery cell market. Supporting the explosive growth of global electric vehicles and energy storage, battery cell manufacturing is going to be around for a while. The ability to provide billions of high-quality, high-precision components from a reliable, proven company that can support global expansion, appears to be what the key cell manufacturers need and IntriPlex can support. IntriPlex looks forward to playing a key role in the future electrification of the world.

Donald J. MacCrindle is Business Development Director at IntriPlex Technologies (www.intriplex.com)

LITHIUM ION'S ATMOSPHERE

Benchmark speaks to **Dr. Rocky Wei**, R&D Project Manager, and **Dr. Lynn Zhu**, Marketing & Communications, of **Linde** about the role gases play in various stages of the lithium ion battery supply chain, including anode and cathode production and raw material processing



Credit: Linde

Benchmark: Can you give *Benchmark's* readers an overview of Linde's business?

Rocky Wei: Linde is a leading global industrial gases and engineering company with 2019 sales of $28 billion. We live our mission of making our world more productive every day by providing high-quality solutions, technologies and services which are making our customers more successful and helping to sustain and protect our planet.

The company serves a variety of end markets including chemicals & refining, food & beverage, electronics, healthcare, manufacturing and primary metals. Linde's industrial gases are used in countless applications, from life-saving oxygen for hospitals to high-purity & specialty gases for electronics manufacturing, hydrogen for clean fuels and much more.

Linde also delivers state-of-the-art gas processing solutions to support customer expansion, efficiency improvements and emissions reductions.

Lynn Zhu: Linde develops a series of gas production equipment and supply solutions for different industries from the design and construction of gas production facilities, to operation, distribution, installation and tailor-made logistics support. Linde provides numerous gas products, including oxygen, nitrogen, argon, carbon dioxide, helium and other special gases, and related solutions with customised systems, ranging from a packaged or bulk liquid storage tank to an on-site equipment or facility to meet the diverse needs of different customers around the globe.

Benchmark: Where does Linde and gas supply fit into the lithium ion battery supply chain?

RW: Gas is widely used in all aspects of productions across the whole lithium ion battery industry value chain, including raw material refining and processing, manufacturing of cell component such as cathode, anode, and electrolytes, cell and battery pack manufacturing and assembly, final product integration, reuse and recycle of battery product, and so on.

Linde has conducted in-depth research on gas applications in all the above fields. For different materials and processes, Linde has accumulated rich experience in gas supply modes, atmosphere and impurity control, and related auxiliary equipment and programs to help with intensive, environmental-friendly and safe production for manufacturers in the lithium ion battery industry.

With the rapid development of the lithium ion battery industry, the market demand for gas has also increased sharply. Meanwhile, the production and process of different materials and products bring different requirement for gas, thus a big challenge for manufactures and suppliers.

To meet with different needs from different customers, such as the accuracy and dew point of the atmosphere in the preparation of materials and cells, and to help the customers achieve intensive and safe production, solid and innovative gas application technology, as well as stable gas supply capability are essential for the gas company.

LZ: Linde has gained vast experiences in gas supply, atmosphere control and gas injection systems across a variety of industries and applications. Furthermore, Linde has various customers at the leading position worldwide in the market fields of mineral processing, battery material and battery manufacturing, electric vehicle manufacturing and battery recycling.

Serving the whole value chain of the lithium ion battery industry for over 10 years, Linde has accumulated rich experience and good understanding on many aspects of the industry, especially for active materials manufacturing and battery recycling.

These insights are utilised and developed into the EMOFLEX technology for the lithium ion battery and e-mobility industry. With

An example of the need for gas supplies in battery material production

> Gas is widely used in all aspects of productions across the whole lithium ion battery industry value chain
>
> Rocky Wei,
> R&D Project Manager,
> Linde

optimised and thorough gas solutions, Linde provides stable and reliable industrial gas supply, innovative and targeted gas application technology, as well as prompt and proactive technical services for the customers in the lithium ion battery industry. The complete solution is backed by technical expertise with close cooperation with the customer at all steps to maximise the customers' return on investment.

Benchmark: What role do gases play in anode and cathode production? Which gases are used?

RW: Our products such as oxygen, nitrogen and helium are literally invisible and are not directly involved in the electrochemical processes of lithium ion batteries. However, in many of the battery production processes, our gases are in direct contact with the active materials and key components of lithium ion batteries and often have a key impact on the production cost, quality and safety of batteries.

During the calcination of cathodes and anodes, oxygen or nitrogen is used to provide the required atmosphere in the furnace. One priority to our cathode customers is to have reliable, uninterrupted gas supply. Linde as a leading global industrial gases and engineering company, can provide the optimal mode of gas supply to ensure that.

During the initial pilot and initial ramp-up phase, we can install gas storage tanks with gases delivered by trucks. When cathode plants ramp up to mass production, we can offer our industry-leading onsite gas production & supply systems to deliver larger gas volumes at lower cost. For example, the calcination process of NCM cathode material requires an oxygen atmosphere up to 90-93% purity. Our industry-leading Vacuum Pressure Swing Adsorption (VPSA) systems can produce oxygen onsite to meet such demand at a competitive cost. Our remote monitoring of gas tank inventory and remote monitoring & operation technology for our gas production systems ensures that our customers never run out of gases.

LZ: In addition to the gas supply itself, our global teams of application scientists and engineers also study how we can help our customers optimise their processes with our application technologies and get the most out of our gas products. For example, during the calcination process of NCM cathode manufacturing, the furnace atmosphere is critical to the quality and cost of the cathode products. Taking advantage of our decades of applications know-how in atmosphere monitoring and optimisation, we worked with leading cathode customers and developed our EMOFLEX Atmosphere Monitoring and Optimisation solution for roller hearth kilns. This technology provides opportunities to detect process deviations for online adjustments, and also provides a lower operating cost and higher throughput.

Benchmark: In what other parts of the supply chain are gases are used?

RW: Gases are used not only for cathodes and anodes, but throughout the entire lithium ion battery value chain. During the smelting of metals like nickel, cobalt and copper, Linde's oxyfuel platform helps reduce fuel consumption and carbon dioxide/NOx emission. Our proprietary oxyfuel burners substitutes air with oxygen, taking out the nitrogen that naturally exists in air. With oxyfuel combustion, heat loss via nitrogen pass-through is prevented. As a result, fuel consumption is reduced, which in turn reduces the carbon dioxide emission from the metal raw materials production. NOx, which is generated when nitrogen is present together with oxygen in the high-temperature combustion environment, is also significantly reduced from the flue gas. Laser welding is widely used in the assembly of lithium-ion batteries. Our laser welding experts are working with our battery manufacturing customers on gas solutions to enhance welding quality. Our gas application technologies are also deployed in the hydrometallurgy and pyrometallurgy processes of battery recycling, which is quickly emerging in all geographies we operate in.

Credit: Linde

Linde's gas supply operations

> Gas application technologies are also deployed in the hydrometallurgy and pyrometallurgy processes of battery recycling
>
> Rocky Wei, R&D Project Manager, Linde

Benchmark: What should be considered when establishing gas supply for a project?

LZ: Combining our gas supply capability and application technologies, Linde has established a solid customer base consisting of industry-leading battery producers throughout the entire value chain. When a new project is looking for a gas supplier, one critical question early on is how much gas is needed and what kind of gas supply system, including the gas supply piping and components are the best fit. Our local salesforce together with our global technology experts can leverage our experience in this area to propose the best fit gas supply solution to cover the entire project lifetime from the initial pilot phase to full ramp-up. Depending on the type of products and manufacturing processes, our application experts in the lithium ion battery can also propose the appropriate application technologies, whether it's our atmosphere optimisation for cathode & anode production, or any of our application technologies throughout the lithium-ion battery value chain. As the industry grows globally, it is not uncommon to see the same customers expanding to other regions of the world. Linde operates in more than 100 countries. We would be also happy to work with our existing customers on their growth in other parts of the world.

GIYANI METALS' AFRICAN AMBITIONS

The feasibility for Giyani Metals K.Hill project is underway

Benchmark spoke with **Robin Birchall**, CEO, **Giyani Metals Corp**. about the K.Hill manganese project in Botswana, the challenges in financing battery metal projects, the role of Africa in the battery supply chain and more

Benchmark: You're currently undertaking a feasibility study for your K.Hill manganese oxide project. Can you provide an overview of the project and your timeline? What is your long-term plan for the project?

Robin Birchall: The K.Hill Project is a near-surface manganese oxide deposit that is close to the town of Kanye, in South East Botswana. The K.Hill Project is well served with local infrastructure, primarily due to its proximity to the town of Kanye and the history of mining in surrounding area. The K.Hill Project sits halfway along the Trans-Kalahari Highway between Jwaneng, which hosts one of the world's richest diamond mines and the South African border.

K.Hill has a mineral resource of 1.1Mt at 27% MnO. This is sufficient for a 10-year project life, producing between 30kt to 40kt per annum of contained high purity manganese metal. We are targeting at least a 25 year project life, and we expect the additional resources to be delineated from the exploration upside to the south of K.Hill, as well as from the nearby Otse and Lobatse prospects. Otse is especially exciting as we expect this to be higher grade than K.Hill. Exploration work will commence later this quarter, once we have completed the in-fill

Credit: Giyani Metals

The K.Hill Project has a mineral resource of 1.1Mt at 27% MnO

drilling which is currently ongoing at K.Hill.

We expect the ESIA (Environmental and Social Impact Assessment) and feasibility to be complete by mid-year this year, which will take us on to the mine permitting phase. Based on the extensive conversations we've had to date with the Government of Botswana, we expect this process to take no longer than 3 months, after which we will break ground.

Benchmark: There has been a distinct lack of funding for battery raw material projects. What has Giyani's experience been to date and what needs to change to bring sufficient supply online to meet battery demand?

RB: I agree there has been a lack of funding across the battery metals space in recent years. This may be due to investors being cautious following the couple of false starts that have occurred so far in battery metals. We saw lithium and cobalt boom too early back in 2015 and 2017, respectively, and as a result many fingers got burnt. However, this time it feels different as you now actually see a lot of EVs on the road. Over half the cars sold in Norway last month were EVs! Also, there are now mid and large caps investing and supporting the junior market, so I feel confident it's happening for real this time.

Up until quite recently, we experienced what it's like to not have the access to capital that we'd like. However, I must really thank the team at Cormark Securities, who on hearing the Giyani story towards the end of last year fully backed us. We closed our brokered private on the 23rd December 2020, raising C$7.5m. It was an early Christmas present. The demand for the deal far out stripped our highest expectations and the funding provides Giyani with all its funding requirements for 2021.

> Africa is already a crucial component of the battery supply chain. Speaking with potential off-takers, especially those in Europe, they acknowledge that much of their future raw material demand will be supplied from there
>
> Robin Birchall, CEO, Giyani Metals Corp.

Benchmark: Can you talk us through the production of high purity manganese for the battery supply chain? Are you targeting a specific end product, such as high purity manganese sulphate monohydrate (HPMSM) or high purity electrolytic manganese metal (HPEMM)? If so, please explain why.

RB: Manganese deposits are typically either formed as carbonate, semi-carbonate or oxide ores. There are advantages and disadvantages to mining and processing both. To produce high purity manganese, the ore (oxide) is leached and then processed via solvent extraction, electrowinning (commonly known by its abbreviation; SX/EW). It is not too dissimilar to a SXEW circuit for copper oxide, except that the starting grade is much higher. The K.Hill Mineral Resource grade is just under 30% MnO. To produce HPMSM, we skip the electrowinning stage and precipitate out (crystalise by drying) the pregnant leach solution.

In the past, many end buyers have

A visualisation of Giyani Metals' K.Hill manganese project in Botswana

purchased HPEMM, rather than HPMSM, despite using HPMSM as the raw material to make the precursor (the process upstream of making the cathode). In order to manage purity levels, due the lack of high quality HPMSM, end buyers would by HPEMM and dissolve it in a dissolution plant using acid to produce the HPMSM. This was and still is a costly way of producing HPMSM.

Ultimately the product mix of HPMSM vs HPEMM will be determined by our future end buyers, but to date all have said they want HPMSM, over HPEMM. This is because there is an additional capital and operating expense for the end buyer by having to install a dissolution plants to dissolve the HPEMM down to HPMSM.

The K.Hill Project has an advantage over some of our peers in that we can produce HPMSM direct from our ore, without having to first produce HPEMM. This is because our ore grade is high and there are low levels of impurities. This is what makes us confident we will be at the bottom of the cost curve.

Benchmark: Manganese is a key input material in NCM (nickel, cobalt, manganese). Today, the bulk of battery cathode production is located in Asia but developments will see cathode production ramp up in Europe in the coming years. How do you see this developing in the future and where do you see Giyani Metals fitting in this?

> It is our focus to be one of the largest non-Chinese suppliers of high purity manganese to the battery market
>
> Robin Birchall, CEO, Giyani Metals Corp.

RB: Just like Rare Earth Elements (REE), over 90% of high purity manganese is produced in China. This is a major supply risk to all the Non-Chinese precursor, cathode and battery manufacturers. According to **Benchmark**, the Nickel-Cobalt-Manganese (NCM) cathode chemistry is expected to grow in market share over the coming decade to >75% (up from ~40% in 2020).

Therefore, these manufacturers are scrambling to source and qualify non-Chinese sources of high purity manganese, of which there are currently only three (Africa, Europe & Japan). We aim to be the fourth.

Benchmark: Will your focus be solely on the battery market or other end markets?

RB: High purity manganese is consumed in other markets outside of battery manufacturing, such as specialty steel and aluminium, as well as the chemicals and fertiliser markets. However, it is our focus to be one of the largest non-Chinese suppliers of high purity manganese to the battery market. As a new producer outside of the Chinese supply chain, it has already opened a few doors to those battery manufacturers and vehicle OEMs who wish to stay clear of China.

In addition, we are looking into some green initiatives that will bring down our carbon footprint and provide a more premium product.

Benchmark: What are the main challenges of bringing a project online in Botswana?

RB: Botswana is a very safe place to do business. It has the highest-ranking country on the Corruption Index, according to transparency.org, of any African, Middle Eastern, Central Asian, South Asian, South East Asian nation. It even ranks higher than most countries in Central and Eastern Europe.

The main challenge we have, is the same that many other junior mining companies face at the moment; COVID-19. As we near the completion of the K.Hill Project feasibility study and move onto the construction, there will be more materials, expertise and parts crossing borders. We expect there to be some unforeseen delays, but nothing that will inhibit the overall project development.

Domestically, we don't foresee any roadblocks. The local labour force is English speaking and highly skilled, and to date we have had incredible support from all government departments and fully expect that to continue. Since Botswana's independence in 1966, the diamond mining company, Debswana, has been one of the country's largest tax revenue generators both directly and indirectly for Botswana. The country has long supported and nurtured its mining industry, however, is now in the process of diversifying away from diamonds.

Benchmark: When it comes to Africa's role in the battery supply chain, cobalt in the DRC gains most headlines. How important is the wider success of other battery minerals in the region and for Africa as a whole?

RB: Africa is already a crucial component of the battery supply chain. Speaking with potential off-takers, especially those in Europe, they acknowledge that much of their future raw material demand will be supplied from there. This is because there is not the quantity nor quality of raw materials availability closer to home.

However, there is a general lack of understanding about Africa, and so many countries across the continent are often

> Headlines about child labour, corruption scandals and kleptocracy are assumed to be endemic of all African nations. This may be the perception, but it is not the reality
>
> Robin Birchall, CEO, Giyani Metals Corp.

Credit: Giyani Metals

tarred the same brush. And so, headlines about child labour, corruption scandals and kleptocracy are assumed to be endemic of all African nations. This may be the perception, but it is not the reality.

Botswana has low levels of corruption, poverty and extortion, its economy operates a balanced budget, and its democracy is fully functioning. It will not be long before western economies realise that the positive impact that EVs have on their society would not be possible without the resource wealth of Africa.

However, it is up to the respective African governments to work with the mining companies operating in their countries to sustainably enrich its economies. In-turn the middle classes, just like those in Botswana, will flourish and they will have their own voice and tell the world of the positivity reality the mining industry has on their economy.

Change across Africa will not happen overnight, as there are still mining companies and Governments that continue to act irresponsibility. However, because the sustainability of supply for battery metals is so important, it will be catalyst for positive change.

BENCHMARK
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BENCHMARK MINERAL INTELLIGENCE IS THE LEADING PRICE REPORTING AGENCY (PRA) FOR RAW MATERIALS USED IN LITHIUM ION BATTERIES, ELECTRIC VEHICLES (EV) AND ENERGY STORAGE.

Our team of expert analysts intensively collect market data to mineral-specific methodologies in order to assess prices for lithium, graphite anode, cobalt, and nickel. Our specialist focus on the lithium ion battery supply chain and unrivalled network of industry contacts make Benchmark Minerals' Price Assessments the world's most trusted source of battery raw material price data, regularly referenced in negotiations and increasingly used in supply chain contracts.

LITHIUM

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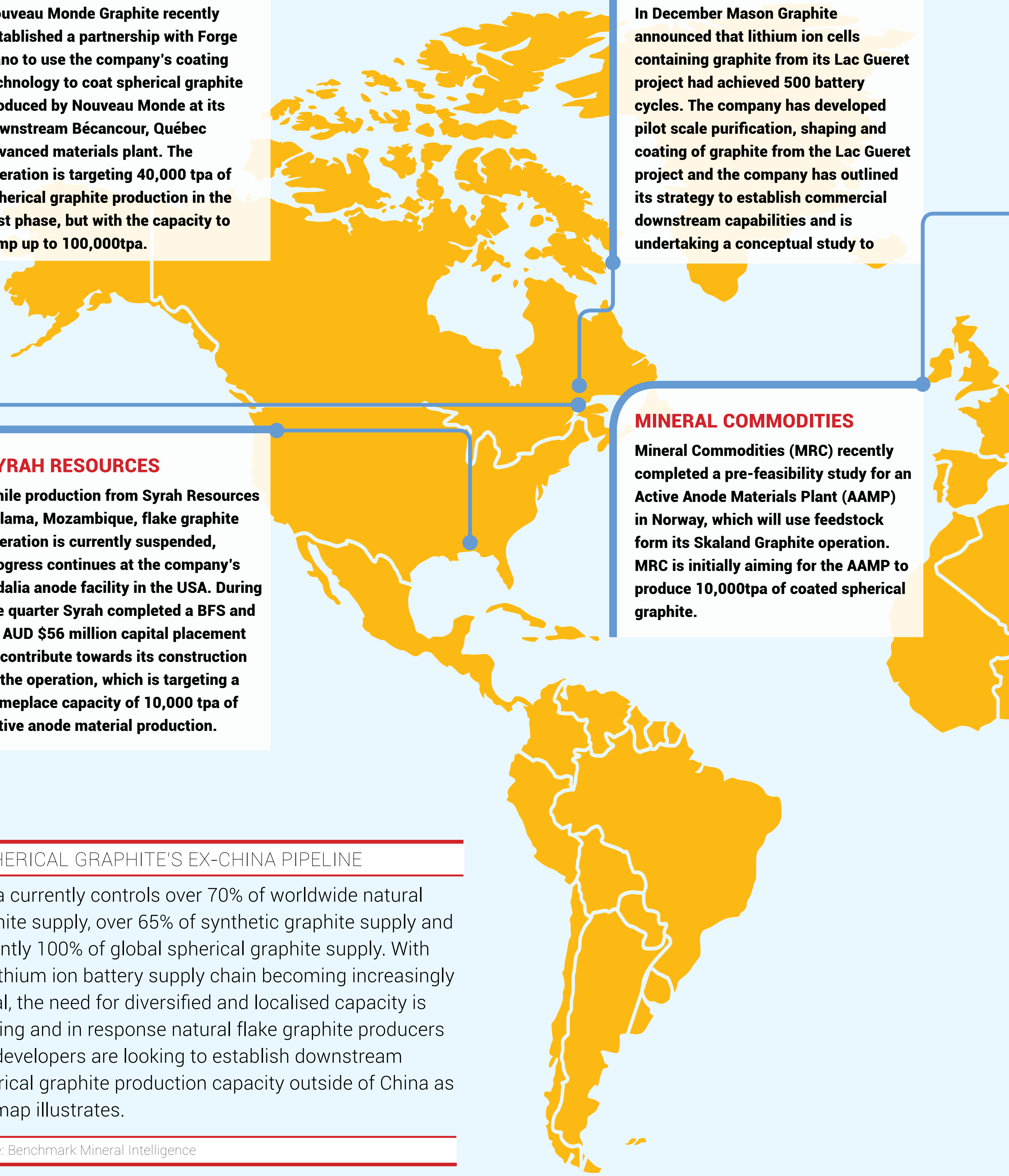


NOUVEAU MONDE GRAPHITE

Nouveau Monde Graphite recently established a partnership with Forge Nano to use the company's coating technology to coat spherical graphite produced by Nouveau Monde at its downstream Bécancour, Québec advanced materials plant. The operation is targeting 40,000 tpa of spherical graphite production in the first phase, but with the capacity to ramp up to 100,000tpa.

MASON GRAPHITE

In December Mason Graphite announced that lithium ion cells containing graphite from its Lac Gueret project had achieved 500 battery cycles. The company has developed pilot scale purification, shaping and coating of graphite from the Lac Gueret project and the company has outlined its strategy to establish commercial downstream capabilities and is undertaking a conceptual study to

SYRAH RESOURCES

While production from Syrah Resources Balama, Mozambique, flake graphite operation is currently suspended, progress continues at the company's Vidalia anode facility in the USA. During the quarter Syrah completed a BFS and an AUD $56 million capital placement to contribute towards its construction of the operation, which is targeting a nameplace capacity of 10,000 tpa of active anode material production.

MINERAL COMMODITIES

Mineral Commodities (MRC) recently completed a pre-feasibility study for an Active Anode Materials Plant (AAMP) in Norway, which will use feedstock form its Skaland Graphite operation. MRC is initially aiming for the AAMP to produce 10,000tpa of coated spherical graphite.

SPHERICAL GRAPHITE'S EX-CHINA PIPELINE

China currently controls over 70% of worldwide natural graphite supply, over 65% of synthetic graphite supply and currently 100% of global spherical graphite supply. With the lithium ion battery supply chain becoming increasingly global, the need for diversified and localised capacity is growing and in response natural flake graphite producers and developers are looking to establish downstream spherical graphite production capacity outside of China as this map illustrates.

Source: Benchmark Mineral Intelligence

TALGA RESOURCES

Sweden's state-owned mining group, LKAB, signed a letter of intent with Talga Resources and Mitsui during the quarter to jointly develop Talga's Vittangi project in northern Sweden. Talga's vertically integrated plans see it targeting 19,000 tpa of anode material production from 2023 onwards, for which it is currently undertaking a feasibility study.

RENASCOR RESOURCES

Renascor Resources entered a Memorandum of Understanding (MOU) with Chinese anode producer Shanxi Minguang New Material Technology Co. Ltd for spherical graphite from Renascor's planned anode material operation in South Australia. The MOU would see up to 10,000 tpa of spherical graphite purchased from Renascor's project, which has a nameplate capacity of 28,000 tpa.

ECOGRAF

At the start of Q4, EcoGraf announced an agreement with the Western Australian government to establish the construction of its spherical graphite plant in Rockingham, WA. The facility will cost US $72 million and is targeting a nameplate capacity of 20,000 tpa.

LITHIUM ION AND BEYOND

In 30 years, the lithium ion battery has become the world's leading rechargeable battery. But what will be the dominant battery technology going forward? **Ben Campbell, Battery Analyst, Cairn ERA** explores the trends and technologies that could support the next leap in energy storage

In 1991, Sony introduced the lithium ion battery (LIB) to the world stage. Its energy density was significantly higher than incumbent battery technologies such as nickel cadmium (NiCad) and lead acid batteries, most notably. But it also had serious flaws: it was costly to make and died quickly after a short number of cycles.

Over the last three decades, the LIB has incrementally improved to the point where it is the dominant rechargeable battery technology for almost all applications. It powers computers, cars and electricity grids.

LIBs have a limit to future improvements though. Conventional cathodes paired with graphite anodes will never reach a gravimetric energy density much higher than 350 watt-hours per kilogram (Wh/kg) and they will always contain flammable ingredients that present a safety hazard.

Throughout the lifetime of LIBs, scientists in universities and battery companies have worked relentlessly to create the next great battery. A review of the scientific literature provides a dizzying array of potential successors to the throne. A few approaches, however, are starting to make progress and will soon make their appearance in the battery industry.

The most promising near-term technology is the addition of silicon to the anode. Using silicon is advantageous for several reasons. It can improve the cost of making the battery, its energy density, and fast charge (measured in C-Rate) capability. It should eventually lower the cost of making the battery because the energy density improvements allow the same size and weight of battery pack with the same energy capacity—despite the higher-cost silicon material. Energy density improvements stem from silicon atoms' ability to store as much as 3 times more lithium than carbon atoms found in graphite anodes. This enables a high-capacity anode out of less material, resulting in a thinner and lighter anode. Reducing the thickness of the anode reduces the distance the lithium ions need to travel to reach the cathode during charging, which enables higher conductivity and the use of faster charging.

Silicon isn't entirely new. Most battery manufacturers have already begun integrating it into their anodes in small amounts. The batteries made by Panasonic for Tesla's Model 3 have ~3% silicon, which is at the high-end of silicon content in today's batteries. Larger proportions of silicon cannot be added to the anode due the enormous volumetric changes it experiences when storing lithium. As lithium ions move to the anode during the first charge, the silicon swells and fractures. Graphite experiences volumetric changes as well, but to the tune of a manageable 7%. Silicon's volume changes by 3X during charge and discharge. Swelling leads to delamination and the breaking-apart of silicon particles. During this process of first-charge, a thin layer of reacted materials forms on the exterior of the anode particle. This layer is called a Surface Electrolyte Interface

Research into metal fluoride cathodes has made substantial recent progress at the University of Maryland

Tesla-Panasonic cells used in the model 3 use approximately 3% silicon in the anode

(SEI). Graphite SEI's are well understood thanks to decades of development. The SEI on a silicon particle is very different and more difficult to make work in a long-lived battery. This malformed SEI results in reduced efficiency of the battery (known as first-cycle loss) and unwanted side reactions with the electrolyte that shorten the lifetime of the battery. Solving this SEI problem is key to making silicon work in the LIB and is the most notable secret sauce of emerging silicon anode startups.

A critical part of that recipe is the source of the silicon. Several precursor silicon materials are being considered by manufacturers for the sake of cost reduction and supply chain diversification. These different sources of silicon input materials present their own challenges. Metallurgical silicon, touted by Tesla for its future batteries, has the advantages of high-abundance and low cost. This material, however, has a high amount of impurities compared to the standard for most battery input materials. It therefore requires more expensive processing methods. Silane, a highly reactive silicon gas, is high in quality and purity but is relatively expensive due to safety issues surrounding its processing and transportation. Most high-capacity silicon anode materials will eventually use silane as a source material.

> While significant progress has been made in developing lithium-metal anodes and solid-state electrolytes, major engineering and electrochemistry challenges must still be overcome

Regardless of the form of silicon being used, the problems of silicon chemistry inside the battery and sourcing the material cheaply are being worked on by more than thirty startups and in the laboratories of most battery manufacturers. Most of them focus on creating a highly engineered silicon particle and then formulating the ideal electrolyte recipe that will work with the new anode material. No one research program has solved all the problems, but great advances have been made in the last five years. This opens the possibility of high-proportioned silicon blended with carbon. Eventually, proportions of 50/50 silicon to carbon anodes will be available, dramatically improving the weight, cost, and other specifications of the LIB.

Silicon isn't the only candidate for next-generation batteries. Lithium metal anodes

Reducing the thickness of the anode enables higher conductivity and faster charging

are another emerging technology that could provide tremendous improvements to LIBs. Some claim metallic lithium is the crown jewel of LIB input materials, as metallic lithium can have up to five times more energy capacity than graphite anodes, and two times more than a graphite anode with 50% silicon. In addition to this material advantage, metallic lithium anodes derive some of their energy density improvements from how they differ functionally from graphitic anodes. Lithium ions are stored in typical graphite anodes via intercalation, meaning the ions find refuge in openings within the porous graphite particles. In a lithium metal anode, the lithium ions plate onto the anode as pure metal. The lithium metal grows on the surface of a substrate (usually copper foil) as the battery charges. This improves the anode's energy density because the lithium is stored more densely and efficiently. This energy density improvement would significantly reduce the $/kWh of LIBs. It also makes the battery significantly lighter, which has cascading benefits for the battery pack and the electric vehicle itself.

> The lithium-ion battery has transformed over the last three decades from a cutting-edge but flawed battery to an industrial workhorse of a nearly $50 billion industry

Batteries with lithium metal anodes are potentially safer than batteries with graphite anodes. This stems from the replacement of liquid electrolytes (which include hydrocarbon solvents that can burn) with a non-flammable solid electrolyte. Lithium metal anode batteries can also be constructed with wet electrolytes, but the safety advantage of a solid-state structure is lost

While significant progress has been made in developing lithium-metal anodes and solid-state electrolytes, major engineering and electrochemistry challenges must still be overcome. The most significant obstacle is that of lithium dendrite formation during plating. Dendrites are metallic lithium

filaments that resemble microscopic Christmas trees. They can form when the surface of the electrolyte or separator is not perfectly smooth. Once they start to grow, they will pierce the separator or at least deform it, leading to failure of the cell. This can cause short circuits or even thermal runaway. Dendrite formation accelerates as the rate of charge increases, making lithium-metal anode batteries impractical for applications that require fast-charging.

Another significant challenge for lithium-metal anode battery development is that solid-state electrolytes experience significant coulombic efficiency loss during the first few cycles. According to Dr. Shirley Meng and her team at the University of California, San Diego, this efficiency loss is mostly caused by the unintentional formation of an SEI layer around breakaway globules of the metal. This segregates the non-dissolved particles and transforms them into an inactive material. Reducing the amount of active materials in a battery consequentially reduces the coulombic efficiency and the energy capacity of the battery.

The problems don't stop there for lithium metal anode batteries. Other challenges range from manufacturing the extremely thin solid electrolytes in a cost-effective manner, creating an airless environment during manufacturing to avoid corrosion of the lithium metal and determining the right recipe for cathode additives that enable adhesion to the solid electrolyte material. All these issues must be solved before lithium metal anode batteries reach mass commercial success. Cairn ERA expects that these batteries will soon be manufactured on a small scale in the next two years and will be available for some niche applications. Incremental improvement of the cells will continue but it should take many years before they appear in mass market applications, such as EVs.

In the meantime, one market that is especially anxious for the success of solid state batteries is aviation. This segment will likely be the largest early adopter of the technology, thanks to its extreme energy density requirements and its relative price insensitivity. Other market niches, such as robotics and specialty consumer electronics, will also open to lithium metal anode batteries as soon as they become available.

Anodes aren't the only game in town when it comes to next-generation battery materials. There are several novel cathode compositions under development that have the potential to reduce the cost of LIBs and improve energy density. A high-manganese content cathode is one promising technology. Manganese has similar properties to nickel, but usually costs as much as 75% less. The most promising near-term candidates for high-manganese batteries are variations on traditional NCM cathodes (i.e. nickel-manganese-cobalt), with a much higher proportion of manganese and lower proportion of nickel. To reach widespread use, this type of cathode has to prove its ability to work well with traditional electrolyte ingredients. If that can be achieved, it will be significantly cheaper than traditional NCM. Progress is being made in overcoming this challenge, and using manganese-rich cathodes remains one of the shortest paths to a cheaper LIB.

Another approach to adding more manganese to cathode materials is to mix the manganese with LFP (lithium iron phosphate) cathode material. If successful, this cathode will see a significant energy density boost over conventional LFP. Still one more option is to add nickel to an LMO (lithium manganese spinel) material, to make LMNO. Once such a cathode can be made to work, it will result in a much higher voltage battery (as high as 5V), thereby increasing energy density.

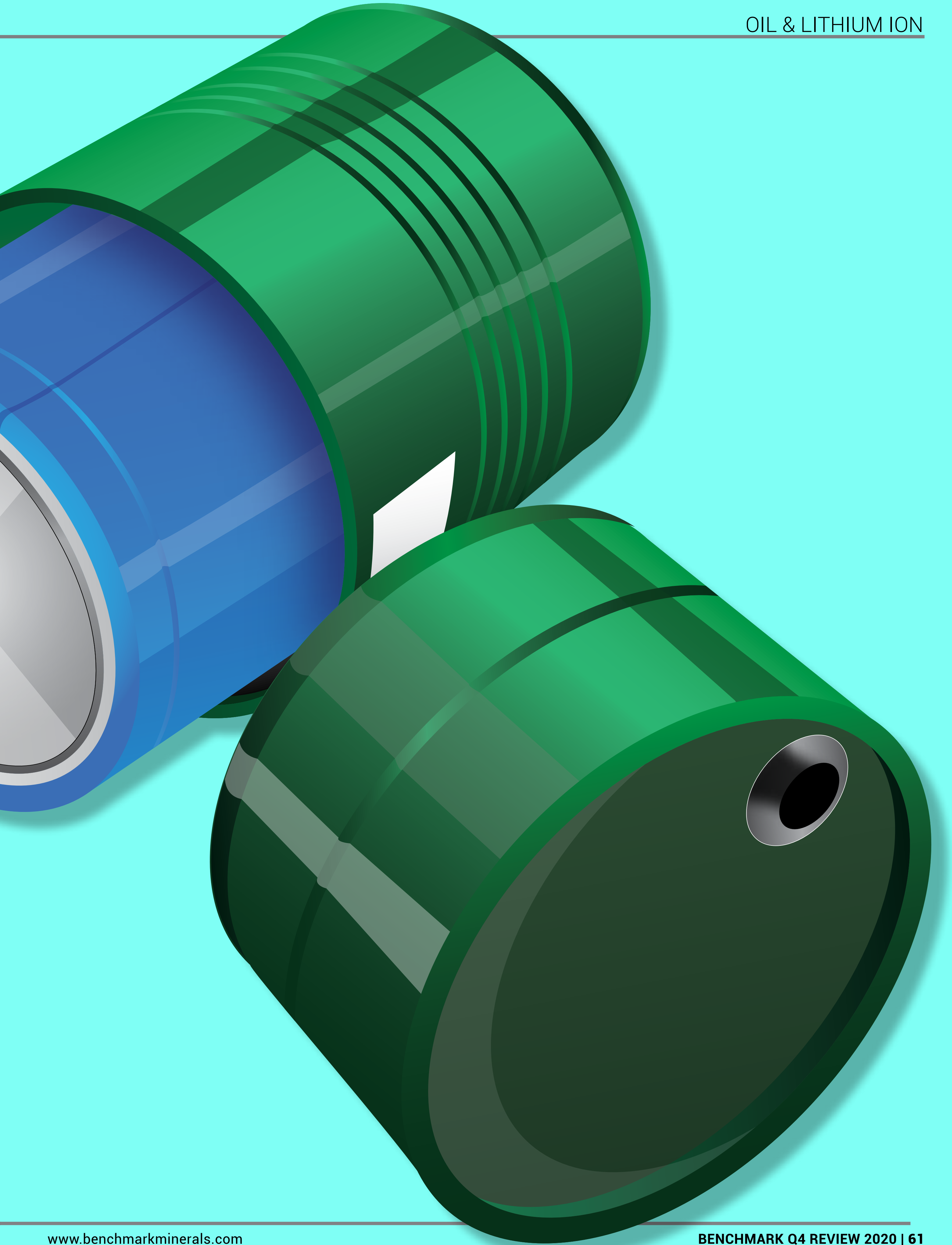
Farther out into the future, two of the most promising new battery materials are metal fluoride cathodes and sulfur-based cathodes. While these materials have a smaller chance of entering the supply chain by 2030 than manganese-rich cathodes, their potential advantages justify the amount of effort and investments needed to make them work. Metal fluoride cathodes have been in development for the past decade, and substantial recent progress has been made by the laboratory of Dr. Chunsheng Weng at the University of Maryland, as well as a research program led by Dr. Gleb Yushin at Sila Nanotechnologies. If conductivity of these materials can be improved, they could see a significant increase in energy density as well as cost.

Likewise, the promise of sulfur-based cathodes, when paired with a lithium metal anode, could enable mouth-watering gravimetric energy density gains. Sulfur cathodes have a wide array of obstacles between them and market viability. One issue is that while gravimetric energy increases, the volumetric energy density either remains unchanged or decreases. Moreover, the voltage of the cell decreases to somewhere around 2.6V. Most battery applications are sensitive to volumetric energy density and voltage, so these issues are not insignificant. The polysulfide shuttle problem is a basic science obstacle with lithium sulfur batteries that also needs to be overcome. This process refers to the phenomenon of the sulfur degrading through unwanted side reactions, which eventually result in chemicals that are toxic to the battery.

The lithium-ion battery has transformed over the last three decades from a cutting-edge but flawed battery to an industrial workhorse of a nearly $50 billion industry. This battery, however, is starting to bump its head on the ceiling. The race is on for which of the many candidates will knock it from its throne.

THE BARREL AND THE BATTERY: OIL, LITHIUM AND THE ENERGY TRANSITION

Ahmed Mehdi, Principal Consultant, **Benchmark Mineral Intelligence**, assesses the implications of the energy transition on the oil and lithium ion battery industries



A look at today's energy mix provides a sobering reminder that oil, gas and coal continue to dominate the global energy system (see Fig 1).

Oil reigned supreme throughout the 20th century (reaching its peak in the mid-1970s) and while its share in the energy mix has fallen by 20% over the past 50 years, on an absolute level, oil consumption has grown year-on-year (see Fig. 2).

This is an important consideration when discussing the 'energy transition' – a byword for achieving a net-zero energy system by 2050.

'Energy transitions' are not new. The world has already been through multiple transitions: the shift from coal to oil being the most noteworthy over the past 100 years.

So, what makes the current 'energy transition' so different? We highlight three key areas:

1) Previous energy transitions have been driven primarily by cost, utility and availability; the current 'energy transition' is driven by climate risk. With the energy sector accounting for over two-thirds of total Greenhouse Gas (GHG) emissions, fossil fuels are a key target for reduction;
2) As highlighted by BP during their inaugural presentation at **Benchmark**'s **Lithium Day**, the absolute demand for coal and oil are set to decline over the next 30 years – an unprecedented development in the history of modern energy systems.
3) The current 'energy transition' will also be defined by greater inter-fuel competition. Coal may have dominated the first half of the twentieth century (and oil the second half), but the path to a net-zero future will be defined by the growing availability of renewables in the energy mix as electrification of the energy system takes root. As a result, customer choice as to energy source becomes more important.

It is in this context that we must understand why lithium ion batteries are being deployed to tackle carbon emissions from transport (see Fig 3) – which account for approximately 23% of total energy-related CO_2 emissions.

Unlike industries such as steel or cement, cost-competitive technologies exist for transport.

Lithium ion batteries sit on the lower end of the CO_2 abatement cost curve, a dynamic supported by the decline in lithium ion cell prices over the past five years (from $230/kWh in 2015 to $110/kWh in 2020).

Strategies to tackle transport emissions have not gone unnoticed in the oil industry, either.

Saudi Aramco, for example, is taking a different approach: investing R&D funds to improve the fuel efficiency and well-to-wheel CO_2 emissions of ICE vehicles – a signal that despite technological improvements in lithium ion battery cell design and cathode chemistry, there remains competition from the incumbent players.

Regardless, the growing electrification of the energy system – supported by growing EV deployment - will also require a decarbonised power sector (driven by solar and wind) which in turn further feeds battery demand (as the need for power balancing to address renewable intermittency grows).

Peak oil demand: not the right question

What does this mean for oil demand?

Let's start with the facts. Transport accounts for almost 60% of oil demand, with gasoline accounting for around 25% of the total. As can be seen in Fig 4, Light Duty Vehicles (LDVs) took up 27% of 2019 oil demand, with Heavy-Duty Vehicles (HDV) not far behind.

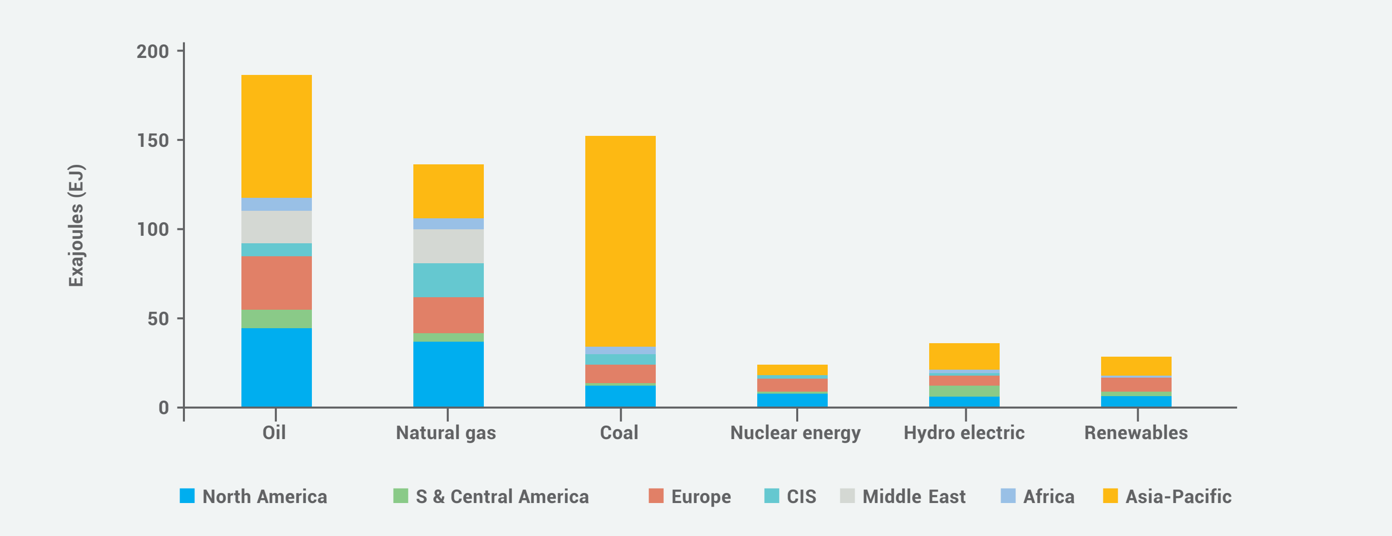
Gasoline displacement by EVs is not a one-to-one measure: emerging market growth (and secondary ICE vehicle markets), rising incomes and population growth all remain key drivers of oil demand growth.

Likewise, petrochemicals remain a bright spot as a result of rising demand for plastics.

However, both advancements in lithium ion technology and hydrogen fuel cells are set to pressure gasoline and diesel demand out to 2030 and beyond.

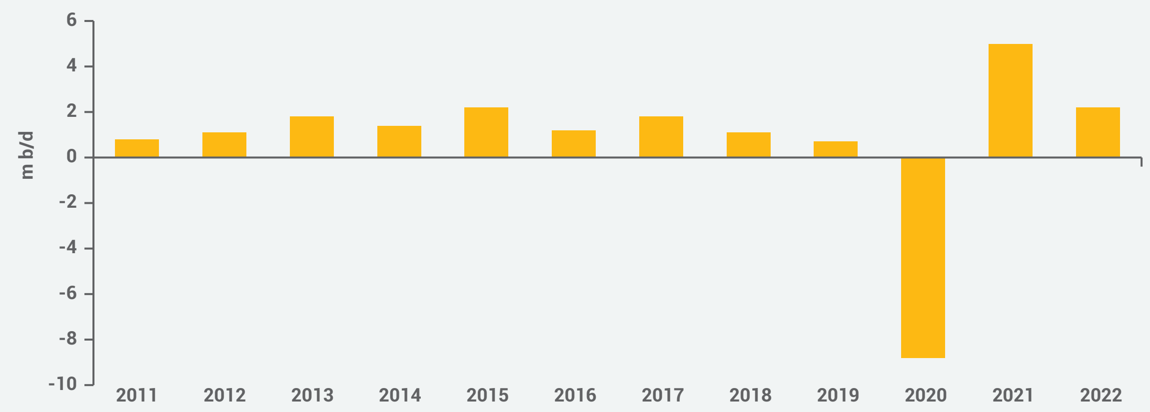
In many ways, attempts to pinpoint when

FIGURE ONE: PRIMARY ENERGY CONSUMPTION BY FUEL AND REGION, 2019 (EJ)



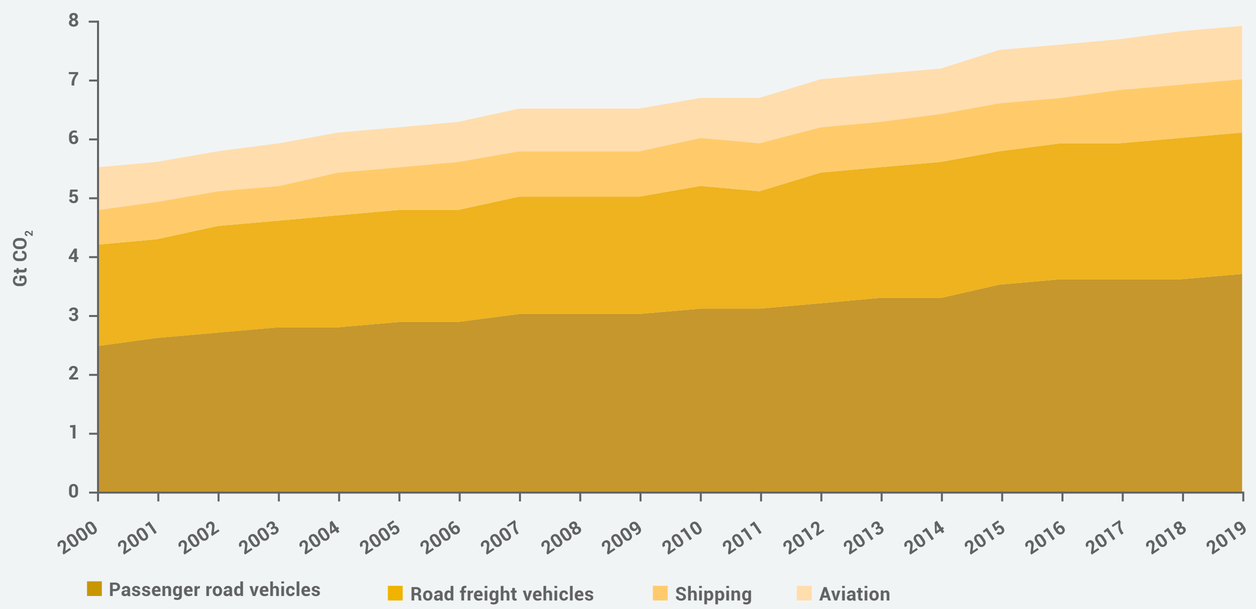
Source: BP, Benchmark Mineral Intelligence

FIGURE 2: YEAR-ON-YEAR (YOY) OIL DEMAND GROWTH (MILLION BARRELS PER DAY)



Source: Benchmark Mineral Intelligence

FIGURE 3: TRANSPORT SECTOR CO2 EMISSIONS



Source: BP, IPCC, Benchmark Mineral Intelligence

oil demand might peak (2020, 2025 or 2040) are moot. The confidence bands around oil demand projections are wide and vary across fuels and geographies.

What matters and is happening today is investor perceptions.

Big Oil majors, especially in Europe, recognise that devising a carbon emission strategy broadly aligned with the goals of the Paris Climate Agreement (PCA) is a non-negotiable.

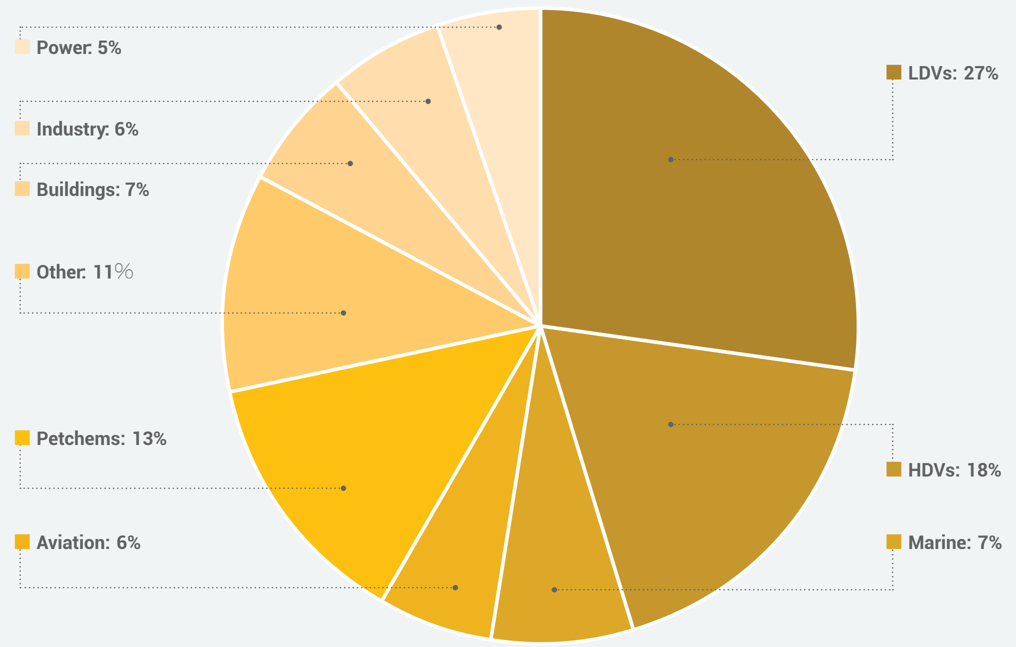
These efforts are not being driven by peak oil demand anxieties but rather investor demands. BP, for example, has announced an ambitious target to cut its oil and gas production by 40% (1.1m b/d) over the next decade; likewise, BP will aim to ramp-up its renewable portfolio, with the aim of reaching 50 GW of capacity by 2030 (from 2.5 GW today).

Likewise, Total – a major player in batteries – outlined its long-term goals during **Benchmark Week 2020**, outlining a ramp-up in installed renewable capacity from 7GW today to 35GW by 2025. Long-term stable returns brought by renewables (and zero short-run marginal costs) are playing a role in this capital allocation shift.

According to **Benchmark** estimates, the levelised cost of solar PV has fallen by over 80% in the past decade. Furthermore, auction prices in certain locations – particularly the Middle East – reached record levels this year. Wind costs have fallen too. Unlike the previous financial crisis of 2008, these costs are now below the total costs of new gas plants.

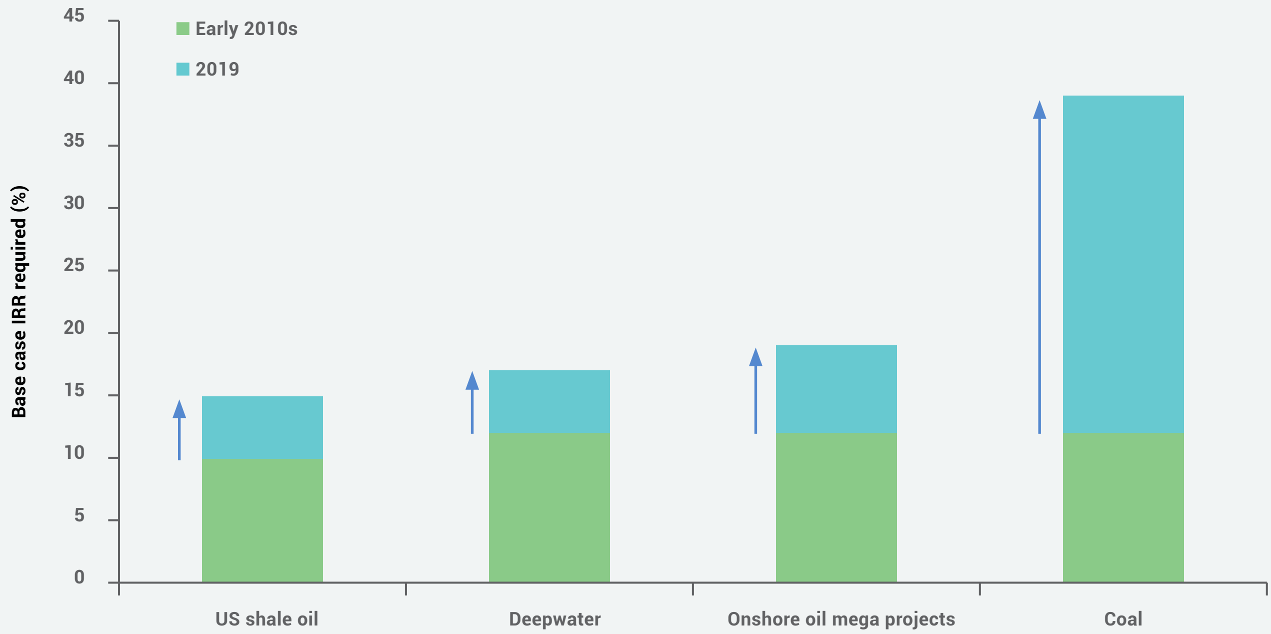
Declines in renewable energy costs play an important role in the cost sensitivity analysis of lithium ion cell costs – further incentivising IOCs to invest in the downstream segment of the battery supply chain.

FIGURE 4: OIL DEMAND BY END-USER



Source: BP, IPCC, Benchmark Mineral Intelligence

FIGURE 5: RISING COST OF CAPITAL FOR OIL PROJECTS



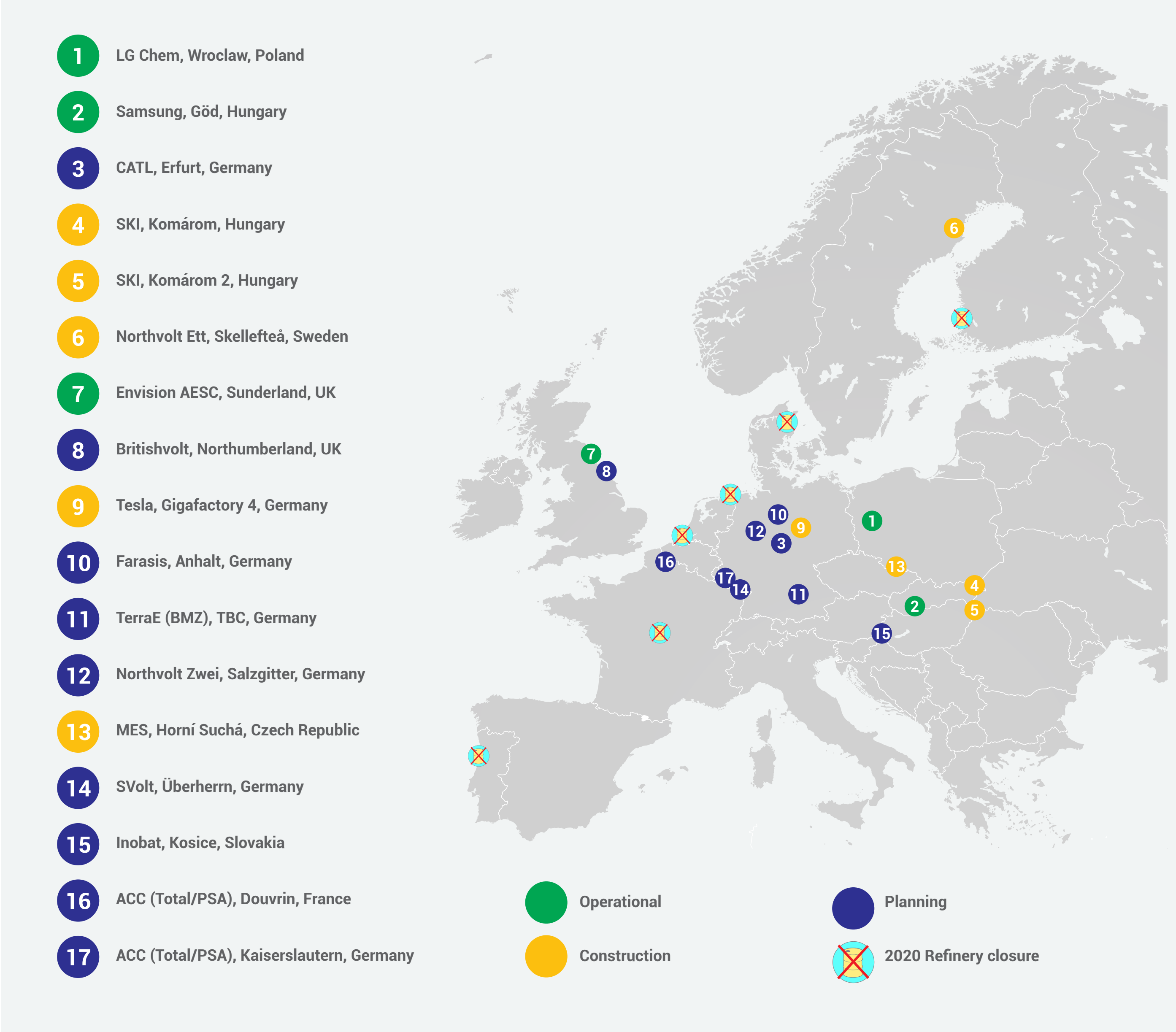
Source: Benchmark Mineral Intelligence, Oxford Energy

Indeed, all European energy majors have now set out plans to increase their renewable energy footprint (some with a dedicated focus on battery investments).

In the US, however, oil majors have largely shunned the strategies deployed by their European peers – preferring instead to make big bets on rising oil and gas demand and using their proprietary technologies to reduce the carbon intensity of their upstream operations (via Carbon Capture and Storage technology, for example).

In the Middle East, the rising cost of capital for Big Oil (see Fig 6) and the cuts to upstream capex (both due to covid-19 and

FIGURE 6: A TALE OF TWO INDUSTRIES – BATTERY CELL PLANTS VERSUS OIL REFINERIES IN EUROPE



Source: Benchmark Mineral Intelligence

Big Oil's strategy shift to Big Energy) bring different opportunities as low-cost producers with spare capacity (primarily Saudi Arabia and the UAE) can increase market share in a more competitive market as oil's share in the energy mix gradually declines.

2020 has been a tale of two industries

As the IEA made clear during their presentation at **Benchmark**'s **Lithium Day, 2020** saw energy demand drop by 5%, with only renewables (solar and wind) registering an increase this year.

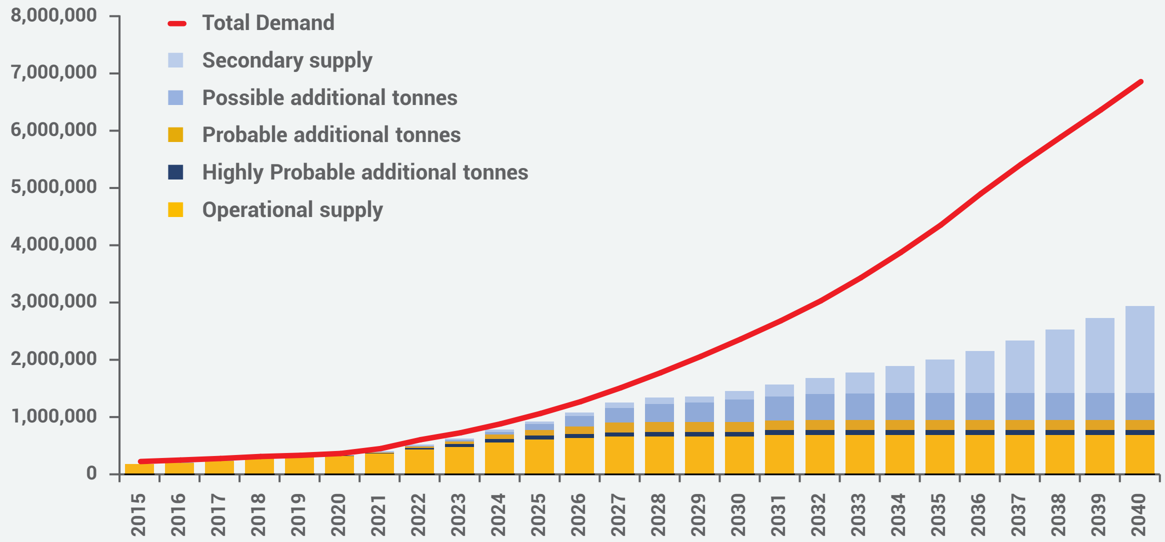
For the oil sector, demand is expected to fall by 8.8m b/d this year, wiping out six years of demand growth with expectations that demand will not return to pre-covid levels until at least 2023-24.

2020 has also been brutal for downstream oil refinery margins: the year witnessed negative margins for gasoline and jet fuel. While gasoline demand has largely recovered to pre-covid levels, jet demand is set to remain weak throughout 2021, with its future prospects pinned on the future health of the aviation industry.

Refining has always been a tough business with razor-thin margins and Europe was already expecting a wave of consolidations and closures.

Covid-19 has accelerated this process as new capacity additions outpace demand growth. Likewise, the onslaught of new mega-refineries in the Middle East and Asia has exacerbated the problem, forcing refiners to either adjust product yields, close down or convert their operations to bio-fuels, for example.

FIGURE 7: LITHIUM SUPPLY DEMAND BALANCE TO 2040 (tonnes LCE)



Source: Benchmark Mineral Intelligence

On the other end of the spectrum, 2020 also witnessed the roll-out of EV-friendly policy announcements and ambitious EV sales targets by OEMs. In November, the UK brought forward by a decade its timetable for a ban on the sale of new petrol and diesel-only cars to 2030. Europe has pushed forward with its Green New Deal ambitions; China has pledged carbon neutrality by 2060; and President-elect Biden has outlined plans for a net-zero economy by 2050.

2020 also signalled the growing appetite of energy majors to make big battery bets.

Giants such as Equinor signed a JV with Panasonic and Norsk Hydro to develop a lithium ion battery business in Europe – driven not only by Europe's growing EV demand but also Equinor's growing renewable energy portfolio.

Increasingly, we are likely to see further JVs or direct debt-financed investments by the energy majors as interest rates remain low and energy majors tackle the question of how to balance the intermittency of renewables in the power system.

Where bottlenecks bring opportunity for the oil majors

Clearly then, Europe's shift from Big Oil to Big Energy has begun and the investment case for lithium ion batteries is not only being spurred by EV demand but also the rise of renewables.

However, these investments have so far focused on the downstream: cell capacity, EV charging and storage.

As **Benchmark** have previously highlighted, upstream mine financing challenges remain a key bottleneck going forward. In short, investment dollars are being allocated to finance the demand of key metals – lithium, nickel, and cobalt – but not their supply.

Ever-declining lithium ion battery cell prices have been treated as a canonical axiom. However, further declines in cell costs cannot be taken for granted – particularly as some forecasts suggest lithium ion cell prices dropping to $55-60/kWh by 2030.

With the cathode as the most expensive part of any lithium ion battery configuration, cell costs are highly sensitive to raw material prices – particularly Nickel, Lithium and Cobalt. While battery manufacturers are working to new cathode chemistries and aiming to source cheaper cathode active materials, the surge of downstream investments is not being matched in the upstream.

To take one example, Lithium, Figure 7 shows the scale of the gap in supply-demand balances required to meet surging demand.

The prospect of major bottlenecks in the lithium ion supply chain not only risks derailing the cost-competitiveness of lithium ion batteries but also its investment case for integrated majors as they seek to build new renewable and power businesses.

One solution going forward could be that the integrated energy majors take the initiative to invest directly in the upstream. This could make sense for a number of reasons:

- Energy majors are already making big bets on the downstream sector – from cell capacity investments (Total/PSA, Equinor/Panasonic) to EV charging (BP, Shell, Total). The ability of energy majors to take an active upstream position gives them leverage to control costs and create a vertically integrated battery supply chain as renewables become the new king of electricity;
- European Energy Majors have huge experience in upstream technologies – a pre-requisite for complex mining operations (particularly Lithium and Cobalt operations);
- Oil Companies are already involved in the lithium ion supply chain (for example in the supply of petroleum coke as a feedstock for graphite production used to produce anodes in batteries).

CHARGING FORWARD

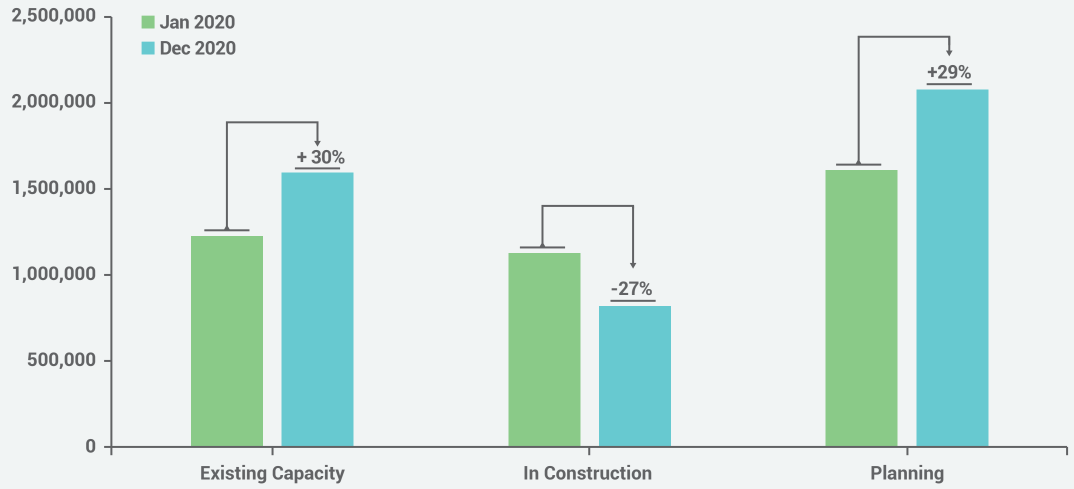
Credit: BASF

Drawing data from **Benchmark**'s **Cathode & Anode Assessments** and **Benchmark**'s **Lithium ion Battery Database**, we chart the key trends and developments in the battery cathode and anode markets as they ramp up for a decade of stellar demand growth

CATHODE CAPACITY (tpa): JANUARY 2020 vs DECEMBER 2020

Existing & planned capacity growth

Between January and December 2020 cathode production capacity in the pipeline grew by 13%, with an additional 531,230 tpa added to the Benchmark Cathode Market Assessment. While capacity under construction has fallen, total existing capacity increased by over 350,000 tpa as more projects came online in 2020. There remains a strong pipeline of both planned capacity and capacity under construction



Source: Benchmark's Cathode Market Assessment

ANODE CAPACITY (tpa): JANUARY 2020 vs DECEMBER 2020

Anode's pipeline surge

While existing anode production capacity increased by 7% between January and December, there was a surge in planning activity with an additional 685,300 tpa of planned capacity added to the Benchmark's Anode Market Assessment during the year. The anode market remains China-centric and the bulk of this new capacity will be based on the Chinese mainland

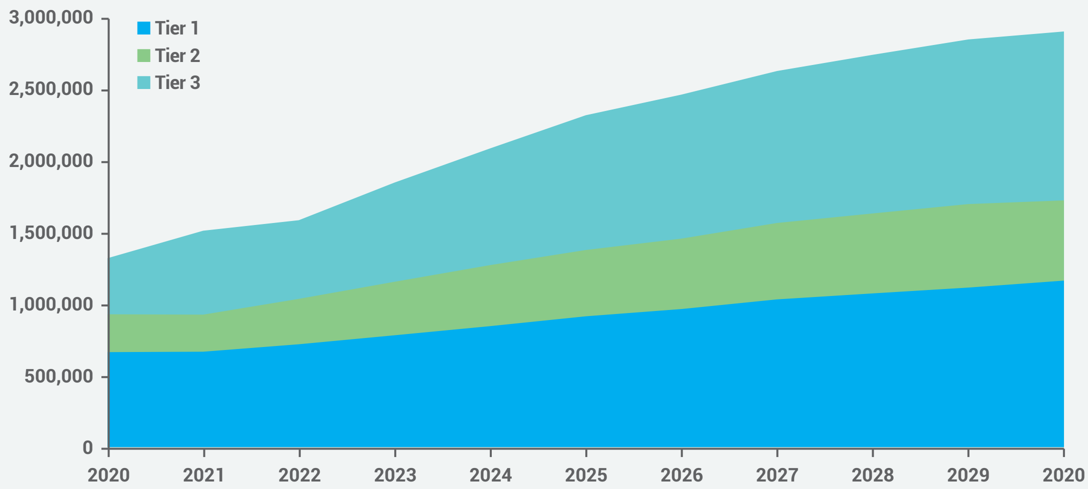
Source: Benchmark's Anode Market Assessment

CATHODE TIER CAPACITY (tpa): 2020-2030

Growth across tiers

This chart shows cathode capacity from 2020 to 3030 split by production tier. The quality of material and experience of producers is key at each stage of the supply chain and cathodes are no exception. The definitions of cathode production tier are:

- Tier 1: Producers with access to significant scale production and qualified to supply into global EV market
- Tier 2: Producers qualified to supply into domestic markets or non-EV sectors
- Tier 3: New or small-scale producers not yet qualified into automotive applications

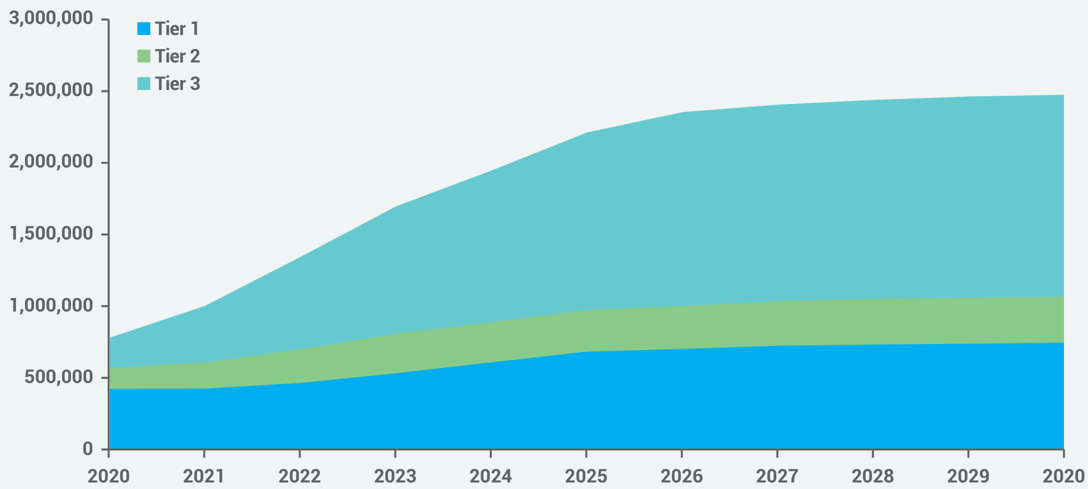


SOURCE: Benchmark's Cathode Market Assessment

ANODE TIER CAPACITY (TPA): 2020-2030

Third tier leading expansions

The tiering definitions outlined in the cathode chart above also apply to anode producers. This chart shows that while today most existing anode capacity is held by tier 1 producers, the majority of future capacity in the anode supply chain is being developed by relatively inexperienced and small-scale producers that do not yet qualify for automotive applications. As with raw materials and battery cells, bottlenecks in quality may have a limiting factor in scaling up both anode and cathode production for electric vehicles, particularly in western markets

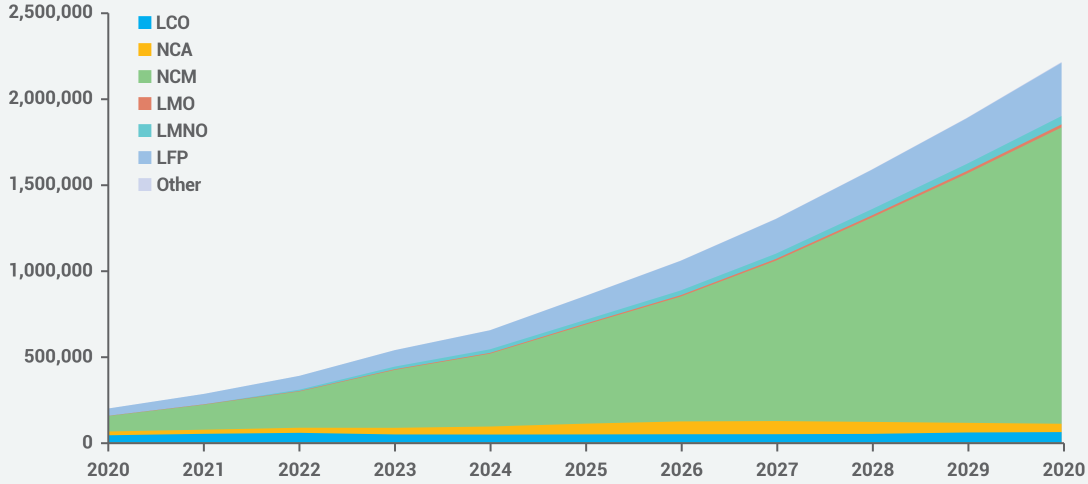


Source: Benchmark's Anode Market Assessment

NCM & LFP DEMAND SURGE

NCM & LFP dominate

Taking demand data from Benchmark's Lithium ion Battery Database, this chart indicates the impact soaring battery cell demand will have on the cathode market. While all cathode materials will be in demand, the clear beneficiaries are NCM (nickel cathode manganese) and LFP (lithium iron phosphate) chemistries. Within NCM there are of course a number of different chemistries and the preference for higher nickel variants will continue through the decade

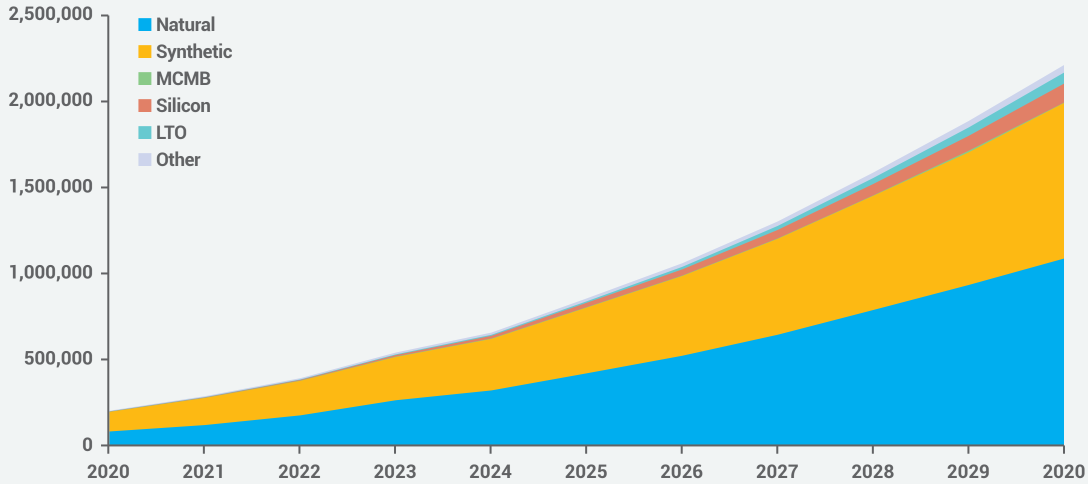


SOURCE: Benchmark's Lithium ion Battery Database

ANODE DEMAND BY CHEMISTRY (GWH): 2020-2030

Natural Synthetic's battle

Here, we have taken the same demand data from Benchmark's Lithium ion Battery Database as in that chart above but split this by anode material. Anode materials will continue to be dominated by natural and synthetic graphite through the decade, with natural taking an increasing share. However, demand for silicon which is almost invisible in 2020 will take a growing share of demand as its use increases



SOURCE: Benchmark's Lithium ion Battery Database

BATTERY SUPPLY CHAIN: 2020 REVIEW

Drawing from our monthly price and market assessments **Benchmark** looks back at some of the key developments during 2020, a year overshadowed by the ongoing COVID-19 pandemic, which affected all segments of the supply chain


Credit: Steve Jurvetson

Tesla continued to pave the way for supply chain change in 2020, with new cells, terawatt hour production plans, and a move upstream

LITHIUM

Prices in 2020 were characterised by consistent downward movement, more for lithium carbonate than hydroxide, throughout the year until the final quarter. Then a trend of stability and even upward movement in domestic Chinese carbonate began, with international prices remaining stable or ticking downward. **Benchmark**'s Global Weighted Average Carbonate price was down 18.4% for the year compared with 7.9% for hydroxide.

The latter half saw consolidation in the lithium market with Altura entering receivership and being sold to Pilbara, Tianqi agreeing to sell part of its Greenbushes and Kwinana share to IGO.

During the year, lithium chemical producers, and especially spodumene producers were impacted by market prices falling beneath cash operating costs this year. Larger producers strengthened their position, with smaller players facing financial difficulty this year.

With the COVID-19 pandemic dominating from late-January onwards, many producers cut spending and delayed expansions in the first half of the year.

While this made sense in the environment, it will likely encourage volatility in the future as consumers struggle to contract adequate supply to account for their downstream requirements.

A new marker in the supply chain's developed saw Tesla pave the way for OEMs to move upstream as it announced plans to develop its own lithium hydroxide processing capacity.

COBALT

The impact of COVID-19 at the start of the year was particularly pronounced for cobalt, with the slowdown in Chinese demand hitting European automakers. Initially the demand for cobalt from the electric vehicle industry dropped, however, changing customer habits and the demand for consumer electronics propped up demand prior to electric vehicle recoveries in the second half of the year.

The shutdown in South Africa and port closures, in response to the pandemic, affected the supply of raw materials to China. Initially this was not seen in prices, as demand was still affected by the virus and there were stocks to work through. However, price rises really took effect in July-August and were driven by market tightness due to ongoing

The buildout of 5G base stations in China boosted demand for energy storage systems, in turn benefiting LFP cathode technologies

logistical delays.

Importantly the payable levels of hydroxide have remained elevated since then, despite imports of raw materials into China returning back to pre-pandemic levels due to rapidly increasing EV demand and fears over market tightness for hydroxide in 2021.

Looking at the Democratic Republic of the Congo (DRC), which is responsible for the bulk of the world's cobalt supply, there were developments to formalise the artisanal sector. In the first half of the year, the DRC government formed the Entreprise Générale du Cobalt to establish a monopoly to purchase all artisanal cobalt in the country. This effort was then backed by Swiss trading house Trafigura, which will support the financing of six controlled artisanal concession zones in the DRC.

ESG factors remain a major concern for downstream consumers of cobalt, particularly with the ethical issues that have been associated with DRC artisanal cobalt production. The biggest consumers and producers of cobalt continued in efforts to support the ethical side of the supply chain, for instance both Tesla and Glencore joined the FCA (Fair Cobalt Alliance).

By the second half of the year, EV sales recoveries in Europe and China played a key role in supporting growing cobalt demand.

NICKEL

After falling to lows across February and March, nickel prices rallied throughout 2020 to reach year-to-date highs in December, driven in large part by China's 'V-shape' economic recovery.

Concerns over the potential for long-term tightness of 'battery suitable' nickel supply helped contribute to the rally, aided in part by Tesla CEO, Elon Musk's public comments encouraging mining companies to 'mine more nickel… in an environmentally sensitive way."

Future nickel supply remained a long-term concern for electric vehicle consumers, and although delayed somewhat by the COVID-19 pandemic, the build out of battery-targeted supply from HPAL projects in Indonesia continued in earnest in 2020 ahead of the now expected initial start date of H1 2021.

As these mines begin operations, and start ramping production towards nameplate capacity from 2021 onwards, their success in meeting both cost projections and tightening environmental standards is likely to be play

Credit: Volkswagen

Volkswagen took a stake in Chinese battery manufacturer Gotion as it looked to maintain its auto position in China

a fundamental role in how the lithium ion battery industry develops over the coming decade, both in terms of battery costs and technological pathways.

Following the implementation of a nickel ore export ban early in the year, Indonesia increasingly looked to capitalise on its strategic position as the emerging heart of the global nickel industry to court investment across the battery supply chain in 2020, as the country looks to establish itself as a hub for the electric vehicle industry in Asia. Key players from across the supply chain are now mulling over investments in Indonesia, a trend likely to develop further into 2021.

The resurgence of LFP (lithium, iron, phosphate) cathode technology in China compounded the negative impacts of COVID-19 on nickel demand from the battery industry throughout H1 2020.

However, by Q3, burgeoning EV sales in Europe, driven by generous subsidies introduced as part of 'green' economic stimulus packages, in tandem with China's supply chain recovery, helped nickel demand from the battery industry outstrip previous years in H2.

GRAPHITE

Graphite prices were ticking down steadily across the year.

The structural oversupply that exists across most mesh grades has limited the impact that COVID-19 had on pricing. Following some good demand recovery in China from both the industrial and EV supply chain, we are beginning to see some stability and price increases for larger mesh sizes, which are most uncommon in Chinese mines.

We have seen expansions in China throughout the entire year, with graphite miners and processors announcing further expansions and carrying out technical modifications to increase production capacity – good industrial and EV demand in domestic market has led to strong domestic sales and a strong market within China.

Many of these expansions have been undertaken in partnership with local governments. Minmetals, a large state-owned mining corporation, has intervened in graphite mining by reforming mining permits in Heilongjiang. The Chinese central government values graphite's strategic position in the EV supply chain as largest mineral content by volume, and wants to focus on producing large amounts of it.

Another development is the rise of integrated graphite producers and developers outside of China. As China looks increasingly inwards (exports and imports declining through time) for its flake graphite market, only exporting when products are value-added, other regions will need to develop their own sources of flake and value-added facilities to support the EV industry. With efforts to move to more environmentally friendly processes, the answer of the industry so far has been the nascent development of integrated graphite and value-added facilities in western jurisdictions

ANODE

In 2020 we saw increased Chinese dominance of the supply chain, with all the major anode expansions being located in China.

We also saw increased price competition through the year as China's new, lower-cost synthetic graphite capabilities forced price competition for anode feedstock.

Recent advances in anode technology have mostly been in natural and synthetic graphite blends, however, there is increasing support

Durban, South Africa. The H1 coronavirus shutdown and port closures in South Africa had a major impact on cobalt supplies to China

for silicon anodes – as highlighted by Tesla during their battery day – and lithium metal in the long-term.

Towards the end of the year, there were rumours of quality concerns from some Chinese shipments. While OEMs are not tied to anode producers, this highlights the need for consistent quality inputs at every stage of the supply chain.

CATHODES

During the year majors have stepped up their pursuit of new cathode capacity, with more joint ventures being established between tier 1 participants.

The cathode industry, in a similar vein to the anode industry, is shaping up to be China-centric although to a lesser-degree.

We saw developments towards cathode production outside China during 2020, particularly in central and eastern Europe where a number of cathode operations are due to come online in the next two years. On Tesla's Battery Day Elon Musk announced the company's intentions to move upstream to cathode production, and while details were light on the ground it indicates the trend among OEMs to move upstream.

At a technology level, LFP batteries were back on the agenda with growing energy storage demand and cell-to-pack technology allowing greater energy density – bringing into question whether the industry needs to move to NCM 811 cathodes to meet growing the growing demand for more energy density.

There was also further focus on cobalt-free cathode chemistries, such as SVOLT's unveiling of a cobalt-free cathode in May but the buildout of these will take some time.

BATTERY CELLS

Volkswagen's (VW's) investment in Gotion at the start of the year was the first investment in a Chinese cell maker by western automaker, adding to VW's partnerships with Northvolt in Europe. This trend of auto-battery tie ups continued through the year as shown by LG Chem and GM's Ultium battery, Panasonic's and Toyota's partnership, Total/SAFT's and PSA's European megafactories.

The LG Chem and SK Innovation (SKI) lawsuit rumbles on over trade secrets infringements. The United States International Trade Commission (ITC) has delayed its decision until February, but the outcome could be a major blow for SKI and its customers if the result is in LG Chem's favour.

During Tesla's Battery Day, Musk confirmed Tesla's new 4680 cylindrical cell format at Tesla's Battery Day, also confirming that in-house production was already underway at the company's pilot plant in Fremont and plans to expand this in Texas and Berlin.

The company also outlined aggressive capacity expansion targets: 100GWh of production by 2022 and 3,000GWh of production by 2030.

Tesla's China expansions continued. Earlier in the year, Tesla confirmed it would be using LFP cells in its standard range Model 3 in China.

The LFP renaissance continued in China as the expansion of 5G infrastructure in the country saw rapid adoption of energy storage systems (ESS) using LFP batteries in the network's base stations.

In general, across the supply chain there were issues with ramping up production at new battery plants, even for experienced tier one producers. In Europe, there were fears of insufficient battery cell supply earlier in the year but this did not ultimately cause any major issues. While cell production continued to ramp up, there were a number of high-profile electric vehicle recalls across major automakers using tier 1 cells. Both of these issues highlight the challenges facing all battery makers in producing consistent battery cell technology.

Rapid investment in battery cell production capacity continued through the year as data from **Benchmark**'s **Lithium ion Battery Megafactory Assessment** shows. In January 2020 the assessment was tracking 121 megafactories with 2,224.5 GWh in the pipeline. By the end of 2020 this had increased to 181 megafactories with 3,009.7 GWh.

BENCHMARK LAUNCHES NEW ESG DIVISION

Benchmark ESG, our new Environment, Social and Governance division, is creating unique and specific methodologies for the electric vehicle supply chain that will provide independent analysis and benchmarks for social and environmental standards in our industry.

Benchmark ESG will provide a standardised approach to the ESG challenge, allowing clients to access key data and rankings from raw material mine through to lithium ion battery cells and end markets – for every step of the lithium ion battery value chain.

Andrew Miller, Product Director, at **Benchmark** said: "At a time when questions are mounting on not just the availability, but also the sustainability of EV supply chains, we are excited to launch a new team that will add to the industry leading market intelligence Benchmark provides.

BENCHMARK ESG

"The new division will offer independent assessments of ESG variables across the battery market, starting with lithium.

"Our comprehensive and granular understanding of the lithium ion battery supply chain is unparalleled and allows us to conduct more accurate and relevant analysis, providing greater ESG transparency and giving confidence to downstream users that important thresholds have been met."

- **Contact Benchmark ESG today with your questions: ESG@benchmarkminerals.com.**

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Linde is a leading global industrial gases and engineering company. We live our mission of making our world more productive every day by providing high-quality solutions, technologies and services which are making our customers more successful and helping to sustain and protect our planet.

Gas is widely used in all aspects of productions across the whole Lithium-ion battery industry value chain, such as raw material refining and processing, manufacturing of battery active material, cell and battery pack manufacturing and assembly, final product integration, reuse and recycle of battery product, and so on.

Linde has conducted in-depth research on gas applications in all above fields. For different materials and processes, Linde has accumulated rich experience in gas supply modes, atmosphere and impurity control, and related auxiliary equipment and programs to help with intensive, environmental-friendly and safe production for manufacturers in Lithium-ion battery industry.

Linde – ideas become solutions.

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