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Charging ahead

FINDING INVESTMENT OPPORTUNITIES FROM THE GREAT BATTERY TAKE-OFF

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Executive Summary

Following on from the work presented in our white paper "Enabling a Revolution", this paper is intended as an update on the sector, and the continuing work we have undertaken.

Over the past nine months the idea that we are on the verge of an electric vehicle take-off has become increasingly palpable. Tesla announced the launch of its long-awaited Model 3 at the end of March 2016 and already has a pre-order book of more than 400,000 deposits.[1] At the same time, heightened media and sell-side analyst coverage has seen a wave of interest in the thematic. Companies are also starting to invest significant capital expenditure in anticipation of demand – Umicore, which manufactures cathodes, an essential battery technology, recently announced its intention to triple capacity for its NMC cathode materials by 2018.[2]

Lithium spot prices in China have surged over 250% since the beginning of 2015,[3] driven in part by a supply shortage in the domestic Chinese market, but also by speculation of further price rises. While we would argue this is somewhat misleading, we are encouraged to see that such prices are being bought on a commercial scale for use in cathodes, and then batteries, as it supports our thesis that there is room for both volume growth and price inflation for lithium suppliers.

In this white paper, we delve deeper into the supply chain to further identify the potential winners from this structural growth theme. We remain permanently cognisant of both the potential for disruptive technology to be, itself, disrupted, as well as for a bubble to emerge within such nascent thematic trends. We identify the next rung of potential winners, and also re-examine the investment case for those stocks we previously identified as beneficiaries.

Specifically, we look more closely at the value chain to identify where we believe economic profit can be generated. In particular, we provide a detailed overview of battery manufacturers, cathode and separator manufacturers, and the various raw materials, including lithium and graphite, used in the production of lithium-ion batteries.

The economics behind the take-off

- Battery producers have invested significantly to increase production capacity, while original equipment manufacturers have driven down prices in an effort to reach the take-off point for mass commercialisation of electric vehicles
- Within the battery supply chain, we expect that some component suppliers will have greater bargaining power than the manufacturers themselves
- As cathode and separator manufacturers possess intellectual property and are, ultimately, the differentiating factor for safety and performance, they should retain a greater degree of pricing power, and hence profitability
- Within raw materials, we see potential supply bottlenecks from the rapid growth in the rechargeable battery segment, which we believe will create a marked increase in demand for inputs such as lithium, graphite and cobalt

Priced to sell

Critical to the ability of electric vehicles to achieve scale is a commercially competitive price relative to internal combustion engines (ICEs). Presently, the battery cost is the key component preventing this.

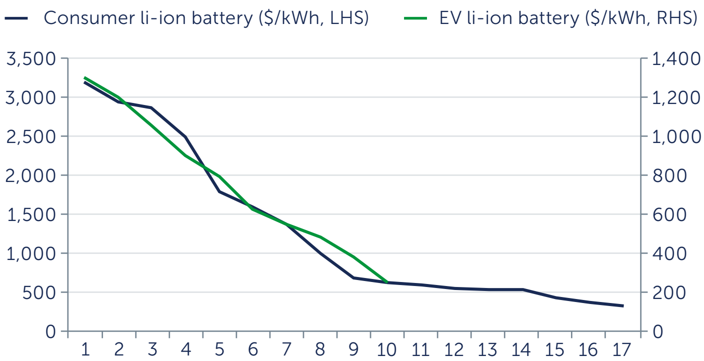
However, contracts with original equipment manufacturers (OEMs) show that lower pricing is already being factored in – LG Chem's recent deal with General Motors (GM) not only has a price lower than many expected (US$145/kWh at the cell level), but also includes an implied step-down to US$120/kWh as early as 2020.[4] In other words, there is a need to offer both scalability and low and declining prices to win contracts.

OEMs have demonstrated their willingness to aggressively compete on price to drive down global battery prices. GM's open announcement of the price in their contract with LG Chem was probably not designed to give GM a competitive advantage in the market, but rather to accelerate the rate of global price declines.

OEM's recognise that electric vehicle (EV) take-off depends upon falling global prices. They are keen to accelerate this given the importance of looming CO_2 emission standards, which would see companies fined on a per car basis for every gram over the permitted amount on an average fleet basis. Introducing even a small percentage of EVs into the global fleet by 2020/2021, when these targets begin to come into force, could save the OEMs billions of dollars. Therefore, putting pressure on battery manufactures to reduce costs by openly disclosing prices is a much easier way to reduce their costs than through expensive R&D.

We expect battery manufacturers to face 10-20% p.a. pricing pressure (prices have been declining at a CAGR of over 15% p.a. for the last 10 years[5]). Accordingly, they must cut their costs at a similar rate just to maintain profitability, which we believe is currently largely non-existent.

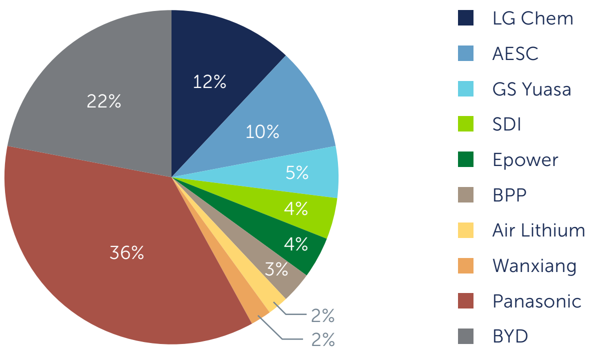
Cost evolution of lithium-ion batteries*



Source: Barings, January 2016; Bjorn Nykvist and Mans Nilsson, 'Rapidly falling costs of battery packs for electric vehicles,' Nature Climate Change, 23 March 2015; 'Lithium, The future is electric' Citi Research, 16 October 2015

*Note: rebased to t=1 (1995 for Consumer, 2006 for EVs)

Top 10 EV battery producers' market share (2015)



Source: Deutsche Bank, "EV battery makers," 2 June 2016

Scaling up – an expensive endeavour

Battery manufacturers have focussed on capital expenditure for capacity build out and economies of scale to achieve efficiency gains and to reduce production costs. The result has been a significant increase in global manufacturing capacity over the past few years. Total global capacity will stand at more than 80GWh by the end of 2016; enough to produce more than one million Teslas.[6]

Capacity is a prerequisite to achieve project wins with OEMs as scalability that can support mass commercialisation is crucial for the success of electric vehicle manufacturers. For the battery makers themselves, however, the result has been low utilisation rates – which we estimate to be around one third of capacity – and hence paltry margins pretty much across the board due to the low fixed cost dilution.

The winners and losers

While production is fairly concentrated amongst the major battery manufacturers, our analysis indicates that they have relatively little bargaining power with OEMs due to the current global overcapacity and inherent importance of declining prices to the volume growth story.

Therefore, one has to look further up the supply chain to the component manufacturers to find the economic winners of this long-term structural growth story. They own the intellectual property and produce essential inputs for the end products accepted by OEMs, which we believe offers them relatively more bargaining power than battery manufacturers. In other words, we believe the manufacturers will get squeezed both in terms of end product price and input costs in much the same way that solar cell manufacturers have been over the past decade. In the near term, there may be some first mover competitive advantages and certainly volume growth, but longer term we remain concerned by the manufacturers' ability to make and maintain economic profits.

The upstream component makers are generally in a much better bargaining position than the manufacturers. While some of the burden of price declines will fall on the component manufacturers, given that they generally possess the IP and are, ultimately, the differentiating factor in the safety and performance of the battery, we believe that they will retain a greater degree of pricing power, and hence profitability. In particular, on the cathode and separator side, both components are crucial to the performance and safety of the battery itself, and hence could be specified by OEMs in contracts with manufacturers, giving the component makers a strong bargaining position.

Battery manufacturing: competition and commoditisation

- We believe that battery manufacturing, as a simple, outdated and capital intensive process, is ripe for commoditisation akin to solar photovoltaic cell manufacturing
- In our opinion, the best investment opportunities are to be found in companies that offer genuine competitive advantages in niche areas further up the supply chain

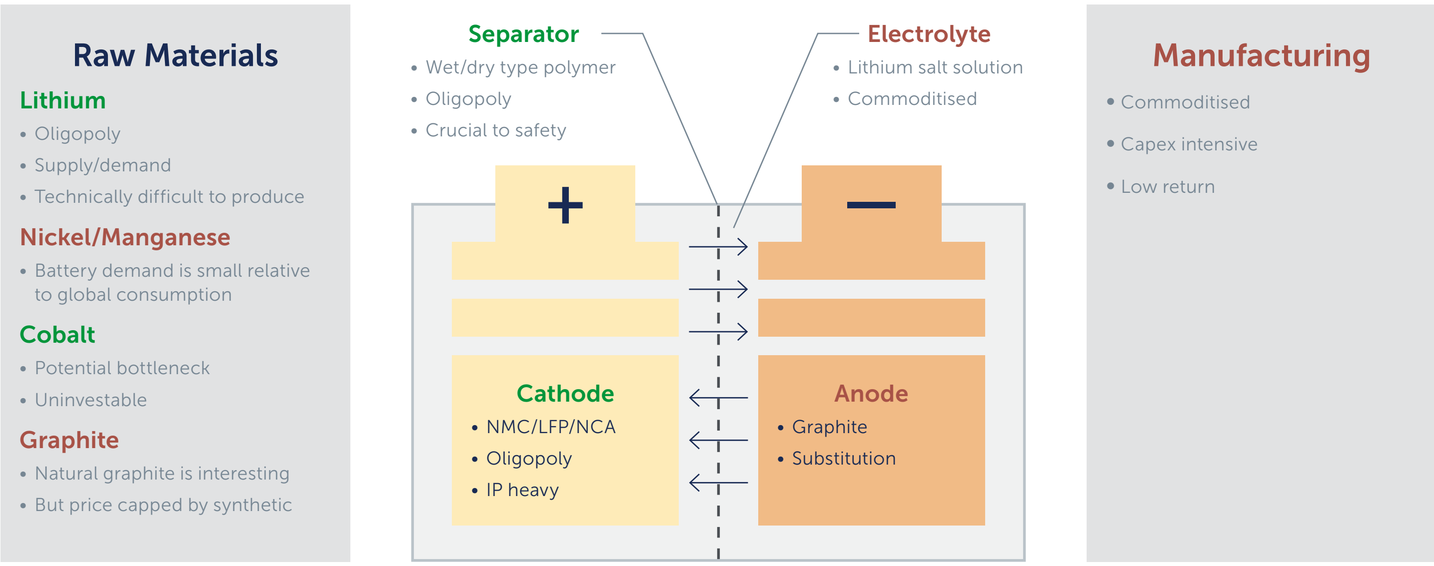
Simple technology, simple process

The first commercial production of lithium-ion batteries began in 1991. Sony needed a more compact and powerful battery to reduce the weight of its new camcorders. As CDs rapidly replaced cassette tapes, Sony adapted the long manufacturing lines for producing films coated with magnetic slurry from cassettes to lithium-ion batteries.

Today, the process remains largely the same. The difference is that instead of coating film to create a magnetic tape, metal sheets are coated to create electrodes. Ever since, lithium-ion batteries have been made following the same principles. As Yet-Ming Chiang, founder of A123 and 24M puts it, "We got side-tracked by a historical accident and a reluctance to switch to something that works (better)."[7]

The building blocks of the battery are surprisingly simple. At the most basic level, a lithium-ion cell consists of an anode, cathode, separator and electrolyte. The active electrode materials (anode and cathode) are generally produced as a black powder and must be mixed into a slurry with a conductive binder before being coated onto metallic foil (usually copper for the anode, aluminium for the cathode) and baked dry. The metallic foil acts to conduct current in and out of the cell. A separator (thin polymer) is then sandwiched in between the anode and cathode.

Once this electrode structure has been created, it is either stacked or wound (prismatic or cylindrical) and placed in a casing material. At this stage, the liquid electrolyte is added and the cell is then sealed.



Source: Barings, November 2016

Green = Areas of opportunity

Fundamentally, building a lithium-ion battery is not a technically demanding process. Many chemistry undergraduates will have built one during their time at university and although larger manufacturers are focussing on full automation to bring down overall costs, many smaller manual production factories are still cropping up.

Indeed, on a recent trip to China we witnessed small-scale manufacturers renting floor space in run-down industrial estates. This simplicity in the manufacturing process is a key reason that we are not convinced the battery manufacturers will be able to maintain economic profits in what we expect to be a very competitive market, and in which declining prices will drive volumes.

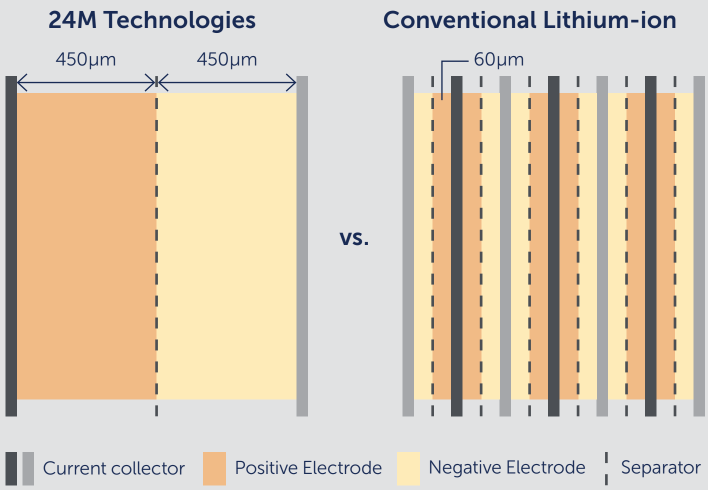
Winners and losers - finding opportunities

In the context of a growing opportunity in battery production with mass commercialisation pending, we expect to see growing competition as firms seek to modernise and make efficiency gains to the production process.

Given the simplicity in manufacturing and comparatively low barriers to entry, we expect to see greater commoditisation of batteries ahead. It is therefore necessary to understand the economics behind the battery supply chain and today's competing technologies to gain an understanding of where the best opportunities exist and which companies are likely to be the winners and losers in the great battery race.

Is there potential for a step change in the process?

A number of companies and universities are seeking to reinvent the battery manufacturing process. 24M, a US-based start-up that intends to have a battery produced commercially for US$85/kWh by 2020,[8] is the most notable. The company is focussed on going back to basics to completely redesign the manufacturing process. Gone are the layers of slurry coated metal sheeting, to instead be replaced by a semi-solid cathode and anode that allows a reduction in the inactive material present in the cell. Previously, layering was required to minimise the distance travelled by the lithium-ion between cathode and anode, but this increased the amount of inactive material and reduced the cell's capacity. 24M's new semi-solid electrode design reduces the amount of inactive material, but crucially also removes the drying step that requires such large manufacturing plants, long lead times and increased costs.



Source: "24M Unveils the Reinvented Lithium-Ion Battery", Green Tech Media, 22 June 2015

The technology of tomorrow

- We believe the combination of lithium nickel cobalt manganese oxide (NMC) chemistry in a pouch cell structure will win out as the dominant battery technology for at least the next five years given its superior performance characteristics
- The pouch cell structure offers a higher energy density and lighter packaging, making it the preferred design by many OEMs and the leading battery producer, LG Chem
- Lithium NMC offers energy efficiency, cost and safety advantages. With only a limited number of producers, we believe the market will maintain some pricing power. Umicore is currently the main producer, but BASF and Johnson Matthey may become stronger comepetitors

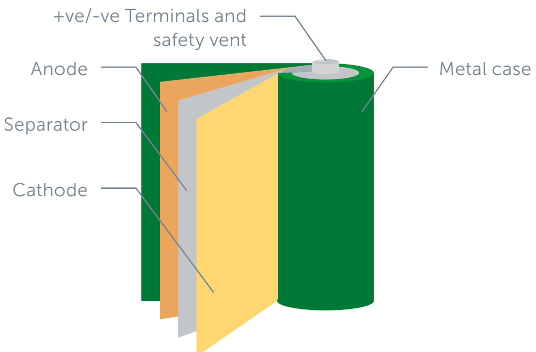
What differentiates cell technologies?

Competition relies on both price and technology. Although some differentiation currently exists, we believe manufacturers are all, largely, heading towards pouch-type NMC based offerings, increasing the importance of competing on price when negotiating with OEMs. In our analysis, there are two key determining factors for the effectiveness of a battery from a competitive manufacturing standpoint: chemistry and cell structure.

Cell structure

The type of cathode chemistry largely determines the energy density of the cell, but the area where manufacturers have more control is the cell structure. Currently, three cell structures dominate: cylindrical, can and pouch types.

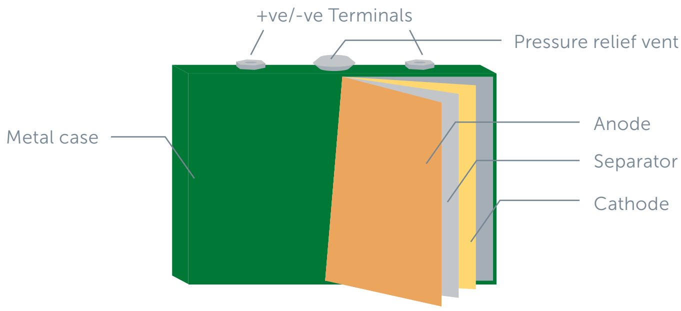
Cylindrical



Source: "Our Guide to Batteries", Johnson Matthey Battery Systems, 2012

Generally, NCA-based and in the 18650 format, cylindricals are currently the favoured battery type in Tesla models. Historically a mainstay for consumer electronics and laptops, Tesla chose cylindricals due to their wide availability and lower cost. In appearance, they mirror the typical AA batteries in many respects. Despite their prevalence, we fundamentally believe they are not the optimal choice for an EV – simply put, stacking a lot of cylinders into a rectangular box results in a loss of space and hence a larger and heavier battery. Stacking rectangles of prismatic cells (can and pouch) results in far less loss of space and smaller battery packs.

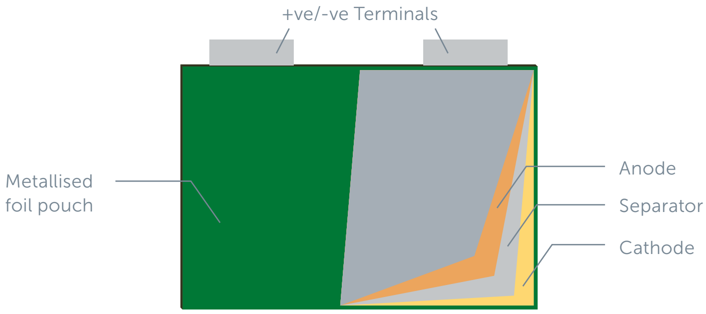
Can



Source: "Our Guide to Batteries", Johnson Matthey Battery Systems, 2012

Can cells are typically found in mobile phones. Aluminium or steel are often used for the metal casing and help to ensure both structural stability and humidity protection. Finally, due to their casing structure, they also allow the introduction of extra safety features, such as pressure relief valves, which are not possible in pouch cells. Overall, we believe that can cells for EVs will ultimately be supplanted by pouch type due to the fact that there is an energy density advantage inherent in the lower levels of electrolyte required in the pouch type.

Pouch



Source: "Our Guide to Batteries", Johnson Matthey Battery Systems, 2012

Favoured by LG Chem and many OEMs, we believe pouch cells will ultimately be the technological winners given their ability to achieve a higher energy density and lighter packaging. Currently, some drawbacks remain.

First, pouch cells appear to have a slightly shorter life cycle vs prismatic can-type batteries and second, they have an inferior thermal management given the lack of a metal casing.

Notwithstanding this, as a comparatively young technology, we see significant scope for both cost and energy density improvements through streamlining of the manufacturing process. The energy density advantage lies in the fact that less electrolyte is required, allowing faster transmission of electrodes from anode to cathode while the polymer-based packaging results in lower overall weight per cell.

Chemistry

The next defining characteristic is chemistry, and this is largely determined by the cathode material. Different manufacturers have focussed on, or rather have access to, different cathode materials, which in turn determines the relative performance characteristics of the batteries they produce (see below).

Technology	Abbreviation	Anode	Commercialised	Specific energy (Wh/kg)	Advantages	Disadvantages	Uses*
Lithium Nickel Cobalt Manganese Oxide	NMC	Graphite	2008	150-200	High energy density, safety, cost effective		EV/PHEV/HEV
Lithium Iron Phosphate	LFP	Graphite	1996	100-170	Safety and power	Low energy density	HEV/storage
Lithium Nickel Cobalt Aluminium Oxide	NCA	Graphite	1999	130-240	High specific energy	Largely only in 18650 format	EV

Source: Johnson Matthey Battery Systems, "Our Guide to Batteries", 3rd Edition, 2015;
* EV = electric vehicle; PHEV = Plug-In Hybrid Electric Vehicles; HEV = Hybrid electric vehicle. For further explanation see appendix.

Leading cathode materials

NMC: Lithium Nickel Cobalt Manganese Oxide – We believe NMC is currently the best technology for EVs due to its high energy density, safety and low cost. The main producers are Umicore and Nichia, but BASF and Johnson Matthey have recently acquired licences and we believe they will also become increasingly active in the market. There are very few producers of the chemistry. As such, we believe it is a market that will, on a relative basis, maintain some pricing power. That being said, one leading market participant we have spoken with has already seen margins decline from mid-teens to mid-single digits over the past few years, and expects 10% price declines year on year going forward. The company will have to compensate for this by improving energy density and reducing their costs. Tanaka, Targray, Nichia, Nippon Chemicals and Henan Kelong New Energy Co are the only other producers we have identified that can supply at even modest scale. Of which, only Tanaka and Nippon Chemicals are public companies.

LFP: Lithium Iron Phosphate – LFP offer high power and safety and are often used as micro-batteries, starter batteries and in buses. The main producer is Johnson Matthey, but BASF is also present. Unlike NMC, the market is more fragmented with many private Japanese, South Korean and Chinese manufacturers present. In China, there has been a focus on using LFP in buses as it is relatively less technical to produce than NMC. As a result, we would be wary of Asian-facing producers given that competition in that market will likely drive down prices over time. However, for Johnson Matthey, given their relationships with OEMs through their pre-existing auto-catalyst business, and in light of the safety and grade requirements of major European manufacturers, we believe they are well placed to benefit from the growing micro-hybrid market as tighter CO_2 regulations come into force in Europe in 2020/21 and the emphasis on fleet fuel efficiency thus increases.

NCA: Lithium Nickel Cobalt Aluminium Oxide – NCA cells offer high energy density and are used in consumer electronics and form the basis of the Panasonic cylindrical batteries used in current Tesla models. When first investigating potential batteries, Elon Musk, CEO of Tesla Motors, needed a product that could be readily procured at scale. In the early 2000s, the NCA-based 18650 cells, originally designed for the electronics industry, were the only battery design that had enough potential energy density that were already in mass production due to their use in the electronics industry, primarily for laptops. However, from a chemistry perspective, NCA, although energy dense, is also markedly more flammable than other chemistries, as demonstrated by some of the early issues Tesla had with its Roadster.[9] In short, cylindrical NCA-based cells were the obvious choice for a start-up company given that they were readily available at a competitive cost, but in our view neither the cathode material nor the cell type is ultimately optimal for use in an EV. Sumitomo Metal Mining is the main supplier of NCA to Panasonic and hence Tesla.

The winners and losers

We believe that, outside of and increasingly within China, the trend towards a focus on NMC will continue due to its chemical characteristics being well suited to use in EVs. We think NCA will gain a strong foothold in the market if Tesla's Model 3 launch is successful, whilst LFP will continue to be prominent in China in the near term given its relative simplicity to produce. However, in our opinion, it remains an inferior technology for use in EVs.

Potential disruptors

NEXT STEPS:
For the battery manufacturers, there is also significant risk of technological disruption. The evolution of the lithium-ion battery is a hotly debated topic. While we remain reasonably certain that given the lead time for testing – it takes close to five years to "design-in" a new technology once commercialised, particularly from a safety perspective – lithium-ion batteries will remain the dominant battery type for use within EVs for the next 5-10 years. Nevertheless, it is worth highlighting the following potential disruptors:

Lithium-sulphur[10]: Lithium-sulphur cells are a potentially attractive long-term candidate for high energy EV batteries given their theoretically high energy density (potential is five times greater than lithium-ion) and low cost raw materials. Although companies such as Oxis Energy are actively investing commercial applications for lithium-sulphur batteries, their first commercial launch will likely not be before 2019/2020, and there will then follow a period of OEM testing before they are used within EVs. The potential, however, is undoubted, and lithium-sulphur offers a very cost-attractive way to achieve a 400-500 mile range EV.

Lithium air: Although currently only at relatively early R&D stages, lithium-air offers potentially 5-10x the energy density of lithium-ion cells, which at 12kWh/kg is very comparable to the theoretical specific energy of gasoline at 13kWh/kg. Lithium-air batteries work by essentially ensuring that an oxidation reaction of lithium takes place at the anode, and a reduction of oxygen takes place at the cathode, inducing the flow of electrons through the cell and creating a current. Although recent breakthroughs by Argonne National Laboratory[11] and Cambridge University[12] have grabbed news headlines, even the teams developing them flag that they are at least 10 years away from commercialisation due to issues around either life cycle or charging rate.

Metal-air cells: Metal-air cells, for example zinc-air, are currently used for applications such as hearing aids. However, they are generally primary (i.e. non-rechargeable) and as a result impractical for use in EVs.

Sodium-ion cells: Some have suggested the use of sodium as a low cost alternative to lithium due to the relative abundance of sodium globally. Although we reject the premise that lithium is a scarce raw material, we must accept the fact that it is a more expensive raw material than salt. That being said, given the lower energy density, and thus far lower rate capability, we do not see it is a long-term competitor to lithium-ion cells, even in the event of significant lithium price increases (which we do not envisage).

Fuel cells: These are essentially another electrochemical energy storage system, generally running off hydrogen for cars, although they can also run off natural gas. There are already a range of commercially available fuel cell based cars, and Japan in particular, is heavily subsidising the development of fuel-cell based automobiles. We believe that hydrogen fuel cells face a couple of large problems when competing with electric vehicles:

- Energy efficiency: due to the high costs to extract/separate and then compress/liquefy hydrogen, we believe, as Tesla CEO Elon Musk does,[13] that hydrogen is ultimately "an energy storage mechanism (and) not a source of energy". Indeed, Tony Seba, the Standford lecturer and clean energy specialist, has argued that "Electric vehicles are at least three times more energy efficient than hydrogen fuel cell vehicles."
- Infrastructure: the next issue is the cost of infrastructure build out. Although potentially convertible ICE fuel station networks already exist, the conversion costs will be large, especially while there remains a mix of gasoline and diesel cars on the road alongside hydrogen.

Although we believe there will be some pressure to pursue this technology from the hydrocarbon lobbyists, we fundamentally believe that the economics are not as attractive for EVs, nor is the idea of driving around with a large hydrogen tank the easiest commercial sale.

On the need for infrastructure requirements for EVs, we believe that it is a complex and overlooked problem that will be solved through a combination of energy storage solutions and de-centralised electricity generation.

Spotlight on companies – Battery manufacturers

Company	Description
Panasonic	Panasonic, the consumer electronics maker, generates only a small proportion of sales and profits from automotive battery production. Its position as Tesla's supplier makes the company the world's largest auto battery manufacturer by market share with 36%.[14] We do not believe Panasonic's cylindrical NCA batteries will dominate longer term, but the company is leveraged to the launch of the Model 3 as Tesla's primary supplier and joint partner in constructing the US Gigafactory. We believe Panasonic is well placed to benefit from Tesla's Model 3 launch, especially if Tesla can produce the 500,000 cars planned in 2018 and one million in 2020. However, this will not come without significant investment by Panasonic. The company may need to invest at least ¥65bn in FY3/17 and spending could continue at that rate through to 2020.[15] That equates to nearly 20% of Panasonic's total capital expenditure plans this year. While Panasonic can probably afford these costs, risks of such a build-out of capacity may threaten margins and profitability, particularly nearer term. Considering Tesla's aggressive production schedule, and track record of delays, achieving that target seems incredibly ambitious. If Tesla misses its target, Panasonic will have significant spare capacity and will be unable to supply other OEMs given that Tesla is the sole user of cylindrical NCA batteries produced at the Gigafactory. This could have a negative impact on margins in the near term, and we believe, given the recent addition of LG Chem to Tesla's list of suppliers, that Tesla will be quite aggressive in trying to bring down battery costs over the coming years. Panasonic could be hard pushed to generate economic profits in the medium term as a result. A worrying conclusion given the level of capital expenditure being invested currently.
BYD	BYD, the Chinese handset and automotive manufacturer, is currently the world's largest EV maker in terms of vehicles sold.[16] The A-share listed company is heavily exposed to the potential growth in the Chinese EV sector and accompanying risks – specifically, declining government subsidies after 2017 and increasing OEM and domestic competition. BYD also makes lithium-ion and nickel metal hydride batteries for use in consumer electronics and its electric vehicles. BYD mainly produces LFP-based batteries, although it is developing NMC batteries for its next generation models. Considering the Chinese government's desire to reach a battery energy density of 300Wh/kg by 2020[17] and that BYD's LFP is currently at only 117Wh/kg,[18] the step change in chemistry is definitely required. However, as with any new technology there are associated risks. Currently, BYD enjoys a significant competitive advantage in China due to its operational scale and technological know-how. We also like the company's rechargeable batteries business in which they develop batteries for use in energy storage solutions as integration for renewable energy and demand smoothing. BYD is also investigating the potential for recycling of automotive batteries into energy storage, which is an option we believe, could gain significant traction over time. Ultimately, we believe the company will continue to leverage its competitive advantages in China. It is potentially a very interesting story, but given the risks surrounding the launch of the new NMC batteries, the potential impact of falling subsidies on EV profitability and slowing global handset sales, we think there are significant execution risks at this stage.
LG Chem	LG Chem is, first and foremost, a petrochemical company and the cyclicality of its earnings reflect the dominance of its petrochemicals division. Yet LG Chem is currently the third largest battery manufacturer with about 12% market share[19] and we believe it is the most advanced, currently offering the most cost competitive pouch type NMC cells on the market. The recently disclosed US$145/kWh per cell contract with GM is testament to their market leading position, as is the fact that the company has won contracts with 20 global automakers.[20] LG Chem is currently expanding capacity to 9GW across its factories in Korea, the US and China.[21] It has a further 1GW planned for 2017 in Poland.[22] The ability to add a further 1GW over 18 months puts LG Chem in a strong position to capitalise on volume growth. LG Chem's bid to qualify as a subsidy-eligible manufacturer in China is still ongoing.[23]
AESC	Automotive Energy Supply Corporation (AESC) is a battery manufacturing joint venture between Nissan and NEC. The company produce pouch type LMO-based lithium-ion cells, which are used in the Nissan Leaf. AESC has gained significant market share through its direct sales into the Nissan Leaf, and is currently the 4th largest battery manufacturer by market share with 11% of the market.[24] The company has tried to tackle the issue of a relatively short cycle life by blending LMO with lithium nickel oxide and improving the electrolytic solution. However, we believe that LMO is ultimately an ineffective chemistry for EVs, and Nissan's recent move towards potentially using an NMC-based battery produced by LG Chem supports this view.[25]
GS Yuasa	GS Yuasa, the Japanese lead acid battery manufacturer, has a 99 year history and is now moving to create a competitive lithium-ion battery offering. The company supplies lithium-ion batteries primarily to Mitsubishi and currently has 5% market share.[26] The company has a JV with Bosch and Mitsubishi aiming to launch a next generation battery in 2020. We believe their focus on energy storage and specialised end uses for lithium-ion batteries, outside of the more competitive EV environment, is interesting, but remain concerned about the sustainability and longevity of their lead acid business.

Spotlight on companies – Battery manufacturers

Company	Description
Samsung SDI	Samsung SDI has historically been a major supplier of small batteries for consumer electronics, directly supplying its parent company. The company is also active in electronic materials, supplying polarising film and OLED materials, again often to its parent company. Samsung SDI is arguably the purest play of the global battery manufacturers given that automotive batteries account for over 6% of sales,[27] but with significant potential to grow to nearly 20% by 2020, in our analysis. On the EV battery front, Samsung SDI supplies can type, and more recently pouch type, NMC batteries to EV manufacturers, in particular BMW. Of the three major battery manufacturers, Samsung SDI currently has the lowest margin profile within its large battery business: the operating margin was -54% in Q2 2016[28] due to its high fixed cost base. The company expects its restructuring efforts to result in a profitable business by 2018. SDI has been slow to move towards pouch-type NMC, and the added costs of switching technologies partially account for the large overhead costs, symbolised by the fact that the company has announced a major restructuring by 2017. Although the acquisition of Magna Steyr's battery pack business in 2015 should help costs and SDI's competitive standing, we remain concerned that the company has grown too aggressively too quickly with the inevitable fixed cost overhang on earnings. Furthermore, outside of BMW, SDI had targeted the Chinese market as a major area for growth in 2016, yet given its failure to get onto the approved list of battery makers we believe its growth outlook may be challenged. Current capacity is 4.5GW, expected to reach 6.0GW by the end of 2016. The company have announced plans to spend KRW3trn (US$2.7bn) on expanding capacity,[29] and again, we remain concerned that this is a huge amount to spend on a potentially low return, low value add business.
Guoxuan High-Tech	Guoxuan is the 4th largest EV lithium battery manufacturer in China by sales, but is also the purest play with most revenue and profit coming from lithium-ion battery sales.[30] Most of its production is used in commercial e-buses, with Guoxuan supplying several of China's largest e-bus manufacturers. The company has approximately 6% market share in China.[31] The company currently produces LFP, but is looking at moving into a NMC-LFMP production later in 2016 at its two new plants. These new batteries are also more geared towards the EV rather than e-bus market. It is one of the 25 government listed companies, and with a strong client list, it is aggressively securing orders for the coming years giving it a very attractive growth profile. However, we expect LFP pricing to decline very rapidly in China due to the fragmented competitive landscape, and, as such, believe the company's margins will come under significant pressure going forward and see risks surrounding the launch of new NMC-based products.
SAFT	Saft is a battery systems provider highlighted in our initial paper, "Enabling a Revolution". The company offered a complete suite of lithium-ion technologies, but was focussed on offering top of the range performance in terms of cycling, weight and safety for niche applications where it believed it could maintain a degree of pricing power. We thought it was a very interesting company due to its focus on niche markets, and market leading technologies stemming from its experiences in providing battery technology for military and space projects as well as energy storage. On 9 May 2016, Total launched a "friendly" €36.50/share offer to acquire Saft, representing a premium of more than 38% above the closing price from the previous trading day and the offer was unanimously accepted by Saft's board.[32]
Leclanché	Leclanché is a fully integrated energy storage system supplier based in Switzerland. The company has specific IP for LTO and graphite NMC lithium-ion cells, which, combined with its systems integration knowledge on the IT/system side, has seen it win high profile energy storage contracts in the last year. These project wins are of particular interest given that the company was able to offer far more economic solutions than its much bigger competitors such as GE, Siemens, LG Chem. Specifically it has won projects to build the world's largest e-ferry, a renewables integration system for an island in the Azores, and a utility grid storage system for Ontario's hydro-based power stations.[33] It is seeing a significant turnaround, with a new CEO installed in June 2014 to engage upon a new "growth path". That growth path has been expensive, with acquisitions and capacity expansions resulting in negative earnings for the last few years. However, the business model they are building enables impressive growth potential longer term. Given the company's specific strengths it targets becoming the Cisco of energy storage – being the only fully integrated provider of energy storage solutions and with significant market leading technological know-how which we believe is demonstrated by the recent project wins. We believe the company is also a very attractive acquisition candidate given the wave of consolidation we are starting to see in the sector.

Cathode manufacturers

- Cathode manufacturers produce the chemistry that largely determines battery performance and own or licence the IP surrounding it
- Unlike manufacturing, it is a complicated process for the newer technologies and a more oligopolistic market
- We believe that BASF, Umicore and Johnson Matthey will likely come to dominate the cathode materials market

What is a cathode?

Cathodes are the positive electrode within the lithium-ion cell. The specific chemistry of the cathode largely defines performance. There are a variety of competing technologies, but NMC is the current frontrunner due to its higher energy density. Currently, Argonne National Laboratories and 3M licence the IP for cathode chemistry to manufacturers, who can then tailor the chemical composition for their specific needs. CAMX owns but does not yet licence their IP for cathode technology.

> *"We believe that BASF, Johnson Matthey and Umicore will likely come to dominate the cathode materials market"*

Company	Description	Licencees
Argonne National Laboratories	ANL is a world leading Chicago-based research centre, originally founded as part of the Manhattan Project. The research laboratory still seeks solutions to pressing national problems in science and technology and is the US Department of Energy's primary national laboratory for battery research.	BASF, LG Chem, Toda Kogyo
3M	3M is a US-listed US$106bn[34] global innovation company, probably best known for making Scotch Tape and Sticky Notes. As part of the company's Electronics and Energy Business Group, 3M licences out its NMC technology.	Umicore, Hunan Reshine New Material Co, EcoPro Co
CAMX	CAMX is a US technology company, spun out of TIAX LLC in 2014. It's flagship CAM-7 is a nickel-rich cathode material and has been extensively tested by the US military amongst others. Currently, this technology is in the testing phase with its recent licence acquirers.	Johnson Matthey, BASF

Given only a limited number of patents will be issued, current incumbent owners of the licence operate at a significant competitive advantage. Of those with licences, we believe Umicore, Johnson Matthey and BASF to be the three companies best placed to supply the required materials at the scale required to meet growing demand. Indeed, Umicore has recently announced its intention to triple its current production by 2018, focussing specifically on NMC. The €160m investment program includes sites in China and South Korea and has given Umicore a first mover advantage in the cathode materials market.[35] Johnson Matthey and BASF arguably are behind in the cathode material space, but we believe they have sufficient technological expertise, industry knowledge and ambition to be significant market players in the next five years.

We believe the cathode manufacturers will follow the auto-catalyst market structure, with the suppliers essentially becoming Tier 1 suppliers to the OEMs. It is no coincidence that the major players, as we see it, will likely be the same three European multinationals. The risk of cannibalisation to their existing business from EVs (there is no need for an auto-catalyst in a pure EV), combined with the fact that expertise derived in auto-catalyst manufacture is highly complementary (need to reduce metal content to lower prices, understanding importance of uniform batch chemical processes) and their pre-existing relationships with OEMs, means we believe that BASF, Johnson Matthey and Umicore will likely come to dominate the cathode materials market in much the same way that, outside of China, they dominate the global auto-catalyst market.

Potential disruptors

We believe that although NMC appears to be a clear winner for the next five years within the cathode material space for EVs, the extent of R&D within the area means that it is ripe for disruption. In particular, cathode materials will be completely disrupted by a move away from lithium-ion technologies to other forms of lithium-batteries such as lithium-air or lithium-sulphide. Although we need to be aware of these risks, we do not believe that a viable, commercial next-generation lithium battery will be available within the next 10 years and, as a result, believe that cathode manufacturers, particularly those with NMC chemistry, are well placed to benefit from the structural growth in demand stemming from EV take-off.

Within NMC, the focus at the moment is on increasing nickel content to up the energy density further. Future improvements will focus on manganese content, but there are currently safety/stability issues surrounding this. That being said, we believe the current focus on increasing nickel content is potentially misplaced given that nickel is a relatively high cost element to include within the cell chemistry and, as such, increasing nickel content is approaching and has potentially reached the price/energy density trade off equilibrium. Indeed, Umicore believe that the focus should not be on increasing nickel content further, but instead on step improvements in chemistry to reduce cost and enhance energy efficiency.

Spotlight on companies – Cathode manufacturers

Company	Description
Umicore	Umicore have >24% market share in NMC and a complete cathode material offering.[36] Their focus on innovation has helped to make them a market leader in cathode technology. Our research shows that they supply Samsung SDI and LG Chem with NMC, the two market leading NMC battery manufacturers. Umicore licence the IP for their NMC production from 3M. We believe Umicore is one of the best positioned companies to benefit from the growth in EVs globally. Their diversified product offering across cathode materials and, in particular, their expertise in NMC and NCA helps to reduce potential risks from technology disruption. The company is also a leading auto-catalyst manufacture, and operates one of the largest and most complex metal recycling plants in the world. We believe the company is well placed to be a closed-loop (from cathode material, to recycling used batteries, back to cathode material) solutions provider to OEMs and battery manufacturers alike.
Johnson Matthey	Johnson Matthey bought Clariant's LFP business in 2014 (completed 2015) and are still looking to expand their battery materials business. We like their battery management systems business more than the LFP business longer term, but in the near term we can see the argument for using micro-batteries as range extenders and hence increasing fuel efficiency and reducing CO_2 emissions ahead of the 2020/2021 CO_2 emissions standards that are coming into force in Europe. We are unconvinced by the potential for LFP in EVs and even busses, but see great potential within micro-batteries and uses within energy storage. Johnson Matthey recently acquired a licence for NMC from 3M alongside a licence from CAMX, and, as such, we believe they are positioning themselves to compete aggressively in the NMC market in the future. Johnson Matthey are also a leading auto-catalyst manufacturer, as well as operating a variety of specialty chemical divisions and a precious metals recycling division. Although they are entering the battery materials space relatively late, we believe their industry knowledge and chemical expertise will make them an important player in cathode materials for electric vehicles.
BASF	BASF is the world's largest chemical company. It plans to become "the world's leading system supplier of functional materials for high-performance batteries"[37] producing both cathode materials and electrolytes for lithium-ion batteries. The company has an impressive track record in the sector having invented the Nickel Metal-Hydride battery, and is well placed to aggressively grow market share given its relationships with OEMs, stemming from its auto-catalyst business. Within lithium-ion, BASF has a licence from Argonne National Laboratories for a certain production process of NCM and recently acquired a licence from CAMX. Given its auto-catalyst expertise, track-record with developing NiMH batteries, and significant R&D capability, we believe that BASF will join Umicore and Johnson Matthey to form an oligopolistic cathode materials market structure.
Nichia	Nichia is a private Japanese chemical company with significant expertise in LEDs and fine chemicals. The company has approximately 11% market share within NMC,[38] but also produces LCO and LMO. We believe Nichia to be a significant market participant, but also believe that despite its technological expertise, it lacks the financial backing required to grow capacity aggressively enough to continue to reduce costs through economies of scale and hence maintain market share.
Sumitomo Metal Mining	Sumitomo Metal Mining is a key supplier for Panasonic, and hence Tesla. The company mines nickel and produces NCA for Panasonic which in turn manufactures batteries for Tesla. SMM has been supplying effectively all of the nickel-based material used in Panasonic's positive electrodes for Tesla. Now SMM is increasing its capacity by opening a new plant in Naraha, Fukushima and plans to invest a further US$180m over the next three years to further raise capacity within NCA.[39] However, we remain slightly concerned, given recent operational issues at the Sierra Gorda mine in Chile, about the likely ramp up of production and the impact on earnings.
Shanshan	Shanshan is an interesting company in that it is a conglomerate that had developed from being a simple apparel manufacturer. It has now branched out into producing cathode materials alongside its fashion, financial service, urban complex and trade logistics divisions. The US$2.6bn A-Share listed company[40] has indicated it has a strategic relationship with Mercedes-Benz and Panasonic. Our research suggests that Shanshan produces LCO and LFP, and as such are slightly unsure about the nature of its strategic relationship. A potentially interesting company, but its conglomerate nature makes it difficult to invest in.

Spotlight on companies – Cathode manufacturers

Company	Description
Tanaka Chemicals	Tanaka Chemicals is a US$155m market cap Japanese chemical company that produces cathode materials for NCM and nickel metal hydride batteries.[41] Given its relative size, we remain concerned about its ability to compete with the likes of BASF and Umicore in winning large contracts with both battery manufacturers and OEMs.
Nippon Chemical Industrial Co	Nippon Chemical Industrial Co is a US$200m Japanese listed inorganic chemicals company.[42] Under its "Cellseed" brands, Nippon produces LCO, NCO and LMO. Our research leads us to believe that it, even more so than Nichia, will be constrained financially by its inability to grow capacity to reduce costs and compete for larger orders.
Targray	Targray is an interesting private cathode materials companies. Like Umicore it supplies a full suite of cathode materials (NCA, NCM, LFP, LMO, LCO) but also supplies anode materials, lithium carbonate and lithium hydroxide, separators and packaging materials. Its business model is based upon being the one-stop supplier to businesses, having supply agreements with various manufacturers across different parts of the supply chain.

Separator manufacturers

- Due to the important safety function of separators we see significant barriers to entry in this market that should provide some pricing rigidity, allowing manufacturers to generate economic profit
- In our view, wet-type separators are likely win out as the dominant technology
- We believe that both Asahi Kasei and W-Scope benefit from expertise and competitive advantages that should position them well among separator manufacturers

What is a separator?

A separator is a polymer based membrane that has been constructed to have small holes through which an electrolyte fluid can pass. They are a safety mechanism – when a cell overheats, the polymers melt and close holes that stop the electrolyte from flowing. With this, the current no longer passes, thereby shutting down the cell. There are essentially two classes of separator: dry and wet types. Each name refers to the specific manufacturing process.

"Separators provide a crucial safety component within a battery, and as such, is an area where margins are likely to be maintained"

Separator types	Description
Dry type	The dry type is made by stretching polyethylene or polypropylene film along one axis after melting. This is a relatively simple process and the multilayer structure means that it is easy to change the separator properties for different shutdown temperatures simply by changing the combination of materials. However, the membrane tends to be relatively thick due to being multi-layered and possessing lower tensile strength due to being stretched in only one direction.
Wet type	Wet-type separators are formed by mixing a plasticizer wax with a base polymer (usually polyethylene). After extrusion of the plasticizer wax this gives rise to a micro-porous separator. The compound material is stretched multiple times, both lengthways and sideways to ensure even distribution of the pores. The multiple-stretching process does increase costs. However, this provides for greater strength and it is easy to adjust the pore size due to the biaxial stretching. Lastly, they are also much thinner than dry-type separators.

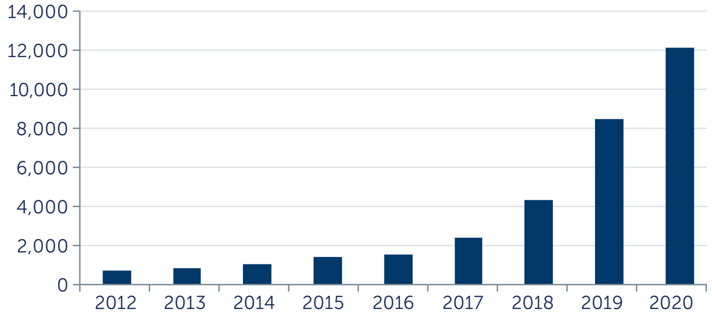
Winners and losers

Historically, although wet type have been used predominantly in consumer electronics destined lithium-ion batteries, dry-type separators were largely used in automobiles due to their lower costs. However, over recent years there has been a significant decline in wet-type prices. We believe that given their thinness (allowing easier electron flow, and hence higher energy capacity cells) and also enhanced safety from the uniformity of pores, wet type will be the dominant separator type in the long run.

This is a view backed up by the fact that W-Scope are rapidly gaining market share producing a wet-type separator for EV focussed lithium-ion batteries. As such, we believe some credence must be given to their claims that wet type are potentially superior from a cost and performance perspective. Dry type retain important market share, particularly in China, but prices have been rising due to capacity shortages. In the near term, therefore, we can see dry-type separator margins remaining strong, but longer term we view the wet type as a likely dominant technology.

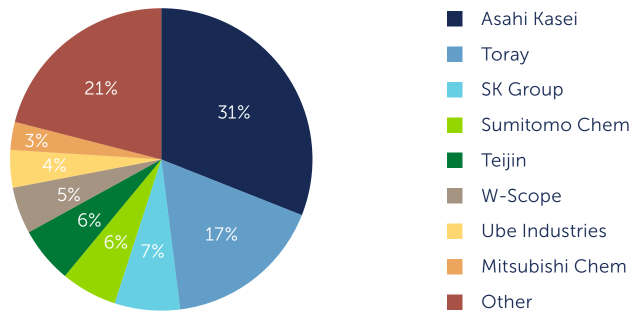
Separators provide a crucial safety component within a battery, and as such, is an area where margins are likely to be maintained. Separators currently make up 30% of the cost of a cell.[43] Notably, W-Scope, the cost-leader, is currently running operating margins over 30%[44] thanks to its unique manufacturing process.

Demand forecast for the global separator market (millions of meters squared)



Source: Barings analysis, September 2016

Company shares of global separator market



Source: Citi Research, "Ube Industries", 15 April 2016

Potential disruptors

We believe that separators will form an integral part of any lithium-ion battery under any cathode technology, and, as such, believe the market is relatively immune from disruption. That being said, we note that Leclanché and Saint Gobain have an agreement in place to develop a new ceramic separator for lithium-ion cells. Although this is at least 18 months from the market and focussed on stationary storage lithium-ion batteries, this is a development we will watch with interest, but do not see as being a disruptive influence over the next five years.

Spotlight on companies – Separator manufacturers

Company	Description
Asahi Kasei	Asahi Kasei is a Japanese conglomerate involved in petrochemicals, fibres, housing, construction materials, medical equipment and electronics. The company was involved in a scandal surrounding the falsification of pile-driving data by an external contractor,[45] and this has led to a significant de-rating. On the separator side, Asahi Kasei is the market leader with a market share of 31%.[46] Hipore (original Asahi production, both wet and dry) and Celgard (acquired through Polypore acquisition, dry type) are the two operating brand names. Although primarily a market leader within consumer electronics, we believe Asahi can leverage its technical expertise and safety track record to enter the larger EV market. They already supply LG Chem and hence are well placed to benefit from future EV growth given our view that LG Chem is a frontrunner in the race to supply EV batteries to OEMs.
W-Scope	W-Scope is a market disruptor, and the only pure play in the separator industry. The company was founded 10 years ago by a former marketing manager at Samsung. The company currently has 8% market share, mainly in China, but is looking to grow to 15%[47] by 2020 by aggressively adding capacity. The company produces wet-type separators and supplies SK Innovation and many Chinese firms. W-Scope expanded from four lines at end of 2015 to seven at end of 2016 (+40% capacity), and plans to add lines eight and nine in 2017. The company has further, fully funded, plans to build lines 10-13 to be fully operational by the end of 2018, increasing capacity by 250% from the end of 2015, with conviction in order volumes driven in part by their growing relationship with LG Chem.[48] They argue they have a technological advantage in manufacturing allowing them to make higher margins. Given the Chinese government's focus on registering manufacturers before allowing them to be eligible for subsidies, we believe W-Scope will continue to gain market share in light of the importance of safety, for which a separator is one of the key components.
Sumitomo Chemical	Sumitomo Chemical is a leading global chemical company, with significant exposure to global petrochemicals, agrochemicals and pharmaceuticals. Separators make up a small and undisclosed proportion of revenues. They are the exclusive supplier of Panasonic and hence leveraged to the Tesla story. As a result, however, they are purely used in cylindrical batteries (Tesla is the only company using cylindrical cells for EVs) and essentially remain exposed to the fortunes of one company (Tesla). We believe that leaves them in a potentially disadvantaged position, being so reliant upon one major cell type and the fortunes of one OEM. Although leveraged to the Tesla story, the separator business is such a small part of earnings that it cannot offset the expected decline in earnings from falling methionine prices and lower petrochemical margins.
Ube Industries	Ube is a diversified chemicals company that produces a dry type separator. The company currently has about 4% market share[49] and intends to progressively increase capacity to some 300mn m^2 by 2020, around twice the level of its current capacity.[50] Although involved from an early stage with potential e-bus applications, it has been a latecomer to the EV market. They are in the 4th generation Toyota Prius (battery manufacturer not disclosed, some internal production through Toyota JV), but we believe they will struggle to gain market share due to the inherent preference for wet-type over dry-type separators. Furthermore, we remain concerned about the company's exposure to the oversupplied nylon-lactam market.

Spotlight on companies – Separator manufacturers

Company	Description
Toray Industries	Toray is an integrated textiles manufacturer and diversified chemical company. Toray is now the number two player with 17% market share,[51] producing a wet process separator. The company recently purchased a plant from LG Chem, who they now supply and who are looking to outsource all their separator needs. That new plant upped production capacity significantly. IT-related products, including semi-conductors, electronic components, circuit materials as well as separators, comprised 12.6% of sales and nearly 20% of operating profit in FY15,[52] but given the lack of visibility on the breakdown within the sector it is hard to determine the extent to which improving separator fundamentals could drive earnings. More fundamentally, the current weak retail environment appears to be a significant headwind for the fibres market, and we believe the market is potentially too optimistic on the near-term uplift to earnings from increased carbon fibre penetration in both autos and aerospace.

Commodities

- While a number of the materials used in battery production are industrial metals subject to typical cyclical supply and demand trends, we see structural demand growth for batteries acting as a significant demand driver for several key commodities

- As the ever present raw material, the outlook for battery grade lithium presents a notably attractive opportunity for producers in this space. In particular, we think Albemarle, Orocobre, Galaxy Minerals and Nemaska Lithium are well placed to capitalise on this trend

What are the key commodities needed to build a battery?

There are a number of commodities used in the production of lithium-ion batteries, depending on the chemical technology used for specific designs and manufacturers. Below we focus our attention on the key commodity inputs that are currently used in the prevailing technologies and those that we believe should benefit from the take-off in electric vehicles and stronger lithium-ion battery demand. These include materials such as lithium, graphite, nickel, cobalt and manganese. As all of these have industrial and other uses, we examine their battery and broader market prospects with a subsequent focus on the winners and losers at the commodity level and look at lithium producers specifically.

While lithium accounts for just 2-3% of battery production costs,[53] it is set to remain a key beneficiary of the battery take-off as the ever-present raw material. Until recently, demand was dominated by industrial applications and historically has grown at 1.1 times GDP growth. We have modelled our estimates forward on this basis utilising IMF forecasts. Beyond industrials, consumer electronics have been a key demand driver. Here, we model markets based on internal projections for smartphone, tablet, laptop, camera and power tool growth, alongside projections for power capacity per unit, and consequent lithium demand per unit to give an overall base demand excluding autos. For autos demand, as per our previous whitepaper, we assume a 7% of new sales EV penetration in 2020, and model out expected lithium demand per vehicle as a function of increasing battery size due to the increasing range we expect EVs to offer over time.

We have closely watched for a supply adjustment in response to the strong prices seen in the market over the first half of 2016. Given the oligopolistic nature of the lithium market, with 99% of production controlled by just five producers,[54] we believe the risk of an exaggerated supply response is limited. While there have been a number of companies looking to enter the market, we believe the technological difficulties of producing battery grade lithium carbonate or hydroxide on a consistent batch basis is underestimated. Battery manufacturers require a continuous plant run of over a year, and battery grade material must be more than 99.98% pure – which is difficult to achieve with often heterogeneous lithium deposits. It took Orocobre five years from the completion of initial funding to approach full commercialisation of production and it took another two years prior to that to secure funding and approval.

Therefore, we believe that many junior miners' claims of reaching commercial production in two to three years are too optimistic. While recent price increases and the wave of media and investment attention will no doubt add to demand, we believe the demand increase will remain great enough to offset any supply response in the medium term. Furthermore, in our lithium demand projections, there is additional upside to demand from energy storage, the potential for which we believe continues to be underestimated by the market. In short, we remain confident that the lithium market continues to represent a very exciting investment space.

Graphite demand has historically been driven by the steel sector. Going forward, we believe graphite in electric vehicles and stationary power storage will drive graphite demand. In line with our forecasts for softer global steel production over the next five years, we forecast weaker demand for graphite from the 'old' economy applications. In addition, we believe demand from other traditional end uses such as refractory and foundry sectors is also moderating. However, we fundamentally believe that this will be more than offset by the strength in demand for spherical graphite from lithium-ion batteries in both the power storage market and the mobility EV market in the longer term. Unlike lithium, which has a higher elasticity of supply, the supply of graphite is more concentrated and less responsive to price changes. As such, we see scope for a potential supply deficit over the next five years given the outlook for supply and demand dynamics ahead.

BARINGS

In terms of supply, Chinese firms dominate global production, but new entrants such as Syrah Resources and Talga Resources are emerging. Notably, these firms offer a comparatively lighter environmental footprint, which in combination with the benefits of geographic diversification may result in stronger demand from end users and a premium for these resources. Outside of technologically driven substitution of lithium-ion batteries, the biggest risk to the graphite story is from the synthetic graphite products. Currently the supply-demand deficit is balanced by synthetic graphite production. However, we believe that we will initially see the market share of the synthetics being eroded by the increased availability of natural graphite. Synthetic graphite is a high cost product, which means manufacturers prefer 'natural' graphite on cost benefit grounds. However, synthetic graphite therefore provides a price ceiling, particularly in the near term in light of weak demand for steel.

Nickel is an established and widely used input for industrial, consumer and electronic applications. As an integral component for both NMC and NCA cathode materials, we expect electric vehicle take off should spur much stronger demand from this structural growth area over the medium to longer term. Shorter term, the outlook remains mixed. Inventories on the London Metal Exchange (LME) have been sufficient to meet stronger demand for products such as stainless steel, a primary demand source for nickel. In addition to a number of mine and refinery closures globally, political factors in nickel-rich Asian producers Indonesia and the Philippines, have also affected global nickel stocks.

Our analysis suggests global nickel supply growth of circa 2.0% per annum over the next five years. On the demand side, stainless steel growth is projected at circa 3.0% over this same time frame driven principally by rising appetite from China. Taking this into account alongside expectations for stronger demand from other sources, most notably the electric vehicle take-off, we expect prices to be supported. Although LME inventories currently equate to some 20 weeks of annual demand,[55] which is significant, on balance we believe demand growth will outstrip supply, driving down stocks and supporting prices at a higher level. However, this trend may materialise in the medium to long term, rather than shorter term as demand relating to EVs will be relatively small compared to the overall market.

Cobalt consumption should rise with battery demand for electric vehicles and therefore has one of the strongest demand growth forecasts within industrial commodities. The main concern is that the primary supply source comes as a by-product of copper and nickel mining. As such, irrespective of the cobalt demand outlook, the supply response could be anaemic. Any supply response will be driven by the outlook for copper and nickel and with supply growth from both these commodities likely to contract or remain uninspiring over the next few years, we could see cobalt prices supported at higher levels as the market tightens. However, with limited means to respond to higher prices, ultimately this could be a driver towards substitution. Other than substitution, the other key supply risk is geographic as a large share of global output comes from the copper belt straddling the Zambian and DR Congo border.

Notwithstanding this, we see cobalt moving into a sustained annual deficit driven by demand robustness from the battery sector, coupled with a declining supply contribution from copper and nickel mines. We believe that a potential cobalt supply deficit is one of the biggest risks to NMC and our declining battery price thesis.

Although the manganese market has a forecast surplus for the next two-to-three years,[56] we believe this will move to a deficit as the strength of stainless steel demand combines with a projected contraction in supply. The demand story for

Salar de Uyuni, Bolivia - the world's largest source of lithium reserves

manganese from stainless steel is fairly robust as we have already discussed.

However, with crude steel production accounting for most demand and with the outlook for commodity grade steel unflattering, we believe this could be a headwind. As such, the story is more about contracting supply as high cost operations, particularly in the area of electricity cost which as a key input cost makes it uneconomic to run the furnaces. We are forecasting that the projected contraction in supply will see the market move into a sustainable annual deficit over the next five years, supporting prices at higher levels than expected. The biggest risk to the manganese outlook is that higher prices will re-incentivise production to start capping the upside.

Winners and losers

With NMC and NCA growth underpinned by the lithium-ion battery take-off, we expect several commodities used in the production process to benefit. In particular, we would highlight lithium, as the mainstay raw material input and with a market structure that limits the potential for fresh supply to flood the market, as the commodity with a notably bright outlook. While nickel and manganese are key commodities, they are also very large markets, with the result that the impact of EV growth will be far less pronounced on the market balance. For cobalt, we believe the market could become very tight, but it is also very difficult, if not impossible, to find a pure way in which to play the story. Finally, graphite is a very interesting area, and one in which we believe there is significant potential for structural growth. Although prices for natural graphite may be capped by synthetic substitution, that price is significantly above where we are today. Below, we examine some of the main producers involved in this space.

Spotlight on companies – Lithium producers

Company	Description
Albemarle	Albemarle is the market leading lithium player, with a stated aim of capturing 50% of the growth in global lithium demand.[57] Through its acquisition of Rockwood in 2014, Albemarle is fully integrated from raw material production through to processing and finally derivative production. Albemarle's main resources lie in the Salar de Atacama in Chile (a low cost Brine operation), in Silver Peak, Nevada, USA (another brine based operation) and 49% stake of production from Talison Lithium, Australia (operated by Tianqi, a spodumene resource, providing access to the Chinese market). Currently, Albemarle produces lithium carbonate in Chile and the USA, sending spodumene to converters in China under tolling arrangements, and has recently built a plant in North Carolina, USA to produce lithium hydroxide for the battery industry. We like Albemarle's position as a market leader in the industry, its technological expertise, and its move to long-term contracts with price escalators that give it both a security of demand but also exposure to rising lithium prices. The recent sale of its Chemetall Surface Treatment business to BASF for US$3.2bn[58] will allow the company to both significantly reduce debt, but also increase its ability to invest production capacity, both organically and through acquisitions (the recent agreement to buy spodumene conversion assets in China from Jiangli New Materials) is evidence of this in process. Assuming that the divestiture of Chemetall is completed, Albemarle will become a specialty chemical company operating a bromine business as a cash source to fund growth in its lithium business, and a catalyst business producing catalysts for the refining industry in an oligopolistic market. In short, despite how well the share price has performed since our last white paper, we continue to believe that the earnings potential of the company is under appreciated.
Tianqi	Sichuan Tianqi Lithium Ltd is the world's largest spodumene producer, converting this hard rock lithium into a variety of lithium concentrates. It is a US$5.5bn,[59] China A-Share listed company, whose main resource base is its 51% stake in Talison Lithium (which operates the world's largest spodumene mine in Greenbushes, Australia), as well as owning mineral rights through its wholly owned subsidiary Shenghe Lithium to spodumene at Cuola, a mine in Yajiang County, Sichuan. Talison Lithium currently supplies roughly 70% of the Chinese lithium carbonate market,[60] with the result that Tianqi essentially can control pricing in the Chinese market. Despite its impressive resource base and market position, the tightly held shareholder register (over one third of shares are controlled directly/indirectly by Jiang Weiping, Chairman[61]) means liquidity is low and hence difficult to invest in.
FMC	FMC is a US$6.0bn US listed agrochemical,[62] nutrition and lithium company. On the lithium side, FMC is an integrated player with a focus on lithium hydroxide and butyllithium (a catalyst to produce synthetic rubber). Although FMC has lithium carbonate capacity equivalent to approximately 9% of global production,[63] its focus from a battery grade standpoint is lithium hydroxide, and the company produces around half of the world's lithium hydroxide for EV batteries. FMC operates a brine deposit, the Salar del Hombre Muerto, in Argentina, but is higher up the cost curve than SQM, Orocobre and Albemarle. Despite its dominant current market position within lithium hydroxide, FMC's lithium division makes up less than 4% of earnings,[64] with the result that the company's earnings outlook is dominated by the difficult crop protection backdrop.
SQM	Sociedad Quimica y Minera de Chile SA is a US$7bn Chilean specialty fertiliser producer that also produces iodine,[65] lithium and industrial chemicals from brines and caliche ore in Chile. SQM's lithium resource comes from the Salar de Atacama where it operates alongside Albemarle. SQM is one of the world's largest lithium producers, but its focus on lower grade, industrial lithium derivatives mean it is less geared into the EV take-off story. Furthermore, current arbitration over SQM's lease and hence lithium and potash operations in the Salar de Atacama is ongoing, and, given the potential risks, we currently view the risk-reward as unfavourable.

Spotlight on companies – Lithium producers

Company	Description
Neometals	Neometals is the minority partner in the Mount Marion Joint Venture through its 27% stake. The JV is located in the southern part of Western Australia not far from the Kalgoorlie mining complex. The Mount Marion project is being constructed by Mineral Resources who have a 30% stake in the project and will be the operator. The project could ultimately produce some 200ktpa of a 6% spodumene concentrate.[66] They have also signed a life-of-mine offtake agreement with a large well-established offtaker. The balancing holder is Ganfeng which is one of the largest lithium producers in China and has a 43% stake in the project. Neometals also owns 100% of the Barrambie titanium project and has a 70% stake in Reed Advanced Metals, which is advancing an alternative process to produce lithium hydroxide.[67] Although the project has many interesting points, we currently view the risk-reward as unfavourable.
Lithium X	Lithium X is a Canadian listed explorer and developer through its Sal de Los Angeles project in the Salta Province, Argentina. The project is forecast to produce 15-25ktpa of lithium carbonate.[68] They are working on a feasibility trial which is due to be completed by the end of 2017. They also have a large land package in the Clayton Valley, Nevada comprising circa 15k hectares located between the Clayton Valley North Project and Clayton Valley South extension. Their land packages are contiguous to the Albemarle's Silver Peak project and a three to four hour drive to Tesla's Giga factory. In our view, Lithium X makes for a compelling investment case and we are carrying out further due diligence on the company.
Orocobre	Orocobre is an Australia-listed lithium producer through its primary asset the 66.5% owned Olaroz lithium brine project, located in Jujuy Province, Argentina.[69] The project is operated under a JV with Toyota Tsusho Corp (25%) and the Jujuy Provincial Government (8.5%). Olaroz commenced Li2CO3 production in late 2014, and following an extended commissioning, is ramping up to nameplate capacity of 17.5ktpa, with production costs estimated at <US$2,000/t.[70] Current reserves support a mine life of greater than 40 years, after which only 15% of the total resource will have been depleted. The company also operates the 100% owned Borax Argentina business, which produces c.40ktpa of borate mineral products used in the fertiliser and industrial chemical sectors.
Galaxy Resources	Galaxy Resources is an Australian listed lithium player through its primary Mount Cattlin spodumene operation in Western Australia, the Sal de Vida lithium brine development project in Argentina and the James Bay spodumene exploration project in Canada. First production from Mount Cattlin is due at the end of 2016,[71] and it also produces a small amount on tantalum. We believe that they could present an investment opportunity as they are the most advanced of the next wave of entrants to the sector thematic.
Nemaska Lithium	NMX is an advanced stage lithium project developer through its Whabouchi project in Quebec Canada. The project is a high-grade deposit (1.5% Li20) and has easy access to fixed tariff, low-cost hydro power. They have updated their feasibility study, have key permits and are fully-funded for the Phase 1 plant to produce lithium hydroxide. A 500tpa plant should be fully operational by the end of the year and they have signed an offtake agreement with Johnson Matthey for the first commercial production with discussions around further offtake agreements with Johnson Matthey now ongoing.[72] In a similar fashion to Galaxy Resources, they are a strong investment prospect.
Bacanora Minerals	Bacanora is an AIM and TSX listed developer with the Sonora lithium project in Mexico. The company has completed a pre-feasibility study on the project which confirmed the positive economics of producing 35ktpa of battery grade lithium carbonate (Li2CO3) at the Sonora project.[73] The project benefits from food infrastructure through its close proximity to the west coast of Mexico. We expect first production from the site to commence in early 2019. They also won the Magdalena Borate Project in Mexico. Although the project looks interesting, the production of lithium from clay based deposits is a new area and we are continuing to study the technology involved.

Spotlight on companies – Graphite producers

Company	Description
Syrah Resources	Syrah is an Australian listed company which is developing the Balama graphite project in Mozambique. The Balama feasibility study which was published in mid-2015 presents a globally significant graphite project with the potential to supply around 50% of global graphite demand. The feasibility study envisages a 42 year life OP processing 2Mtpa of ore to produce c.315ktpa of concentrate over the life of the mine.[74] At nameplate capacity the mine will be the largest single source of graphite globally. It is also the most advanced of all its peers in terms of achieving commercial production. We are continuing to conduct our due diligence on Syrah as we believe that the investment case is interesting in many areas, but at the current time the risk-reward balance does not appear sufficiently compelling.
Alabama Graphite	Alabama Graphite is a US based graphite project developer. AGC believe that their unique selling point is being able to feed into the 'Made in America' focus that many US OEMs currently have. There is probably some merit in this, but there is a long way to go with the project and details over funding and timing of the project needs more clarity. They state that they have produced a high performance Coated Spherical Graphite (CSPG) for lithium-ion batteries. They completed a Provisional Economic Assessment (PEA) on the Coosa Graphite project in 2015 which showed that they can produce two products a CSPG for lithium-Ion batteries and a Purified Mechanized Flake Graphite (PMG) for use in polymer, plastic and rubber composites, powder metallurgy, energy materials and friction materials.[75] Again there is much about the project that we find interesting, but given some of the uncertainties around project funding and development timelines greater clarity here is needed to determine its attractiveness as an investment opportunity.
Talga Resources	They are an Australian listed, Scandinavian graphene producer with a German pilot plant facility. Key unique selling point is particle size, Syrah, for example, is a large flake producer, while Talga is a micro particle focused producer. They are three years away from full scale operation in Sweden, but early stage production is possible with material trucked to a pilot plant in Germany which will be used to showcase the product with potential clients for approval. The deposit is high grade, with minimal waste material. The 'raw ore' is highly conductive electrically making it particularly attractive to offtakers when combined with a simple processing methodology. We are drawn to the company's simple production and processing method, although at the moment the risk-reward balance is unfavourable we believe that they could make a compelling future investment opportunity.

Conclusion

Electric vehicle-take off is becoming more tangible confirming our original investment case, but also bringing with that increasing investor attention. As such, it is increasingly important to understand the value chain and identify where economic profits will be made in the future. We are interested in five-year earnings growth, and not multiple expansion, to justify investments. Furthermore, any stock identified through this research must stack up against the rest of the strategy under the Barings investment framework.

Much has been written about the potential supply cliff in lithium. However, we fundamentally believe that not only will demand surprise on the upside, but that the supply reaction will be significantly delayed. This is due to our belief that EV demand will surprise to the upside with the start-up of the new Tesla Gigafactory a contributing factor to lithium demand growth, and that the technological difficulties of both extraction and processing to produce 99.98% pure lithium carbonate are being underestimated.

In this paper, therefore, we have delved deeper into the supply chain to identify the companies that we believe are best placed to benefit from EV take-off. In this respect, we have identified companies such as Galaxy Lithium, LG Chem, Leclanché and SK Innovation as potential winners, while re-confirming our conviction in existing investment case for companies such as Albemarle, Orocobre, W-Scope, Asahi Kasei, Johnson Matthey, Umicore and BASF.

A further consequence of declining lithium-ion cell prices, and the potential future abundance of "used" automotive batteries, is that energy storage economics are becoming much more compelling. We therefore remain focused on the opportunities and implications of energy storage solutions for renewable energy, infrastructure and the underlying materials.

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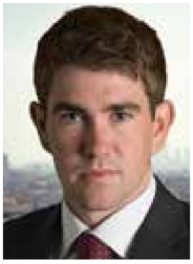

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Appendix

Types of electric vehicles and the batteries used:

1) Internal combustion engines: even gasoline and diesel engines still use batteries to either start the ignition process or improve fuel efficiency. Batteries in ICEs fall into two main types:

   a. Starter batteries: Also known as SLI (or starting, lighting and ignition) batteries. Traditionally lead-acid chemistries, these have been used in traditional ICE"s for more than 50 years. Starter batteries, simply put, are used to start a vehicle's engine by providing the power to start the ignition system as well as providing the power for car electronics when the motor is switched off. The running of the engine acts to recharge the battery. Lead acid batteries are typically used for starter batteries.

   b. Micro-hybrids: Micro-hybrid batteries act as range extenders and increase efficiency in traditional ICEs. With increasingly more stringent carbon-dioxide emission standards expected to be introduced in 2020/21, OEMs are increasingly looking to micro-batteries as a cost efficient way to improve overall fleet efficiency. Increasingly these look like being lithium-ion technology, but given that they act in short bursts, providing power in stop-start situations and charging through generative braking, a chemistry such as LFP is more suited than NMC due to the higher potential power density.

2) Electric vehicles:

   a. Pure EV: Often called BEVs or BOEVs (for Battery Electric Vehicle or Battery Only Electric Vehicle), these have been the focus of our work as we believe the simplicity of having one engine (rather than two as required in a hybrid) is a key attraction due to the lower maintenance costs and greater available space that result. We believe pouch-type NMC cells will come to dominate this market, and battery sizes will be well in excess of 40kWh (most likely rising over time as prices fall towards the 100kWh mark to ensure a range of in excess of 300 miles)

   b. Hybrid electric vehicle: Made famous by the Toyota Prius, HEVs make use of their electric motors for short bursts of power such as when pulling away from a stop or driving at low speeds when small amounts of energy are needed. The battery is recharged purely through regenerative braking. The battery is typically only 1-2kWh in size, and given the power needs, rather than range requirements, greater power density rather than energy density is required making LFP a more likely cathode material than NMC.

   c. Plug-in hybrid electric vehicles: PHEVs are hybrid vehicles (with an electric motor and a traditional ICE). Unlike more traditional hybrids, the battery is slightly bigger (at 5-15kWh), and the battery is used as the primary motor until it runs down, with the ICE essentially acting only as a range extender. Due to the importance of range, we believe that NMC will likely come to dominate the PHEV market.

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