FUNDAMENTALS

Are battery prices in for a shock?

Key Points:

- Battery costs have declined rapidly in recent years, but the market is likely too optimistic about both the timeline for lower battery costs and what happens when we get there
- Raw material cost increases threaten to delay the time when electric vehicles (EVs) will be competitive with internal combustion engine-powered cars on an economic basis without subsidies
- The focus on average battery costs obscures cost differences among suppliers and overstates the impact of battery-cost declines on EV penetration rates

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The electrification of the automobile will likely be remembered as one of the most important technological shifts of our lifetime. The transition is still in the early stages but is certainly off to a fast start. Sales of pure battery electric vehicles in 2017 were relatively small, at just below 700,000 units, but this represented a 61% increase from the previous year. To date, rapid growth has been driven by subsidies, favourable regulatory policies and early adopters eager to join the green revolution. But in order for sales to accelerate into a higher gear, battery electric vehicles (BEVs) will need to close the price gap with their gas-guzzling counterparts, primarily attributable to the high cost of batteries relative to the internal combustion engines, which power the cars of today.

Fortunately, in recent years, battery cost declines have outperformed even the most optimistic expectations, falling from $1,000/ kilowatt-hour (kWh) in 2010 to $209/ kWh in 2017[1]. But 2018 could be the year that bucks the trend, as a spike in the cost of key raw materials used to make batteries and shifts away from short-range, low-cost batteries in China represent meaningful headwinds to the decline in average battery costs. The prevailing consensus is that average battery costs must fall to $100/kWh in order for BEVs to compete with internal combustion engine vehicles (ICEs) on an economic basis, without the benefit of subsidies. However, can battery costs continue moving towards this level, if higher demand puts further stress on the supply of raw materials? Can improvements in lithium-ion energy density offset the impact of the higher costs of raw materials? Or will next-generation technologies be required to drive electric vehicles from the fringe to the mainstream?

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BATTERY RAW MATERIALS: FROM MINE TO MODEL S

Every electric vehicle requires a battery, and every battery using the prevailing lithium ion technology requires a combination of mined commodities which were used mainly in niche applications until recently. All lithium ion batteries contain two electrodes: the anode — or negative electrode — that releases electrons as the battery discharges, and the cathode, or positive electrode, which absorbs these electrons. The two electrodes are separated by a liquid electrolyte, typically made of a lithium salt solution, while the anode itself is normally made of graphite. The current battle in electric vehicle battery materials is over the makeup of the cathode, with the vast majority comprised of various combinations of nickel, manganese and cobalt (NMC); nickel, cobalt and aluminium (NCA); or lithium, iron and phosphate (LFP). The choice of cathode material involves a trade-off between the battery's energy density, safety, life cycle and cost.

Figure 1: Characteristics of lithium-ion battery types

	LCO	LMO	NMC	LFP	NCA	LTO
Cathode	Lithium cobalt oxide	Lithium manganese oxide	Nickel, manganese, cobalt	Lithium iron phosphate	Nickel, cobalt, aluminium	Lithium titanate
Specific Energy[A]	150-200 Watt-hour/ kilogram (Wh/ kg)	100-150 Wh/kg	150-220 Wh/kg	90-120 Wh/kg	200-260 Wh/ kg	50-80 Wh/kg
Cycle Life[B]	500-1000	300-700	500-2000	1000-2000	500-1000	3000-7000
Thermal Runaway[C]	150°C	250°C	130-250°C	270°C	150°C	One of safest Li-ion batteries
Used in…	Laptops, cell phones, cameras. Not used in EVs	Power tools, medical devices, short-range EVs	Chevy Volt, BMW i8, Toyota Prius, VW e-Golf	Short-range EVs in China	Tesla	Mitsubishi i-MiEV, Honda Fit EV

Source: www.batteryuniversity.com, Bloomberg New Energy Finance[2]

All of these materials in batteries will experience demand growth from electric vehicles but lithium, cobalt and nickel will see the largest increases in demand relative to current production rates. Separating relative winners from losers among these metals requires digging into the supply-side fundamentals.

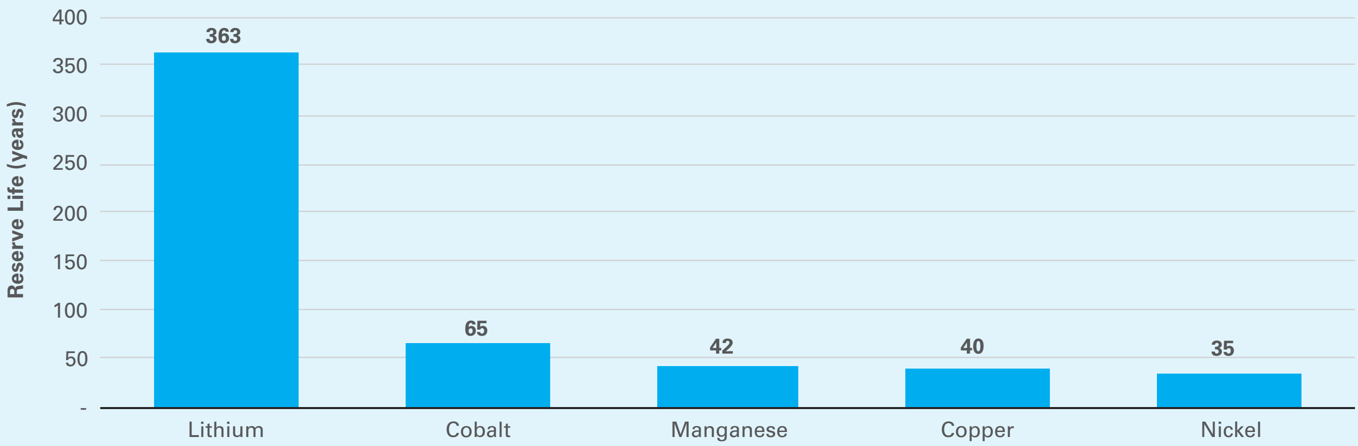
A. Specific energy is the energy density of the battery and determines the range of the vehicle.

B. Cycle life is the number of times the battery can be fully charged and discharged without degrading.

C. Thermal runaway is the temperature at which heat causes a reaction that causes more heat and so on, frequently leading to a destructive result.

Figure 2: Battery materials' supply-side dynamics

Reserve lives of key raw materials at 2017 production rates



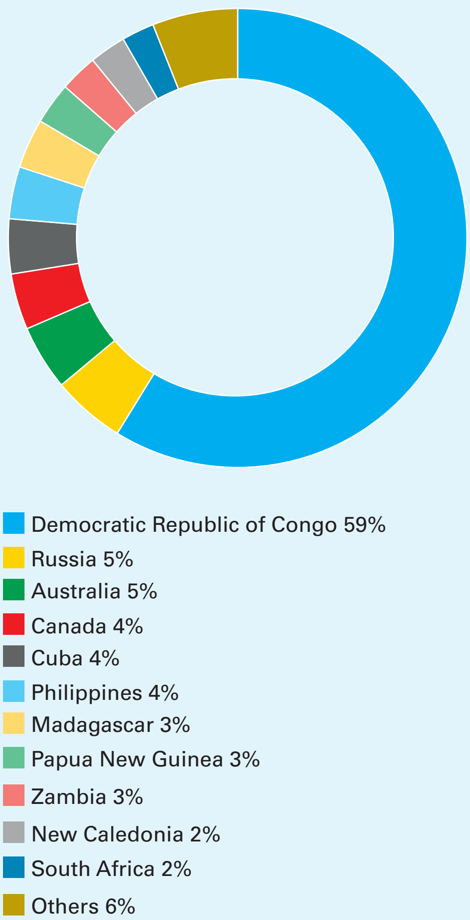
Source: US Geological Survey

We expect **lithium** to experience the strongest demand growth rates from a greater take-up of electric vehicles (EV), albeit from a relatively low base. The key differences between lithium and other EV commodities are an abundant reserve life (**363 years at 2017 production rates!**), relatively low capital intensity, and a short lead time for bringing on new projects, relative to other base metals. This has led to a surge in new entrants and a robust pipeline of new projects scheduled to hit the market, while market leaders also have significant capability to expand low-cost production. Given the abundance of reserves, we do not anticipate that lithium supply will constrain battery production, even if the most optimistic EV adoption estimates prove correct.

Nickel is perhaps the most misunderstood battery metal, partly because only the highest quality product (Class 1 nickel) is suitable for making nickel sulphate for use in battery cathodes. Class 1 nickel comprises roughly half of global production and generally comes from two sources: sulphide ores or limonite that has been extracted via high-pressure acid leaching (HPAL). Unfortunately, sulphide ores comprise only about 20% of remaining global nickel resources, while HPAL projects are very expensive, take years to develop and have a troubling history of significant delays and cost overruns. The demand from electric cars will have to compete with traditional uses of Class 1 nickel, such as super-alloys for aerospace-defence applications where buyers are less sensitive to higher prices.

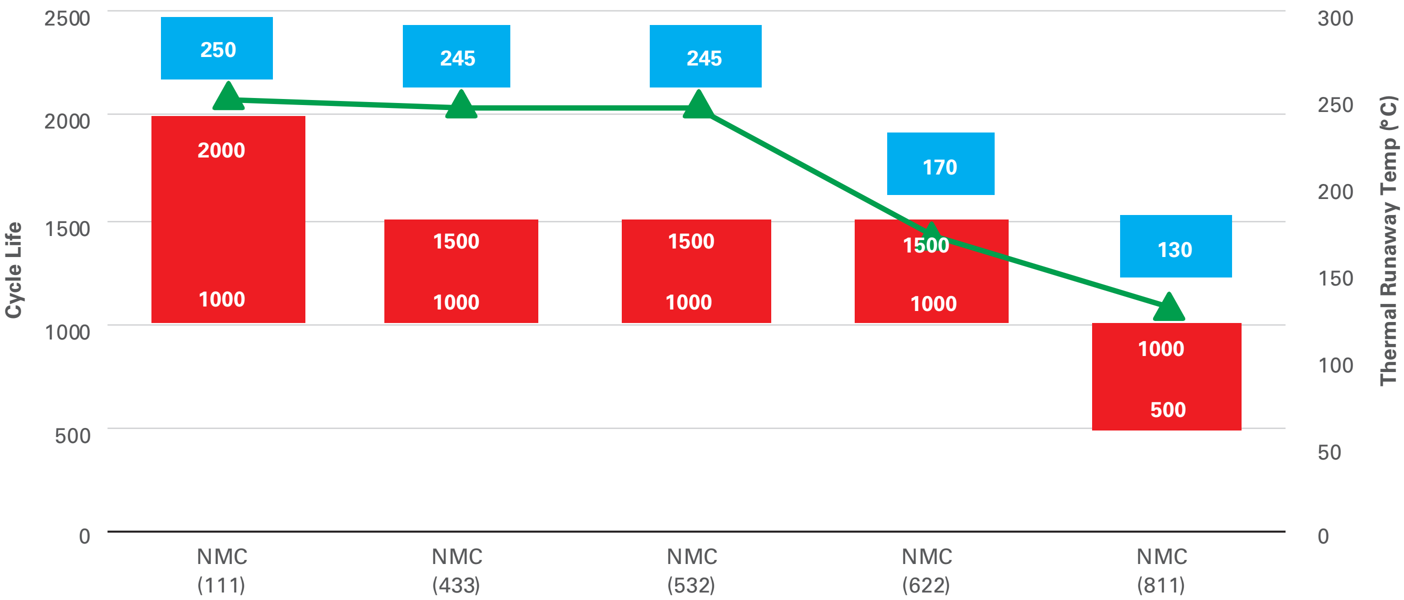
Cobalt is arguably the most supply-constrained battery metal. It is generally produced as a by-product of copper or nickel mining and is heavily concentrated geographically, with 59% of 2017 mined supply and half of global reserves coming from the Democratic Republic of Congo (DRC). DRC ranks 163rd out of 180 countries on Transparency International's Corruption Perceptions Index, and parts of the country are experiencing heightened levels of social unrest. In addition, proposed changes to the mining code will increase royalty charges on cobalt and may threaten future investment. Yet another concern is that a meaningful share of cobalt is produced via artisanal mining, which lacks safety standards and is frequently alleged to exploit child labour.

2017 Cobalt production by country production rates



In our view, either cobalt or nickel will experience the most significant supply constraints depending on the mix of nickel-manganese-cobalt (NMC) cathode chemistries, which employ varying ratios of each metal. All else being equal, higher nickel content improves vehicle range, while higher cobalt content supports longer life and improved safety. The current direction of travel is toward higher nickel content as manufacturers seek to increase vehicle range and reduce dependence on expensive cobalt. However, given cobalt's role in stabilizing the battery, this comes at the expense of safety and longevity, and pushes up demand for higher purity 'class one' nickel.

Figure 3: Performance specs for various NMC chemistries



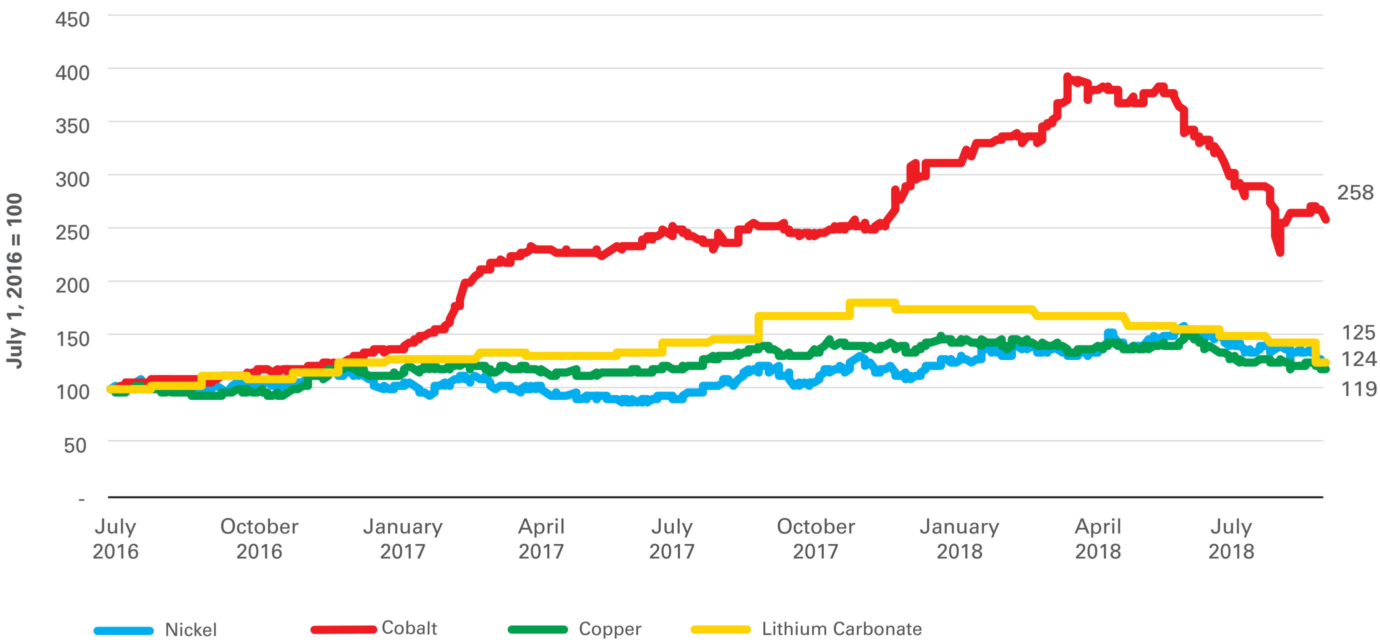
Source: Bloomberg New Energy Finance. Nickel-manganese-cobalt (NMC) cathodes with different ratios of each material. For example, NMC (111) contains equal parts nickel, manganese and cobalt.

We expect that this trend toward greater nickel content will continue, and thus favour nickel over cobalt within the EV theme. Copper may also benefit from increased EV adoption, as EVs use more than four times as much copper as conventional vehicles, though the increase in demand relative to existing production is far smaller than for cobalt, nickel or lithium. Still, as copper demand growth is largely agnostic to the choice of cathode material, the metal represents a less risky way to play the electrification theme.

MATERIAL HEADWINDS

But if raw material prices increase significantly, what does this mean for battery prices? 2018 will likely give us a glimpse of the answer. Over the twelve-month period through June 2018, the average prices for nickel, cobalt, copper and lithium carbonate increased 29%, 85%, 32% and 17%, respectively compared to the previous year. As battery costs generally incorporate raw materials prices with a six-month lag, we have yet to see the full impact of these price increases. We estimate that 2017 average battery costs would have been more than $10/kWh higher if similar commodity prices had prevailed from mid-2016 to mid-2017.

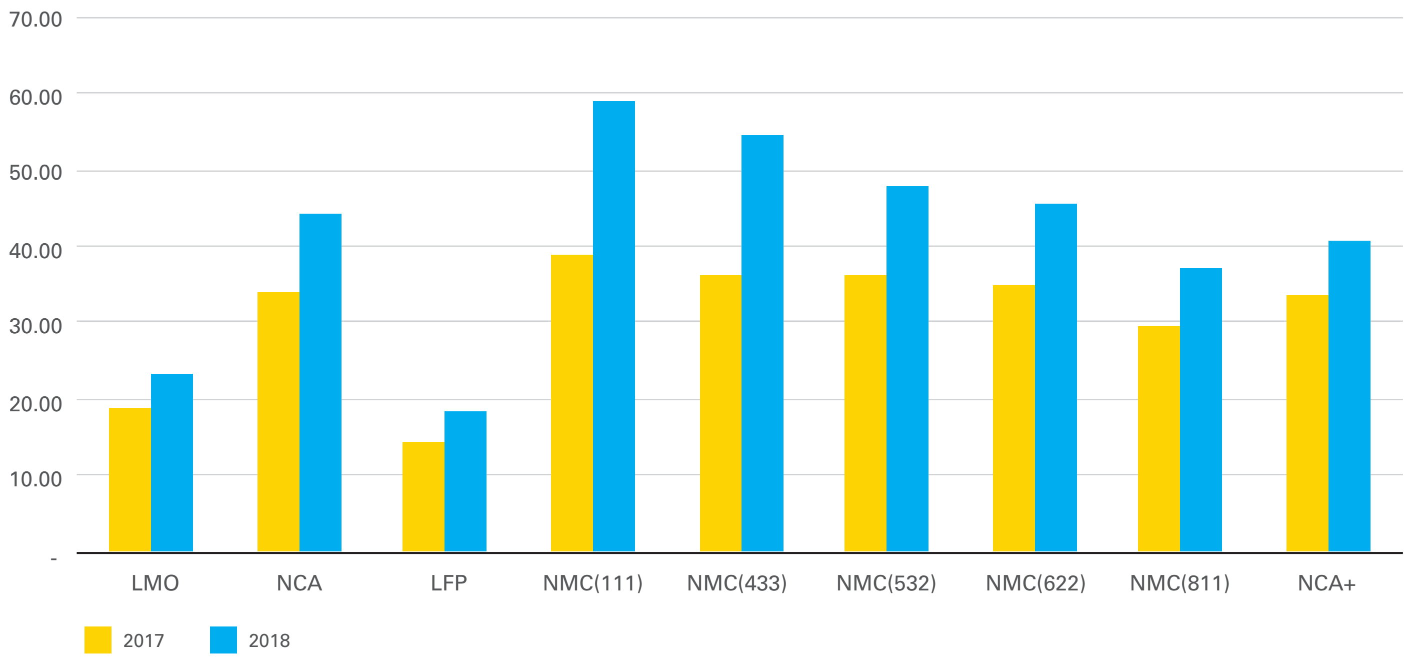
Figure 4: Price history of key battery materials



Source: Bloomberg, LME

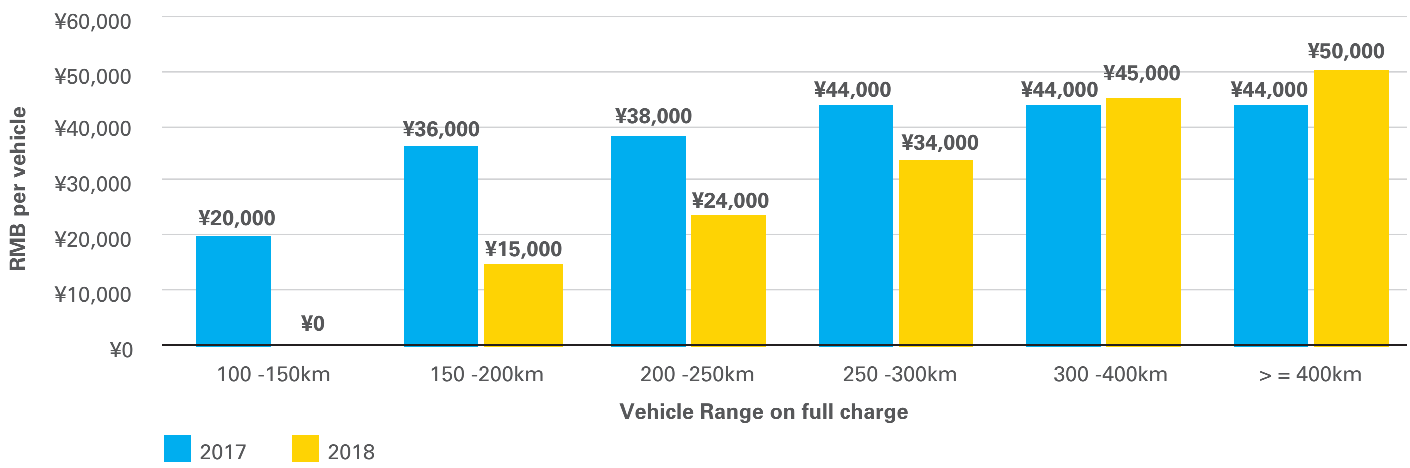
While battery manufacturers can work to offset these cost pressures through continued efficiency gains in manufacturing, battery-pack density improvements and shifting toward chemistries with lower cobalt intensity, at a minimum they threaten to slow the rate of progress seen in recent years. As illustrated in the chart below, the increase in raw materials costs for 2018 vintage batteries has already more than offset the savings from moving from NMC (111) in 2017 to NMC (622) in 2018.

Figure 5: Materials costs by battery type ($/kWh)



Source: Bloomberg, Bloomberg New Energy Finance, LME.

Figure 6: China BEV Subsidies 2018 vs 2017



Source: Bloomberg New Energy Finance[3]

SHIFTING SUBSIDIES

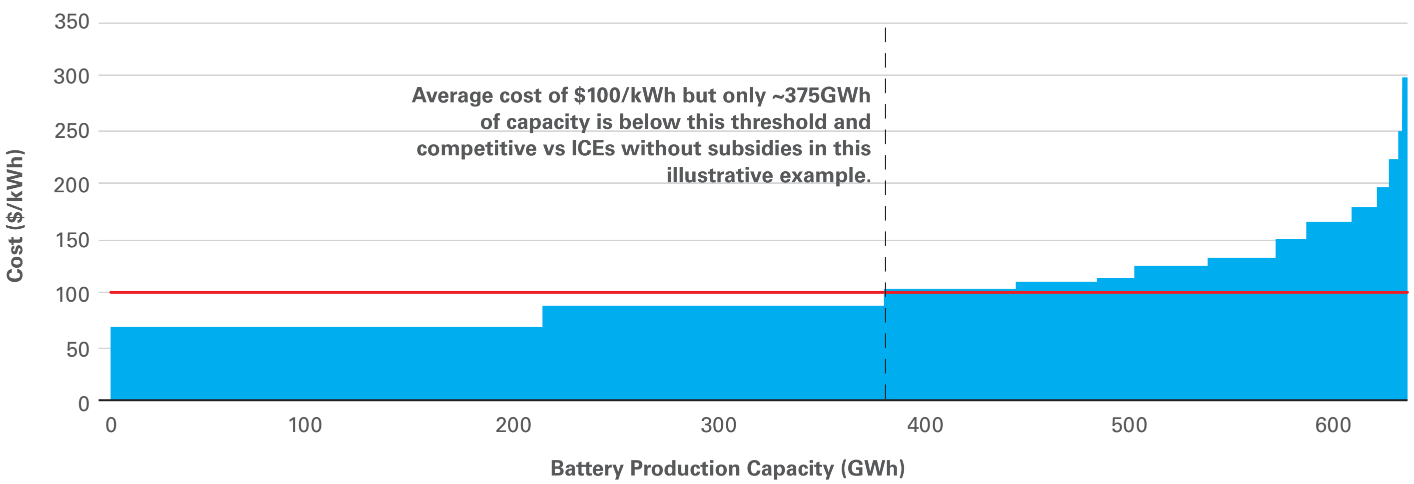
A second headwind for battery prices comes from a recent shift in Chinese EV subsidies. From June 2018, the Chinese removed subsidies altogether for the lowest-range EVs and significantly reduced subsidies for mid-range EVs while slightly increasing subsidies for longer-range vehicles.

The expected result of these subsidy shifts is that sales will migrate toward longer-range vehicles at the expense of shorter-range vehicles, an area where low-cost lithium iron phosphate (LFP) batteries have been dominant. LFP batteries accounted for 30% market share in China and 17% globally in 2017, and will likely reduce to almost zero over the next 1-2 years as a result of subsidy changes and the desire for longer ranges. If 2017 LFP sales were spread across other chemistries, average battery costs would have been another $5/kWh higher, on top of the impact of the higher raw material prices highlighted above.

NOT EVERYONE CAN BE AVERAGE

Another problem we see with the consensus view is the focus on average cost, which fails to account for significant cost differentiation among battery manufacturers. We illustrate this point with the hypothetical cost curve below, which shows actual manufacturing capacity that has been announced, is currently producing or under construction and fictitious cost estimates that are inversely related to manufacturing capacity.

Figure 7: Illustrative Battery Manufacturing Cost Curve



Source: Bloomberg New Energy Finance, LGIM estimates

In this example we can clearly see that while average costs are $100/kWh, just over half of the manufacturing footprint is cost-competitive versus internal combustion engine powered vehicles (ICEs), while the remainder is not. Large-scale battery-makers with efficient operations may become cost-competitive against ICEs in the not-too-distant future, but higher-cost producers could take significantly longer to get there. In order for EV sales to see the expected step-change in growth rates, either lower-cost manufacturers must further expand production volumes or high-cost producers must fall below the $100/kWh threshold. Efforts at the former are on-going but the latter could be challenging, not least because marginal producers are less likely to have favourable supply agreements for raw materials. We also highlight that in this example, battery production at around 375 gigawatt hours (GWh) of capacity translates into roughly 7.5 million electric vehicles per year, significantly higher than today's levels, but a far cry from EV ubiquity.

A SLOWER DRIVE?

While battery costs will likely continue their downward direction of travel, higher raw material prices could slow progress and increase the likelihood that technological innovations beyond traditional lithium-ion will be necessary for a broader scope of EVs to compete economically with ICEs. As a result, while the best-positioned EVs may start battling for market share with ICEs without the aid of subsidies in the next few years, the step-change in EV adoption envisioned by the industry may take longer to materialise. Ironically, this means that higher-cost battery producers may be facing the same stranded asset risks that the EV revolution presents for the extractive industries, and oil products might have more time in the sun as the fuel of choice for passenger transport. It also means that automakers aiming to produce EVs would be well served to solidify supply agreements with low-cost battery manufacturers and secure access to crucial raw materials in order to minimize the margin impact of electrification. Finally, while many forecasters are predicting a surge of EV adoption and a demand-driven price spike in key battery raw materials, we find it very difficult to see both of these occurring at the same time.

Sources:
1. Bloomberg New Energy Finance: "2017 Lithium-ion Battery Price Survey" (5 December 2017)
2. Bloomberg New Energy Finance: "Battery Components: Capacity, Shipment and Supply Chain (26 October 2017)
3. Bloomberg New Energy Finance: "China Changes its Electric Vehicle Subsidy Program "(14 February 2018)

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