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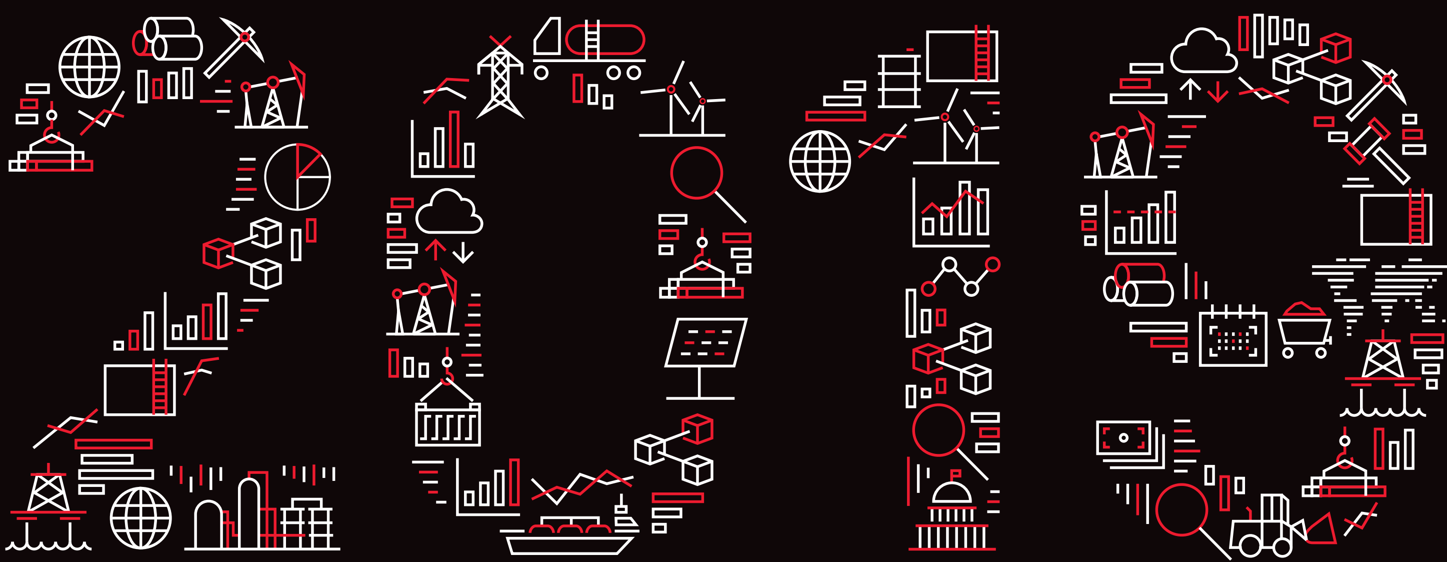
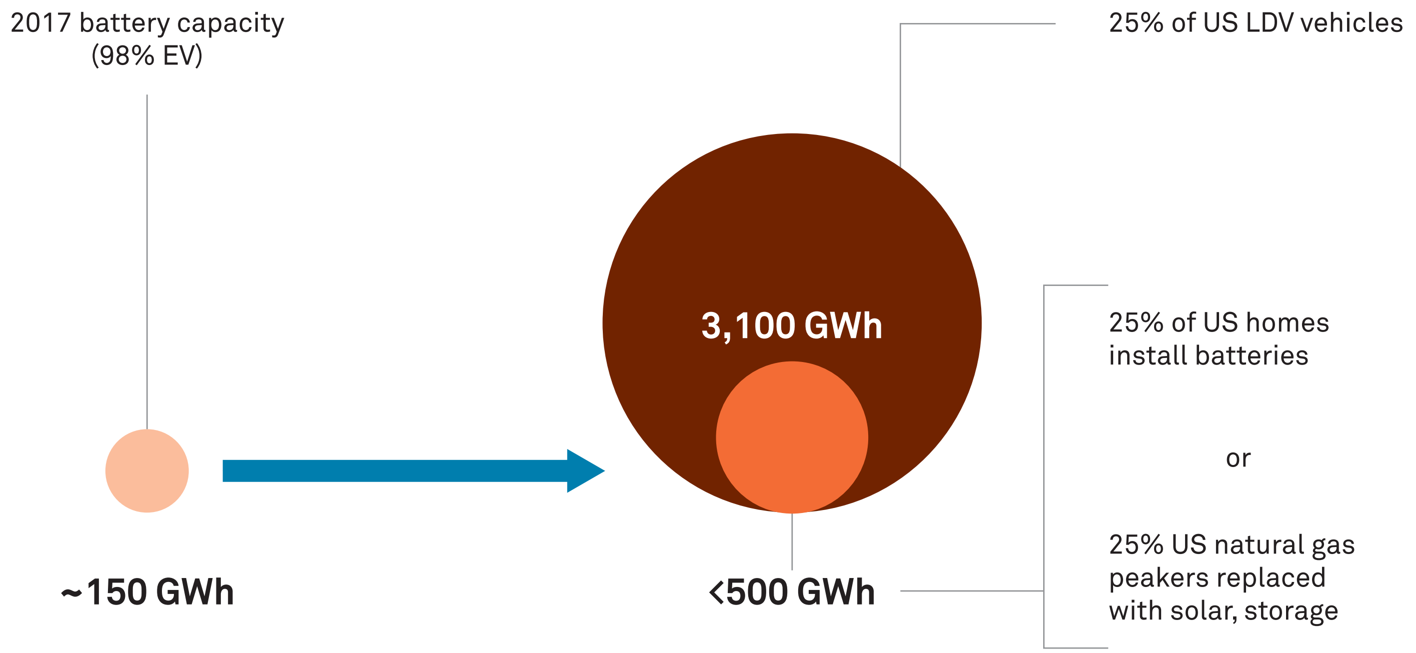


Lithium-ion batteries: in the fast lane

An accelerating need from transport is expected to drive demand for lithium-ion batteries during the coming years. Felix Maire and Roman Kramarchuk of S&P Global Platts Analytics outline the issues around the technology, as well as the sourcing and substitution of key metals

EV battery demand significantly larger than power storage market



Source: S&P Global Platts Analytics, US Census, IEA

Both the transportation and power industry have been facing significant changes, driven by a combination of policy and technological factors, and S&P Global Platts Analytics sees lithium-ion batteries playing an instrumental role in these transformations.

When it comes to batteries, there have been and will continue to be synergies of power storage and transport sector battery technology. In the power sector, large deployments of wind and solar photovoltaics will increase the need for storage to manage their intermittency. Recently, the US has seen several RFPs in which developers have bid projects combining solar PV assets and lithium-ion batteries – a trend discussed recently in S&P Global Platts Analytics' *U.S. Power Storage Outlook.*

Because of the often-siloed nature of the energy sector, there is a need for some perspective regarding the relative size and importance of the sectors. The fact is that energy sector applications of batteries are and will continue to be dominated by uptake in the transport sector (see chart, above).

Intuitively, this should not be surprising, as batteries provide for the full energy transport needs of an electric vehicle, but they only play a supporting role to other generating sources in the power sector. Globally, there is currently only 2–4 GWh of lithium battery storage installed in the power sector, according to the International Energy Agency, whereas batteries in electric vehicles account for 140 GWh.

The right-hand side of the chart gives a sense of the relative size of battery demand under some strong battery storage penetration scenarios. On the transport side, assuming 25% of light-duty vehicles in the US were EVs (with a 60 kWh battery) this would imply 3,100 GWh of battery needs. On the power side, assuming 25% of all US households installed home batteries (sized at 13.5 kWh), the total need would be <500 GWh. This is about the same level of battery needs under a scenario in which 25% of US natural gas fired peaking generation plants are replaced with a combination of solar and storage. As can be seen, the potential on the power side is clearly much smaller in scale – and the power sector can also choose from a wider range of non-lithium ion alternatives.

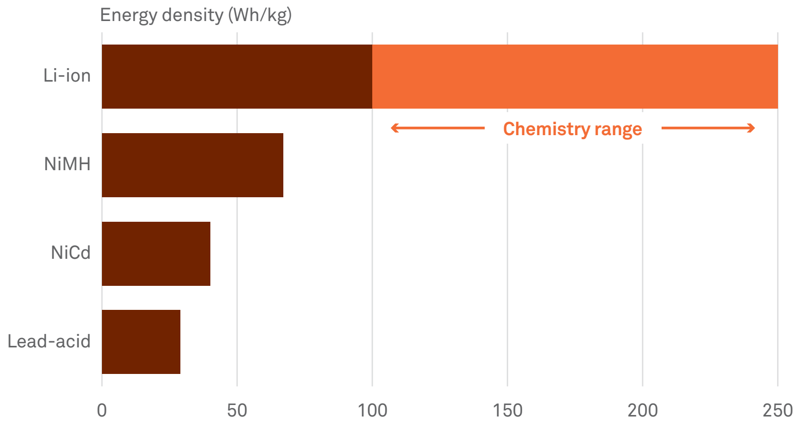
The role of transport

The electrification of the transport sector is seen as a potential solution to reduce local air pollution and potentially also greenhouse gas emissions (depending on factors such as the carbon intensity of the power sector). Developments in battery technology have been critical to this.

Research on lithium-ion batteries began in the 1970s. In 1991, Sony commercialized the first lithium-ion battery to increase the battery capacity of its video recording devices. However, it took much longer for the transport sector to adopt lithium-ion batteries, despite its ability to store much more electricity by unit of weight or volume than older technologies. Early EV designs from the 1960s relied mostly on nickel-cadmium batteries. And for a while, lithium-ion batteries were too expensive to be used in transportation applications while nickel-cadmium (NiCd) or nickel-metal hydride (NiMH) batteries were too heavy to provide EVs with adequate ranges. In contrast, electric hybrid vehicles needed less battery capacity and were able to utilize the relatively inexpensive NiMH batteries. The earliest Toyota Prius hybrid had a battery capacity of less than 1 kWh, while the Tesla Model 3 houses a 75 kWh battery.

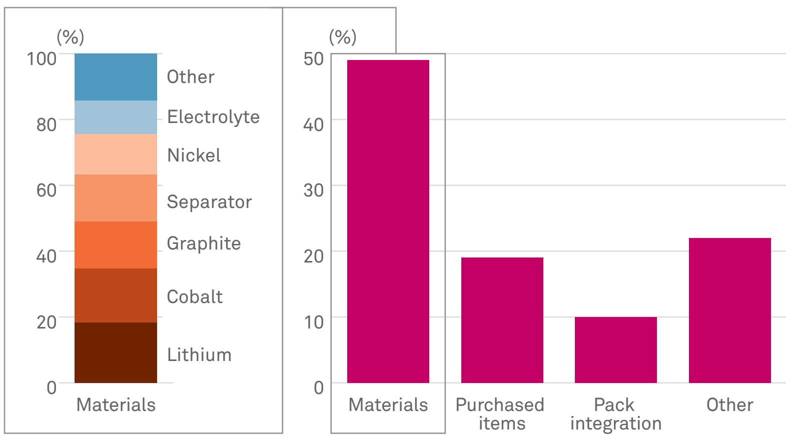
While EV sales are increasing, they remain a small fraction of new car sales and the total vehicle fleet. EVs will account for 2.5% of total 2018 passenger vehicle sales, according to the latest S&P Global Platts Analytics *Electric Vehicle Sales & Policy Scorecard.* Cost will be a key determinant of further uptake. The purchase price of EVs is expected to remain higher than that of gasoline or diesel vehicles, largely due to the high cost of batteries. S&P Global Platts Analytics modelling indicates that savings in the costs of fuel

Lithium-ion batteries have a clear advantage over other batteries for electrifying transportation



Source: S&P Global Platts Analytics, specific energy at the cell level

Will raw materials drive battery cost trajectory?



Source: S&P Global Platts Analytics, assumes future improvements in NMC 622 chemistry, based on ANL BatPac model

and maintenance will not be sufficient to make EVs competitive on a total-cost-of-ownership basis for a while. However, we do expect further EV cost reductions and technology improvements over time. We estimate that passenger EV sales will continue to accelerate, reaching 24 million in annual sales in 2030.

This fast ramp-up of EV sales will significantly raise demand for raw materials such as lithium, cobalt, manganese and nickel. Development of new mines

and intermediate conversion and processing plants takes time, raising concerns that supply will not be able to keep up with demand, and that shortages will raise battery prices and slow down the price competitiveness and uptake of EVs.

Material world

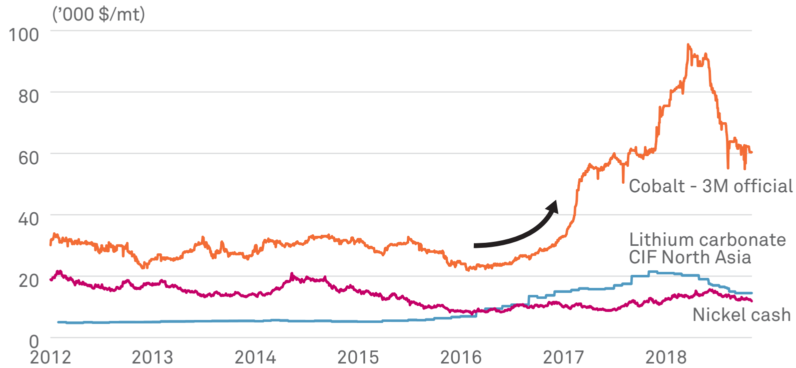
Materials currently account for nearly 50% of the total battery cost, among which cobalt, lithium, nickel and graphite are the most expensive, accounting for 30% of total cost. Process and chemistry improvements and pack engineering advances will lower battery prices, all else being equal. In turn, the battery cost exposure to metal price risks will increase as these key raw materials account for a larger share of the battery price.

How this ramp-up in demand for metals plays out will depend in part on developments in battery chemistries. The industry has developed a wide range of lithium-ion battery types, varying in capacity, chemistries and performance. There is no commercially available ideal lithium-ion chemistry suitable for all applications. The choice of chemistry is typically a trade-off between energy density, power density, safety, life and cost requirements, and the metal needs vary.

Energy density is critical for the electrification of transportation. Within the industry, the concept of "range anxiety" has been widely discussed as one of the factors limiting customers' interest for EVs. Increasing battery capacity is the primary option for increasing vehicle range. However, as there is a limit to how much battery capacity can be installed due to vehicle space and weight limits, high energy density is key to achieving long-range EVs.

In addition, the feasibility of heavy-duty vehicle electrification will partly depend on future increases in energy density. Electrifying long-range heavy-duty trucks with current lithium-ion batteries would shrink the amount of goods trucks can transport over long distances.

Battery metal pricing



Source: S&P Global Market Intelligence, S&P Global Platts

However, energy-dense chemistries are also the ones that use expensive raw materials, such as cobalt. While some early EVs sold outside China relied on low-energy density batteries – for instance, the first Nissan Leaf used the cobalt-free lithium-ion manganese oxide (LMO) chemistry – automakers use high energy density batteries in their latest EV models to achieve higher

Lithium spodumene and brine volumes are coming to market in increasing numbers from places such as Argentina

vehicle ranges. Tesla has been the main proponent of the lithium nickel aluminum cobalt oxide cathode (NCA). Other manufacturers use the lithium nickel manganese cobalt oxide (NMC) chemistry.

Since 2016, prices for cobalt traded on the London Metal Exchange more than quadrupled to reach a peak of $95,500/mt in March 2018. Similarly, the price of lithium carbonate more than doubled since 2016, but has been decreasing recently. Since the launch of S&P Global Platts battery-grade lithium carbonate assessment on May 4, the seaborne price has fallen significantly from its opening assessment of $18,000/mt.

Longer range EVs use the NMC and NCA chemistries, which favour the use of lithium hydroxide instead of lithium carbonate. Despite the growing demand, prices for lithium hydroxide have been dropping recently, highlighting ample lithium supply. Indeed, concerns over lithium supply have shifted towards concerns about lithium conversion capacity, which is needed to upgrade raw material to the carbonate and hydroxide needed in batteries.

Lithium spodumene and brine volumes continue to come to the market in ever-increasing numbers from Australia, Chile, Argentina, Bolivia and China. While Chinese brine and spodumene is largely seen as lower quality it can be upgraded to battery-grade quality. Weakening S&P Global Platts battery-grade lithium carbonate assessments for the seaborne as well as Chinese domestic market suggest easing concerns over near-term supply, with all four assessments down from where they were assessed when first launched.

Ensuring a steady supply

Automakers have tried, with varying success, to lock-in raw material supply of cobalt and lithium. Earlier this year, Gangfeng signed a deal with LG Chem to supply lithium for the period 2019–2025 and signed a contract with Tesla for a two-year supply, with an option for three additional years. However, Volkswagen failed last year to secure long-term cobalt supply after asking for 10-year contracts. Cobalt also faces a concentration risk, as most of the production and reserves are located in the Democratic Republic of Congo. On the contrary, lithium reserves are more widely spread, but Chile and Australia account for almost 80% of 2017 production.

It is important to note that there is currently no real alternative to lithium for the batteries used in the transport sector. While the battery industry is using different forms of lithium – lithium carbonate or lithium hydroxide – the need for lithium is relatively comparable among all the different lithium-ion battery chemistries. Finding a good replacement would not be an easy task for the industry. By 2025, S&P Global Platts Analytics expects a 10-fold increase in lithium demand from passenger EVs.

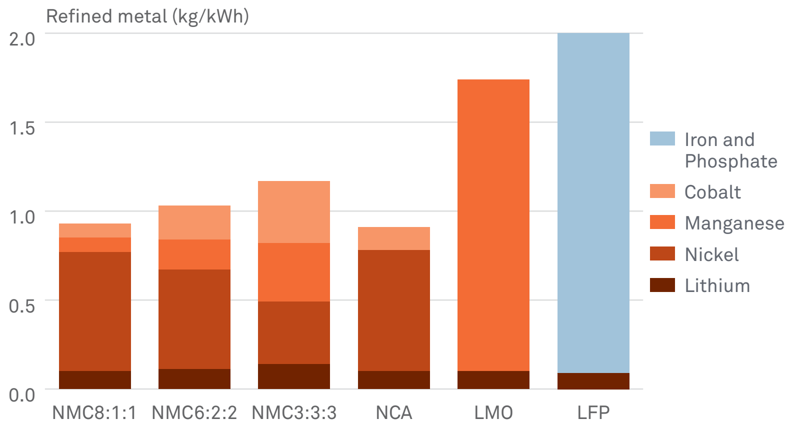
Technology development will be instrumental in reducing cobalt exposure. Battery manufacturers are partly replacing cobalt with nickel in new batteries to reduce cobalt needs and increase energy density. The battery of the first BMW i3 used the NMC 3:3:3 chemistry (with three parts nickel, three parts cobalt and three parts manganese). A doubling of cobalt prices would lead to a 13% increase in battery cost for this chemistry. However, the industry is moving towards the NMC 6:2:2 (with six parts nickel, two parts cobalt and two parts manganese). This would cut the cobalt need, limiting the battery price increase to 8% if cobalt prices double (see chart, upper right).

Research is ongoing to further reduce cobalt content in batteries, and possibly even to eliminate it. The industry expects the commercialization of the NMC 8:1:1 within the next few years, though safety concerns due to lower cobalt content may delay this.

While several companies are working on cobalt-free chemistries, technology advances generally take a long time in the battery space, as time is measured in decades. Cobalt provides stability to lithium-ion batteries and is difficult to remove completely while keeping high energy density. New technologies, such as solid-state batteries, may decrease the need for cobalt, but are still many years away from mass commercialization. New cobalt supply will still be needed in the interim, as the scale of the expected growth in EVs will outpace such technological developments.

Finally, battery recycling will become a critical topic, as EVs reach new segments and take up an increasing share of new vehicle sales. It is likely that governments will play a key role in supporting recycling driven by waste and sustainability concerns, as well as the risk of raw material scarcity. Automotive manufacturers typically guarantee batteries for 100,000 miles or eight years, but batteries' capacity degrades with use and they ultimately need to be replaced. There are increasing discussions about the second use of batteries, with some OEMs investigating the reuse of EV batteries for power storage applications. ■

Battery chemistries can vary



Source: S&P Global Platts Analytics

S&P Global Platts pricing and analytics

S&P Global Platts has been working to better understand the implications of changes in the battery metals sector through an increased focus on analytics in this space, and by launching four new battery-grade lithium price assessments in the past year.

S&P Global Platts Analytics provides research and data on the global commodity markets, and covers the transformations the power and transport industries are currently facing.

Our battery-grade lithium assessments are available to view in our *Metals Daily* newsletter or on Platts Metals Alert Page 8888.