S&P Global
Platts

BATTERY METALS INSIGHT

July 2021

ONGOING TRANSFORMATION: THE FUTURE OF LI-ION BATTERIES—AND WHAT IT MEANS FOR METALS

QUARTERLY PRICING WRAP: Battery metals prices lose momentum, but keep rising

Prices of lithium, cobalt and nickel lost momentum in the second quarter of 2021, compared with the first, but the uptrend continued. The support is likely to persist for the rest of the year on the back of healthy demand from the electric vehicles industry, sources said.

The bullish sentiment started easing in March and persisted into the second quarter. Lithium carbonate and cobalt hydroxide finished the quarter slightly below prices seen in early April, while the rest of S&P Global Platts battery metals assessments were up in the end of Q2.

Lithium

Q2 saw the inversion of the spread between lithium carbonate and lithium hydroxide in China, with the latter moving back to leading position for the first time this year.

The shift occurred on May 27, when lithium hydroxide DDP China hit Yuan 90,000/mt, Yuan 500/mt higher than the lithium carbonate DDP China price. Since then, the hydroxide premium widened and finished the quarter at Yuan 9,000/mt – with hydroxide at Yuan 96,000/mt and carbonate at Yuan 87,000/mt.

In early April, carbonate was at a Yuan 12,500/mt premium to hydroxide, with carbonate at Yuan 88,500/mt and hydroxide at Yuan 76,000/mt.

Hydroxide's 20,000/mt jump during the quarter was driven by renewed interest for nickel-rich chemistries in China, as well as increasing exports to Japan and South Korea, where most of the hydroxide demand is located.

Simultaneously, carbonate lost steam as the warmer season neared, bringing with it increased output from Chinese brines. These operations produce cheaper sub-battery grade lithium carbonate, but most of the local lithium iron phosphate (LFP) producers can use it instead of battery grade lithium carbonate.

In the seaborne market, which doesn't adapt as quickly to new market trends as the Chinese domestic market, lithium carbonate price still moved up in April. It started the quarter at $11,000/mt before plateauing at the $13,000/mt level, with some volatility along the way.

Hydroxide, on the other hand, benefited from the increasingly tight supply and kept rising over the period, jumping to $16,200/mt from $12,000/mt.

Cobalt

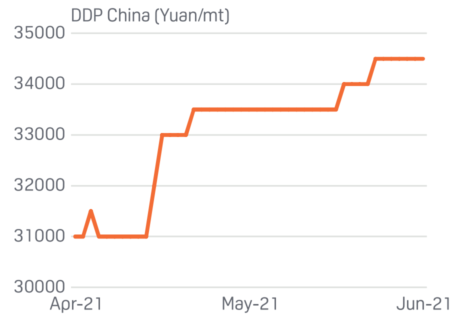
Cobalt prices started Q2 under pressure. The market was under a significant price correction since March, as some participants said prices had too much during the January-February period.

Cobalt hydroxide continued to fall from $21.8/lb CIF China in early April to hit the floor at $17.6/lb on June 10. Despite rising electric vehicles sales, demand was lower than some market participants anticipated, and spot trade was minimal for several weeks. Some sources said buyers previously stocked up or pre-purchased, leading the market to adjust to a new balance.

With increasing concerns about logistics due to the enforcement of stricter lockdown measures in South Africa, prices rebounded quickly in the last few weeks of the quarter and were expected to remain supported in the short term, sources said. Cobalt hydroxide CIF China finished Q2 at $19.6/lb.

The cobalt sulfate market followed the same dynamics as the hydroxide market, with high feedstock availability weighing on prices during most of the quarter. The potential limitation on cobalt hydroxide supply due to logistics concerns in South Africa also drove up prices towards the end of the quarter. Cobalt sulfate DDP China finished the quarter at Yuan 77,000/mt — up 4% from Yuan 74,000/mt in early April.

NICKEL SULFATE PRICING



Source: S&P Global Platts

Nickel

Similar to cobalt chemicals, battery grade nickel sulfate was also falling towards the end of Q1, entering April under a bearish note. There were still several concerns about a potential flood of nickel intermediates in the future due to Tsingshan's announcement in early March that it would convert nickel pig iron, or NPI, into nickel matte.

The higher availability of intermediates such as matte could radically increase the supply of feedstock for conversion into nickel sulfate, shifting some long-term forecasts from a significant deficit into a comfortable surplus.

Although the real extension of NPI conversion into matte is still to be seen, current market fundamentals are more bullish than bearish, and have started to prevail in Q2 after the initial shock with Tsingshan's announcement. Raw material prices were still on the rise in that period, as well as LME nickel prices.

With the LME getting close to $18,000/mt in early May -- versus $16,000/mt a month before -- as well as strong demand for nickel briquettes to be used as a feedstock, nickel sulfate followed the uptrend and reached Yuan 34,500/mt on June 22, maintaining the value -- which was Yuan 3,500/mt above what it was at the beginning of the quarter-- until the end of the month.

The plunge in the LME after the Chinese government's announcement that it would start selling part of its metals inventories was not enough to impact nickel sulfate prices in the short term due to tight supply of raw materials. It's not clear, however, if a deepening in China's destocking could eventually reach a level where chemical prices would also be impacted.

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Chemistries diversification to prevail in the battery industry

Cathode chemistries will play a key role in segmenting the electric vehicles industry, and the battery industry will require a wide variety of compositions, according to market participants.

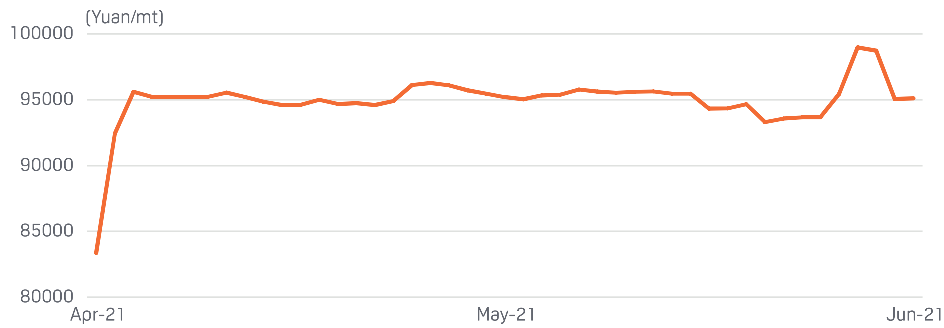
Nickel-rich chemistries -- which were once expected to dominate the market -- will be essential because of their inherent higher energy density, which translates to longer driving ranges at a single charge. However, its higher cost, as well as improvements in other chemistries, will drive diversification, sources said.

"Most OEMs have two technology tracks: design to energy and design to cost," said Tom Van Bellinghen, materials technology company Umicore's marketing and sales director. In the first one, which comprises high-end vehicles and was the priority for several European and Asian automakers, performance's relevance will keep driving the use of nickel-rich compositions.

But by volume, the "cost" segment will probably be bigger, he said.

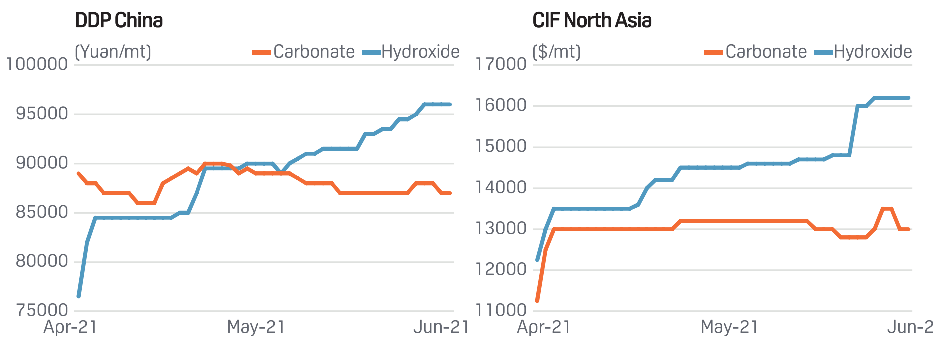
"We have to address the mass markets. Not everyone can pay $100,000 for a car," he said. That will increase the room for other cathode active materials such as LFP, non-nickel-rich versions of NCM, as well as manganese-rich.

LITHIUM CARBONATE 99.5% CIF NORTH ASIA IMPORT PARITY



Source: S&P Global Platts

LITHIUM CARBONATE AND HYDROXIDE PRICING

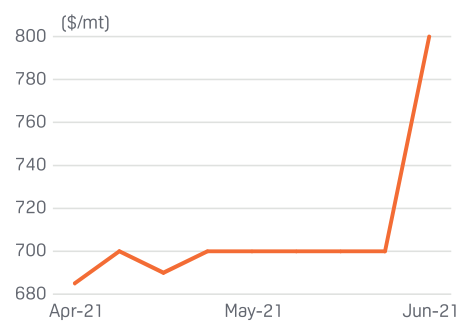


Source: S&P Global Platts

COBALT HYDROXIDE PRICING

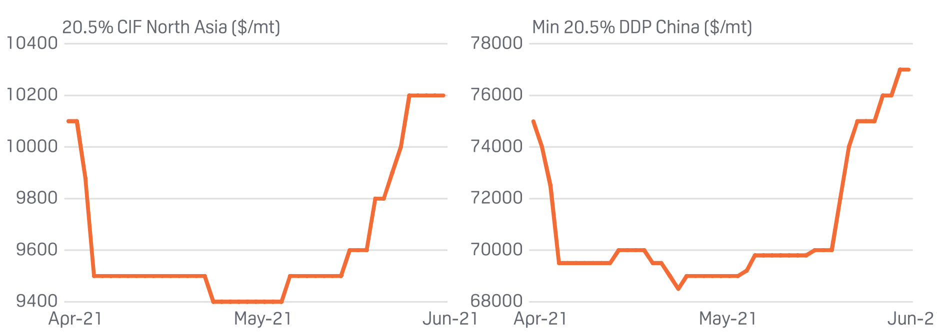
Source: S&P Global Platts

SPODUMENE CONCENTRATE 6% PRICING



Source: S&P Global Platts

COBALT SULFATE PRICING



Source: S&P Global Platts

Plenty of options

In March, Volkswagen announced it would employ manganese-rich chemistries in what it categorized as "model volumes." LFP was chosen for "entry models" and nickel-rich for "special solutions." The company's planned unified cell, with different chemistries, will cover 80% of the models.

"We will see a coexistence of several battery technologies in the long run along the lines of cost-optimized, main and best in class," a spokesperson for Volkswagen Group Components told Platts. "We still believe that the mentioned chemistries will cover most automobile battery use cases over the next years."

A spokesman from Johnson Matthey's battery materials business told Platts, "LFP will likely creep into the passenger vehicle market outside of China, too, but this is something that hasn't materialized at any substantial level just yet."

However, "we do expect nickel-based cathodes, especially those with a high nickel content, to be a critical enabler for electrification for at least the next decade" because "range anxiety is likely to remain a barrier for a while as many consumers will be first-time users of EVs," he added.

Although "the current trend is towards materials with more than 80, even more than 90% nickel for the performance segment … cobalt-free, high manganese cathode active materials represent a promising class in our portfolio," chemicals group BASF told Platts in a statement.

"By 2025, with our innovations in electric car battery materials, we aim to double the driving range of midsize cars from 300 to 600 km on a single charge," the company added, or 186 miles to 373 miles.

The company's 7 parts manganese to 3 parts nickel material "has shown significant improvement on cycle life, energy density and thermal stability, which will play a crucial role in the future for the further development in the low cost segment," BASF said.

In addition to manganese-rich and LFP, high-voltage spinels such as LNMO, LMO and LTO will also be able to capture some of the mass market in the future, as well as solid state batteries (see separate story), battery technology company Nano One's CEO, Dan Blondal, said.

"High-nickel NCMs are full of challenges, but we are now getting closer and closer," he said. "They will continue to play a dominant role, especially in high-end EVs, in North America and Europe to some extent; but in the entry level, LFP will have to play an important role, and towards the end of the decade, solid state and high voltage, too."

Away from the EV market, however, "manganese-rich chemistries can't be applied in power and storage batteries," so "LFP will coexist with NCM/NCA/NCMA in the long term," a Chinese battery producer source said.

Environmental impact

In addition to cost, the environmental impact of nickel-rich chemistries is another aspect the industry should consider, sources said.

Battery-grade nickel sulfate requires very high purity usually found only in sulfide deposits, which account for the smallest portion of the world's nickel assets. Moreover, a significant portion of the known sulfide projects are already operational.

The alternative is to process lower-grade laterite material into intermediates that will need further upgrading before reaching battery quality. However, the options that have gained more attention recently -- such as high pressure acid leach (HPAL) plants or the conversion of nickel pig iron into an intermediate called matte -- are very heavy on emissions.

"If you use your 700+ km [at a single charge] driving range only two weeks per year, from a CO2 perspective, maybe it's not the best solution," Umicore's Van Bellinghen said.

The higher the nickel content, the higher will be CO2 emissions, he added, although there might be other factors in the equation: "The capacity will also be higher [with higher nickel], which could partially offset emissions relatively to the capacity."

Nickel's environmental impact could be softened through Nano One's technology, which employs metals directly, skipping the sulfening stage, Blondal said. Without the need to convert nickel metal into sulfate, energy use and emissions are much lower, according to the company. Moreover, "this addresses the large loss waste stream, sulfate waste stream -- which is four times the size of the product stream," he added.

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Battery technology to keep evolving, but cathode chemistry will remain essential

Cathode chemistries will remain a priority for battery technology developers in the coming years, but improvements in several different areas will also be key to address issues on energy density and safety, sources said.

Solid state batteries and lithium metal anode are seen by many as the next target, despite the long path needed to be covered until these technologies could start to be used by the electric vehicle industry on commercial scale.

Batteries are the biggest cost in an electric vehicle (EV), and improving the cathode level alone isn't enough to bring batteries' costs down "to the point where EVs become more competitive than ICE vehicles," a spokesperson from Johnson Matthey's battery materials business told S&P Global Platts.

"Using cell to pack [design], solid-state [electrolytes] or silicon-based anodes combined with any cathode chemistry would provide a further increase in performance," he said, stressing that "using a high energy density cathode material simply means your starting point on which to improve is higher."

Solid state electrolyte

Current batteries employ a liquid, flammable electrolyte in between the cathode and the anode sides of the battery. Batteries at an all solid state are expected to address not only the safety aspect, but also increase lifespan and reduce the battery size.

However, there are still many challenges regarding solid state batteries' cycle life, as well as the natural formation of dendrites that ultimately lead to short-circuits.

"We partner and research on next generation systems although the chemistry for solid state batteries has its known challenges and it will take a while," chemical company BASF told Platts in an emailed statement.

Despite increasing the energy density -- and therefore, the driving range of electric vehicles --, solid state batteries should not lead to significant changes for the cathode chemistry choices, a spokesperson for Volkswagen Group Components told Platts. "Small adaptions may be necessary but lithium-metal-oxide compounds will be the cathode material for a long time," he said.

The cathode chemistry "can be LFP, NCM… but spinel [such as LNMO and LMO] is what makes more sense [for the future solid state batteries] due to its higher stability," said Dan Blondal, CEO of battery technology company Nano One.

"There is a lot of work to be done before large scale adoption, you will see solid state in niche applications first," he said, adding that he expects solid state batteries to be closer to mass adoption by the end of the decade.

There has been an increasing discussion in China about "semi solid state" electrolytes, with different levels of enthusiasm amongst market participants.

"If the semi-solid state can solve the safety problems in the next ten years, original equipment manufacturers will prefer to use it," said Mo Ke, founder of China's RealLi Research. Liao Zhenbo, vice general manager of BAIC Group, said during the China Auto Bluebook Forum on June 12 he was in favor of using semi-solid state as a step to ultimately reach mass production of solid state batteries.

Chinese battery maker Farasis said its semi-solid state battery was just entering mass production stage, with the company targeting to reach solid state by 2030. Another battery maker believes that liquid electrolytes will prevail until the end of the decade.

Anode

On the anode side, the most typical material being employed by the industry is graphite since it meets the voltage requirements at a relatively low cost. However, the expected future deployment of solid state batteries would open room for the use of lithium metal anodes, which would dramatically improve energy density compared to the existing batteries due to graphite's lower capacity.

Before lithium metal becomes a reality, the increase of silicon content in the mix with graphite should be the next step, sources said. Silicon's higher specific capacity compared with graphite would also provide relevant energy density increases. The biggest hurdle, however, is physical swelling, which will require improved particle engineering for solving.

"This technology [silicon based anode] is becoming more and more mature, being implemented on electronics-- also some smaller percentages of silicon in automotive already as well," said Tom Van Bellinghen, materials technology company Umicore's marketing & sales director.

He believes the barriers that prevent a larger adoption of silicon in the anode could be overcome by 2025, or even sooner. "It will not be a big massive step at once, it will be a gradual increase, but it already started," he said.

In addition to the anode and the electrolyte discussions, Van Bellinghen also stressed the possibility of operating the battery cells at higher voltages. The advantage is that "you don't need to put more cathode material [in the battery to improve energy density], you extract more energy from the same weight of cathode active material," he said.

Some portable electronics already have batteries operating at as high as 4.45 volt, considerably higher than the usual 4.2 volt from other applications, reaching up to 1,000 cycles, he added.

Ongoing transformation

Several other improvements have already been deployed recently, both outside and inside the cathode level. One of the most interesting was the cell-to-pack design, said Nano One's Blondal.

In summary, the new cell-to-pack design allowed a biggest portion of the battery pack to be filled with cells, improving energy density of LFP-based batteries produced in China by battery majors such as CATL and BYD. The breakthrough increased the driving range of cars using LFP batteries to over 400km in one single charge—BYD stated that its Han model could reach up to 605km at a single charge.

Such a novelty "forces automakers to move away from design off the shelf," said Blondal. "They [automakers] don't want to be chemical producers, their interest is securing intellectual property and knowhow-- they will want to own it, it defines their battery," he added, stressing that ultimately this is where all automakers will need to shift to.

Nano One itself is also on the forefront of innovation on single-crystal cathode materials. Usually the cathode material is composed of several crystals—which are eventually protected by coatings added separately. Even in the case of other single crystal technologies, additional heating is required before coating, which adds costs.

The company developed a process in which lithium is mixed with metal feedstock --such as cobalt, nickel and manganese, depending on the chemistry--, as well as protective coatings --which could be made of niobium--, all at the same stage. The result is increased durability of the precursor.

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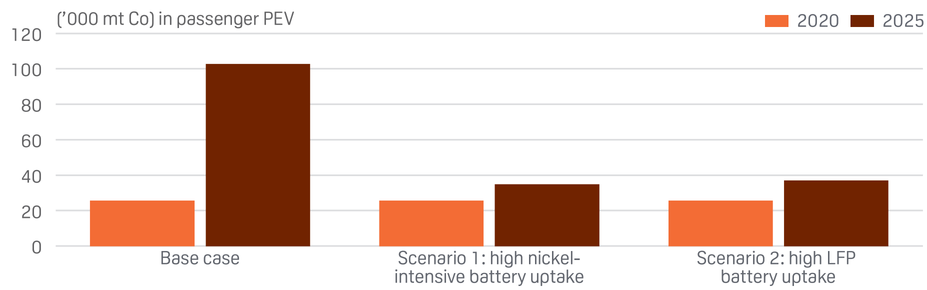
POTENTIAL SCENARIOS: THE VIEW FROM S&P GLOBAL MARKET INTELLIGENCE

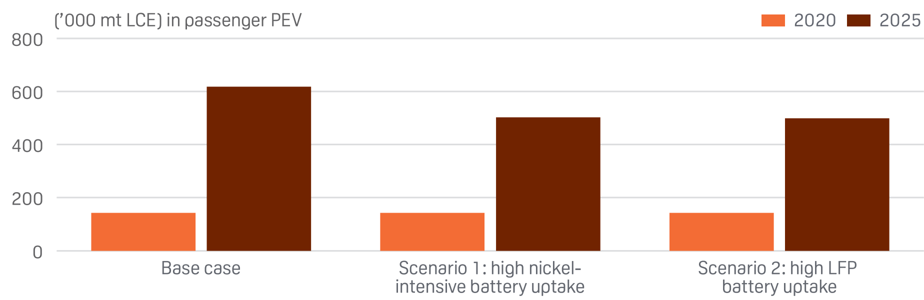
Battery technology innovations could bring wider adoption of high-nickel and lithium-iron-phosphate chemistries

COBALT DEMAND UP TO TWO THIRDS LOWER COMPARED WITH THE BASE CASE IN 2025



Date as of July 9, 2021. PEV = plug-in electric vehicle; LFP = lithium iron phosphate
Source: S&P Global Market Intelligence

LITHIUM DEMAND 19% LOWER UNDER BOTH SCENARIOS COMPARED WITH THE BASE CASE IN 2025



Date as of July 9, 2021. LCE = lithium carbonate equivalent; PEV = plug-in electric vehicle; LFP = lithium iron phosphate
Source: S&P Global Market Intelligence

Cathode chemistry preferences in the electric vehicle industry can have significant impact on the demand for lithium, cobalt and nickel, according to S&P Global Market Intelligence (MI).

MI ran a two-scenario analysis comparing lithium, nickel and cobalt demand against its base-case views for 2025 from the June SPGMI Commodity Briefing Services for these metals, and concluded that innovation in battery technology and the resulting fluidity in battery chemistry choice will have significant long-term implications for demand.

MI's base case assumes the LFP cathode deployment share in global BEVs to increase from 12% in 2020 to 24% by 2025. MI assumes the corresponding NMC share of deployment to rise from 66% in 2020 and 68% in 2025.

Scenario 1 assumes the proliferation of high-nickel battery chemistries. Batteries using nickel-manganese-cobalt, or NMC, cathodes currently dominate global passenger battery electric vehicle deployment. Research and development in NMC battery composition is focused on increasing the nickel content at the expense of thrifting out cobalt, due to the higher cost of cobalt and raw material supply concentration risks, as well as reaping the benefit of higher nickel content in increasing battery energy density.

Commercial production of NMC811 started in 2018, led by battery makers in South Korea and China. Prior to the commercialization of NMC811s, the most common NMC cathodes were NMC532 and NMC622, which contains up to 61% less cobalt and 31% more nickel. Despite superior characteristics of the NMC811 chemistry, safety concerns have discouraged broader adoption by the industry, with numerous reports of vehicles with NMC811 batteries catching fire.

In 2020, LG Chem started the rollout of NMC721 batteries, to achieve a better balance between cost, energy density and safety. At the same time, battery makers are also developing the next-generation lithium-ion chemistry mix, with up to 90% nickel content — including SK Innovation's NMC 9-1/2-1/2 battery and LG Chem's nickel-cobalt-manganese-aluminum, or NCMA, battery — for BEVs with a higher range requirement.

In scenario 2, we assume a high uptake of lithium-iron-phosphate, or LFP, battery technology. LFP batteries are a cost-effective choice for entry-level BEVs due to lower cathode active material costs, even if there is a trade-off for the consumer of lower drive range. LFP deployment in Chinese passenger BEVs increased to 29% in 2020 from 10% in 2019, as automakers turned to LFP batteries to reduce cost amid a low subsidy environment.

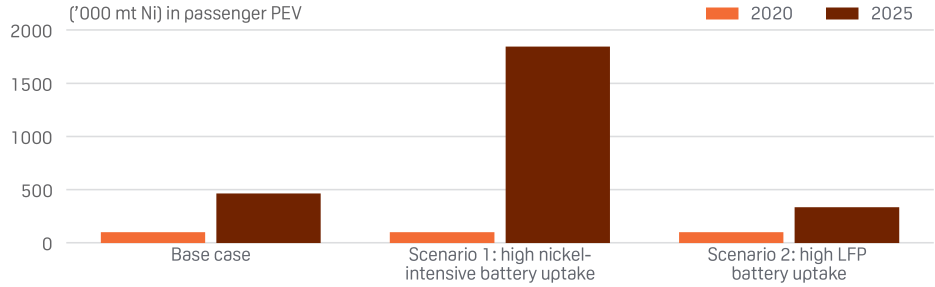
So far, the LFP chemistry has had fairly limited application outside China. But global automakers are starting to disseminate their experience with the chemistry in ex-China markets, led by Tesla and Volkswagen, which are planning to deploy LFP across all their entry-level BEVs globally. Tesla recently extended its current LFP battery supply deal with Chinese battery maker Contemporary Amperex Technology Ltd., or CATL, to the end of 2025, from June 2022. The move came after Tesla CEO Elon Musk said in late February that the company planned to shift its standard-range cars globally to LFP batteries amid concerns over a potential shortage of battery-grade nickel.

CATL and BYD Company Ltd., another Chinese battery maker, are leading the charge in improving the energy density of LFP batteries through design innovations [see previous story], increasing the possible range of BEVs to 400-600km, and could potentially fully displace NMC532 and NMC622 batteries deployed in popular BEVs models today.

Scenario results: Cobalt demand is the most affected, and lithium the least

Lithium demand is the least affected under both scenarios. In 2025, lithium demand in passenger plug-in electric vehicles, or PEVs, which includes battery demand in BEVs and plug-in hybrid electric vehicles, is 19% lower under both two scenarios when compared with the base case. Despite this, lithium demand in passenger PEVs is still projected to rise 3.5-fold by 2025 compared with 2020 under the two scenarios. Lithium prices are likely to be supported by the need to incentivize sizable supply additions.

NICKEL DEMAND FOUR TIMES HIGHER UNDER SCENARIO 1 COMPARED WITH THE BASE CASE IN 2025



Date as of July 9, 2021. PEV = plug-in electric vehicle; LFP = lithium iron phosphate
Source: S&P Global Market Intelligence

Cobalt is the most affected battery metal across the two scenarios. In 2025, cobalt demand in passenger PEVs is 66% and 64% lower under scenarios 1 and 2, respectively, compared with the base case. The likelihood of scenario 2 nonetheless requires broad acceptance and adoption of CATL's and BYD's technologies; BYD's batteries are predominantly supplied to its integrated car production at present. Novel LFP technology patent rights also increase stand-alone automakers' sourcing risks.

Nickel faces very different demand outcomes under the two scenarios. In 2025, nickel demand in passenger PEVs could be four times higher than assumed by our base case under scenario 1, the nickel-intensive case; but 28% lower under scenario 2, the high LFP case.

Nickel's place in battery sector dependent on availability of ESG-friendly material

The use of nickel in lithium-ion batteries will nevertheless depend on the availability of feedstock that can be used to produce battery-grade nickel sulfate, a key component of lithium-ion batteries. One example of such feedstock is LME-grade class 1 primary nickel, which contains at least 99.8% nickel content. LME-grade class 1 nickel, which can be derived from nickel sulfide ore deposits, was considered the most suitable feedstock for nickel sulfate production because of its high nickel content. The lack of significant nickel sulfide ore discoveries over the past decade, however, suggests that there will be insufficient growth in class 1 primary nickel output to meet the battery sector's long-term needs.

Potentially game-changing plans by China's Tsingshan Holding Group to process nickel pig iron, or NPI, into high-grade nickel matte that can be converted into nickel sulfate for use in PEV batteries could meet rising demand for battery-grade nickel. Concerns over the potential environmental, social and governance implications of Tsingshan's NPI/nickel matte production strategy, such as the significantly higher global-warming potential of NPI production compared with LME-grade class 1 nickel production, could, however, deter battery producers outside China from using nickel sulfate derived from Tsingshan's nickel matte output. If not addressed, such dynamics could enable technologies such as LFP to gain market share versus nickel-containing batteries in the long term.

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