Is traceability the solution to sustainable batteries?

Traceability and digital passports are key to ensuring EVs are as sustainable as they claim, writes Elle Farrell-Kingsley

Batteries do much more than just power electric vehicles (EVs)–they also help determine their performance, service life, charging speed and costs. Inside the batteries, there are materials to consider. There's the anode and a cathode. Inside the cathode is typically a copper-coated film made of nickel, copper, manganese and lithium.

Nickel, primarily used to produce stainless steel, is already one of the world's most prominent metal markets, reaching a value of US$31.5bn in 2021. Looking forward, it's expected that the market will reach US$43.8bn by 2027, exhibiting a compound annual growth rate (CAGR) of 5.57% during 2022-2027, according to market researcher consultants IMARC.

Turning nickel into battery-grade material is significantly energy-intensive. There are two types of nickel: sulphites and laterites. Laterites found in nickel pig-iron require environmentally damaging chemical processes to extract the material. An enormous amount of energy and electricity is invested in refining it into something usable. According to UBS financial services, the nickel manganese cobalt (NMC) cathode formulation used by the Chevy Bolt is expected to lean heavily on nickel in the coming years. It is predicted that nickel will make up 80% of the mass in lithium nickel cobalt aluminium oxide (NCA) and NMC cathodes used by companies such as Tesla and Chevy.

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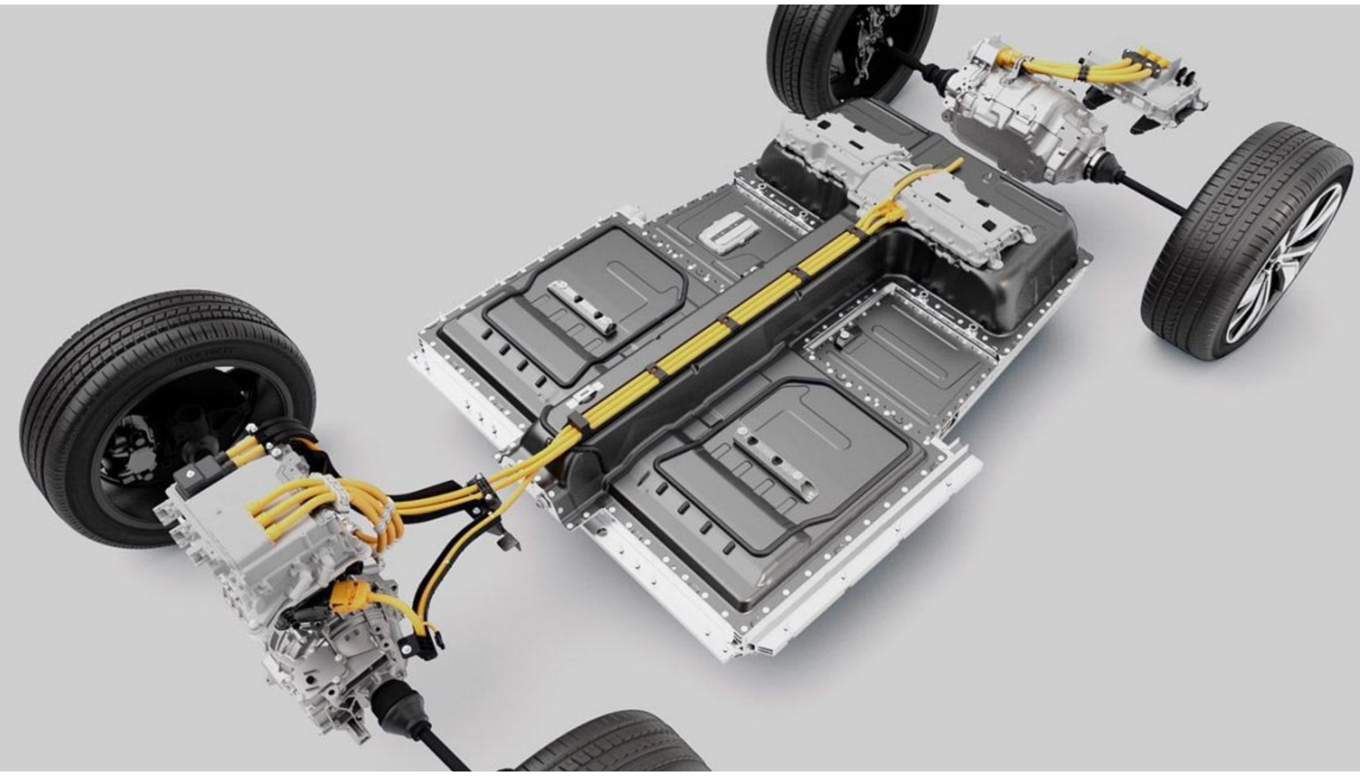
In the last few years, EV material shortages have been a significant topic–impacting just about everybody. Tesla, Volkswagen, Toyota and General Motors have all been forced to scale back production in 2022.



Inside Volvo's XC40 Recharge battery, where all of its cobalt is traced

Are EVs really more sustainable?

One reason many automotive players are interested in supply chains for batteries is an expected growth in demand that will outpace availability. Increased necessity is driven by the global boom in EV sales, with 23 million EV passenger vehicles expected to be produced by 2030, says the United Nations Conference on Trade and Development (UNCTAD). The worldwide market of lithium-ion batteries, the most common rechargeable car battery, was estimated at US$7bn in 2018 and is expected to reach US$58.8bn by 2024, according to the report.

Furthermore, battery materials have major responsible sourcing and sustainability concerns. Reserves of the raw materials for car batteries are highly concentrated in a few countries. Two-thirds of world cobalt reserves are in the Democratic Republic of the Congo (DRC); 20% of cobalt excavated from the DRC comes from artisanal mines where child labour and human rights abuses have been reported, according to United Nations International Children's Emergency Fund (UNICEF). Similarly, the same report revealed that up to 40,000 children work in hazardous conditions. Meanwhile, research from UNCTAD reveals that 58% of lithium reserves are in Chile, 80% of natural graphite reserves are in China, Brazil and Turkey, while 75% of manganese reserves are in Australia, Brazil, South Africa and Ukraine.

Battery passports

On 10 December 2020, the European Commission published a proposal for a new Battery Regulation, which is expected to take effect as of 1 January 2022 and will replace the current Battery Directive 2006/66/EC and amend Regulation 2019/1020. It aims to ensure that batteries on the EU market are sustainable and safe throughout their lifecycle.

Further announcements on 25 April 2022 revealed that a consortium of carmakers and battery producers, including BMW, Umicore, and BASF, have come together to develop an official battery passport for Europe, receiving US$8.78m from the German government. The battery passport is a digital representation that shares data about all applicable environmental, sustainability and governance (ESG) and lifecycle requirements following the definition of a sustainable battery. Circulor, a supply chain traceability solutions start-up, is also part of the German battery passport.

"We're interested in battery passports and responsible sourcing… so that the engine transition achieves its objective rather than us swapping one problem for another–tailpipe emissions for manufacturing emissions," says Circulor's Chief Executive, Douglas Johnson-Poensgen. According to Reuters, the project has raised US$45m during the previous two years, led by Tesla investor Westly Group along with such players as Volvo Cars, Jaguar Land Rover and the world's largest listed miner, BHP Group. BHP has used Circulor's blockchain platform to track the carbon emissions of nickel from the point when it was mined to Tesla's Shanghai Gigafactory via battery passports.

Finite raw materials

"Lithium, manganese and nickel are the three that everyone's running after because some sources of supply are more sustainable than others," Johnson-Poensgen tells Automotive World.

According to the Journal of Cleaner Production, the region bordering Chile, Bolivia, and Argentina, named the South American Lithium Triangle, is estimated to hold 57% of the world's lithium resources. "Lithium raises concerns around water use and pollution in places like the Atacama," Johnson-Poensgen explains. Sustainability concerns from Lithium mining are mostly around threats to local hydrodynamics, pressuring the already limited water, which aggravates social tensions between mining companies and local communities, research from the Journal of Cleaner Production highlights. Johnson-Poensgen further elaborates, "That's why there are smaller producers–Vulcan Energy, Rock Tech Lithium and others–coming onto the market with a proposition to produce sustainable lithium in places like Germany."

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> How cheated will consumers and citizens feel when we've been told to ditch our old cars and buy EVs, and yet it's made zero difference to the climate goals?

Similarly, 10 to 15% of the world's nickel comes from Russia, from companies like Norilsk Nickel. Norilsk Nickel is known to be one of Russia's largest industrial polluters, releasing approximately 1.9 million tonnes of sulphur dioxide into the air annually as of 2020, accounting for 1.9% of global emissions, according to Norilsk Nickel's 2020 sustainability report.

If that electricity is coal-fired, manufacturers release vast quantities of carbon emissions to manufacture something that's supposed to improve the environment. "Except therein lies the challenge: graphite and nickel are the two most polluting, from a CO2 intensity perspective, of the battery materials," says Johnson-Poensgen.

He predicts the world is at least ten years away from the point at which recycled material will meaningfully take up the strain in the gap between primary sources of material now and the growth in demand. “Not all raw material is the same,” he adds. “That means there are more sustainable and less sustainable sources of nickel.” He points to Elon Musk seeking contracts with companies that can produce sustainable nickel.

Significant demand and scarcity drive up prices. Yet EVs are already “too expensive for mass adoption,” Johnson-Poensgen points out. “Similarly, not all the raw material sources are sufficiently sustainable or potentially in places where we want to do business.”

Traceability

Traceability entails understanding the chain of custody of raw materials as they go through the complex industrial supply chain to end consumers. The challenge, Johnson-Poensgen notes, is that the material begins as rock and undergoes many stages of physical and chemical transformation and then amalgamation of elements before becoming a battery in a car.

Therefore, “a reliable chain of custody is inherently complicated to achieve, but new technologies often help unlock old problems.” Johnson-Poensgen points to technological advances, such as machine learning and blockchain, which have helped develop new approaches to these issues by identifying patterns and trends. Circulor’s blockchain technology is today used throughout Volvo Cars’ battery supply chain.

Circulor has created a digital twin for a physical commodity at a source. Using cobalt as an example, he notes that this could be as simple as putting a QR code on the material, which means that it now has a digital identity and physical presence. “The input ingredients created the output product multiple times, so when you get to the other end of the supply chain, you can confidently claim that there is no cobalt in their supply chain that’s come from mine sites that, for example, have child labour.” However, he warns that the digital thread can become complicated due to the transportation of materials.

Racing to zero emissions: regulations vs reality

As the 2030 Euro-centric EV goal moves closer, practicalities such as parking, charging, and renewable energy in the grid are frequent topics of interest. One often under-discussed topic, he notes, is that the production of EV batteries—which currently account for 50% of the total supply chain’s contribution to the emissions of manufacturing an EV, “will see global emissions spike, not fall.”

“How cheated will consumers and citizens feel when we’ve been told to ditch our old cars and buy EVs, and yet it’s made zero difference to the climate goals because everyone’s just rushed ahead to try to mass-produce?” Therefore Johnson-Poensgen considers battery regulations a viable option as it creates a dual-drive of responsibility and sustainability. He believes the solution lies in the automotive industry unifying through “one voice”, such as the Global Battery Alliance or Drive Sustainability, stressing the importance of German Supply Chain law and the EU Batteries Regulations—and threatening not to continue working with suppliers not meeting these regulations. “Take the German Supply Chain law principles and apply them to batteries. The European proposal around the Corporate Sustainability Due Diligence Directive would take those themes and make it national law in each of the European countries.”

Developments around "the heart of the battery" advancing rapidly

Cell technology is prolonging and transforming the battery as we know it. By Elle Farrell-Kingsley

In August 2021, Sprint Power announced it was leading Project CELERITAS, a new US$11.67m UK government-backed project aimed at developing ultra-fast charging cells and battery packs for battery electric vehicles (BEVs) and fuel cell hybrid electric vehicles (FCHEVs). Sprint Power delivers advanced electrification solutions and systems engineering to customers in multiple industries–from off-highway to on-highway, aircraft, and automotive.

One of its core specialisms is the development and supply of battery technologies and systems. Although it doesn't do internal cell engineering directly, it collaborates extensively with cell companies. "We work with these suppliers to understand what is going well in their innovations, and then we integrate those cells into battery packs and the vehicle's systems," says Sprint Power's Chief Engineer of High Voltage Drive Systems, Brian Cooper. Cooper leads the high voltage team to deliver high propulsion systems, batteries, power electronics and drive solutions–specifically focusing on automotive solutions in electric vehicles (EVs).

Sprint Power designs the battery by focusing on the systems, engineering, and cell pack design. Its area of development covers power electronics and its associated challenges, including welding, bonding, thermal management, and electrical connections. "There's a whole-system engineering approach to designing the battery, and we have to work closely with the material suppliers to use the best materials for the right applications to hit client targets," says Cooper.

Pack processes

The energy density of the vehicle's battery is greatly impacted by the materials used. "The battery system is an area where performance can vary based on material selection," highlights Cooper.

He points to different strategies when designing the battery's subsystems: "Because every battery is required to have a different purpose, there isn't one right answer in design."

The first strategy is cooling, where Sprint Power takes the temperatures of the cells and monitors their thermal properties. Then comes the manufacturing and recycling process, followed by electrical resistance. These processes are all crucial aspects of battery design and engineering, says Cooper, as battery materials are involved in all of these areas.

"First, we evaluate systems engineering and understand what the vehicle must do. Then, we break that down into understanding the subsystems and how we design that battery and optimise the application of the material to get the best outcome," he explains. A prototype can typically be delivered within six months from the initial conversation with the client, with a three-year programme from initial discussion through to production.

Challenges

"The heart of the battery are the cells, the technologies of which are a rapidly advancing area," says Cooper. The energy density, primarily the weight and volume of the cells, are key challenges, as there are often size constraints when it comes to placing the battery in the vehicle.

Another challenge includes the power requirements of charging and discharging. "We want to charge faster. In our new collaboration with lithium battery producer AMTE Power, we aim to charge the battery to 80% in less than 12 minutes with these new cells." This project boasts an 800V battery platform. Sprint Power's collaboration with AMTE Power aims to accelerate the development of next-generation battery technologies. The CELERITAS project also incorporates the application of a new dielectric fluid from Castrol. The combination of optimised power cell, high-performance cooling and novel structural design promises faster charging in a compact, lightweight battery pack.

Power Module Unit cutaway

Cost is another hindrance, he adds. "We have to make the manufacturing processes cheaper, faster, and more efficient. All of these things are critical to the success of EVs."

Although there is currently a challenge in developing the necessary gigafactories around the world to meet demand, Cooper's 26 years of automotive experience has shown him that engineers adapt to overcome challenges and find solutions when there's a market and business case.

As for battery materials, the engineer acknowledged the concern regarding nickel and cobalt—especially regarding sustainability. However, he notes: "The trend of many new battery designs is to go cobalt-free. So, if you're struggling to find something, the industry adapts to overcome it."

Transformation of the battery

Solid-state batteries could solve one of the industry's most significant concerns—thermal runaway. For EV batteries, "while unlikely, it is possible for the batteries to release too much energy," Cooper explains. For example, there could be a short between the separator if it were damaged or melted. Although it's rare, battery fires in EVs have occurred. Due to the risk of overheating and the potential for fires, several renowned vehicle manufacturers have recalled their vehicles in the last few years, specifically GM, Ford, and Hyundai. These fires have also caused issues for EV two-wheelers, with a reported recall of 7,000 vehicles across India.

If a cell has vents, it releases hot gases which are injected into vent spaces requiring advanced materials to defend the neighbouring cells against these aggressive materials (which can heat the adjacent cell–causing thermal runaway). This can lead to a cascade failure of the battery, which Cooper and his team actively engineer their designs to avoid.

Cooper highlights, “Advanced materials in thermal protection is another very exciting development area. These advanced materials tend to be silicone-based thermal defence materials alongside intumescent materials that swell when subjected to heat to create defensive barriers. But if solid-state batteries come, these issues become irrelevant, and removing the root cause is the best way to solve a problem.” The solid-state battery removes liquid electrolytes, helping to avoid thermal runaway and cell failure.

Additionally, solid-state batteries could increase the energy density of cells, which could be a game-changer in battery design and the structure of the cells. “The whole area of battery cell technology is evolving. The technology works,” he adds, noting that cost and scalability are factored into the equation.

One other innovation within battery materials includes the size of the packaging. Instead of having batteries inside modules and modules inside another box, Sprint Power is looking to integrate cell-to-pack. “Anything we can do that reduces weight and costs, and improves the volumetric characteristics of the battery must be done. So, cell-to-pack is a trend led by companies such as BYD and CATL, but also cell-to-chassis or cell-to-body, where the battery becomes much more of a structural element that takes a load for the vehicle. The battery cell itself adds structure to the vehicle.”

One limitation of this, Cooper observes, is the cost of serviceability. As everything is bonded together, it becomes more challenging to service and dismantle. Sprint Power’s CELERITAS project is developing bonding and injection moulding techniques, where cells are joined in innovative ways to improve efficiency.

> “We have to make the manufacturing processes cheaper, faster, and more efficient

A lifetime?

The US federal government has mandated that EV manufacturers issue the battery warranty at a minimum of eight years/80,000 miles. In California, that mandate is ten years/150,000 miles, according to California Emissions Warranty. However, Sprint Power’s customers are asking for increased life and reduced degradation, and the CELERITAS technology will facilitate this. By applying high performance, dielectric fluid cooling, the cell temperatures are controlled and remain highly uniform throughout the battery pack. Research has shown that this prolongs life, maximises energy utilisation and enables cost reduction.

These innovative engineering insights provide an interesting glance into the future of battery materials and the importance of the battery packs developed by Sprint Power and other competitors. “You can see that many companies are tackling problems differently, and that’s because we’re evolving. We’re all experimenting. It’s natural selection,” says Cooper. “Perhaps in time, we’ll converge more towards a best practice, but we still have a way to go.”