SUPERCHARGING CHINA: CARS, BATTERIES, AND LITHIUM

Barry van Wyk

With no internal combustion engine and no burning of fossil fuels, electric vehicles (EVs) — running solely on batteries — are coming in their billions to electrify mobility. By 2035, at least half of all global passenger vehicle sales will be of EVs, and the proportion will keep increasing.[1] The roadmap for the global energy sector to reach carbon neutrality developed by the International Energy Agency (IEA) requires the number of EVs to increase from eleven million in 2020 to 350 million in 2030 and almost two billion by 2050.[2] In the global race to build batteries and battery-powered cars and to access the vital lithium, cobalt, and nickel that go into them, the People's Republic of China (PRC) is winning hands-down.

A Potent Mix

The most expensive component of an EV is its battery. Up to 99 percent of all batteries currently installed in EVs and hybrids (which have an internal combustion engine as well as a battery) are lithium-ion. Lithium-ion batteries contain base metals such as aluminium, copper, and iron as well as expensive precious metals — notably, lithium, cobalt, nickel, and manganese.

To produce electricity, lithium-ion batteries move lithium ions from the anode to the cathode electrodes via the electrolyte layer, which contains a microporous separator. Graphite — the only natural form of carbon apart from diamonds — is used to conduct heat and electricity in the anode and is the only material that can be used for this purpose.[3] Lithium is the battery's active material and key component, but most of the precious metals are contained in the cathode, which is therefore the most expensive part of the battery. The cathodes contain an ever-increasing share of nickel,[4] which facilitates energy density and longer battery life; cobalt, which prevents the cathodes from easily overheating or igniting; and manganese, which decreases the risk of combustibility.

Given the complexity of the battery and the various components, it is difficult to establish exactly how much of these precious metals go into each battery. One estimate[5] puts the proportion of precious metals at about

eight kilograms of lithium,[6] thirty-five kilograms of nickel, twenty kilograms of manganese, fourteen kilograms of cobalt, and as much as seventy to 100 kilograms of graphite.[7] Other estimates differ.[8]

Extracting these metals poses a variety of environmental and human rights challenges. For one thing, the mining required is highly energy-intensive. Large lithium mines feature big lithium 'ponds' of varying hues (depending on the concentration of lithium carbonate), which have been described as 'surreal landscapes where batteries are born',[9] and have begun to appear in the 'lithium triangle' of Chile, Bolivia, and Argentina.[10] High-pressure acid-leach nickel plants in Indonesia — the leading producer of this metal — have a high carbon footprint, among other environmental concerns.[11] These mining operations cause soil degradation and environmental damage and use vast amounts of water — for example, in the 'lithium triangle', every tonne of lithium requires the use of about 2.2 million litres of water[12] as the mineral is found dissolved in salt flats and must be separated via evaporation.[13] In fact, harmful environmental effects are nearly ubiquitous in the lithium supply chain.

Two-thirds of the global supply of cobalt are mined in the Democratic Republic of the Congo (DRC), where concerns have been raised about human rights abuses and labour issues,[14] involving not only Chinese companies, but also many from the West. In May 2022, for example, the Swiss mining company Glencore, one of the world's largest traders of cobalt, reached a settlement with the US Department of Justice in which the company pleaded guilty to decades of bribery, corruption, and market manipulation in seven South American and African countries,[15] including the DRC, where Glencore has a long record of human rights abuses.[16] And such abuses are not confined to the DRC: there have been violations of the rights of indigenous communities by Chinese and Western companies in Latin America[17] and workplace safety issues occur also in China[18] and Australia.[19]

Battery and EV Kings

In 2021, almost seven million EVs were sold worldwide,[20] and a full 51 percent of these were sold in China. Germany (10.2 percent) and the United States (9.3 percent) were a long way behind. According to data from China's Ministry of Public Security,[21] as of the end of September 2022, there were 412 million vehicles in China, including 315 million cars, and 499 million drivers. Of those vehicles, 11.49 million, or 3.65 percent, were EVs, of which 3.71 million were newly registered in 2022. The EVs included 9.26 million pure electric vehicles — a proportion of 80 percent. In 2022, 6.49 million new-energy vehicles, mostly EVs, were sold in China — a year-on-year increase of 96 percent from the 3.31 million sold in 2021.[22]

EV sales in China are riding a wave of supportive government policies and incentives, including cash subsidies and purchase tax exemptions. EVs are also a key component of China's 'double carbon' objectives[23] — first proclaimed by Xi Jinping at the UN General Assembly in September 2020 — to reach peak carbon use by 2030 and carbon neutrality by 2060. In September 2022, the Ministry of Finance announced that EVs purchased throughout 2023 would remain exempt from vehicle purchase taxes — the third time the policy was extended since it was first implemented in 2014.[24]

The year 2022 recorded a steady drumbeat of achievements in the meteoric rise of BYD (Build Your Dreams) Auto 比亚迪, a company from Guangdong province that was founded in 1995 as a battery manufacturer. In the first half of the year, BYD became the world's leading EV company, with sales of 640,748 units — a fourfold increase on the previous year — and 76,748 units more than Tesla, which is its closest rival. In just one year, it increased its global market share from 5.9 percent to 15.4 percent.[25] In April, BYD announced that it had ceased building combustion engine vehicles and would focus exclusively on EVs.[26] In May, BYD's monthly EV sales in China breached 100,000 units for the first time. In June, the company's market capitalisation exceeded one trillion yuan (almost US$150 billion), which was larger than Volkswagen Group and third on the list of auto giants behind Tesla and Toyota.[27] In October, BYD sold a record 217,800 EVs in China —

EVs sales in China are riding a wave of supportive government policies
Source: Chuttersnap, Unsplash

the eighth consecutive month of record sales.[28] This represented a year-on-year increase of 168.78 percent and 16,541 units more than in September. According to the China Passenger Car Association, 680,000 EVs were sold in China in October, which would give BYD a market share of 32 percent. From January to October, BYD sold 1.19 million passenger vehicles — a year-on-year increase of more than 160 percent — surpassing Tesla's 909,000 units.[29]

The profits are rolling in for BYD. In the third quarter of 2022, it announced a net profit of 5.72 billion yuan (US$788 million) — an increase of 350.3 percent year-on-year. Its global market offensive is in full swing as well. In September, it entered the European market with the Han sedan, the SUV Tang, and compact SUV Yuan Plus.[30] Through 2022, BYD entered markets in Australia (in February), New Zealand and Japan (July), Cambodia and Israel (August), Thailand (September), and India (October).[31] In October, the company signed an agreement with the European rental car company Sixt to purchase 100,000 BYD EVs over the next six years.[32] BYD also announced it was ordering eight cargo ships, at a total cost of five billion yuan (US$689 million), to transport its vehicles to overseas markets.[33]

Yet, an even more meteoric and relentless rise is that achieved by China's largest battery manufacturer, Contemporary Amperex Technology Limited (CATL) 宁德时代, which was founded in 2011 in Fujian province. In 2021, the average capacity of a single EV battery was about fifty-five kilowatt hours (kWh). By the end of June 2022, the cumulative installed capacity of batteries in China was 110.1 gigawatt hours (GWh) (each gigawatt hour is equal to one million kilowatt hours).[34] This represented almost a doubling of cumulative installed battery capacity from the previous year; CATL accounted for nearly 48 percent of this total. Globally, by the end of the third quarter of 2022, cumulative battery capacity had reached 341.3 GWh, with CATL supplying 35.1 percent of that.[35] (BYD ranked third, with a market share of 12.8 percent; it, too, saw tremendous growth in this area, with a year-on-year increase

of 177 percent.) Profits at CATL are soaring. In the third quarter of 2022, CATL announced total revenue of 97.37 billion yuan (US$13.32 billion) — a year-on-year increase of 232 percent — and a net profit of 9.42 billion yuan (US$1.3 billion), which was an increase of 188 percent.[36]

In June 2022, just when CATL joined the 'trillion yuan' market capitalisation club,[37] the company launched its third-generation Qilin 麒麟 EV battery,[38] named after a mythical Chinese beast sometimes likened to a unicorn. The Qilin has a record volume utilisation rate (the percentage of a battery used for driving) of more than 72 percent, and an EV with this battery can drive 1,000 kilometres without having to recharge. When it does need to be recharged, it can reach 80 percent capacity in ten minutes, outperforming Tesla's batteries, thanks to CATL's large surface-cooling technology. Yet, for CATL's founder and chairperson, Robin Zeng (Zeng Yuqun 曾毓群), the Qilin is just the first step. He has promised more advanced batteries to come,[39] including ones based on 'condensed matter', which, as he said at the Qilin's launch in June, 'no-one has heard about'. Zeng, who completed a PhD in condensed matter physics at the Chinese Academy of Sciences from 2002 to 2006, did not elaborate further, but it is likely that condensed-matter batteries will make use of graphene technology. Graphene is a material consisting of a one-atom-thick layer of carbon that has virtually unlimited industrial potential, including as a conductor of heat and electricity.

All Chains Lead to China

For BYD, CATL, and all EV and battery companies around the world, access to lithium and other precious metals is the key to success. But the Chinese companies have one big advantage: China controls crucial links in the supply chains.

Each of the four key metals used to produce batteries, plus the metal-like graphite, requires different conditions for production.[40] Lithium is extracted from brine in high-elevation areas in South America or from hard rock, mostly in Australia. In 2021, China produced 14,000 metric tonnes of

The Greenbushes lithium mine in Western Australia
Source: Calistemon, Flickr

lithium, making it the world's third-largest producer after Australia (55,000 metric tonnes) and Chile (26,000 metric tonnes).[41] In 2021, at least 65 percent of China's lithium needs were met by imports.[42]

Nickel is extracted from two types of deposits: sulphide (mostly in Russia, Canada, and Australia) and laterite (mostly in Indonesia and the Philippines). In 2021, Indonesia was the world's largest producer with one million metric tonnes, while China was the seventh largest, with 120,000 metric tonnes.[43]

Cobalt is a by-product of copper or nickel mining. About 70 percent of cobalt comes from the DRC, where Chinese companies are estimated to control 60 percent of cobalt mining and 80 percent of cobalt refining.[44] In 2021, Chinese companies owned or partially owned fifteen of the nineteen cobalt mines in the DRC.[45]

Manganese and graphite are easier to obtain. Manganese, which is the most widely distributed of all the metals used in batteries, can be extracted at relatively low cost. As for graphite — the relatively common crystalline form of carbon — it can be mined or produced synthetically, and China controls about 80 percent of global graphite mining.[46]

Since 2021, high demand for lithium-ion batteries has led to a spike in the prices of lithium, nickel, and cobalt, which have been exacerbated by supply chain pressures such as COVID-19, Russia's invasion of Ukraine, and limited production capacity. From January 2021 to May 2022, lithium prices increased sevenfold and cobalt prices doubled, while nickel prices almost doubled.[47] To increase their access to lithium, nickel, and cobalt reserves, Chinese companies have undertaken a range of direct investments, equity

deals, and supply or sales agreements with mining companies in Africa, South America, Indonesia, Australia, and Canada.[48] In January 2022, BYD, for example, was granted a contract by the Chilean Ministry of Mining to extract 80,000 tonnes of metallic lithium for US$61 million,[49] although the deal was suspended by a court in Santiago two days later after an appeal by the local governor and a group of indigenous communities on the grounds that the bidding process violated the principles of environmental protection and economic development.[50] In May, however, BYD had reportedly identified six lithium mines for acquisition in Africa that would yield one million tonnes of lithium carbonate — enough to guarantee the company's production for a full decade.[51]

Downstream of mining, China dominates production at every stage of the battery supply chain, from the fabrication of the positive and negative electrodes to the manufacturing of the cells and their assembly into modules and then battery packs.[52] About 75 percent of the global production of battery cells occurs in China, as does 70 percent of production of specialised cathodes, and 85 percent of anode materials. China also produces 66 percent of separators and 62 percent of electrolytes.[53]

The Epic Rush for Lithium

In June 2021, CATL opened the world's largest battery plant, in Yibin, Sichuan province, with a total investment of sixty-four billion yuan (US$9 billion).[54] The plant has capacity to produce thirty gigawatt hours annually. By the end of September 2022, a Chinese newspaper had counted twenty-six new projects to expand battery production in China in that year,[55] involving all the largest battery producers, and a cumulative investment of 290 billion yuan (US$40.7 billion).

Collectively, they would account for a total production capacity of 820 gigawatt hours annually. According to China's Ministry of Industry and Information Technology, national lithium-ion battery production in the first half of 2022 exceeded 280 gigawatt hours, which was a year-on-year increase of 150 percent.[56] CATL's total electric battery production capacity alone

was set to reach 440 gigawatt hours by the end of 2022, and the company expected to enter the one terawatt hour (TWh) era by 2025. By 2030, global battery production capacity is expected to exceed three terawatt hours, of which China will account for about 45 percent.[57]

This headlong expansion of battery production has driven up the price of lithium relentlessly. As more exploration has taken place, estimated global lithium reserves increased from 3.4 million metric tonnes in 2001 to 21 million metric tonnes in 2020.[58] In May 2022, a majority stake in a lithium mine in Sichuan province sold for two billion yuan (US$298.6 million) on the auction platform of online retailer JD.com 京东, which was 596 times the opening price.[59] By September 2022, the price of lithium carbonate was hovering around 500,000 yuan (US$72,200) per tonne, compared with only 40,000 yuan (US$5,700) a year earlier.[60] On 28 October, the price was 559,000 yuan (US$76,700) per tonne.[61] By the end of February 2023, however, the price of lithium carbonate had again fallen below the 400,000 yuan (US$57,500) per tonne mark, a drop of 21.6% from the beginning of the year. According to Robin Zeng of CATL, current global reserves of lithium can produce 160 terawatt hours of lithium batteries, so there is no shortage,[63] but there is pressure on supply until investment in exploration and mining can catch up. According to the International Energy Agency (IEA), lithium shortages could occur by 2025 — before an expansion in mining can be fully implemented.[64] Because of the complicated processes involved, lithium mining has a very long lead time. According to an IEA report, lithium mines can take an average of 16.5 years to develop 'from discovery to operation'.[65]

With the sharp increase in the price of lithium since 2021, the largest profits in China are currently going to the upstream mining companies rather than the battery or EV manufacturers. In the second quarter of 2022, for example, companies extracting lithium from brine achieved a gross profit margin of more than 90 percent, while the gross profit margin of battery manufacturers was less than 15 percent and as low as 10 percent.[66] In the first three quarters of 2022, the net profits of nine Chinese-listed lithium mining companies more than doubled.[67] These included market leaders Tianqi Lithium 天齐锂业 with 15.98 billion yuan (US$2.19 billion) and Ganfeng Lithium 赣锋锂业 with 14.79 billion yuan (US$2.02 billion).

Tianqi Lithium holds a controlling stake in Chile's largest lithium producer, Sociedad Química y Minera de Chile.[68] Ganfeng Lithium — which supplies lithium to Tesla as well as BMW, Volkswagen, and others[69] — obtains most of its lithium from the Mount Marion mine in Australia (which holds the world's second-largest reserves of high-grade lithium concentrate), in which it holds a 50 percent share.[70]

With the highest profits concentrated in upstream mining, China's lithium battery industry in 2022 was marked by a trend of vertical integration, in which electric battery companies invested in raw materials and raw material companies produced batteries. In April 2022, BYD, for example, made an investment in a lithium mining and battery factory project in Yichun, Sichuan province, of 28.5 billion yuan (US$4.1 billion).[71] In July, mining company Ganfeng Lithium started construction of a 5.4 billion yuan (US$758.6 million) battery production base in Chongqing.[72] Much of the focus of new lithium mining projects in China is in Sichuan, which contains 6.1 percent of global and 57 percent of China's lithium ore reserves. By 2025, Sichuan could have a total lithium mining capacity of five million tonnes.[73]

Alternatives: Can Anything Replace Lithium?

Lithium-ion batteries currently constitute as much as 99 percent of all batteries used in transportation. A more sustainable type of lithium battery, the solid-state battery, is expected to be used in EVs from 2025. Solid-state batteries use solid ceramic material instead of liquid electrolytes, making the batteries lighter, faster to charge, and cheaper. They will reduce the carbon footprint of an EV battery by 24 percent. Although these batteries use up to 35 percent more lithium than current lithium-ion batteries, they use far less graphite and cobalt.[74]

Alternative types of batteries that do not operate with lithium or the other precious metals have been under development for decades, but none of these has reached the stage of mass production. This, however, is about to change. In October 2022, CATL announced that it would start mass producing sodium-ion batteries in 2023,[75] and it is not alone. In September

2022, there were 36 companies listed on China's main stock markets involved in the development of sodium-ion batteries, some of which will start to mass produce cathode and electrode materials for sodium-ion batteries in 2023.[76] Sodium-ion batteries are 20–30 percent cheaper than lithium-ion batteries because they do not require lithium, cobalt, nickel, or manganese. The energy density of sodium-ion batteries is inferior to lithium-ion batteries, however, so they are so far mostly used in small vehicles operating over short distances, such as two-wheeled scooters.[77]

Toyota, Hyundai, and BMW have released cars with hydrogen fuel cell batteries that convert hydrogen into electricity using a hydrogen tank. In May 2022, Great Wall Motors 长城汽车 announced plans to launch a new hydrogen fuel cell brand. Hydrogen-powered vehicles produce waste emissions of water instead of carbon dioxide. These batteries are, however, still very expensive. The technology depends on a highly complex production chain, and hydrogen refuelling stations are much more costly to construct than regular EV recharging stations.[78] Nevertheless, the hydrogen energy industry in China has strong government backing and the fuel cell vehicle industry is being pushed forward in five national fuel cell vehicle demonstration clusters. The number of fuel cell vehicles is still small: from August 2021 to August 2022, a total of 2,590 number plates were issued for fuel cell vehicles in the five demonstration clusters.[79]

Another emerging battery technology is redox flow batteries that use the malleable metal vanadium. Vanadium batteries are much safer than lithium-ion batteries, have a long lifecycle, and are almost completely recyclable; China has 39 percent of global vanadium reserves. So far, such batteries have only been used for large-scale power storage for electricity grids as current versions have relatively low energy density.[80] Still other options that are currently in the exploratory research stage include batteries using seawater, iron, magnesium, hemp, and silicon.[81] For now, however, lithium is king, and China is the centre of the EV world.

This text is taken from *China Story Yearbook: Chains*, edited by Linda Jaivin, Esther Sunkyung Klein and Annie Luman Ren, published 2023 by ANU Press, The Australian National University, Canberra, Australia.

doi.org/10.22459/CSY.2023.02