Fears of a lithium supply crunch may be overblown

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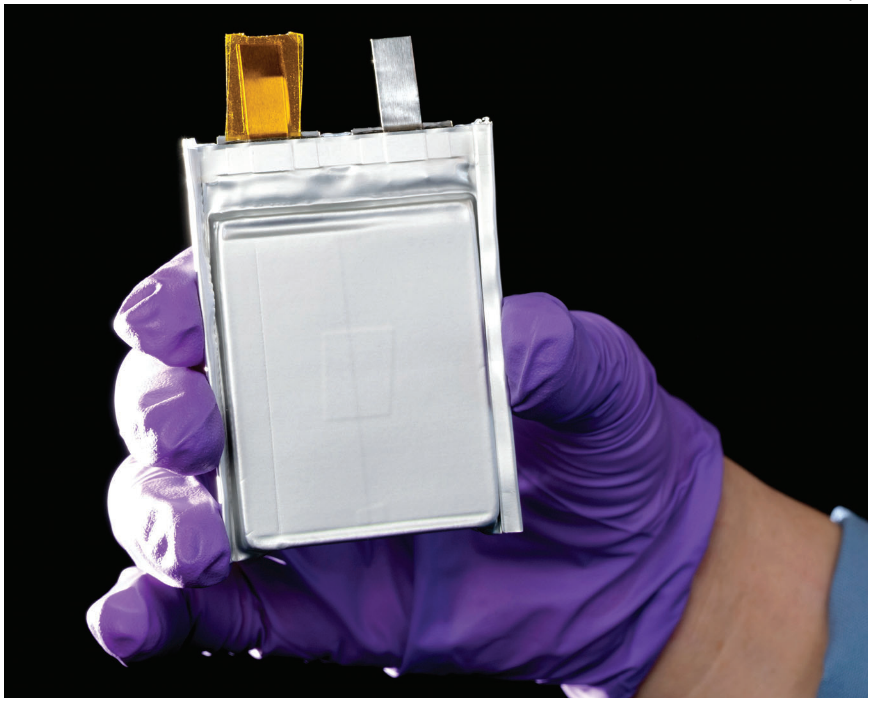
As the world moves to decarbonize transportation and the Biden administration pushes for greater adoption of electric vehicles (EVs), an explosion in demand for lithium for EV batteries may outstrip existing and currently planned supply sources. New deposits around the world and new technologies to extract the light metal are likely to fill the gap, however, and it's possible that cobalt and nickel supplies will become a greater constraint on expanded EV battery production.

According to market analysis firm Benchmark Mineral Intelligence, a deficit of 26 000 tons in lithium supply will develop this year and will widen to 1.1 million tons by 2030. By then, global demand is expected to surge to more than five times today's levels, to 2.4 million tons of lithium carbonate equivalent (LCE), the industry's standard unit of production (see table, page 21). The World Bank last year provided a somewhat less bullish outlook for the light metal but said that a fivefold increase in lithium demand by 2050 will be necessary if the world is to limit global temperatures to 2 °C above their preindustrial level.

Benchmark product director Andrew Miller says the forecast shortage takes into account current mines and mining projects that are known to be in development. "However, lithium is not scarce, so the question is how quickly resources can be developed or accelerated to meet these requirements," he says.

Roderick Eggert, an economics professor at the Colorado School of Mines, agrees. "There is a significant amount of unused mining capacity, principally in Australia, that should allow growth in demand over the next few years to be met without a dramatic increase in price."

GM



A PROTOTYPE lithium-metal battery developed by GM. In March 2021 the automaker announced a joint development agreement with SES, a lithium-metal battery startup.

President Biden's $2 trillion jobs and infrastructure package, announced on 31 March, reserves $174 billion to stimulate the US market for EVs. The prodigious sum underscores the surge in demand that lies ahead for the lightest metal. Nearly all the growth in lithium consumption in the next decade will be attributable to EV batteries, Miller and others say. Some growth in demand for electric utility-scale storage batteries is expected during the latter part of the decade. In the longer term, other types of battery chemistry, such as flow batteries now in the R&D phase, will likely compete with lithium for large-scale storage applications where weight and size are less important.

Although specifics haven't been released, Biden's EV plan would seek to secure domestic automakers' supply chains, beginning with the raw materials, and to stimulate more EV battery manufacturing in the US. But Eggert says a better strategy would be to diversify US lithium sources globally. Self-sufficiency would be much more costly, he says. "It's less of an issue of will there be enough and more of an issue of will there be a diversity of sources brought into production in a time frame that matches the growth in demand."

Western Australia now supplies around 60% of the world's lithium from five mines containing an igneous rock known as spodumene. Most of the remaining global supply comes from salt flats in Argentina, Bolivia, and Chile, in the form of brines that contain high concentrations of the light metal. The brine is pumped up from the ground and put into manmade ponds, where the lithium salts are concentrated via evaporation. "There are a lot of undeveloped resources from both Australia and South America, and they will compete against one another," says Eggert.

The sole US mine, Nevada's Silver Peak, is a brine operation. Its owner, Albemarle Corp, recently announced plans to double production there. The

Lithium Market Balances
(Tons of lithium carbonate equivalent)

Market Balance (+Surplus / −Deficit)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Demand	268 362	300 429	340 662	429 484	584 989	722 701	899 622	1 078 407	1 296 650	1 542 268	1 814 107	2 123 076	2 379 817
Supply	278 508	323 988	343 712	403 340	461 953	563 375	711 683	871 891	987 377	1 107 227	1 168 865	1 207 852	1 274 742
Market balance	10 146	23 559	3 050	−26 144	−123 035	−159 326	−187 939	−206 515	−309 274	−435 040	−645 242	−915 224	−1 105 075

LITHIUM DEMAND will begin to outstrip supply beginning this year and the imbalance will grow rapidly in the absence of further mine development, according to market analysis firm Benchmark Mineral Intelligence. (Figures may have rounding errors.)

amounts were not disclosed.

As with many other critical minerals, China has an outsized hand in the global lithium supply chain. In addition to the lithium mined domestically, China processes almost all Australian raw material to lithium carbonate and lithium hydroxide, the compounds used in the manufacture of cathodes for lithium-ion batteries. Three companies, Japan's Panasonic, South Korea's LG Chem, and China's Contemporary Amperex Technology Co Limited (CATL), produced around three-quarters of all EV batteries in 2020.

A diversity of new sources

The supply base for lithium is expected to diversify over the next decade, even as South American and Australian output increases. As of 2020, brine-based lithium sources were in various stages of development in Argentina, Bolivia, Chile, China, and the US, and mineral-based lithium sources were being developed in Africa, Australia, South America, Canada, and Europe, according to the US Geological Survey.

In addition, new mining techniques and types of deposits are expected to supplement traditional sources. Sedimentary clay deposits are being evaluated in the Southwest US, including at Thacker Pass in Nevada, the world's second-largest prospective new source, according to *MINE* magazine. Thacker's owner, Lithium Americas, estimates the holding could yield enough lithium to make 60 000 tons annually of LCE for 46 years. Australia's Hawkstone Mining, owner of the Big Sandy sedimentary clay prospect in Arizona, says its mine could produce 50 000 tons of LCE annually for 40 years. The mine could be operating by 2025, says Doug Pitts, Hawkstone's US general manager.

A sedimentary clay deposit in Sonora, Mexico, the world's largest lithium project in development, contains an estimated 4.5 million tons of LCE, according to *MINE*. Five of the world's other top 10 mining projects are in Western Australia. The other two are in Quebec and Zimbabwe.

Another potential new source of lithium is superheated brines brought up from deep underground in the production of geothermal energy. In the US, recent interest has focused on the shores of California's Salton Sea, where a handful of companies now operate geothermal plants. The California Energy Commission has awarded $16 million in grants over the past two years to explore the feasibility of piggybacking lithium extraction operations onto those facilities. One awardee, the renewables subsidiary Berkshire Hathaway Energy, operates 10 geothermal plants in the region, which is sometimes called Lithium Valley. If successful, the company says it could produce 90 000 tons of LCE per year—roughly one-quarter of current global demand.

Eggert says that the amounts of lithium from geothermal operations will be nontrivial, "but my impression is that these are dilute sources compared to conventional [mining]." The process hasn't been demonstrated at a commercial scale. What's more, geothermal energy and the extraction of lithium from brines raise environmental concerns, particularly given existing pollution in the Salton Sea. With the infrastructure already mostly built, however, geothermal brines have the potential to quickly become a significant supply source, Miller says. And, as with the clay deposits, geothermal is particularly attractive to US consumers who want to source their material locally.

Standard Lithium, of Vancouver, Canada, is developing a technology it claims can extract up to 90% of lithium from oil-field brines without the need for the evaporation ponds of the conventional evaporative process. The company plans to produce 21 000 tons of LCE per year using the byproduct of bromine production by the German company Lanxess in southern Arkansas.

In southern California, mining giant Rio Tinto's US Borax division is evaluating the recovery of lithium from wastes generated from past borate mining. The company reports its lithium–borate deposit in Serbia is a large undeveloped mineral resource with a potential for 50 000 tons of LCE a year. Spodumene has been mined in North Carolina in the past, and Piedmont Lithium and Albemarle Corp are considering restarting operations there.

Investors have been somewhat hesitant to commit to new mines due to doubts over the duration of the boom in lithium demand, says Eggert. New battery technologies could begin to supplant lithium ion in 15 years. Investors are reluctant to fund a production facility that will have a lifetime of several decades when the technology's future is uncertain beyond 20 years, he says.

Higher-value elements

Other components of the lithium battery are also facing a supply crunch. Surprisingly, the light metal accounts for just 4% by weight of the minerals used in a typical lithium ion cell. Graphite used in the anode accounts for more than half the total mass, and 19% is nickel. Most problematic, at 6%, is cobalt. Not only is it rare and expensive, but most of the world's supply is mined in the Democratic Republic of the Congo, where child labor and other human rights violations are endemic.

Manufacturers of EV batteries have been working to minimize or replace cobalt with different combinations of other transition metals, mainly nickel and manganese, says George Crabtree, director of the Joint Center for Energy Storage Research at Argonne National Laboratory. But some cobalt remains desirable to stabilize the cathode, improve battery life, and enhance EV performance. The cathodes of the first EVs, including Tesla's original Roadster, were made of lithium cobalt oxide, which contributed to the car's high cost.

Most of today's EV cathodes are lithium nickel manganese cobalt oxide, containing much smaller amounts of cobalt. Elon Musk recently reported that Tesla Model Threes sold in China are equipped with cobalt-free lithium iron phosphate cathodes. That chemistry has mostly been limited to power tools because of its lower energy density. (For a discussion of lithium-ion battery chemistry, see the article by Héctor D. Abruña, Yasuyuki Kiya, and Jay C. Henderson, PHYSICS TODAY, December 2008, page 43.)

Given its combination of high energy density and light weight, the lithium-ion battery is expected to dominate for at least the next decade. "Lithium ion is obviously the best battery we've ever had," says Crabtree. But the battery has evolved and will continue to do so. Recent advances suggest that some EVs could require as much as twice the lithium as today's versions. GM and Singapore-based SES, for example, are developing a solid lithium anode to replace graphite. The anticipated increase in energy density should enhance range and potentially reduce charging time, GM says. The partners will build a high-capacity manufacturing line in Woburn, Massachusetts, for a pre-production battery by 2023.

QuantumScape, of San Jose, California, is developing lithium-metal batteries in partnership with Volkswagen. Their design would also eliminate the liquid organic electrolyte that is a feature of all current lithium-ion cells. A solid electrolyte would put an end to the infrequent battery fires caused by thermal runaway reactions.

Some research indicates that silicon graphite composites have a storage capacity about half to three-quarters that of pure lithium, says Crabtree.

Recycling not a factor

Limited recycling of lithium-ion batteries is under way, but the economics are not attractive enough for widespread adoption, says Jeff Spangenberger, group leader of materials recycling at Argonne. Recycling can be accomplished using pyrometallurgical or hydrometallurgical processes.

If recycling were to take hold, cobalt, not lithium, would be the driver, he says. The less cobalt contained in EV batteries, the less attractive are the economics of recycling them. With their high cobalt content, consumer electronics are much more valuable per given weight, but the challenge of collecting cellphones and laptops on a mass scale has stood in the way.

Nitash Balsara, a University of California, Berkeley, chemical engineer, says regulations may be necessary to stimulate recycling. That was the case with lead–acid batteries, nearly all of which have long been recycled. "We didn't know how to do that until we were forced to do it," he says. "It's important enough, and the time is now to develop the processes."

A Department of Energy–supported program known as the ReCell Center is developing direct recycling technology aimed at recovering, regenerating, and reusing lithium-ion battery components without melting them down or otherwise changing their chemical structure.

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A LITHIUM BRINE operation at the Salinas Grandes salt flats in Argentina. Around 30% of the world supply of lithium is from South American brines.