Charging The Future

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The world needs bigger and better batteries: first, to power cars, buses and trucks that will be increasingly electrified; and second, to store electricity for green power grids at times when the sun doesn't shine and the wind doesn't blow. In the 2020s, global battery demand could expand tenfold, and most of that demand will be met by China. A large majority of both current and planned production capacity for batteries is located in China, mainly because it is also the largest market for electric vehicles.

Chinese companies also dominate all segments of the supply chain for solar energy equipment, and are likely to retain that lead (see **The Sun King**). But the picture for batteries is more complicated. Chinese firms do have a big share of the market, are among the technology leaders, and control much of the raw material supply. But a significant (though shrinking) chunk of battery production in China is by international firms. And much future battery capacity will need to be installed close to end-users in other countries. Battery technology is far from mature, and technological breakthroughs could still change the commercial landscape.

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The US and Europe aspire to build major battery industries, and there is a path for them to do so. It will require a multi-year effort to stimulate electric vehicle sales, the buildout of charging infrastructure, and support for new technologies. Even so, it is probable that a decade from now Chinese firms will be commanding leading positions in the global battery industry.

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An industry poised for take-off

Today's battery industry is built around the lithium-ion battery. Its initial market was consumer electronics, and as recently as 2017 such devices accounted for the majority of battery demand. In this type of battery, lithium ions are driven to the cathode (consisting of metals such as nickel, manganese or iron) when the battery is charged, and then flow back to a graphite anode, releasing their stored power. Lithium-based batteries offer the best combination of energy density (electricity stored per unit of volume), safety and prospects for improvement. Since 2010, the cost of lithium-ion batteries has fallen by 90% to US$130/kWh, while energy density doubled.

Improvements in cost and density allowed the lithium-ion battery to move beyond its original uses in consumer electronics to storage for electric cars and power grids. The price of batteries is the key variable determining when electric vehicles will reach cost parity with internal combustion engine vehicles. The industry rule of thumb for the cost-parity point is US$100/kWh; the US Department of Energy is pushing battery makers to reach US$60/kWh. The first target, at least, will very likely be met in the next several years and should accelerate the adoption of EVs.

The price of batteries is a key variable for bringing electric vehicles to cost parity with traditional autos

Between 2015 and 2020, according to Bloomberg New Energy Finance, global EV battery production rose tenfold to 133GWh. EVs now account for more than half of total battery production, mostly for passenger cars. Over the coming decade, BNEF expects world battery production to rise by a factor of 10, to over 2,800GWh. Over 90% of that increased demand will come from EV batteries. There is some risk that these forecasts could prove too rosy, for example if raw material costs surge. But given the political will gathering behind low-carbon transport, a sustained boom in battery production seems all but certain.

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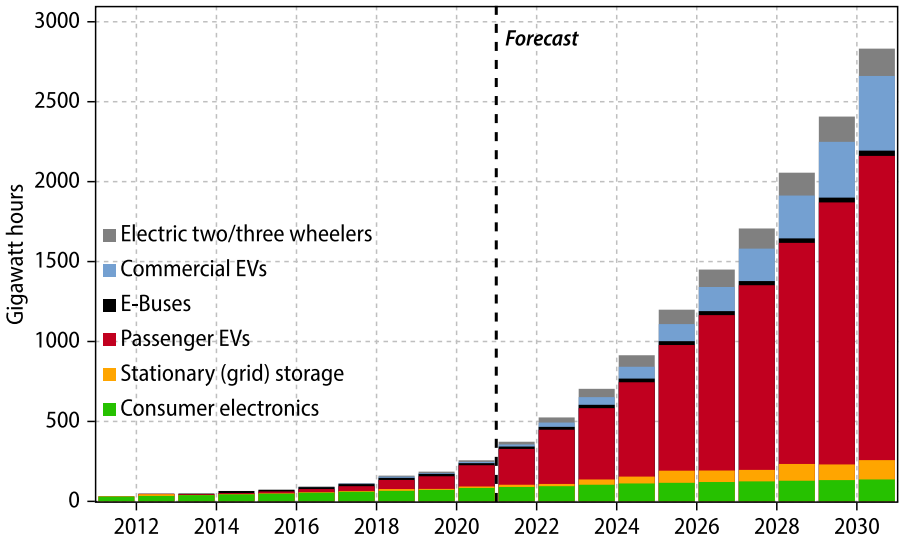
Electric vehicles will drive battery demand in the 2020s

Annual lithium-ion battery demand, by application



BNEF, Gavekal Dragonomics/Macrobond

Battery expertise has been concentrated in Japan, South Korea, and China, due to their historical strength in consumer electronics. (Tesla is well known as a battery maker, but it also works closely with Asian suppliers, notably Panasonic, LG and China's CATL.) China was a latecomer, but now has a slight lead in capacity that is set to surge over the next decade.

A triumph of industrial policy

China's dominance of battery production results from three strategic industrial policies. First, the government encouraged the acquisition of raw material mining sites and the development of processing capacity. Second, it has worked to build a large EV market, so that the country could reduce energy imports, move pollution away from cities and create leading brands in a growth industry. Third, it ran a discriminatory subsidy regime that favored China-headquartered battery makers. Complaints by Korean companies led to an end of this regime, but only after Chinese battery makers had established strong positions.

China's dominance is the result of raw material acquisition, industry expansion and a discriminatory subsidy regime

In battery materials, three minerals are crucial: lithium (mined mainly in Australia, Chile and China), nickel (Indonesia and Australia), and cobalt (Democratic Republic of the Congo). Chinese mining firms have acquired substantial equity interests in the extraction of these minerals over the last

decade. More important is processing: China refines 60% of the world's lithium, 20% of nickel and 70% of cobalt. China's commanding position in lithium and cobalt supply has worried other countries. In a supply-chain security review published in June, the White House noted that the US has little processing capacity for battery materials; a South Korean lawmaker expressed similar concerns in October.

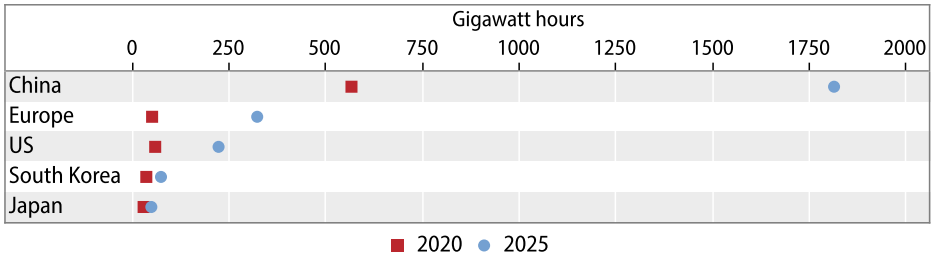
China has around 50% of the world's cathode capacity and the overwhelming majority of planned new capacity

Those processed minerals go into battery components, the most important being cathodes, anodes, separators and electrolytes. Between half and three-quarters of these components are made in China, with the rest produced mainly in Japan and South Korea. The most important component is the cathode, which can make up around half the value of a battery cell. China now has around 50% of the world's cathode capacity and the overwhelming majority of planned new capacity.

These components are then assembled into battery cells, of which 76% are manufactured in China, according to Benchmark Mineral Intelligence. A significant share of China-based battery cell manufacturing capacity is owned by international firms. LG Chem, for example, produces few batteries in its home country of South Korea, and most of its announced expansions are in China. LG now ranks third in utilized battery capacity in China, behind local leaders CATL and BYD. But that ranking will slip if the hordes of other Chinese battery start-ups follow through on their capacity plans.

China leads in battery capacity, and will continue to do so

Battery cell manufacturing capacity, by location



Benchmark Mineral Intelligence, Gavekal Dragonomics/Macrobond

Batteries are expensive and hazardous to ship, so they are typically produced close to auto assembly sites

The biggest reason why battery production is concentrated in China is that electric vehicle sales there have outpaced sales in the rest of the world put together for much of the past decade (see **The Electric Passenger-Car Acid Test**). Batteries are not commodities: producers tend to have dedicated facilities for particular automakers, with whom they work closely to prototype, design and test their batteries. And batteries are expensive and hazardous to ship, so they are typically produced close to auto assembly sites.

Champion CATL

China's largest battery maker is Fujian-based CATL, followed by Shenzhen-based BYD. CATL and LG Chem are the world leaders in battery capacity, each with about 100 GWh, according to BNEF. When the world's major battery makers complete their current planned expansions over the next several years, CATL will tower over its rivals with capacity of 600 GWh,

compared to about 200 GWh for LG Chem and 160 GWh each for BYD and Tesla. The expansion plans of Chinese battery makers are so aggressive that regulators are now warning them not to lose sight of quality and innovation.

CATL is one of China's great technology success stories. Since it listed in Shenzhen in 2018, its market cap has soared to nearly US$250bn, or half of Alibaba's. CATL offers multiple battery chemistries, and has inked partnerships with more automakers than any of its competitors. Prominent customers include Tesla's Shanghai operations and a BMW facility in Thuringia due to open in 2022. CATL is not just big: it is also nimble. In July, it claimed a technological breakthrough in sodium-ion batteries.

CATL's commercial prospects are brighter than those of its domestic rival BYD, which has also made advances, but is hobbled by being an automaker as well as a battery vendor. Other automakers would rather collaborate with CATL, since they can have greater confidence that their designs won't end up in BYD's cars. In the best-case scenario, CATL can imitate the success of TSMC, the world's leading chipmaker. Just as the success of Apple and Nvidia pushed TSMC to be a technological leader, so too might Tesla and BMW sales push CATL to surpass its competition to lead the battery industry.

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The market prefers CATL to BYD

Market capitalization of battery makers

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Can the rest of the world catch up?

Both the US and Europe are keen to build domestic battery production capacity, for both national security and economic competitiveness reasons. The good news for them is that battery production needs to be close to EV production, so once EV sales start to ramp up, local battery production will follow. And there is room for technological breakthroughs that could allow start-ups to wrest market share from incumbents. The bad news—for economic nationalists, anyway—is that in almost any scenario, much of the new battery capacity in the US and Europe will be built by Asian vendors.

There is room for technological breakthroughs to disrupt the industry

Unlike solar PV and wind turbines, battery technology is far from settled. Lithium-ion battery makers are still playing around with different combinations of cathode materials. And sodium-ion batteries are probably only a few years away from commercialization, which is exciting because they do not need scarce cobalt, lithium and nickel. Sodium-ion batteries have low energy densities, making them a poor fit for EVs, but they could work for stationary storage, where space and weight are not so much of a constraint. Even further out on the technological horizon are flow batteries, made of two chemicals dissolved in liquids, and solid-state batteries, which use solid instead of liquid electrolytes.

The varieties of battery technology

Key battery types, commercialized or in development

Battery type	Short name	Comments
Lithium-ion / nickel manganese cobalt oxide	NMC	High power but relies on scarce cobalt
Lithium-ion / nickel cobalt aluminum oxide	NCA	High power but relies on scarce cobalt
Lithium-ion / manganese oxide	LMO	Lower costs but also lower capacity
Lithium-ion / iron phosphate	LFP	Safe, with long cycle life but relatively lower power
Sodium-ion (not yet commercialized)	Na	Avoids lithium and cobalt, but low in energy density; probably good for stationary storage

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The Chinese focus on EV batteries has caused them to lag in other areas

Chinese battery makers are innovative, but they won't capture the lead in all segments. Their focus on EV batteries has caused them to lag in stationary storage batteries, where the global leaders are Tesla and Fluence of the US, and Wartsila of Finland. Many niches in battery technologies do not play to Chinese strengths. Optimizing heat flows and battery charging demand sophisticated energy management system software, where US firms excel.

Technology aside, battery development will depend heavily on the speed of EV market growth. China proved that industrial policy in batteries can succeed, by encouraging EV sales through sticks and carrots, while subsidizing battery makers as well. So long as the US and Europe can show policy consistency in promoting EV sales, the scope for domestic battery production can grow.

Europe is now a bigger EV market than China, prompting big expansions in battery capacity

Europe is more advanced on this score: it is now a bigger EV market than China, prompting big expansions in battery capacity (see **Europe's Battery Boom**). EV promotion policies in the US by contrast have been halting (see **Going Electric In The Land Of The F-150**). The new US infrastructure bill offers US$7.5bn to build charging stations, half the amount asked for by the White House, and Congress is still debating a new federal tax credit for EVs. So far, automakers have remained hesitant to invest: Germany has around the same battery capacity expansion planned as the much larger US.

It will be an uphill battle for US and European companies to succeed against established Asian battery makers

But domestic production does not necessarily mean domestic ownership, and the reality is that Asian firms will build a substantial amount of the next decade's additions to battery capacity in the US and Europe. After they open, in two and five years respectively, the two biggest battery facilities in the US will be an LG Chem site in Michigan serving General Motors and an SK Innovation site in Kentucky/Tennessee serving Ford. Germany enjoys a large commitment from Volkswagen, but the country's two biggest facilities were built by Tesla and CATL. It is possible that domestic US and European companies can succeed, but it will be an uphill battle against the established battery makers with much greater experience.