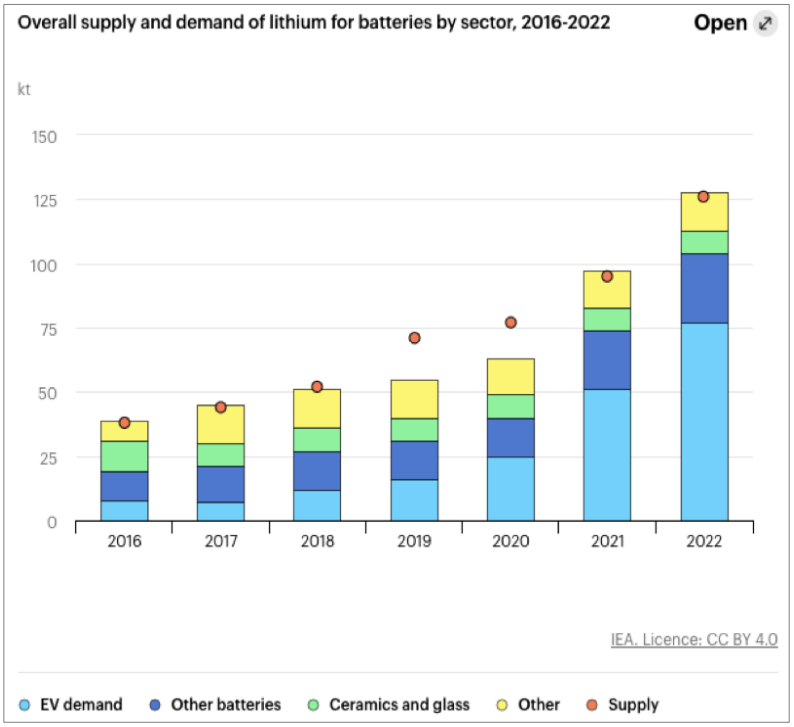
Issues Driving EV Battery Improvements

Battery demand is growing

From 2021 to 2022, battery demand worldwide increased nearly 65%, representing an increased demand of 220 GWh to 550 GWh. This demand was felt primarily in China, which saw an 80% increase in EV purchases from 2021 to 2022.

In the U.S., battery demand also grew by 80% even though EV sales increased only by about 55%. This growth highlights the varied applications for battery technology across the consumer spectrum.



Source: Global EV Outlook 2023 – Trends in batteries. IEA 50. April 2023.

The average EV battery size in the U.S. grew by about 7% in 2022; EV batteries here are about 40% larger than in other countries due to our large demand for EV SUVs and longer ranges, even though most Americans drive about 35 miles a day.

Acquiring raw minerals differently

A significant percentage of raw materials for batteries comes from politically unstable countries with substandard labor rights and practices. This creates vulnerabilities in the supply chain for global EV manufacturing, including:

- Chokepoints that could have major impacts on EV production, decarbonization, and policymaking.
- Unavailability of critical materials due to political disruptions. These materials include: such as:
  - Cobalt: 48% of global known reserves are in the Democratic Republic of Congo.
  - Lithium: 36% of known global reserves are in Chile.
  - Nickel: 21% of known global reserves are in Indonesia.

Worldwide, China processes 76% of the cobalt, 61% of the lithium, 59% of the manganese, and 25% of the nickel. The Western world is attempting to address this vulnerability by

increasing construction of critical mineral processing operations in North America and Europe.[1]

China is also responsible for 70% to 80% of the world's anode and cathode production, 75% of the world's battery production, and over 50% of the world's EV production. With tensions rising between China and the West, it is crucial that these relations do not strain markets and for the West to become dramatically more self-reliant in mineral, cell, battery, and EV production.[2]

Alternative battery technologies

EV battery chemistry is changing rapidly as researchers and companies search for the most efficient combinations of minerals:

- By far the dominant chemistry is a **lithium nickel, manganese, cobalt** (NMC) mix, comprising 60% of EV batteries made today.
- **Lithium iron phosphate** (LFP) is a distant second at 30% of EV batteries made today. LFP batteries are growing in popularity, especially in China with EV company BYD. This technology uses minerals that are more readily available and less expensive, but this technology is less energy dense so the batteries are larger or have smaller capacities.
- **Nickel cobalt aluminum** (NCA) comprise about 8% of EV batteries made today.
- A **sodium-ion** battery is being built by Chinese company, CATL. Because sodium is widely available, it is a cheaper option than lithium. However, this technology has a lower energy density than Li-ion and brings the same concerns as Li-ion batteries.
- **Silicon** is becoming a major new material in anode and cathode technologies because of its higher energy density compared to graphite. This allows for longer ranges and quicker charge times. However, silicon is a more active component than graphite, which makes it more susceptible to degradation and battery wear.

University of Texas researchers are testing a cobalt-free, nickel-based EV battery cathode to reduce the social and environmental costs of acquiring cobalt while increasing energy density, range, and battery lifetimes.[3] Their cathode is 89% nickel; manganese and aluminum make up most of the rest of the cathode. Chinese company SVOLT is working on a similar entirely nickel/manganese (NMx) cathode. With first production runs in 2021, they are working to scale production to reduce the demand for cobalt, increase energy densities, and reduce battery costs.[4]

IBM is working on a prototype for an EV battery derived from seawater elements that will be non-flammable and can be recharged to 80% in about five minutes. There is some

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[1] Critical Minerals for Electric Vehicles: What You Need to Know. Resources. March 7, 2024.

[2] Global Supply Chains of EV Batteries. International Energy Agency. July 2022.

[3] New Cobalt-Free Lithium-Ion Battery Reduces Costs Without Sacrificing Performance. UT News. Jul 14, 2020.

[4] SVOLT Reveals First NMx Cobalt-Free Battery Pack. InsideEVs. Aug 31, 2021.

skepticism to these claims, however, because IBM has not released their technical specifications or peer-reviewed data.[5]

The company Focus believes that graphene is going to be the material of choice for batteries in the 2030s, with society-wide applications as the price of graphene drops, and extraction and manufacturing processes become more efficient. They believe this technology will improve EV performance and meet emission-reduction goals.[6]

Zinc-air batteries could replace traditional Li-ion batteries because they are not flammable and have higher energy densities. However, they are currently very expensive, and have lower specific energy and voltage levels. Researchers are looking for cheaper alternatives to current components.

Bringing battery production to the U.S.

From 2022 to 2030, the Li-ion battery market is expected to grow in value by 30%—to $400 billion—and increase in capacity from 700 GWh[7] to 4.7 TWh.[8] Mobility applications such as EVs will consume an estimated 4.3 TWh of that capacity.

China currently dominates global battery production, producing approximately 75% of the world's EV batteries. According to Bloomberg,[9] China's production alone came close to matching the global demand for batteries. Other countries are attempting to ramp up their own manufacturing processes. The U.S., Canada, the European Union, Australia, and India announced their own plans for major EV battery production sites to increase reliability, security, and supply.

In 2024, 34 battery-manufacturing plants are in construction or planned in the U.S., up from two such facilities in 2019. The Inflation Reduction Act (IRA) provides supply-side tax credits to incentivize EV component manufacturing. Close to $112 billion has been invested to increase battery-manufacturing capacity in the U.S. to 1.2 TWh by 2030, enough for 18 million EVs.[10] [11] With this major increase in global battery manufacturing, battery costs are expected to decrease.

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[5] IBM Reveals "Staggering" New Battery Tech, Withholds Technical Details. IEEE Spectrum. Dec 19, 2019.

[6] Graphene is set to disrupt the EV battery market. Energy Monitor. Feb 5, 2024.

[7] Gigawatt hour (GWh) is a unit of energy that represents one billion watt-hours and is equal to one million kilowatt-hours.

[8] A terawatt-hour (TWh) is a unit of energy that represents one trillion watts of power used for one hour.

[9] China Already Makes as Many Batteries as the Entire World Wants. Bloomberg. April 12, 2024.

[10] Tracking the EV battery factory construction boom across North America. TechCrunch. July 20, 2024.

[11] Analysis Finds U.S. Electric Vehicle Battery Manufacturing on Track to Meet Demand. Environmental Defense Fund. January 3, 2024.

Increasing battery lifetimes

Nanowires

Researchers at the University of California Irvine invented a nanowire that is thousands of times stronger than traditional nanowires. In EV batteries, this technology may be useful to extend battery lifetimes. After extensive testing, these nanowires showed no loss of power or charge, and no fracturing. Conventional EV batteries start to show loss of charge, power, or capacity at 5,000 to 7,000 charging cycles.

Dual-carbon battery

Power Japan Plus is developing a dual-carbon battery that utilizes carbon for both the anode and cathode. This technology offers similar energy densities as Li-ion batteries with a longer functional lifetime, better safety metrics, and more sustainable recycling at battery end-of-life. These batteries are cheaper to produce than Li-ion batteries, can charge up to 20 times faster than current EV batteries, and provide greater power. Carbon batteries also do not use rare-earth metals and do not rely on a vulnerable supply chain. This battery can charge in the 0% to 100% range without degradation.

Increasing battery recycling

To qualify for the IRA EV tax credit, 80% of the critical materials in EVs can be procured from recycled batteries in the U.S. By the end of 2022, 105,000 tons of battery materials were recycled in the U.S., enough to power 220,000 vehicles a year, given that most EV batteries weigh about 1,000 pounds.

Approximately 650,000 tons of recycling capacity could be built by 2030, which could process approximately 1.3 million EV batteries at end-of-life. By 2050, an estimated 1.5 million tons of EV battery end-of-life materials will be in the U.S. so we will need more recycling capacity to keep up with the increased production of EVs.[12]

Under the 2022 Bipartisan Infrastructure Law, the Dept. of Energy provided $2.8 billion to the EV industry, much of it predicated on improved battery handling. There is not currently a large market for recycled batteries because most are still in use. But as more EV batteries are removed from service, the incentives, prices, and processes to reuse or recycle batteries will become more robust and efficient, potentially even creating a closed loop based on battery chemistry innovations.[13]

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[12] Will the U.S. EV battery recycling industry be ready for millions of end-of-life batteries? The International Council on Clean Transportation. Sept 29, 2023.

[13] The truth about EV battery recycling. ChargeLab. April 16, 2024.

Finding new uses for retired batteries

End-of-life EV batteries can be repurposed for stationary grid storage and power. Typically, EV batteries are deemed to be at their end of life at 20% to 30% degradation. But these batteries still have plenty to offer, including "electricity generation and grid distribution, such as time-shifting, seasonal energy storage, large-scale renewable integration, and grid regulation."[14] Large generating facilities can use these repurposed batteries to offset intermittent renewable energy production to support a balanced grid, peak shaving to reduce demand, and dip-rising to satiate high demand.[15]

[14] Can EV Batteries Be Reused? AZO Materials. July 11, 2024.

[15] The future holds many, many more EV batteries. And therein lies a solution to grid storage. Anthropocene. May 28, 2024.

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