COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
U.S. HOUSE OF REPRESENTATIVES
HEARING CHARTER

Pedal to the Metal: Electric Vehicle Batteries and the Critical Minerals Supply Chain

Thursday, April 21, 2022
10:00 AM CT
Woodridge Village Board Room
5 Plaza Drive, Woodridge, Illinois

Purpose

The purpose of this hearing is to discuss the expected surge in demand for electric vehicle (EV) batteries over the next decade and consider the implications for critical minerals required in EV battery manufacturing, including cobalt, lithium, nickel, graphite, and manganese. The Members and witnesses will consider research opportunities to mitigate potential supply chain concerns, including new technologies for minerals extraction and processing, minerals recycling, and alternative battery chemistries. They will also explore strategies to maximize the research, development, and demonstration investments already being supported by the Department of Energy (DOE) pursuant to the Energy Act of 2020 and the Infrastructure Investment and Jobs Act (IIJA).

Witnesses

- **Mr. Nate Baguio,** Senior Vice President of Commercial Development, The Lion Electric Company
- **Mr. Chris Nevers,** Senior Director of Public Policy, Rivian
- **Dr. Venkat Srinivasan**, Deputy Director of the Joint Center for Energy Storage Research (JCESR) and Director of the Collaborative Center for Energy Storage Science (ACCESS), Argonne National Laboratory
- **Dr. Chibueze Amanchukwu,** Neubauer Family Assistant Professor of Molecular Engineering, University of Chicago

Key Questions

- What is the outlook and value proposition for the battery electric trucks and fleets?
- How is demand for EV batteries poised to grow, and what are the supply chain implications for EV battery components?
- What research topics (recycling, exploration, processing, critical material substitutes, alternative battery chemistries, etc.) hold promise for mitigating supply chain concerns associated with EV batteries?
- What are some key considerations for the federal government as it deploys IIJA funds and carries out authorizations in the Energy Act of 2020 related to EV battery research?
- What other activities should the federal government pursue to address this issue?

Background on EV sector growth and the battery mineral supply chain

Vehicle electrification is necessary to achieve net-zero emissions in the United States by 2050 and limit global warming to 1.5 degrees Celsius, as the Intergovernmental Panel on Climate Change says is required to avoid catastrophic climate conditions.

In 2019, global sales of electric cars totaled 2.2 million, about 2.5% of global car sales. In 2020, electric vehicles accounted for 4.1% of total car sales. In 2021, electric vehicle sales doubled again to 6.6 million, representing almost 9% of total car sales.[1] This aggressive growth is taking place in the United States as well as abroad. EV sales doubled in the United States from 308,000 in 2020 to 608,000 in 2021.[2] For context, internal combustion engine car sales grew by just 2.8% in the same period. S&P Global Platts Analytics projects that global EV sales will soar another 400% by 2030.[3]

The explosive commercial uptake of electric vehicles has been enabled in large part by the falling costs of batteries. Battery cells saw an 89% cost reduction in the last decade, falling from an average of $1,200/kWh in 2010 to $132/kWh in November 2021.[4]

But because the outlook for EV industry growth is so aggressive, demand for EV battery minerals is surging and will continue to increase. Raw material prices have already started to tick up. The global price of nickel had already doubled in the two years prior to Russia's invasion of Ukraine,[5] and lithium hydroxide prices increased 254% in 2021 alone.[6]

To be sure, supply chain bottlenecks associated with COVID-19 have yielded price affects for commodities and materials across many sectors of the global economy. But analysts attribute a large portion of surging minerals costs to the rapid increase in demand for EVs specifically. Accordingly, Bloomberg NEF projects that average battery pack prices could increase for the first time in 2022, up about 2% to an estimated $135/kWh.[7]

If EV battery mineral supplies are not diversified and/or increased and battery prices trend upwards as a result, it will be more difficult to achieve the Biden Administration's goal that 50% of vehicles sold in the United States be electric by 2030.[8]

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[1] https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales

[2] https://www.energy.gov/energysaver/articles/new-plug-electric-vehicle-sales-united-states-nearly-doubled-2020-2021

[3] https://www.spglobal.com/commodity-insights/en/market-insights/latest-news/energy-transition/021622-global-light-duty-ev-sales-to-rise-to-268-mil-by-2030-platts-analytics

[4] https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/

[5] https://www.wsj.com/articles/russia-can-hold-nickel-hostage-metals-mining-environment-china-class-domestic-electric-vehicles-11647287911

[6] https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/121421-commodities-2022-global-lithium-market-to-remain-tight-into-2022

[7] https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/

[8] https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/05/fact-sheet-president-biden-announces-steps-to-drive-american-leadership-forward-on-clean-cars-and-trucks/

Critical Minerals in EV Batteries

The Energy Act of 2020 (30 U.S.C. 1606(a)) defines a critical mineral as "any mineral, element, substance, or materials designated as critical" by the Secretary of the Interior. The Department of Interior's list is based on a methodology developed in partnership with the White House Office of Science and Technology Policy's National Science and Technology Council (NSTC) Critical Minerals Subcommittee. The methodology is based in part on the relative insecurity of access for American consumers – e.g., how heavily production is weighted outside of the U.S. and whether there are single points of failure in the supply chain.[9] A "critical mineral" is also considered a "critical material" for purposes of dedicated R&D programs at the Department of Energy (DOE).[10]

The key critical minerals commonly used in EV batteries are lithium, cobalt, nickel, graphite, and manganese.[11] Note that battery EV motors often require a different set of critical minerals, specifically rare earth elements like neodymium.

- **Lithium:** BloombergNEF projects that without battery recycling, cumulative lithium demand will exceed known global reserves by 2050.[12]
- **Cobalt:** Less than 1% of known cobalt reserves are in the United States. The majority of global cobalt reserves are in the Democratic Republic of Congo, and a majority of cobalt processing is performed in China. The International Energy Administration expects global cobalt demand to double from 2020 to 2030, even if no additional policy supports for EVs are put in place.[13] The Federal Consortium on Advanced Batteries (FCAB) seeks to eliminate the need for cobalt in lithium-ion batteries by 2030.[14]
- **Nickel:** Less than 0.1% of known nickel reserves and manufacturing (processing) capacity are located in the United States. FCAB seeks to eliminate the need for nickel in lithium-ion batteries by 2030.[15]
- **Graphite:** Graphite comprises the majority of the battery anode. Virtually all of the global supply of processed graphite comes from China.[16]
- **Manganese:** Manganese is used in battery cathodes and supports energy density and reduced combustibility. Manganese demand may increase as it is substituted for nickel and cobalt. Around 80% of known manganese ore is located in South Africa.

The basic supply chain stages for EV battery minerals are as follows:

[9] https://www.govinfo.gov/content/pkg/FR-2021-11-09/pdf/FR-2021-11-09.pdf
[10] https://science.house.gov/imo/media/doc/Energy%20Act%20of%202020.pdf Section 7002(a)(2)
[11] https://www.govinfo.gov/content/pkg/FR-2022-02-24/pdf/2022-04027.pdf
[12] EVO 2021 (turtl.co)
[13] https://www.iea.org/data-and-statistics/charts/total-cobalt-demand-by-sector-and-scenario-2020-2040
[14] https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf
[15] Id
[16] https://electrek.co/2021/12/20/graphite-will-be-in-deficit-from-2022-heres-what-ev-battery-makers-need-to-do-to-secure-the-critical-mineral/

1. **Extraction and mining**: Some EV critical minerals are dissolved in surface or subsurface fluid, while others are found in clays and solid ores.
2. **Mineral processing:** a variety of processes, including smelting, electrowinning, crushing, separation, hydrometallurgy, comprise this stage. Processing allows for a pure form of the desired metal to be separated from the mined rock, fluid, or clay. The United States relies almost entirely on trade partners, particularly China, for minerals processing.
3. **Component Fabrication**. Once processed and refined, several EV battery minerals must be "doped" with other materials to make the active material used in battery applications. The active materials are then fabricated into recognizable battery components – the anodes, cathodes, and electrolytes. Currently the United States manufactures 0% of cathodes globally and only 10% of anodes, 2% of electrolyte solutions, and 6% of separators. China manufactures 65% of both anodes and electrolyte solutions, and 42% of cathodes.[17]
4. **Cell fabrication** – the anodes, cathodes, and electrolytes are packaged together into uniform electrochemical cells, each with a standardized power output. Tesla currently manufactures battery cells at its Gigafactory in Nevada. Thirteen new battery cell gigafactories are planned to come online in the United States by 2025.[18]
5. **Battery fabrication** – Cells are packaged together into recognizable battery modules, and then into packs, with electrical connections and any necessary cooling equipment. For example, a 2018 BMW i3 battery pack has eight modules, each made of 12 cells.[19]

Research Opportunities

New methods for extraction, processing, and refining: Innovators often seek to solve for environmental outcomes, such as reducing emissions or surface disturbance. For example:

- The ARPA-E MINER program is working on innovations to decrease energy required for comminution (breaking ore up into particles)
- DOE's American-Made Geothermal Lithium Extraction Prize seeks to develop technology strategies that enable direct lithium extraction from geothermal brines, which could avoid mining and additional surface disturbance.[20]
- In 2021, DOE's Advanced Manufacturing Office issued a $5.6 million grant to NOVONIX to support development of a synthetic graphite anode material.
- Talon Metals is planning an in situ carbon capture and storage project to sequester greenhouse gas emissions at its nickel-copper-cobalt mine in Minnesota.

Mineral Recycling: EV batteries last a decade or more. Researchers are planning now for both the chemistry and the logistics of how to extract and repurpose critical minerals from the relatively "young" battery stock in the current EV fleet. One significant engineering challenge is

[17] https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf Page 19
[18] https://www.energy.gov/eere/vehicles/articles/fotw-1217-december-20-2021-thirteen-new-electric-vehicle-battery-plants-are
[19] https://www.samsungsdi.com/column/all/detail/54344.html
[20] https://www.energy.gov/eere/articles/energy-department-announces-phase-1-semifinalists-geothermal-lithium-extraction-prize

designing an adaptable recycling schematic without knowing how the dominant battery chemistries may change in the coming decade. DOE's Vehicle Technologies Office supports an advanced battery recycling RD&D center at Argonne National Laboratory called ReCell.

Alternative battery chemistries: A number of research efforts are dedicated toward new chemistries that reduce or eliminate the cobalt and/or nickel components. New designs that increase the energy density of the cell will also help reduce critical mineral demand, as fewer cells could be required to achieve the same vehicle performance.

Federal Programs and Actions

Since 2011, DOE has funded the Critical Materials Institute, a multi-institution Energy Innovation Hub led by Ames National Laboratory, at about $25 million a year. CMI focused its research on diversifying material supplies, developing substitutes, improving reuse and recycling, and crosscutting research. CMI's last full year of funding was FY2021 and is in the process of closing out in FY2022.

In late 2012, DOE established the Joint Center for Energy Storage Research (JCESR), a separate Hub led by Argonne National Laboratory. In 2018 DOE renewed JCESR for another five-period with annual funding of $24 million per year.[21]

In the fall of 2020, four U.S. agencies – Energy, Defense, Commerce, and State – convened the Federal Consortium for Advanced Batteries (FCAB) to help build a domestic supply chain to manufacture batteries that can be used for all energy storage applications, including electric vehicles. In June 2021, FCAB released the *2021-2030 National Blueprint for Lithium Batteries*, which charts a strategy for discovering critical minerals alternatives and enabling recycling.[22]

The bipartisan Energy Act of 2020, signed into law in December 2020, directed DOE to undertake a critical material recycling and reuse R&D program for energy storage systems which includes a focus on such systems for EVs.[23]

On February 24, 2021, President Biden issued Executive Order 14017, *Securing America's Supply Chains,* which directed DOE to report on risks in the supply chain for EV batteries.[24]

The bipartisan Infrastructure Investment and Jobs Act was signed into law in November 2021.[25] It authorizes and appropriates over $7 billion in funding over five years to support a variety of EV battery minerals programs largely centered at DOE, including mapping of deposits and grants for research, development and demonstration of minerals processing, recycling, and alternatives. Among the funds appropriated are $75 million for the Critical Material Supply Chain Research Facility and $600 million for the Critical Material Innovation, Efficiency, and

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[21] https://www.jcesr.org/jcesr-renewed-for-another-five-years/
[22] National Blueprint for Lithium Batteries 2021-2030 (energy.gov)
[23] https://science.house.gov/imo/media/doc/Energy%20Act%20of%202020.pdf
[24] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/
[25] Public Law 117-58. https://www.congress.gov/117/plaws/publ58/PLAW-117publ58.pdf.

Alternatives program, both of which were originally authorized in the Energy Act of 2020. It also expands the authorization of the Loan Programs at DOE to allow projects that increase the domestic sources of critical minerals, through production, processing, manufacturing, recycling, and/or fabrication.

On February 24, 2022, DOE announced a $44 million funding opportunity through the Advanced Research Projects Agency-Energy (ARPA-E) called Mining Innovations for Negative Emissions Resource Recovery (MINER). MINER aims to develop technologies that would enable greater domestic supplies of nickel, lithium, cobalt, and other critical elements.[26]

On March 31, 2022, President Biden invoked the Defense Production Act to boost U.S. production of battery minerals for electric vehicles.[27]

[26] https://arpa-e.energy.gov/news-and-media/press-releases/us-department-energy-announces-44-million-develop-technologies

[27] https://subscriber.politicopro.com/article/eenews/2022/03/30/biden-to-invoke-defense-production-act-on-battery-minerals-00021691