FEDERAL CONSORTIUM FOR ADVANCED BATTERIES FY2023 END OF YEAR REPORT

DATE: August 2024

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A Message from the FCAB Leadership

This marks the third year for the Federal Consortium for Advanced Batteries (FCAB), formed to foster strategic alignment, coordination, and collaboration across the Agencies in support of a resilient domestic battery manufacturing and technology supply chain.

This FCAB End of Year Report provides an updated status of the domestic lithium-ion battery industry, its supply chain, technology advancements, and progress toward the National Blueprint Goals. By comparing year-on-year gaps in key areas of the lithium battery supply chain, we can assess our impact on domestic batteries to date.

In 2022, electric vehicle sales made up 6.1% of new light-duty vehicles car sales in the United States.[1] For comparison, over 1.2 million plug-in electric vehicles were sold through November of 2023, accounting for 9% of new light-duty vehicles car sales according to the Light Duty Electric Drive Vehicles Monthly Sales Update. Additionally, in January 2023, the Department of Energy (DOE), Department of Transportation (DOT), and the Environmental Protection Agency (EPA) released the U.S. National Blueprint for Transportation Decarbonization which describes a whole-of-government approach to addressing the climate crisis as well as meeting the current Administrations's goals of a 100% clean electrical grid by 2035 and net-zero carbon emissions by 2050.[2] As the Nation approaches these electrification goals, FCAB's goal of establishing a resilient supply chain only becomes more critical.

Over the past three years three major pieces of legislation and an executive action passed that will strengthen the domestic supply chain for batteries (the Bipartisan Infrastructure Law (BIL), the Presidential Determination allowing the use of Defense Production Act Title III authorities for Critical Materials in Large-Capacity Batteries (DPA), the Additional Ukraine Supplemental Appropriations Act, and the Inflation Reduction Act (IRA)). In 2023, FCAB focused on supporting the implementation of that funding. Agencies participating in FCAB administered over $18 billion in federal investments through financial assistance, grants, and federal loans spread over thirty-nine projects that support the domestic battery manufacturing supply chain.[3] Independent industry investments and the matching cost share investments for several of the federal grants are bolstering the battery supply chain within the United States.

FCAB plays a critical role in convening Federal government programs focused on accelerating the deployment of a robust, secure domestic industrial base for commercial and military end-use lithium battery technologies. This year our leadership added representation from the U.S. Environmental Protection Agency to provide invaluable input into the emerging advanced battery recycling. Participation in FCAB now spans across nineteen different Federal agencies and represents over eighty different offices within those agencies. FCAB task groups are implementing the actions to achieve the goals laid out in the National Blueprint for Lithium Batteries.

1 Zhou, Yan. Light Duty Electric Drive Vehicles Monthly Sales Update—Historical Data. Argonne National Laboratory. https://www.anl.gov/esia/reference/light-duty-electric-drive-vehicles-monthly-sales-updates-historical-data. Accessed 15 December 2023.

2 The U.S. National Blueprint for Transportation Decarbonization: A Joint Strategy to Transform Transportation. U.S. Department of Energy. https://www.energy.gov/eere/us-national-blueprint-transportation-decarbonization-joint-strategy-transform-transportation. Accessed 05 December 2023.

3 See Investment graphic on page 4

BLUEPRINT VISION AND GOALS

Establishing a domestic supply chain for lithium-based batteries requires a national commitment to both solving breakthrough scientific challenges for new materials and developing a manufacturing base that meets the demands of the growing electric vehicle (EV) and electrical grid storage markets. As the domestic supply chain develops, efforts are needed to update environmental and labor standards and to ensure equitable development of workforce opportunities including those communities that have been historically underserved.

GOAL 1 Secure access to raw and refined materials and discover alternatives for critical minerals for commercial and defense applications

A robust, secure, domestic industrial base for lithium-based batteries requires access to a reliable supply of raw, refined, and processed material inputs along with parallel efforts to develop substitutes that are sustainable and diversify supply from both secondary and unconventional sources. The goal is to reduce U.S. lithium-battery manufacturing dependence on scarce materials, especially cobalt and nickel, in order to develop a stronger, more secure and resilient supply chain. Working through ongoing U.S. Government initiatives and with allies to secure reliable domestic and foreign sources for critical minerals[4] is as vital as ultimately replacing these materials in the lithium-battery supply chain. New or expanded production must be held to modern standards for environmental protection, best-practice labor conditions, and rigorous community consultation, including with tribal nations through government-to-government collaboration, while recognizing the economic costs of waste treatment and processing.

GOAL 2 Support the growth of a U.S. materials-processing base able to meet domestic battery manufacturing demand

Today, the U.S. relies on international markets for the processing of most lithium-battery raw materials. The Nation would benefit greatly from development and growth of cost-competitive domestic materials processing for lithium-battery materials. The elimination of critical minerals (such as cobalt and nickel) from lithium batteries, and new processes that decrease the cost of battery materials such as cathodes, anodes, and electrolytes, are key enablers of future growth in the materials-processing industry.

GOAL 3 Stimulate the U.S. electrode, cell, and pack manufacturing sectors

Significant advances in battery energy storage technologies have occurred in the last 10 years, leading to energy density increases and battery pack cost decreases of approximately 85%, reaching $143/kWh in 2020.[5] Despite these advances, domestic growth and onshoring of cell and pack manufacturing will require consistent incentives and support for the adoption of EVs. The U.S. should develop a federal policy framework that supports manufacturing electrodes, cells, and packs domestically and encourages demand growth for lithium-ion batteries. Special attention will be needed to ensure access to clean-energy jobs and a more equitable and durable supply chain that works for all Americans. In addition, electrode, cell, and pack manufacturing can benefit from further research and development (R&D) in order to reduce costs, improve performance, and support demand growth.

[4] The term 'critical material or mineral' means a material or mineral that serves an essential function in the manufacturing of a product and has a high risk of a supply disruption, such that a shortage of such a material or mineral would have significant consequences for U.S. economic or national security. Consolidated Appropriations Act, 2021. H.R. 133, 116th Cong. (2021). Page 1381. https://www.congress.gov/116/bills/hr133/BILLS-116hr133enr.pdf. Accessed May 27, 2021.

[5] U.S. Department of Energy, Energy Storage Grand Challenge Roadmap, 2020, Page 48. https://www.energy.gov/sites/default/files/2020/12/f81/Energy%20Storage%20Grand%20Challenge%20Roadmap.pdf. Accessed May 27, 2021.

GOAL 4 Enable U.S. end-of-life reuse and critical materials recycling at scale and a full competitive value chain in the United States

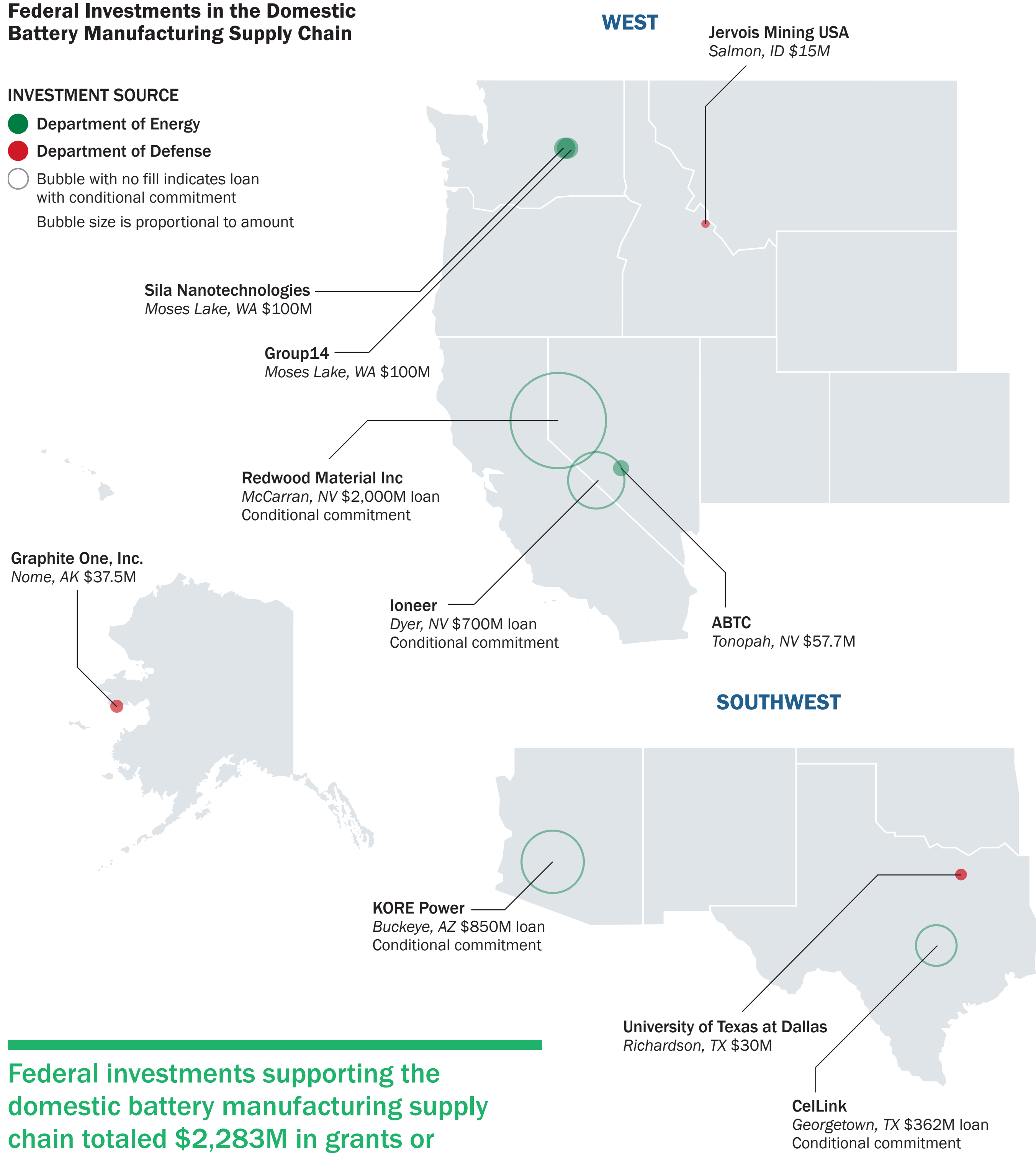
Recycling of lithium-ion cells not only mitigates materials scarcity and enhances environmental sustainability, but also supports a more secure and resilient, domestic materials supply chain that is circular in nature. For lithium-ion batteries, several factors create challenges for recycling. Currently, recyclers face a net end-of-life cost when recycling EV batteries, with costs to transport batteries, which are currently classified as hazardous waste, constituting over half of the end-of-life recycling costs. New methods will be developed for successfully collecting, sorting, transporting, and processing recycled lithium-ion battery materials, with a focus on reducing costs. In addition to recycling, a resilient market should be developed for the reuse of battery cells from retired EVs for secondary applications, including grid storage. Second use of battery cells requires proper sorting, testing, and balancing of cell packs.

GOAL 5 Maintain and advance U.S. battery technology leadership by strongly supporting scientific R&D, STEM education, and workforce development

Establishing a competitive and equitable domestic lithium-battery supply chain in an accelerating EV and grid storage market is only one phase of a global surge toward higher performance and lower costs as part of a new zero-carbon energy economy. The pipeline of R&D, ranging from new electrode and electrolyte materials for next generation lithium-ion batteries, to advances in solid state batteries, and novel material, electrode, and cell manufacturing methods, remains integral to maintaining U.S. leadership. The R&D will be supported by strong intellectual property (IP) protection and rapid movement of innovations from lab to market through public-private R&D partnerships like those established in the semiconductor industry. Undertaking R&D requires a highly skilled workforce, which starts with equitable access to science, technology, engineering, and math (STEM) education at all levels.

Investments

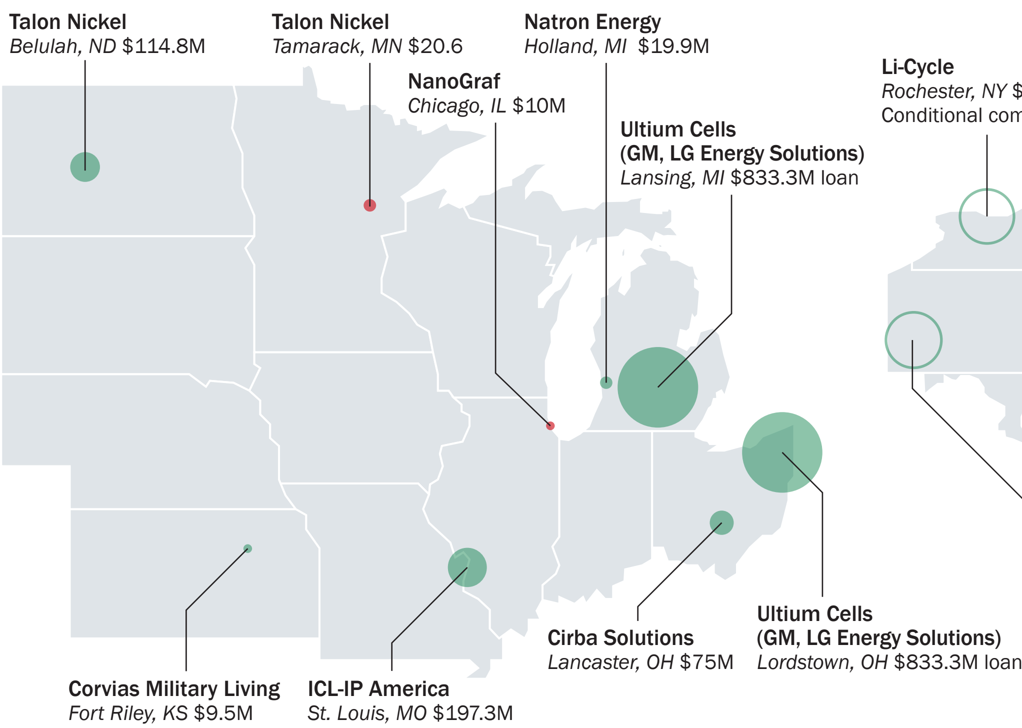
Federal Investments in the Domestic Battery Manufacturing Supply Chain



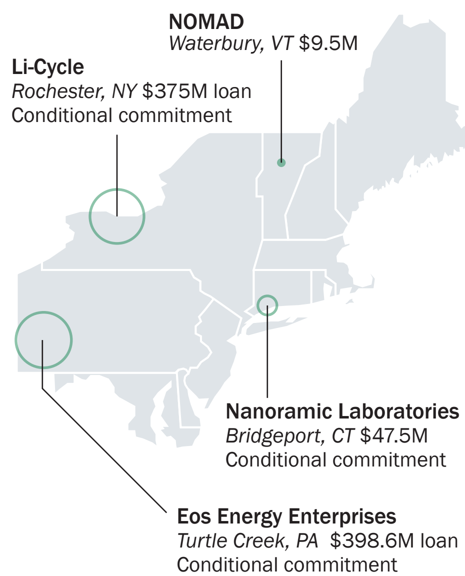
Federal investments supporting the domestic battery manufacturing supply chain totaled $2,283M in grants or financial assistance and $16,488M in loans.

Source: Data for this graphic compiled by various FCAB members for FCAB.

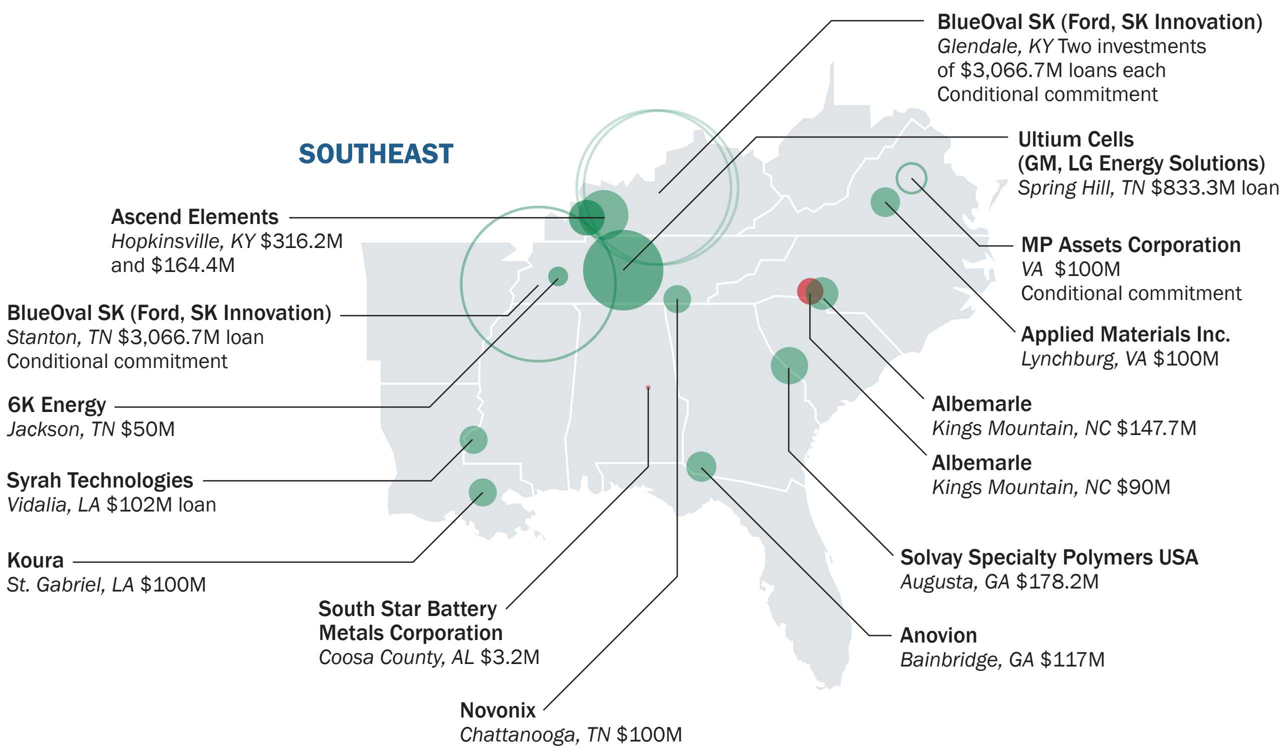
MIDWEST



NORTHEAST



SOUTHEAST

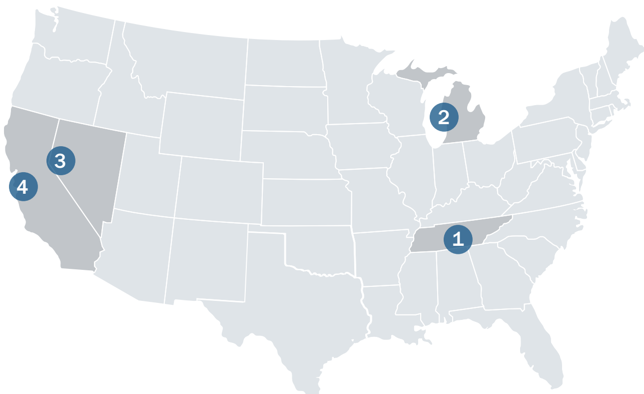


NORTH AMERICAN BATTERY SUPPLY CHAIN

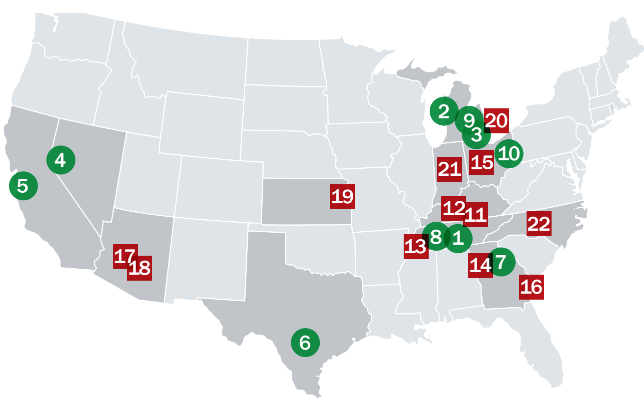
Gigafactories

Active and Planned Battery Plants in the United States

- December 2021
- Active in 2025
- Planned by 2025



Installed EV battery production capacity: **57 GWh**
Implied EV production capacity: **0.6 million**



Installed EV battery production capacity: **296 GWh**
Implied EV production capacity: **3.1 million**
Installed grid battery production capacity: **20 GWh**

December 2021

1 **AESC/Envision**	Smyrna,TN	4.4
2 **LG Energy Solution**	Holland, MI	5
3 **Tesla Battery Pilot Plant**	Sparks, NV	37
4 **Tesla Gigafactory 1**	Freemont, CA	10

2025

Active Plant	Location	Capacity (GWh)
1 **AESC/Envision**	Smyrna,TN	4.4
2 **LG Energy Solution**	Holland, MI	25
3 **ONE**[6]	Van Buren Township, MI	20
4 **Tesla Battery Pilot Plant**	Sparks, NV	100
5 **Tesla Gigafactory 1**	Freemont, CA	10
6 **Tesla Gigafactory 5**	Austin, TX	15
7 **SK Innovation**	Commerce, GA	21.5
8 **Ultium Batteries**	Spring Hill, TN	30
9 **Ultium Batteries**[7]	Lansing, MI	41
10 **Ultium Batteries**[8]	Warren, OH	41

Planned Plant	Location	Capacity (GWh)
11 **AESC/Envision**	Bowling Green, KY	30
12 **BlueOvalSK (Ford/SK)**	Glendale, KY	86
13 **BlueOvalSK (Ford/SK)**	Stanton, TN	43
14 **FREYR**[9]	Newnan, GA	34
15 **Honda/LG Energy Solution**[10]	Jefferson, OH	40
16 **Hyundai**	Bryan County, GA	15
17 **KORE Power**[11]	Buckeye, AZ	12
18 **LG Energy Solution**	Queen Creek, AZ	27
19 **Panasonic**	De Soto, KS	30
20 **Stellantis/LG Energy Solution**	Actual location Canada	45
21 **Stellantis/Samsung**	Kokomo, IN	23
22 **Toyota**	Greensboro, NC	40

Source: Bentley, J. (2023). OEM_EV_Investments_Updated_June_2023. Presentation provided to U.S. Department of Energy; Based on public announcements and publicly available data.

[6] ONE."ONE Announces $1.6 Billion Investment in 20 GWh Michigan Cell Factory Beginning LFP Production in 2024." ONE, 05 October 2022, https://one.ai/news/onecircle. Accessed 14 December 2023.

[7] Ultium Cells. "Lansing, Michigan." Ultium Cells, https://www.ultiumcell.com/our-locations/lansing-mi. Accessed December 28, 2023.

[8] Ultium cells. "Warren, Ohio." Ultium cells. https://www.ultiumcell.com/our-locations/warren-oh. Accessed December 28, 2023.

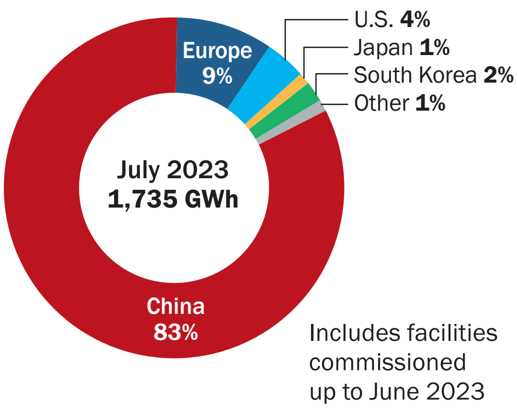
[9] Berntsen, Karen. "FREYR Battery Announces Plans for U.S. Gigafactory in Georgia." FREYR, 11 November 2022, https://www.freyrbattery.com/news/freyr-battery-announces-plans-for-u-s-gigafactory-in-georgia. Accessed 14 December 2023.

[10] Seung Yeon Lee, Sally. "LG Energy Solution and Honda Break Ground for New Joint Venture EV Battery Plant in Ohio." LG Energy Solutions, 28 February 2023, https://lgeshonda.com/lg-energy-solution-and-honda-break-ground-for-new-joint-venture-ev-battery-plant-in-ohio/. Accessed 26 December 2023.

[11] Newton, Aleysha. "KORE Power Receives Conditional Commitment for $850 Million from the U.S. Department of Energy's Loan Programs Office for the KOREPlex Advanced Battery Manufacturing Facility." KORE Power. 09 June 2023. https://korepower.com/media/kore-power-receives-conditional-commitment-for-850-million-from-the-us-department-of-energy-for-the-koreplex. Accessed 14 December 2023.

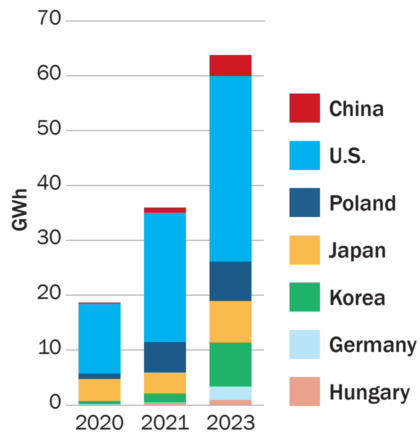
Cell Production

Lithium-cell Manufacturing Capacity by Region of Plant Location



Cell Fabrication

U.S. EV Cells Sourced by Country

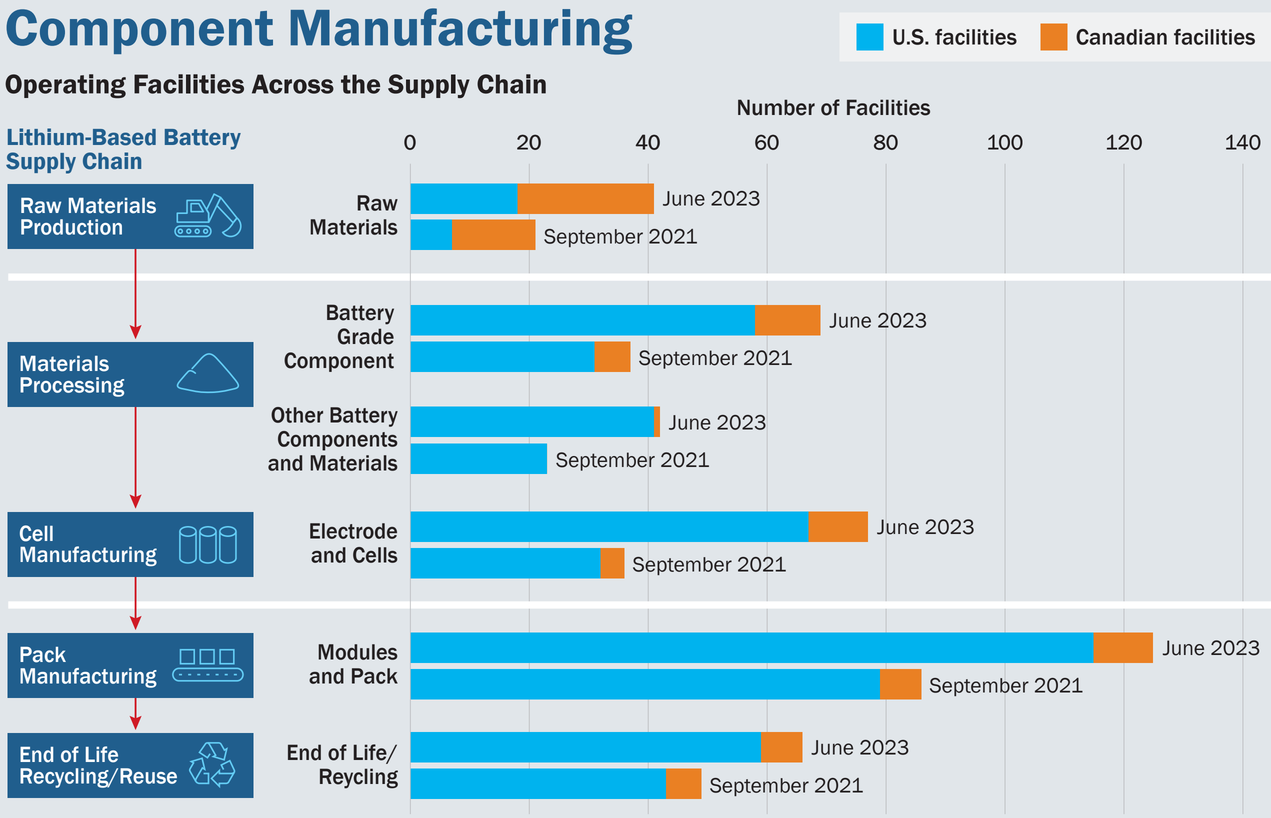


Sourced Country	2020	2021	2022
China	<1%	3%	6%
U.S.	69%	66%	53%
Poland	5%	15%	11%
Japan	21%	11%	12%
Korea	3%	5%	13%
Germany	<1%	<1%	4%
Hungary	<1%	>1%	1%

Sources: (Left) BNEF Long-Term Electric Vehicle Outlook. July 10, 2023. (Right) Gohlke, D., Zhou, Y., Wu, X., and Courtney, C. (2022). Assessment of Light-Duty Plug-in Electric Vehicles in the United States, 2010–2021 (ANL publication No. ANL-22/71). Argonne National Laboratory, Energy Systems and Infrastructure Analysis Division; Zhou, Yan. Light Duty Electric Drive Vehicles Monthly Sales Update—Historical Data. Argonne National Laboratory. https://www.anl.gov/esia/light-duty-electric-drive-vehicles-monthly-sales-updates. Accessed 15 December 2023.

Component Manufacturing

Operating Facilities Across the Supply Chain

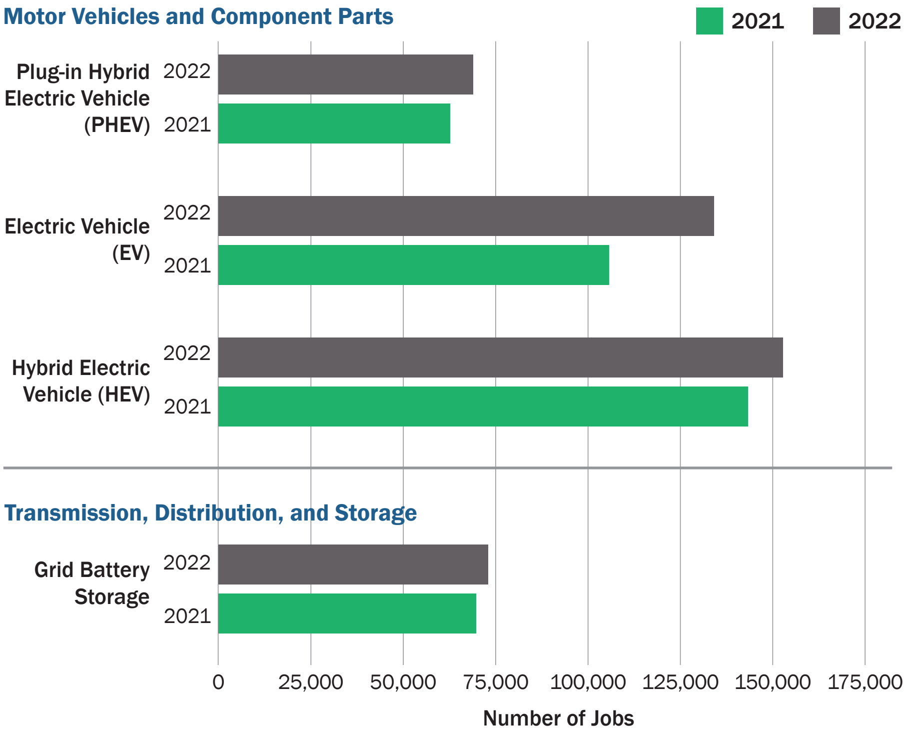


Source: Vicky Putsche, Erik Witter, Shriram Santhanagopalan, Maggie Mann, Ahmad A. Pesaran. National Renewable Energy Laboratory. NAATBatt Lithium-Ion Battery Supply Chain Database: Version 4 June 30, 2023 and National Renewable Energy Laboratory. NAATBatt Lithium-Ion Battery Supply Chain Database. Version 1 September 15, 2021.

Employment

U.S. Employment by Technology, 2021–2022

Competition/small applicant pool was the primary driver of hiring difficulty, according to employers. Lack of experience, training, or technical skills and insufficient non-technical skills (work ethic, dependability, critical thinking) were cited by employers in three out of four industries within motor vehicles and component parts.



One-Year Job Growth
2021–2022

PHEVs: 10%
6,293 jobs

EVs: 27%
28,366 jobs

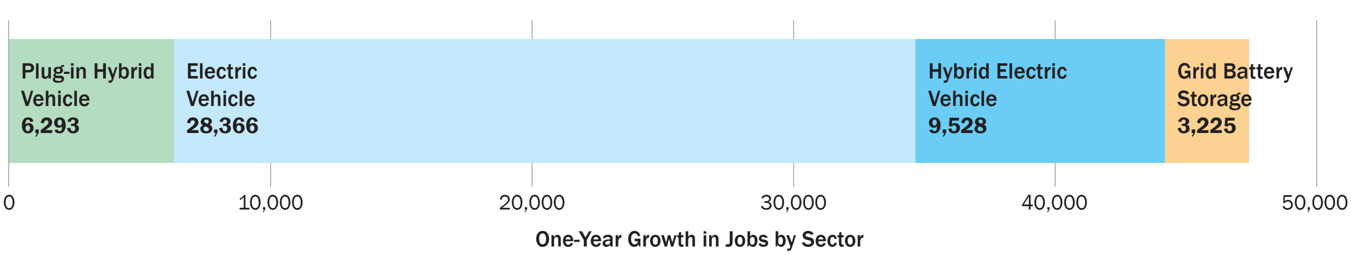
HEVs: 7%
9,528 jobs

Grid Battery Storage: 4.6%
3,225 jobs

There are eight projects underway with over $80M in federal funding to support workforce development for the domestic battery supply chain.

U.S. Job Growth from 2021 to 2022 in Electric Transportation and Grid Battery Storage

Almost a third (31.5%) of battery storage firms classified in transmission, distribution, and storage (TDS) identified vehicles or other transportation as the application of their battery technology.



Source: Office of Policy (2023). United States Energy & Employment Report 2023 (DOE publication No. DOE/OP-0020). U.S. Department of Energy, Office of Policy. U.S. Energy & Employment Jobs Report (USEER) | Department of Energy. Accessed 24 July 2023.

GOAL 1

Secure access to raw and refined materials and discover alternatives for critical minerals for commercial and defense applications

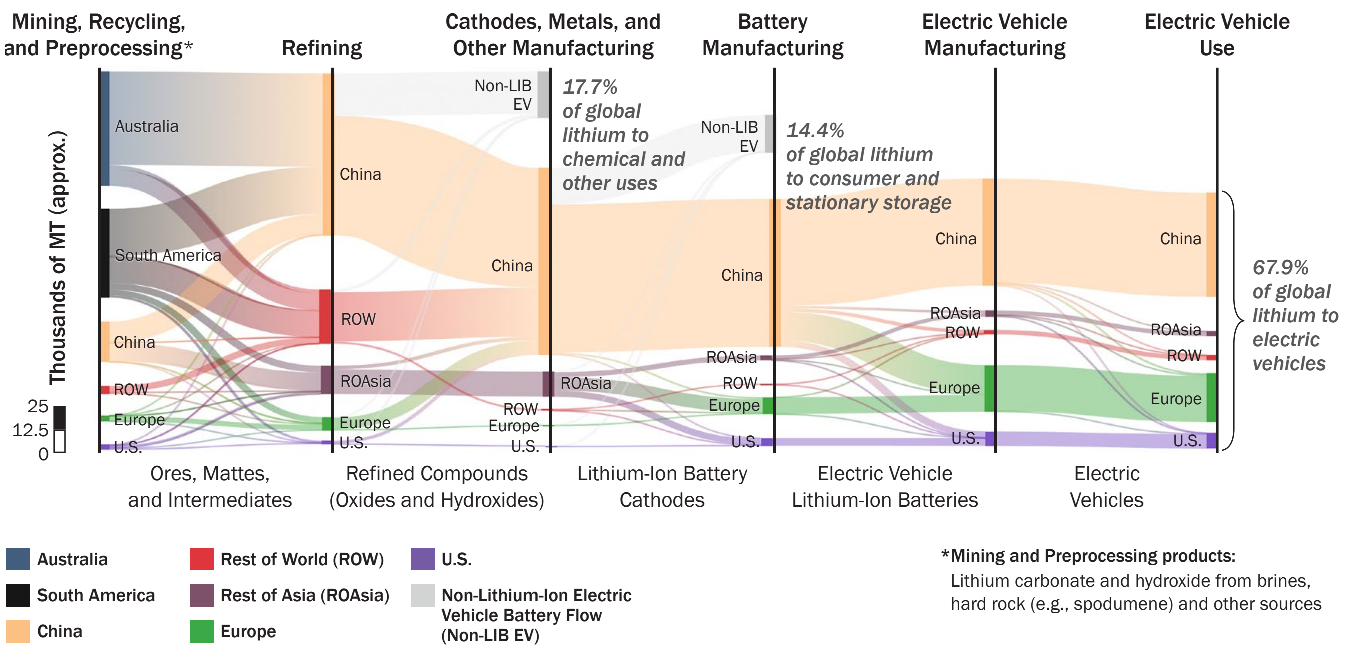
Lithium

Year	U.S. Reserves (1,000 metric tons)	World Reserves (1,000 metric tons)	Total Manufacturing Capacity with U.S. Reserves (GWh)	Total Manufacturing Capacity with World Reserves (GWh)
2021	750	22,000	7,470	209,183
2022	1000*	26,000	9,960	247,216

*U.S. reserves only per USGS. Does not include inferred resources from Salton Sea and other U.S. sites.

Source: Argonne National Laboratory derived from USGS mineral commodities summaries (2022 and 2023) and simulations using BatPaC 4.0 for Li-ion batteries with $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ cathode.

AT THE END OF 2022



Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2023, https://doi.org/10.3133/mcs2023; UN COMTRADE Database, https://comtradeplus.un.org, "Global Lithium Outlook 2020-2030", 1H 2023 Battery Materials Outlook, 2023 Long Term Electric Vehicle Outlook, and Battery Material Manufacturing database, https://www.bnef.com.

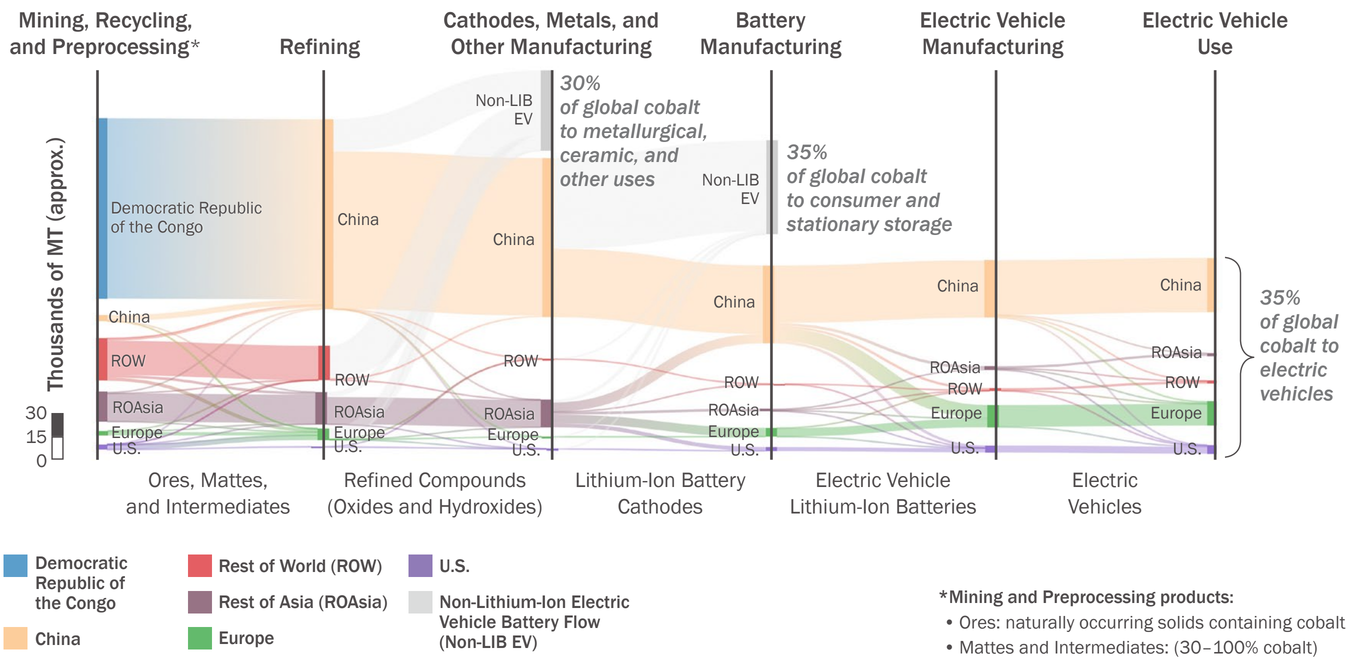
TAKEAWAYS *The EV market and lithium use has overtaken other use markets. Australia and South America continue to lead production in the upstream mining/processing/recycling of lithium, while China continues to control the mid-stream refining segment, with subsequent downstream production. There has been growth within midstream refining for both the rest of Asia and rest of world segments, showing diversification of the lithium supply chain.*

Cobalt

Year	U.S. Reserves (1,000 metric tons)	World Reserves (1,000 metric tons)	Total Manufacturing Capacity with U.S. Reserves (GWh)	Total Manufacturing Capacity with World Reserves (GWh)
2021	69	7,600	915	100,795
2022	69	8,300	915	110,079

Source: Argonne National Laboratory derived from USGS mineral commodities summaries (2021 and 2022) and simulations using BatPaC 4.0 for Li-ion batteries with $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ cathode.

AT THE END OF 2022



*Mining and Preprocessing products:
- Ores: naturally occurring solids containing cobalt
- Mattes and Intermediates: (30–100% cobalt)

Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2023, https://doi.org/10.3133/mcs2023; UN COMTRADE Database, https://comtradeplus.un.org/, "Global Cobalt Outlook 2020-2030", 1H 2023 Battery Materials Outlook, 2023 Long Term Electric Vehicle Outlook, and Battery Material Manufacturing database, https://www.bnef.com.

TAKEAWAYS *The Democratic Republic of the Congo continues to lead mining production of cobalt, feeding Chinese refining and manufacturing downstream. There has been growth within midstream refining for both the rest of Asia and rest of world segments, showing some diversification of the cobalt supply chain.*

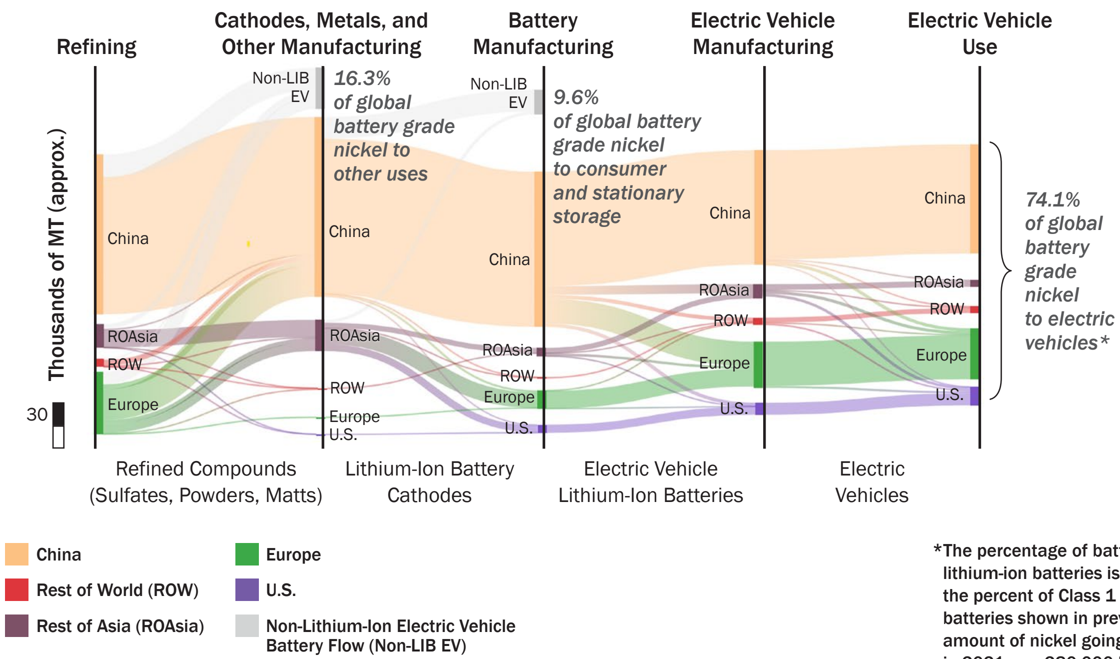
Nickel

Year	U.S. Reserves (1,000 metric tons)	World Reserves (1,000 metric tons)	Total Manufacturing Capacity with U.S. Reserves (GWh)	Total Manufacturing Capacity with World Reserves (GWh)
2021	340	>95,000	568	158,175
2022	370	>100,000	618	166,500

Source: Argonne National Laboratory derived from USGS mineral commodities summaries (2021 and 2022) and simulations using BatPaC 4.0 for Li-ion batteries with $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ cathode.

BATTERY GRADE NICKEL AT THE END OF 2022

Battery grade nickel is battery grade nickel sulfate and is primarily a subset of Class 1 nickel and recently Class 2.



*The percentage of battery grade nickel going to lithium-ion batteries is considerably higher than the percent of Class 1 nickel going to lithium-ion batteries shown in previous year's report. The final amount of nickel going to all lithium-ion batteries in 2021 was 280,000 MT and 300,000 MT in 2022.

Sources: NREL Analysis; USGS,"Mineral Commodity Summaries" 2023, https://doi.org/10.3133/mcs2023; UN COMTRADE Database, https://comtradeplus.un.org/ "Global Nickel Outlook 2020-2030", 1H 2023 Battery Materials Outlook and Battery Material Manufacturing Database, https://www.bnef.com.

TAKEAWAYS *Though other countries lead in production of mined nickel, refining of class 1, battery grade nickel and downstream manufacturing is currently led by China, with Europe showing growth from 2021 to 2022.*

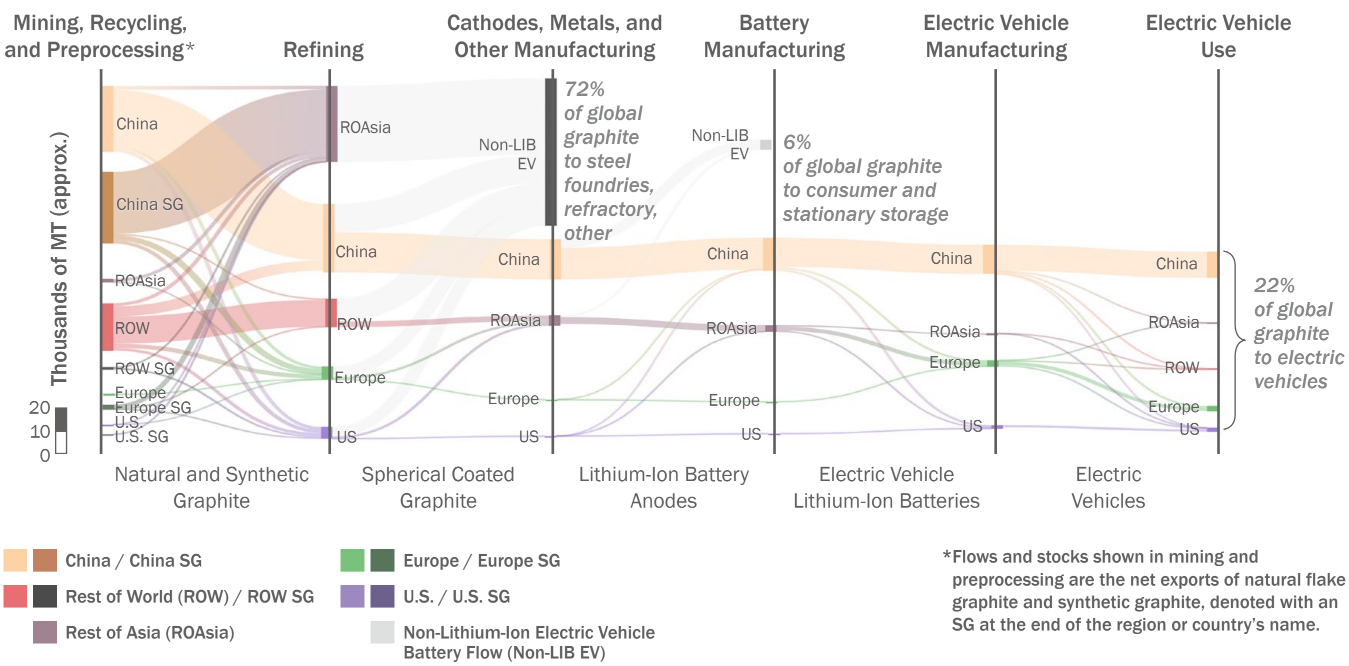
Graphite

Year	U.S. Reserves (1,000 metric tons)	World Reserves (1,000 metric tons)	Total Manufacturing Capacity with U.S. Reserves (GWh)	Total Manufacturing Capacity with World Reserves (GWh)
2021	—	320,000	—	350
2022	*	330,000	—	361

*Per USGS: "North America produced only 1.2% of the world's graphite supply with production in Canada and Mexico. Three companies were developing graphite-mining projects in the United States—two in Alabama and one in Alaska. Two spherical graphite plants were in construction during 2022, located in Kellyton, AL, and Vidalia, LA, with production expected to begin during 2023."

Source: Argonne National Laboratory derived from USGS mineral commodities summaries (2021 and 2022) and simulations using BatPaC 4.0 for Li-ion batteries with $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ cathode.

AT THE END OF 2022



*Flows and stocks shown in mining and preprocessing are the net exports of natural flake graphite and synthetic graphite, denoted with an SG at the end of the region or country's name.

Sources: NREL Analysis; USGS,"Mineral Commodity Summaries" 2023, https://doi.org/10.3133/mcs2023; UN COMTRADE Database, https://comtradeplus.un.org/; Global Graphite Outlook 2020–2030", 1H 2023 Battery Minerals Outlook and Battery Material Manufacturing database, https://www.bnef.com; Miller, G. 2021. "Natural and Synthetic Graphite: A Strategic Review, Presented at Benchmark Week Online 2021, 6 December 2021; Dua, M. "Graphite Market Overview", presented at Benchmark Week 2021, 6 December 2021.

TAKEAWAYS *China controls early-stage production of both natural and synthetic graphite. China is also a major player in later stage production of spherical coated graphite and lithium-ion battery anodes from graphite. Export bans by China may affect supply chain movement of graphite in coming years.*

Manganese

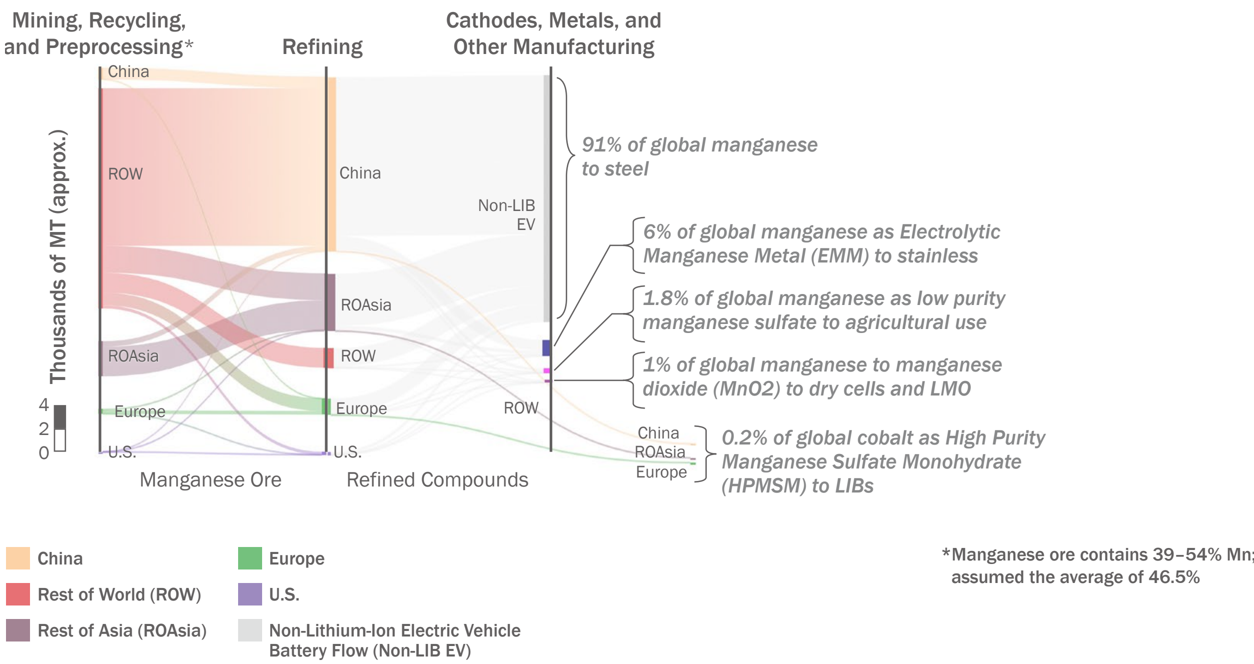
Year	U.S. Reserves (1,000 metric tons)	World Reserves (1,000 metric tons)	Total Manufacturing Capacity with U.S. Reserves (GWh)	Total Manufacturing Capacity with World Reserves (GWh)
2021	—	1,500,000	—	21,337,126
2022	*	1,700,000	—	24,182,087

*Land-based manganese resources are large but irregularly distributed; those in the United States are very low grade and have potentially high extraction costs.

Source: Argonne National Laboratory derived from USGS mineral commodities summaries (2021 and 2022) and simulations using BatPaC 4.0 for Li-ion batteries with $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ cathode.

AT THE END OF 2022

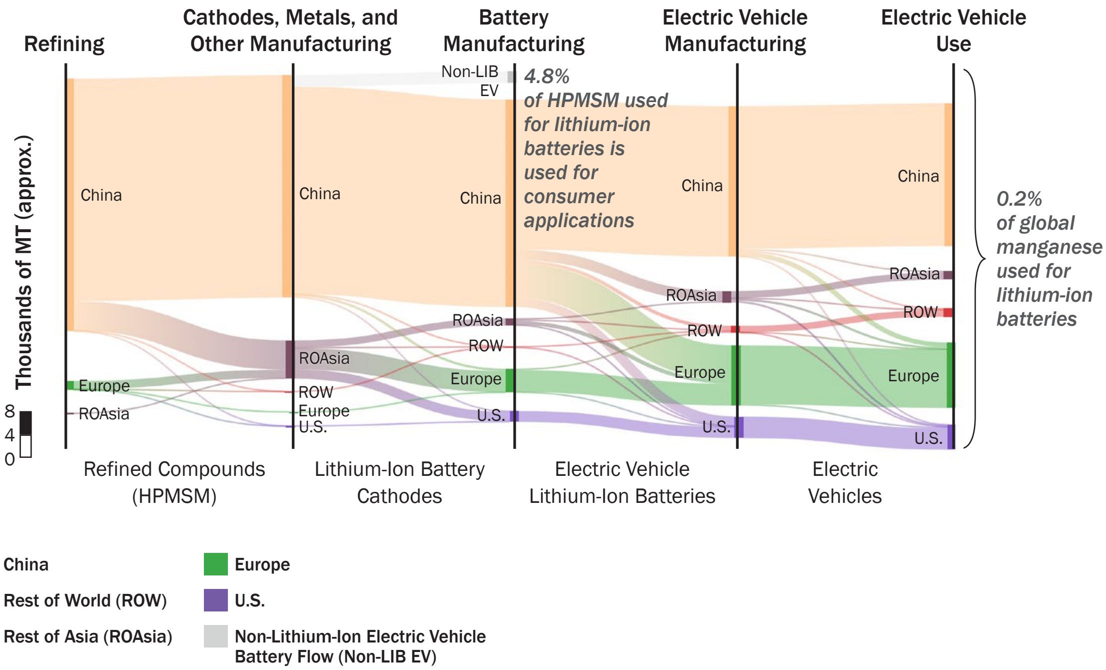
Upstream stages of manganese mining, recycling, and processing



Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2023, https://doi.org/10.3133/mcs2023; UN COMTRADE Database, https://comtradeplus.un.org/, "Global Manganese Outlook 2020-2030", 1H 2023 Battery Materials Outlook, 2023 Long Term Electric Vehicle Outlook, and Battery Material Manufacturing database, https://www.bnef.com.

TAKEAWAYS *Only 0.2% of the mined manganese feeds into the current Li-ion battery supply chain via high purity manganese sulfate, a number that has remained steady between 2021 and 2022. Upstream raw manganese resources come from a wide array of countries, with China continuing to lead refining through battery manufacturing for manganese.*

Downstream stages for the battery supply chain



Sources: NREL Analysis; USGS,“Mineral Commodity Summaries”; 2023, https://doi.org/10.3133/mcs2023; UN COMTRADE Database, https://comtradeplus.un.org/, “Global Manganese Outlook 2020-2030”, 1H 2023 Battery Materials Outlook, 2023 Long Term Electric Vehicle Outlook, and Battery Material Manufacturing database, https://www.bnef.com.

GOAL 2

Support the growth of a U.S. materials-processing base able to meet domestic battery manufacturing demand

Component Overview

AS REPORTED IN THE NATIONAL BLUEPRINT FOR LITHIUM BATTERIES 2021–2030

Country	Cathode Manufacturing (3 M metric tons)	Anode Manufacturing (1.2 M metric tons)	Electrolyte Manufacturing (339,000 metric tons)	Separator Manufacturing (1,987 M sq. m)
United States	—	10%	2%	6%
China	42%	65%	65%	43%
Rest of Asia	48%	25%	16%	49%

Source: BloombergNEF, Battery Components Manufacturing Asset Map. 2019.

AT THE END OF 2022

Country	Cathode Manufacturing (4.7 M metric tons)	Anode Manufacturing (4.5 M metric tons)	Electrolyte Manufacturing (1.9 M metric tons)	Separator Manufacturing (15,895 M sq. m)
United States	0.2%	0.1%	3.8%	0.6%
China	84.3%	96.3%	86.1%	82.5%
Rest of Asia	15.3%	3.6%	6.4%	14.1%
Europe	0.1%	—	3.7%	2.8%
Rest of World	0.1%	—	—	—

Source: BloombergNEF, Battery Components Manufacturers Interactive Dataset. July 10, 2023. This is an interactive dataset which originator can modify as data fidelity improves on past and future entries. Therefore, capacity calculations may vary from year to year as accuracy of information increases and quantification metrics are refined.

TAKEAWAYS *China remains in control of major battery component manufacturing sectors. There has been growth in the cathode market in Rest of Asia, particularly in Japan and Korea. For electrolyte mix manufacturing, there has been growth in the United States though much of the upstream electrolyte salt still is centralized in China. For separators, there is growth in the European and Rest of Asia markets, particularly in Japan.*

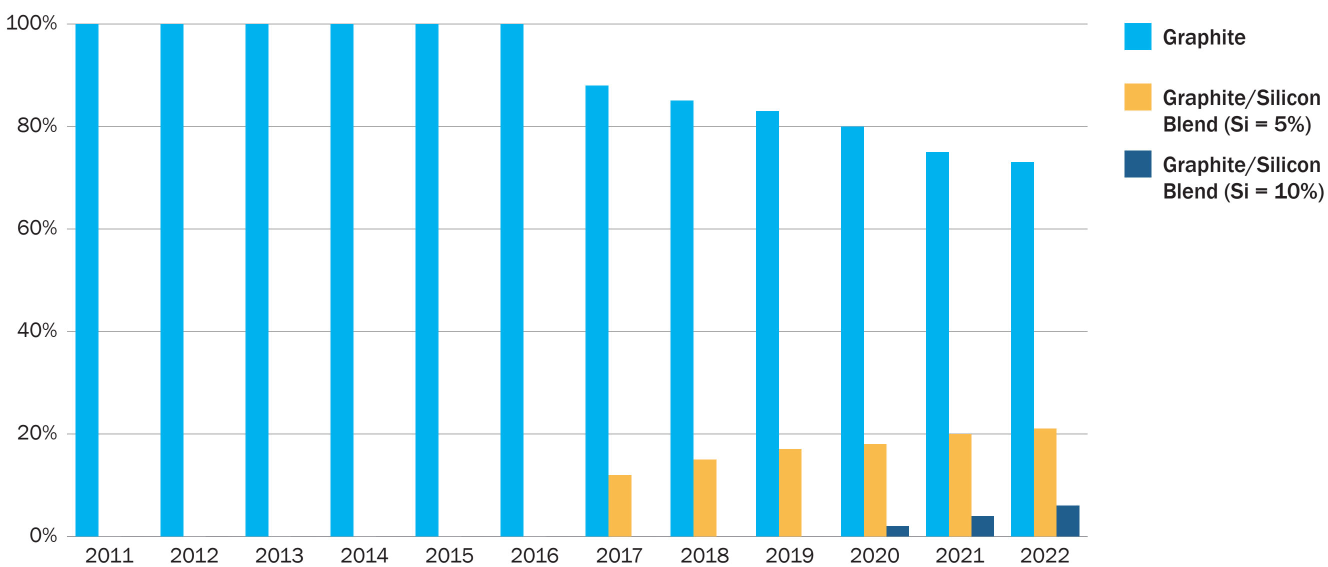
Anode

Country	2021 Anode Manufacturing (3.3 M metric tons)	2022 Anode Manufacturing (4.5 M metric tons)
United States	0.1%	0.1%
China	91.5%	96.3%
Rest of Asia	6.6%	3.6%
Europe	1.8%	—
Rest of World	—	—

Source: BloombergNEF Long-Term Electric Vehicle Outlook, Battery Components Manufacturers Interactive Dataset. Accessed July 10, 2023.

AT THE END OF 2022

Use of Different Chemistries in Anodes Over Time



Source: BloombergNEF Long-Term Electric Vehicle Outlook, Lithium- and Sodium-ion Electric Vehicle Battery Anode Chemistry Outlook. July 10, 2023.

TAKEAWAYS *China remains in control of anode manufacturing for all major chemistries (natural graphite, synthetic graphite, graphite-silicon blend, etc.).*

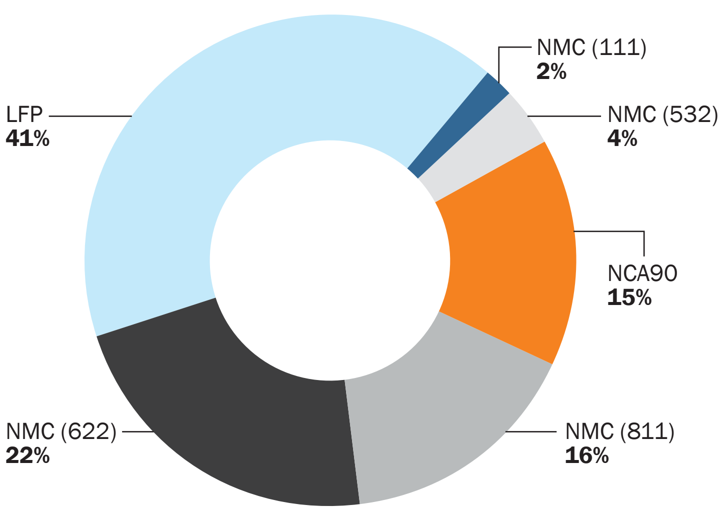
Cathode

Country	2021 Cathode Manufacturing (8.3 M metric tons)	2022 Cathode Manufacturing (4.7 M metric tons)
United States	0.1%	0.2%
China	85.9%	84.3%
Rest of Asia	10%	15.3%
Europe	4%	0.1%
Rest of World	>0.1%	0.1%

Source: BloombergNEF Long-Term Electric Vehicle Outlook, Battery Components Manufacturers Interactive Dataset. Accessed July 10, 2023.

AT THE END OF 2022

2022 Cathode Production Mix



Source: BloombergNEF, Long-Term Electric Vehicle Outlook 2023—Data: Evolution of cathode chemistry across all passenger electric vehicle segments, June 8, 2023.

Cathode Materials

NMC: Lithium Nickel Manganese Cobalt Oxide

NMCA: Lithium Nickel Manganese Cobalt Aluminum Oxide

NCA: Lithium Nickel Cobalt Aluminum Oxide

LNO: Lithium Nickel Oxide

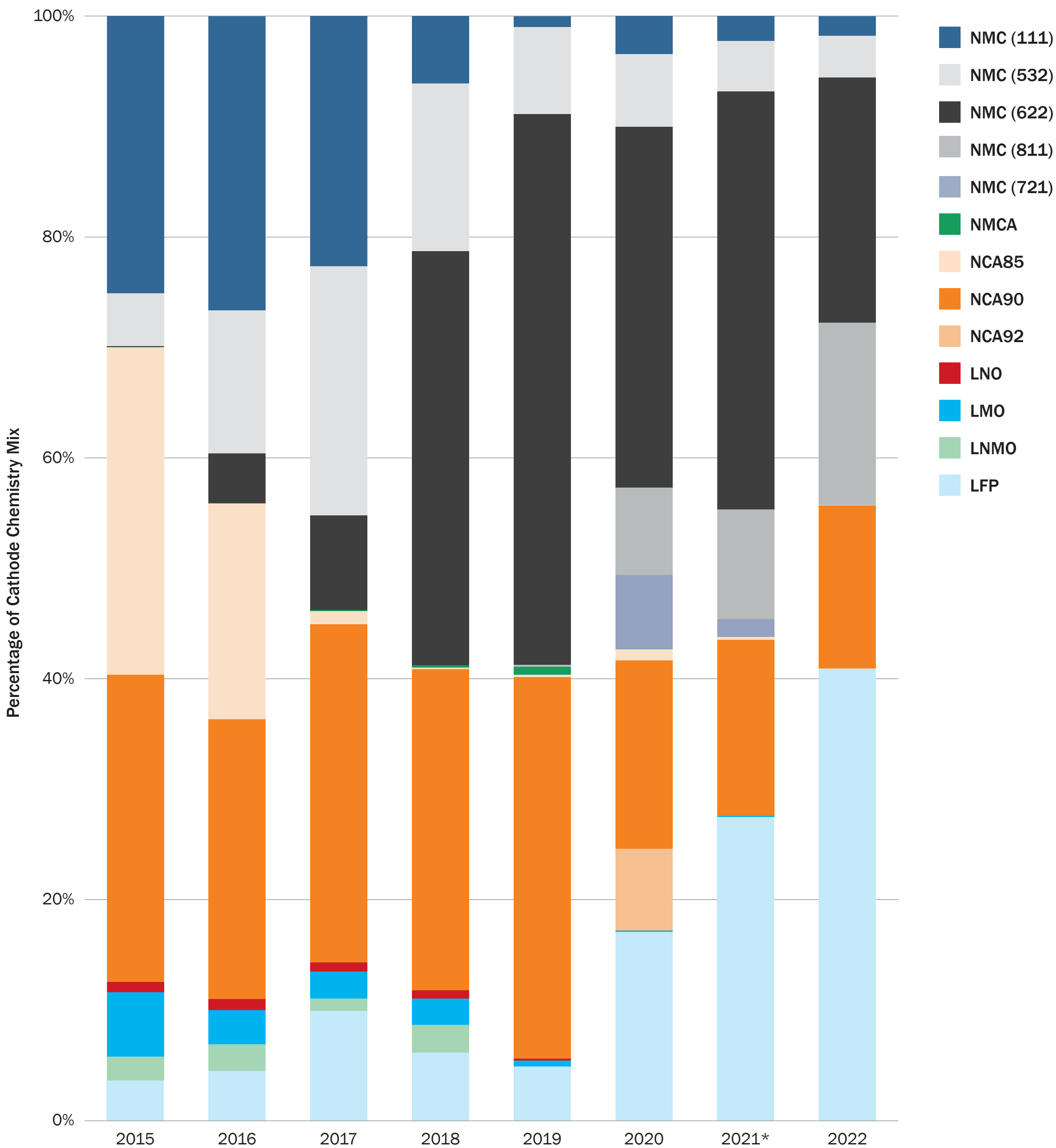
LMO: Lithium Manganese Oxide

LNMO: Lithium Manganese Nickel Oxide

LFP: Lithium Iron Phosphate

TAKEAWAYS *China leads cathode manufacturing. Cathode chemistry mix has changed over time, with Lithium Iron Phosphate (LFP) accounting for 41% of cathode production, a decrease compared to 2021, which is mostly from Chinese production.*

Evolution of Cathode Chemistry Across All Passenger Electric Vehicle Segments



*This data represents the most up to date information available. Differences with previous year's data and reporting are attributable to changes in dataset assumptions including battery pack sizes and reclassification of certain car models.

Source: BloombergNEF, Long-Term Electric Vehicle Outlook 2023—Data: Evolution of cathode chemistry across all passenger electric vehicle segments, June 8, 2023.


NiSO4
(Nickel Sulfate)
NiSO4
(Nickel Sulfate)
MnS04
(Manganese Product)
CoSO4
(Cobalt Sulfate)
CoSO4
(Cobalt Sulfate)
Lithium Product (LCE)
(Lithium Carbonate Equivalent)

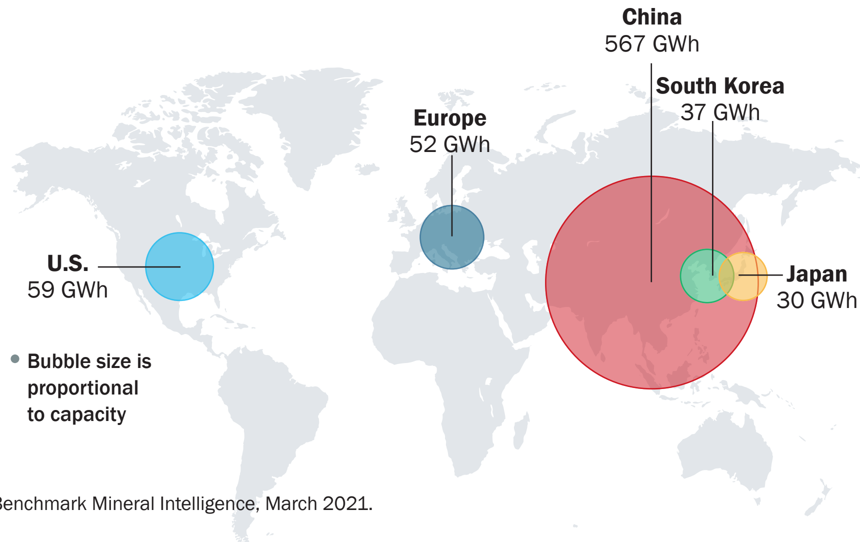
GOAL 3

Stimulate the U.S. electrode, cell, and pack manufacturing sectors

Cell Production

AS REPORTED IN THE NATIONAL BLUEPRINT FOR LITHIUM BATTERIES 2021–2030

Cell Manufacturing Capacity by Country or Region

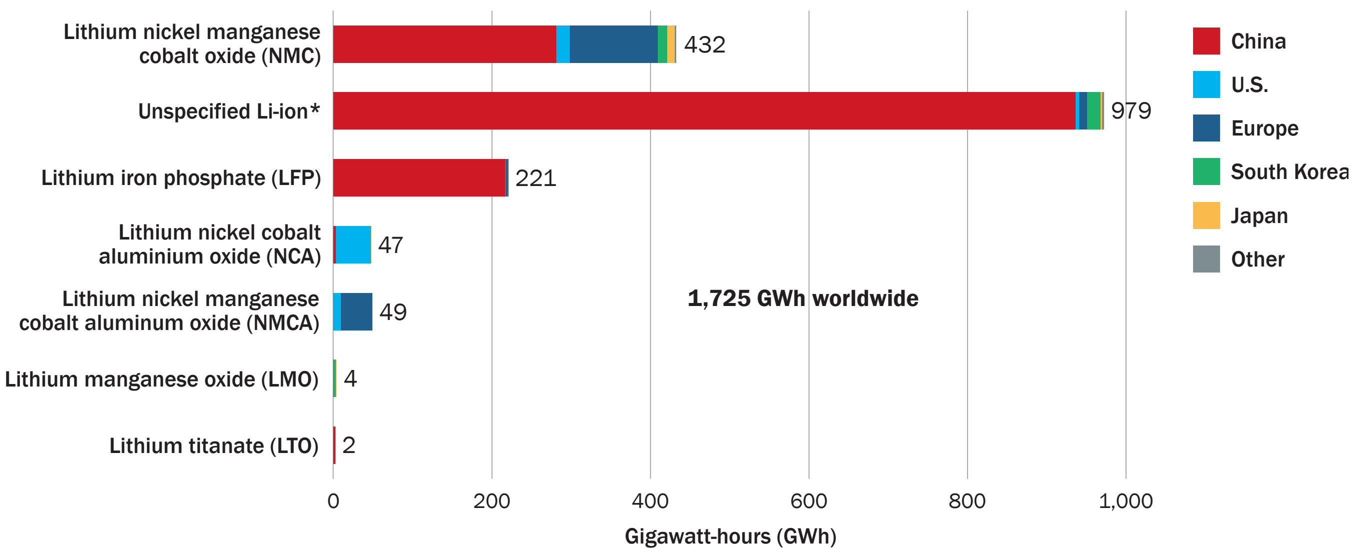


Source: "Lithium-Ion Battery Megafactory Assessment", Benchmark Mineral Intelligence, March 2021.

IN JULY 2023

Utilized Battery Capacity by Chemistry

Battery R&D pack cost (2023) $118/KWh[12]



*This data represents the most up to date information available. Differences with previous year's data and reporting are attributable to changes in dataset assumptions.

Source: BloombergNEF, Battery Component Manufacturers Interactive Dataset, July 10, 2023. Includes facilities commissioned up to June 2023.

TAKEAWAYS *Cell and pack production costs continue to fall, meeting or exceeding Goal 3 targets.*

[12] Cost estimate of battery pack rated energy. Argonne National Laboratory. BatPaC—A Spreadsheet Tool to Design a Lithium Ion Battery and Estimate Its Production Cost. https://www.anl.gov/cse/batpac-model-software. Accessed December 12, 2023.

GOAL 4

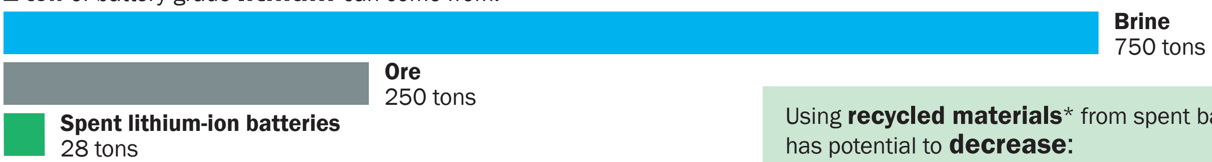
Enable U.S. end-of-life reuse and critical materials recycling at scale and a full competitive value chain in the United States

Reuse and Recycle

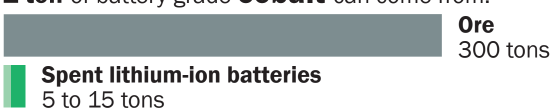
AS REPORTED IN THE NATIONAL BLUEPRINT FOR LITHIUM BATTERIES 2021–2030

Benefits of Recycling for Lithium-ion Batteries

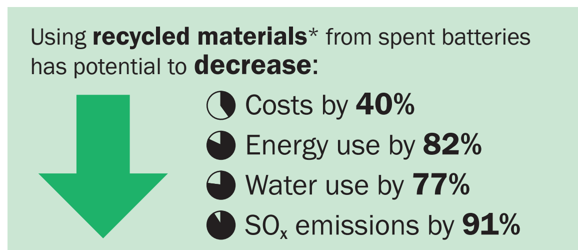
1 ton of battery-grade **lithium** can come from:



1 ton of battery-grade **cobalt** can come from:



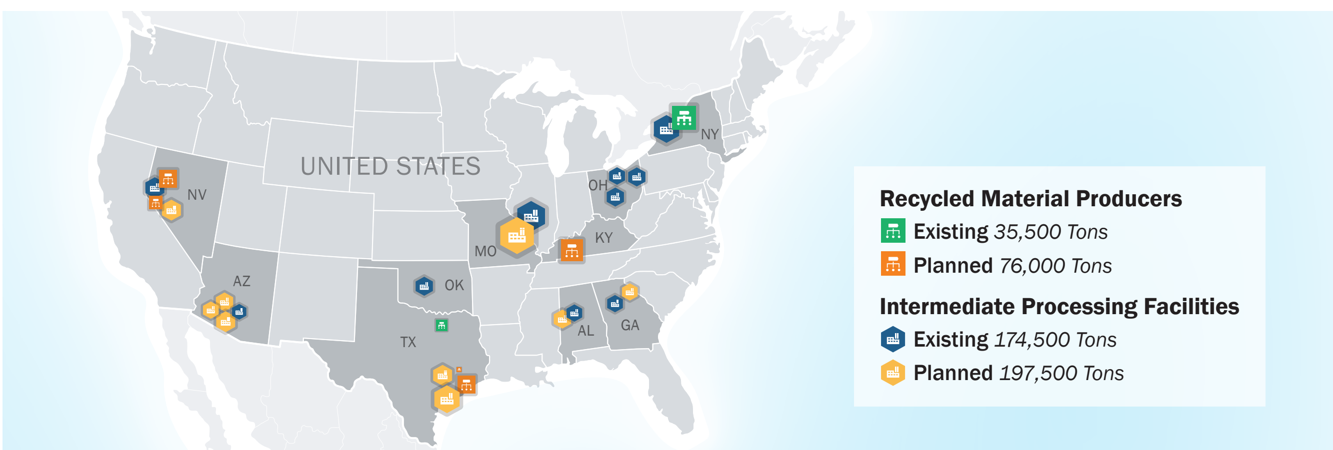
Source: Data from Argonne National Laboratory's ReCell Center, 2019.[13]



*Assumes a direct recycling method

AT THE END OF FY2023

Domestic Battery Recyclers Potential Capacity, 2022–2023



Source: Data for this graphic compiled by various FCAB members for FCAB.

TAKEAWAYS *Existing capacity to make black mass* has tripled since 2022. Capacity to recover cathode materials from black mass has grown more slowly in the last year. Foreign demand for non-U.S. processing of black mass has driven overcapacity of its production domestically.*

*Black mass is a mixture of residual cell materials that is the product of intermediate processing for recycling, typically isolated after shredding cells and sieving.

[13] Gaines L, Dai Q, Vaughey JT, Gillard S. Direct Recycling R&D at the ReCell Center. Recycling. 2021; 6(2):31. https://doi.org/10.3390/recycling6020031. Accessed May 27, 2021.

GOAL 5

Maintain and advance U.S. battery technology leadership by strongly supporting scientific R&D, STEM education, and workforce development

Innovation

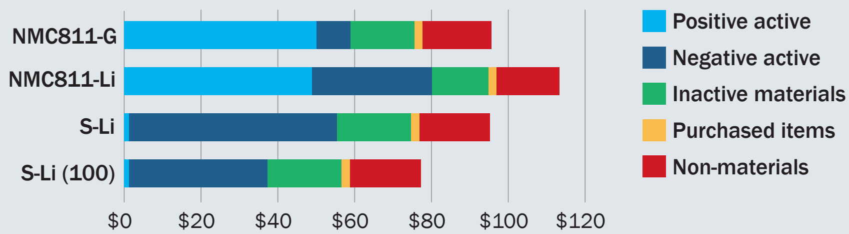
Develop Next-Generation Batteries Using Lithium as the Negative Electrode

Li/high-Ni NMC (Liquid Electrolyte)
500 Wh/kg, 1,000 cycles

Li/S (Liquid Electrolyte)
NEAR TERM:
300 Wh/kg, 1,000 cycles, low cost
LONG TERM:
500 Wh/kg, 1,000 cycles

Solid-state Electrolyte
>3 mS cm^{-1} at 25°C

Modeled Cost of Li-Based EV Battery Cell Advanced Technologies
Assuming technology meets EV performance requirements.

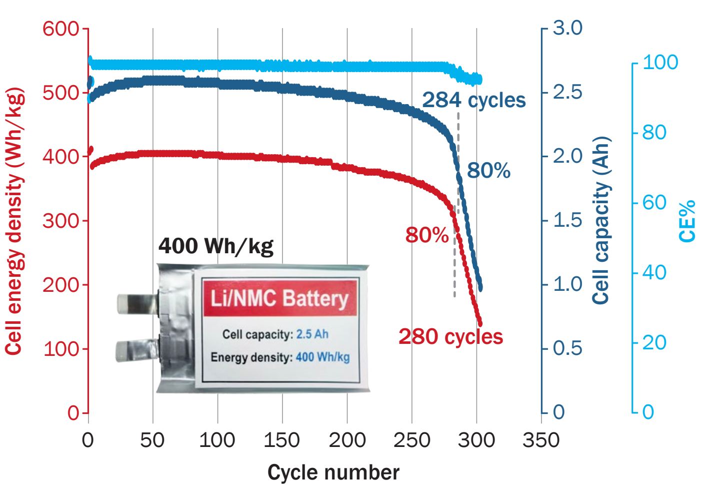


Assumptions:

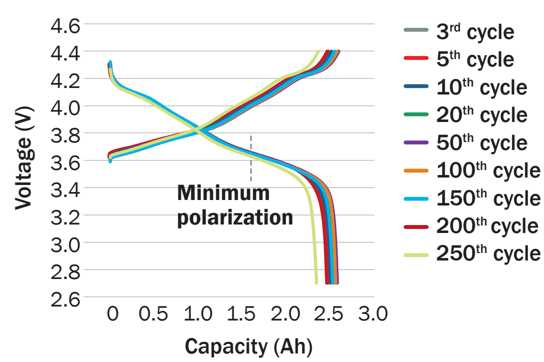
Cathode-Anode	NMC811-G	NMC811-Li	S-Li	S-Li (100)
Cathode Price, $/kg	34.5	34.5	3	3
Anode Price, $/kg	9	150	150	100
N:P Ratio	1.1	2.5	2.5	2.5
Pack Power, kW	300	300	300	300
Pack Energy, kWh	100	100	100	100

Source: Shabbir Ahmed et. al., Argonne National Laboratory, NMC-Li Julieta Francis 30Nov23 BatPaC5 8Mar2022—v49.xlsm, BatPaC 5.0 [2022], doi: 10.2172/1877590

Moving Towards 500 Wh/kg through Innovation Integration



Charge and Discharge Curve



Formation: C/10 charge and discharge for 2 cycles; Subsequent cycling: C/10 Charge, 0.3C Discharge 2.7-4.4V @25°C

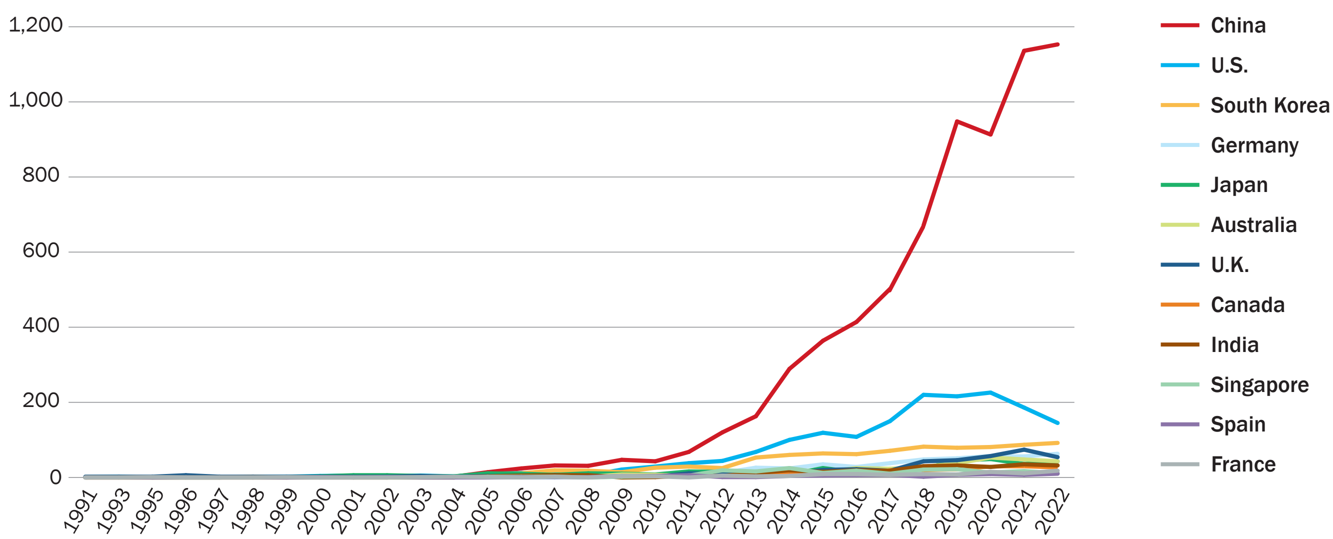
Source: Liu, Jun. Progress and Status of Battery500 Consortium Phase II. June 2023, https://www1.eere.energy.gov/vehiclesandfuels/downloads/2023_AMR/bat317_liu_2023_o%20-%20jun%20liu.pdf. PowerPoint Presentation.

Publications

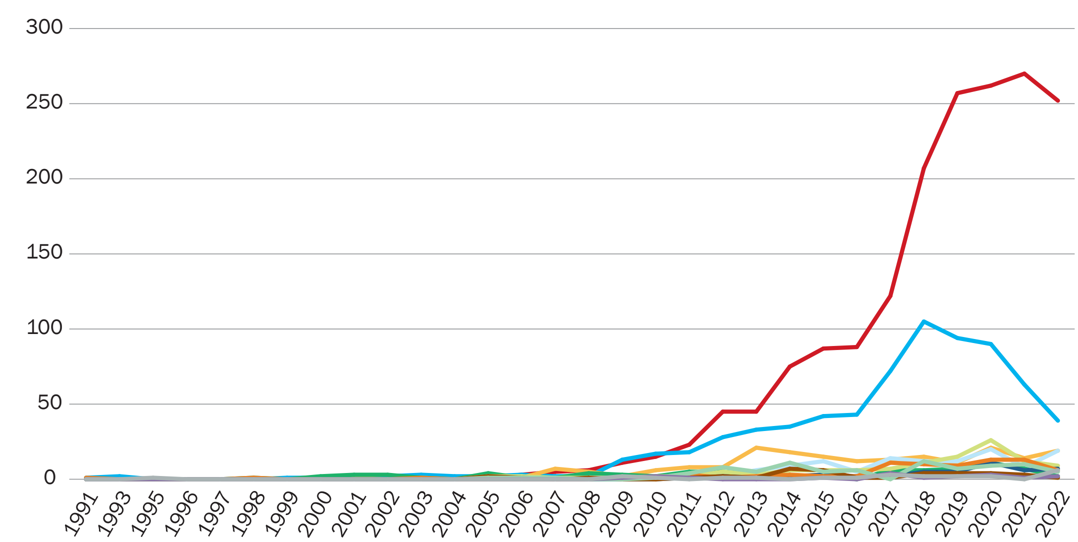
Objective: Retrospective analysis to quantify U.S. investment in battery technologies

Impact: Metrics to inform and to ensure U.S. leadership in battery innovations

Number of Li Metal Publications



Number of Top 10% Cited Li Metal Publications



Source: Data for these graphics compiled by Argonne National Laboratory from various sources for FCAB.

TAKEAWAYS *The gap between Chinese and all other publications is widening.*

DOE/MESC-0107

www.energy.gov/mesc/federal-consortium-advanced-batteries-fcab