FCAB

FEDERAL CONSORTIUM FOR ADVANCED BATTERIES

FEDERAL CONSORTIUM FOR ADVANCED BATTERIES FY2022 END OF YEAR REPORT

ORIGINAL DATE: December 1, 2022

REVISED DATE: August 2024


ENERGY STORAGE
BATTERY
ENERGY STORAGE

A Message from the FCAB Leadership

The Federal Consortium for Advanced Batteries (FCAB) was formed to foster strategic alignment, coordination, and collaboration across the Agencies to support the establishment of a resilient domestic battery manufacturing and technology supply chain that serves commercial and military end-use applications.

This FCAB End-of-Year Report summarizes the status of the domestic lithium-ion battery industry including the supply chain and technology advancements. The information in this report is provided in the context of the National Blueprint Goals to show progress and gaps in key areas of the lithium battery supply chain and assess our impact on domestic batteries as we continue our work.

Over the last year U.S. passenger EVs sales (and hence battery sales) have grown 97%[1]. As battery costs continue to drop, and more states enact laws requiring cleaner transportation, EV sales are expected to increase. Additionally, in September 2022, four agencies signed a Memorandum of Understanding on Transportation Decarbonization and are working towards a government-wide Blueprint which extends beyond the passenger vehicle market.

It has been a historic year of federal investments in clean energy since the release of the National Blueprint. Four major pieces of legislation were passed (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), Additional Ukraine Supplemental Appropriations Act, and the Inflation Reduction Act (IRA)), allocating over $18 billion towards domestic research, development, demonstration, and deployment of advanced batteries' manufacturing and supply chains, as well as end-use incentives over the next five years. Many of these funds require a cost share component from the industry which will only serve to grow the investment in batteries within the United States. This legislation will help position the U.S. as a leader not only in the technological development of these important components, but also their responsible fabrication.

Participation in FCAB spans across 16 different Federal agencies representing 58 different offices within those agencies. FCAB task groups are working closely to develop and implement strategies to achieve the goals laid out in the National Blueprint for Lithium Batteries. FCAB plays a critical role in assuring that Federal government resources are poised to accelerate the development of a robust, secure domestic industrial base for lithium battery technologies.

David Howell, FCAB Chair
Department of Energy
Office of Manufacturing and Energy Supply Chains

Diana Bauer
Department of Energy
Office of Energy Efficiency and Renewable Energy

Oliver Fritz
Department of Defense
Office of Environment and Energy Resilience

Eric Shields
Department of Defense
Office of Industrial Base Policy

Daphne Fuentevilla
Department of Defense
U.S. Navy, Operational Energy, Research Development and Acquisition

Anne Ahrendsen
Department of Commerce
International Trade Administration

Dan Birns
Department of State
Office of Energy Transformation

[1] New Plug-in Electric Vehicle Sales in the United States Nearly Doubled from 2020 to 2021 | Department of Energy. Accessed 27 Sept 2022.

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[2] 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.[3] 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.

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[2] 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.

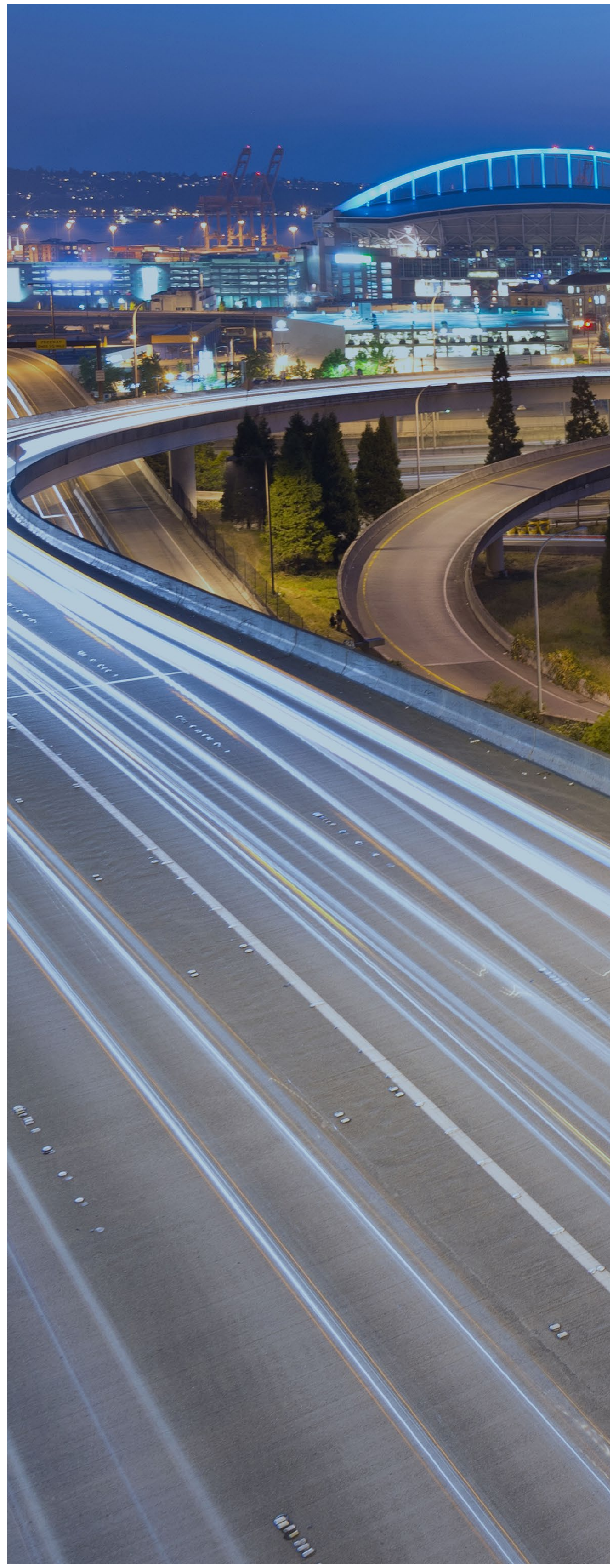
[3] U.S. Department of Energy, Energy Storage Grand Challenge Roadmap, 2020, Page 48. https://www.energy.gov/sites/default/files/2020/12/f81/Energy%20Storage%20Grand%20Challenge%20Roadmap.pdf. Accessed May 27, 2021.

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

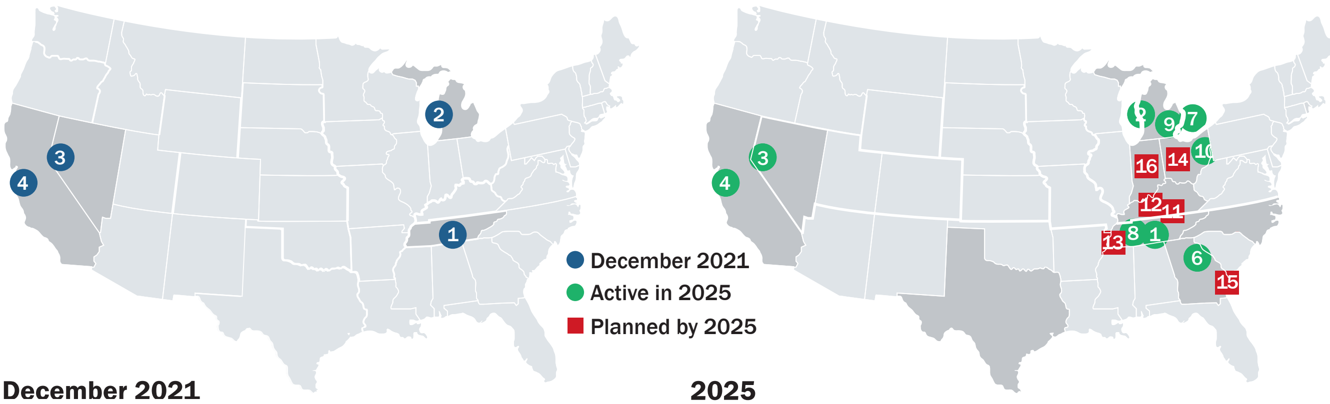
Establishing a competitive and equitable domestic lithium-battery supply chain in an accelerating EV and grid storage market is only one phase of a global surge toward higher performance and lower costs as part of a new zero-carbon energy economy. The pipeline of R&D, ranging from new electrode and electrolyte 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.



NORTH AMERICAN BATTERY SUPPLY CHAIN

Gigafactories

Active and Planned Battery Plants in the United States



December 2021

Installed EV battery production capacity: **57 GWh**

Implied EV production capacity: **0.6 million**

Active Plant	Location	Capacity (GWh)
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

Installed EV battery production capacity: **363 GWh**

Implied EV production capacity: **3.9 million**

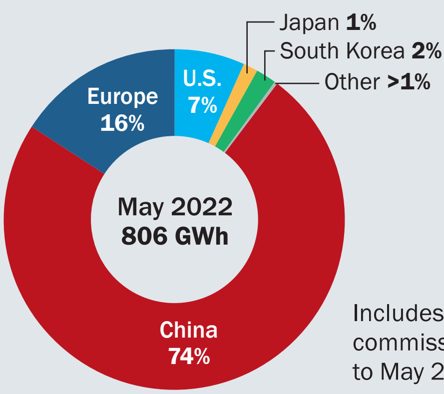
Active Plant	Location	Capacity (GWh)
1 **AESC/Envision**	Smyrna,TN	4.4
2 **LG Energy Solution**	Holland, MI	25
3 **Tesla Battery Pilot Plant**	Sparks, NV	37
4 **Tesla Gigafactory 1**	Freemont, CA	10
5 **Tesla Gigafactory 5**	Austin, TX	100
6 **SK Innovation**	Commerce, GA	21.5
7 **Stellantis/LG Energy Solution**	Actual location Canada	45
8 **Ultium Batteries**	Spring Hill, TN	30
9 **Ultium Batteries**	Lansing, MI	60
10 **Ultium Batteries**	Lordstown, OH	30

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 **Honda/LG Energy Solution**[4]	Jeffersonville, OH	40
15 **Hyundai**	Bryan County, GA	30
16 **Stellantis/Samsung**	Kokomo, IN	23
17 **Toyota**	Greensboro, NC	40

Source: Bentley, J. (2022). *OEM_EV_Investments_Updated_September_2022*. Presentation provided to U.S. Department of Energy.

Cell Production

Lithium-cell Manufacturing Capacity by Region of Plant Location



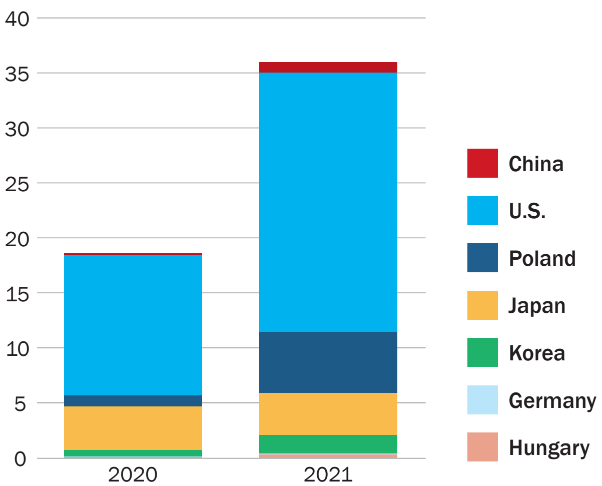
Includes facilities commissioned up to May 2022

Source: BloombergNEF, Long-Term Electric Vehicle Outlook 2022—Data, 01 June 2022.

[4] 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.

Cell Fabrication

U.S. EV Cells Sourced by Country



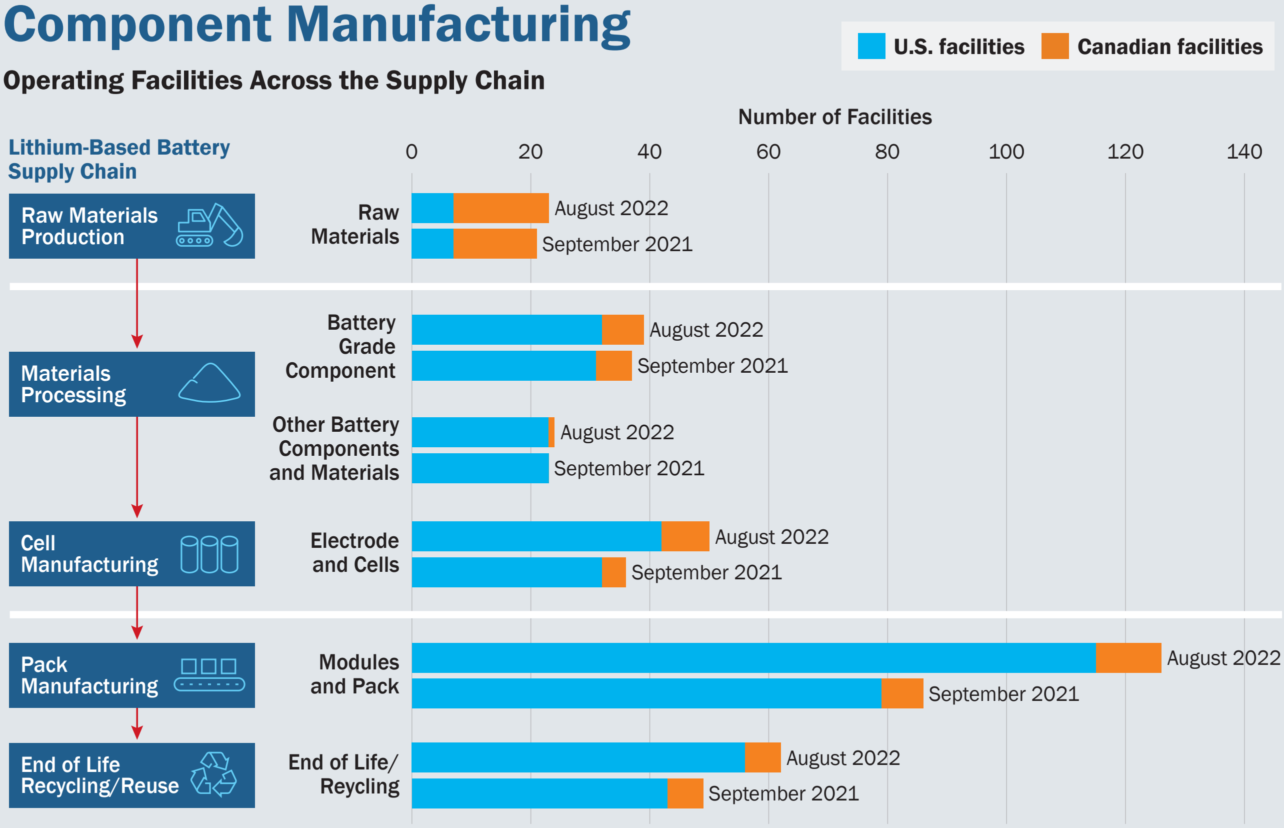
Sourced Country	2020	2021
China	< 1%	3%
U.S.	69%	66%
Poland	5%	15%
Japan	21%	11%
Korea	3%	5%
Germany	<1%	<1%
Hungary	<1%	>1%

U.S. EV cells market increased from 18.5 GWh to 36 GWh in 2021

Source: 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.

Component Manufacturing

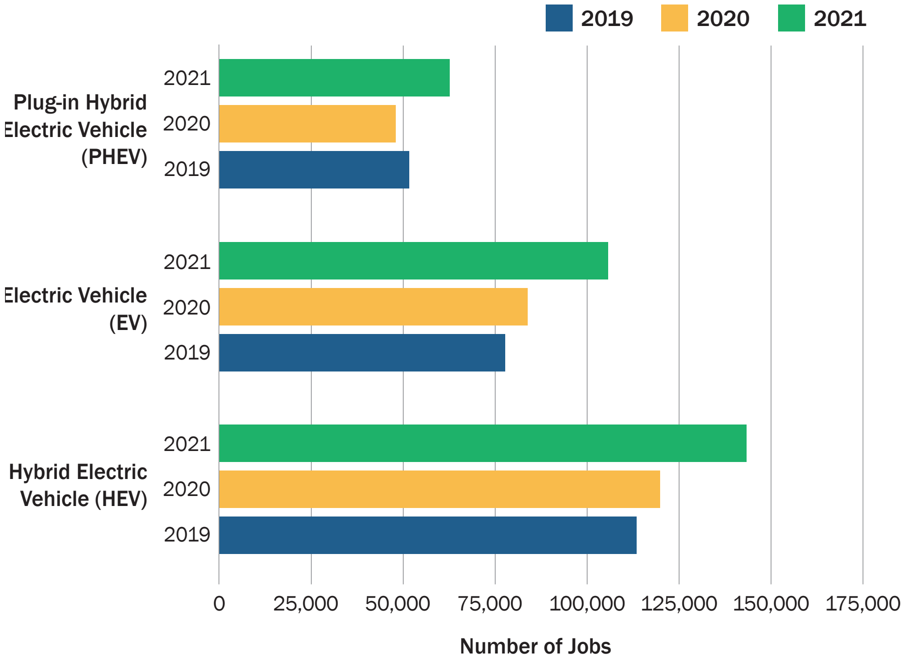
Operating Facilities Across the Supply Chain



Source: National Renewable Energy Laboratory. NAATBatt Lithium-Ion Battery Supply Chain Database. Version 2. August 18, 2022 and National Renewable Energy Laboratory. NAATBatt Lithium-Ion Battery Supply Chain Database. Version 1. September 15, 2021.

Employment

Motor Vehicles and Component Parts
U.S. Employment by Technology, 2019–2021



Two-Year Job Growth
2019–2021

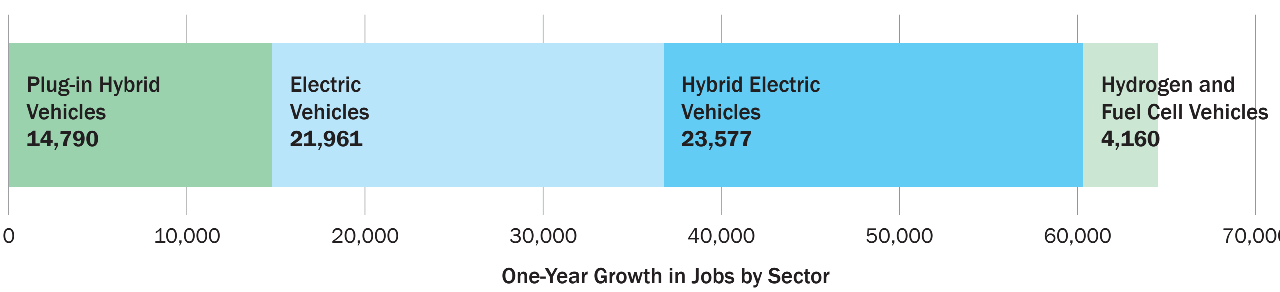
PHEVs: 21%
11,013 jobs

EVs: 36%
28,027 jobs

HEVs: 26%
29,869 jobs

All manufacturing employers found hiring in 2021 very or somewhat difficult.

U.S. Job Growth from 2020 to 2021 in Low-Carbon Vehicle Segment



Carbon reducing vehicle jobs grew a collective 25%

Source: Office of Policy (2022). United States Energy & Employment Report 2022 (DOE publication No. DOE/OP-0016).
U.S. Department of Energy, Office of Policy. (U.S. Energy & Employment Jobs Report (USEER) | Department of Energy). Accessed 21 July 2022.

GOAL 1

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

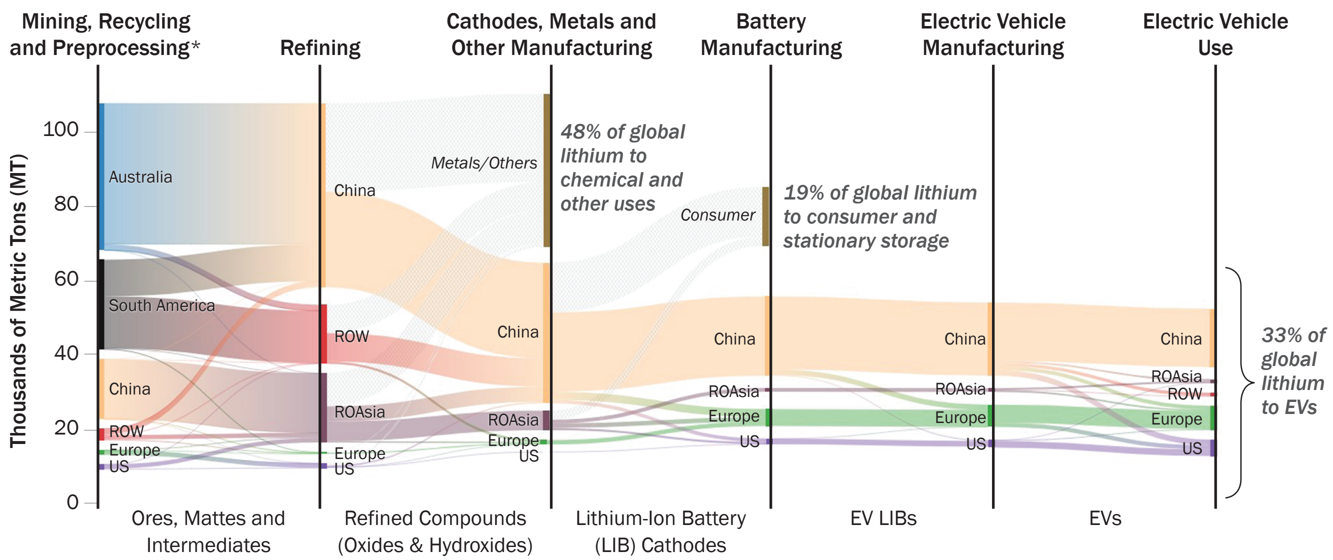
Lithium

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)
2020*	750	21,000	7,470	209,163
2021	750	22,000	7,470	209,163

*As reported in the National Blueprint for Lithium Batteries 2021–2030.

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 2021



Non-LIB EV battery related flow

ROAsia: Rest of Asia

ROW: Rest of World

***Mining and Preprocessing products:**
- Lithium carbonate and hydroxide from brines, hard rock (e.g., spodumene) and other sources

Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2022, https://doi.org/10.3133/mcs2022; International Trade Centre, a joint agency of the World Trade Organization and the United Nations, https://www.intracen.org , "Global Cobalt Outlook 2020–2030" and Battery Material Manufacturing database, https://www.bnef.com

TAKEAWAYS *Australia leads production in the mining and processing space while China continues to control the mid stream refining segment, with subsequent downstream production.*

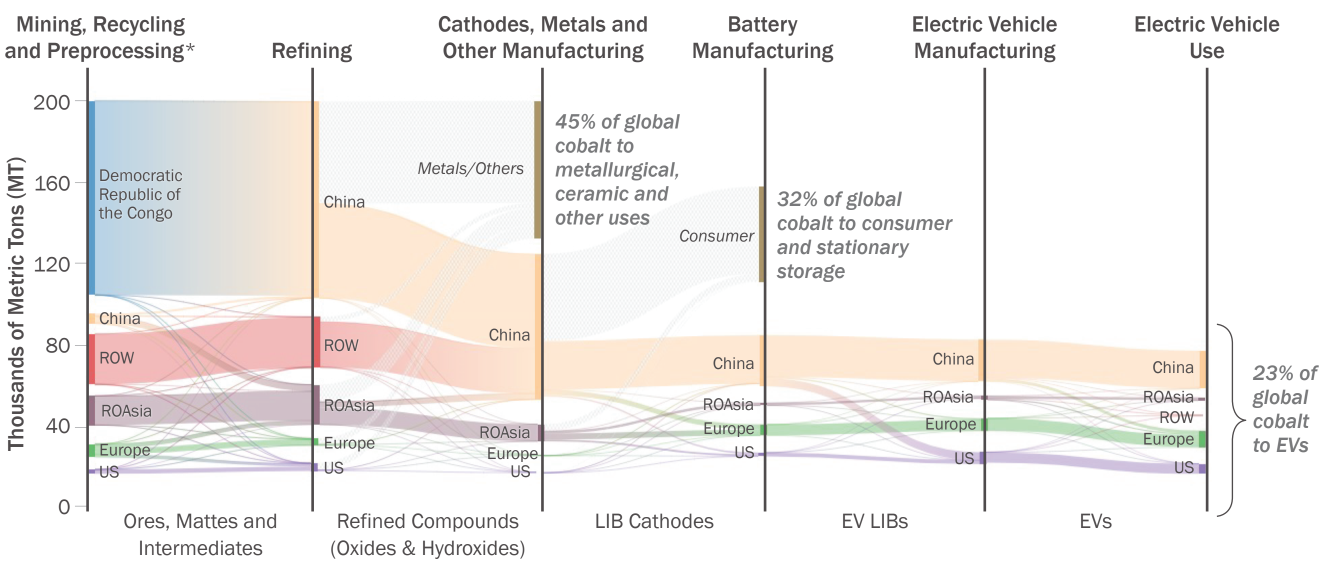
Cobalt

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)
2020*	53	7,100	703	94,164
2021	69	7,600	915	100,795

*As reported in the National Blueprint for Lithium Batteries 2021–2030.

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 2021



Non-LIB EV battery related flow

ROAsia: Rest of Asia
ROW: Rest of World

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

Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2022, https://doi.org/10.3133/mcs2022; International Trade Centre, a joint agency of the World Trade Organization and the United Nations, https://www.intracen.org, "Global Cobalt Outlook 2020–2030" and Battery Material Manufacturing database, https://www.bnef.com; Resources and Energy Quarterly, Lithium, March 2022, https://www.industry.gov.au/OCE

TAKEAWAYS *The Democratic Republic of the Congo continues to lead mining production of cobalt, feeding Chinese refining and manufacturing downstream.*

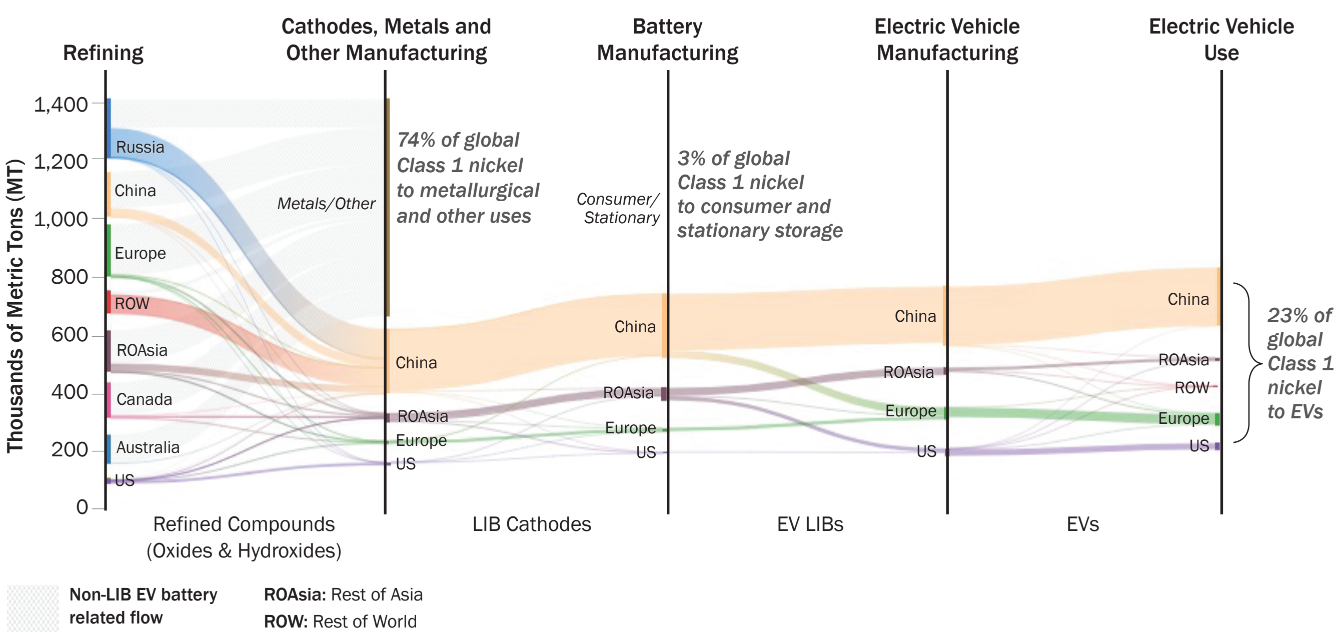
Nickel

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)
2020*	100	94,000	167	156,510
2021	340	>95,000	568	158,175

*As reported in the National Blueprint for Lithium Batteries 2021–2030.

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.

CLASS 1 NICKEL AT THE END OF 2021



Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2022, https://doi.org/10.3133/mcs2022; International Trade Centre, a joint agency of the World Trade Organization and the United Nations, https://www.intracen.org , "Global Cobalt Outlook 2020-2030" and Battery Material Manufacturing database, https://www.bnef.com

TAKEAWAYS *Only 23% of globally produced Class 1 nickel is utilized currently for EV supply chains. Many countries are refining nickel, with China leading in downstream manufacturing.*

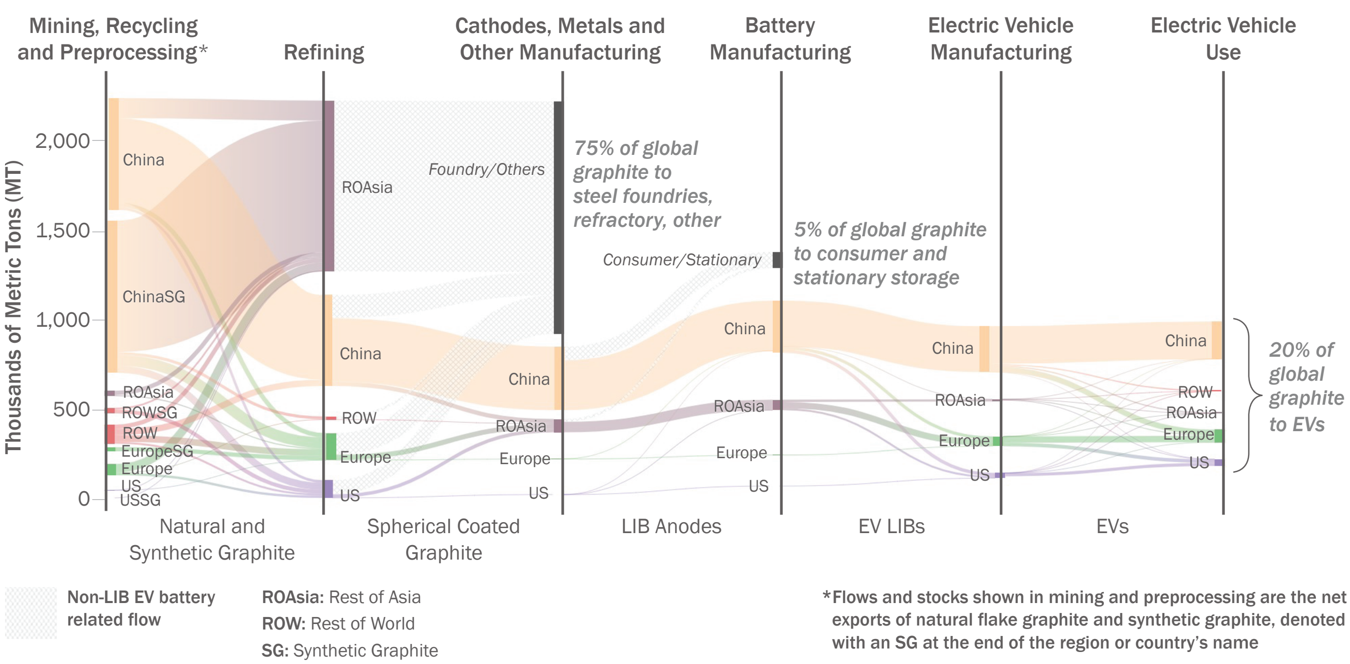
Graphite

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)
2020*	—	320,000	—	350
2021	—	320,000	—	350

*As reported in the National Blueprint for Lithium Batteries 2021–2030.

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 2021



Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2022, https://doi.org/10.3133/mcs2022; International Trade Centre, a joint agency of the World Trade Organization and the United Nations, https://www.intracen.org, Xu, P. "Global Graphite Outlook 2020-2030" 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, Europe, and other parts of the world have significant synthetic graphite production. China controls early-stage production of natural and synthetic graphite. China is also a major player in later stage production of spherical coated graphite and LIB anodes from graphite.*

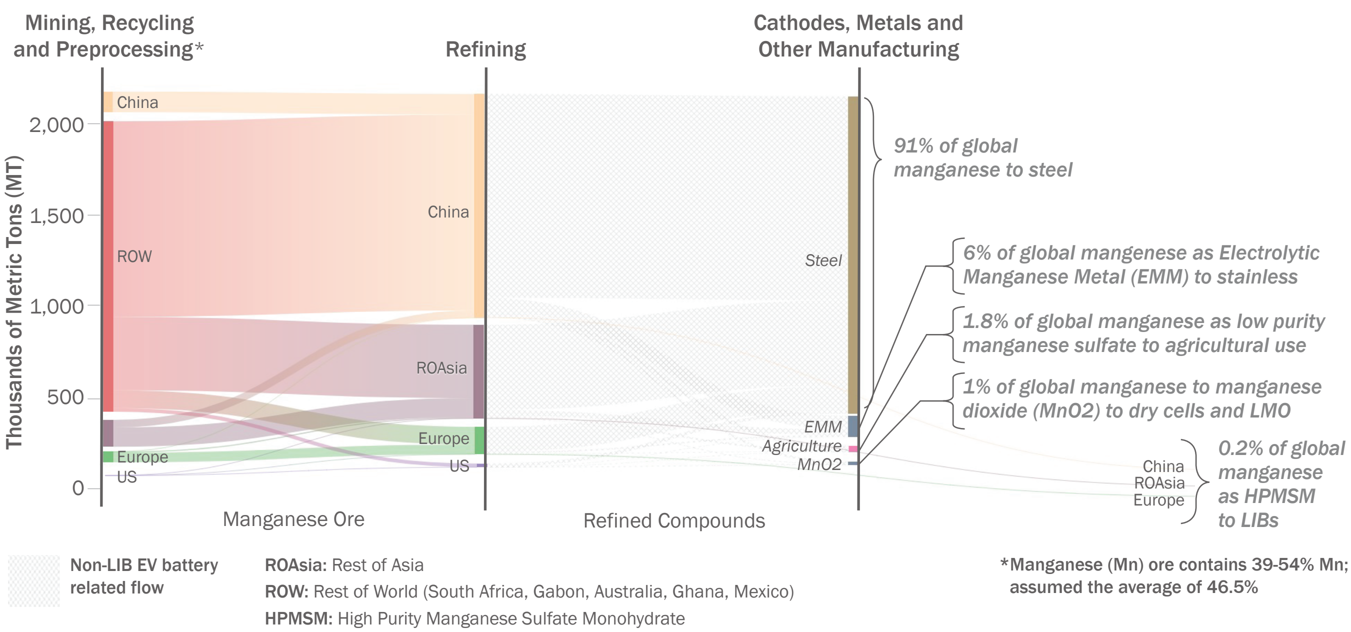
Manganese

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)
2020	—	1,300,000	—	18,492,176
2021	—	1,500,000	—	21,337,126

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 2021

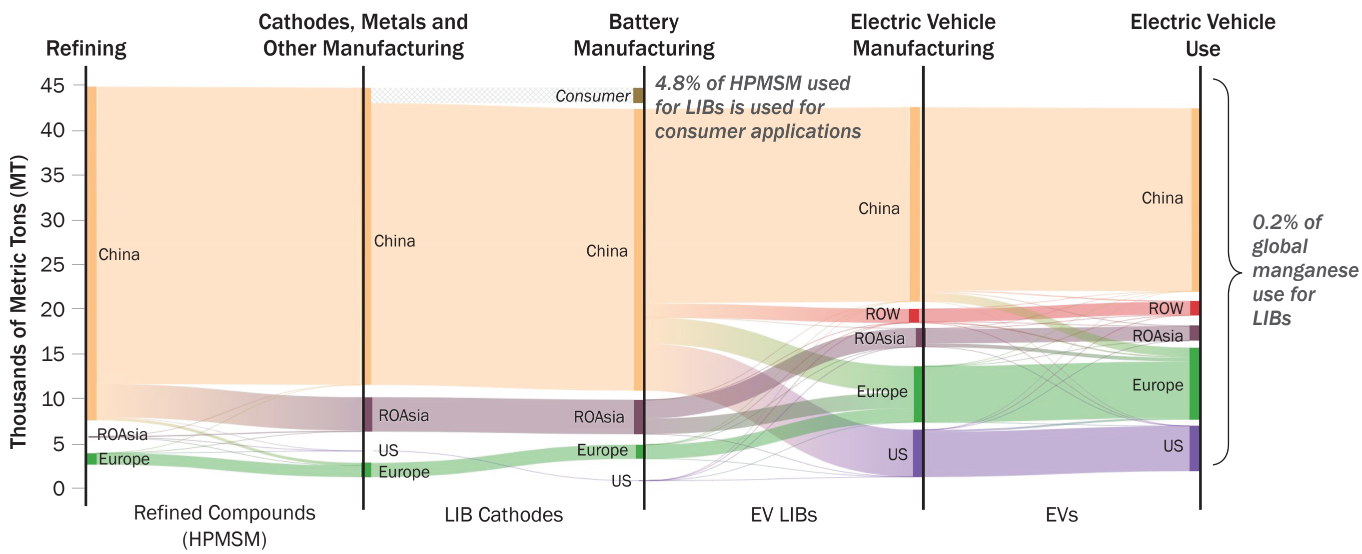
Upstream stages of manganese mining, recycling, and processing



Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2022, https://doi.org/10.3133/mcs2022; International Trade Centre, a joint agency of the World Trade Organization and the United Nations, https://www.intracen.org, "Global Manganese Outlook 2020–2030" and Battery Material Manufacturing database, https://www.bnef.com; Manganese Metal Co. 2022. "Battery Raw Materials Disconnect: the Manganese chapter, Presented at Benchmark Mineral Intelligence World Tour, Cape Town Edition, 10 May 2022.

TAKEAWAYS *Only 0.2% of the mined manganese feeds into the current Li-ion battery supply chain. China leads refining through battery manufacturing in the battery supply chain for manganese.*

Downstream stages for the battery supply chain



Non-LIB EV battery related flow

ROAsia: Rest of Asia
ROW: Rest of World
HPMSM: High Purity Manganese Sulfate Monohydrate

Sources: NREL Analysis; USGS,"Mineral Commodity Summaries"; 2022, https://doi.org/10.3133/mcs2022; International Trade Centre, a joint agency of the World Trade Organization and the United Nations, https://www.intracen.org, "Global Manganese Outlook 2020–2030" and Battery Material Manufacturing database, https://www.bnef.com; Manganese Metal Co. 2022. "Battery Raw Materials Disconnect: the Manganese chapter, Presented at Benchmark Mineral Intelligence World Tour, Cape Town Edition, 10 May 2022.

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 (8.3 M metric tons)	Anode Manufacturing (3.3 M metric tons)	Electrolyte Manufacturing (2 M metric tons)	Separator Manufacturing (38,832 M sq. m)
United States	<0.1%	0.1%	3.6%	0.7%
China	85.9%	91.5%	82.5%	82%
Rest of Asia	10%	6.6%	6.4%	9.8%
Europe	4%	1.8%	7.5%	7.5%
Rest of World	<0.1%	—	—	—

Source: BloombergNEF, Battery Components Manufacturers Interactive Datasets. 2021.

TAKEAWAYS *There is an overall ramp up of component manufacturing from 2019 to 2021. China is currently leading the production of all component segments.*

Anode

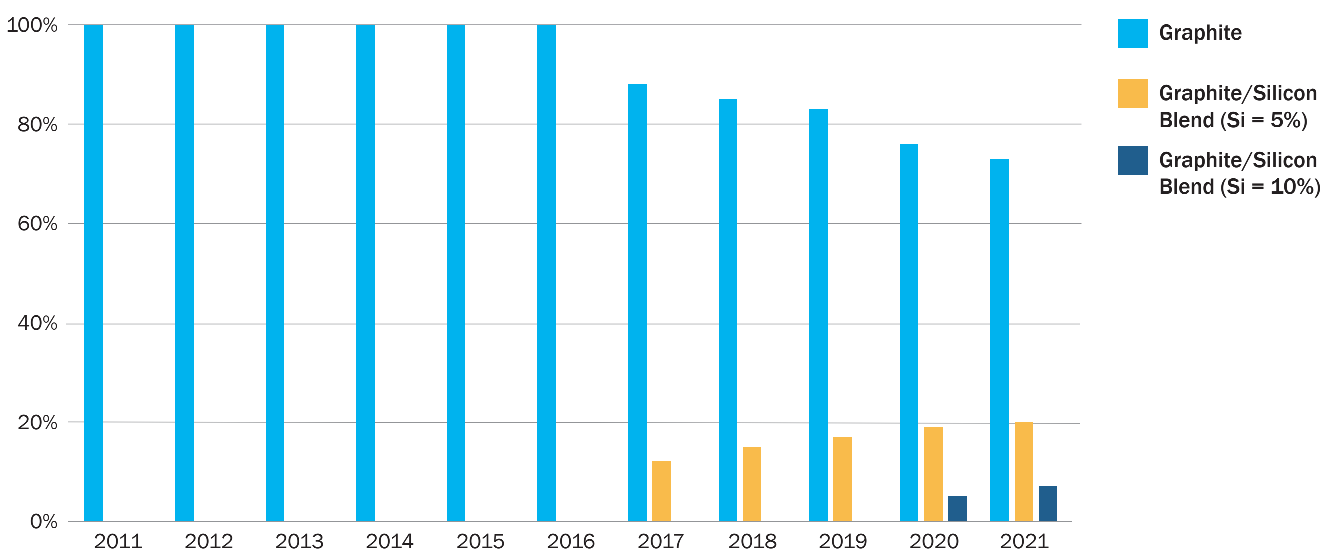
Country	2019 Anode Manufacturing* (1.2 M metric tons)	2021 Anode Manufacturing (3.3 M metric tons)
United States	10%	0.1%
China	65%	91.5%
Rest of Asia	25%	6.6%
Europe	—	1.8%
Rest of World	—	—

*As reported in the National Blueprint for Lithium Batteries 2021–2030.

Sources: BloombergNEF, Battery Components Manufacturing Asset Map. 2019. BloombergNEF, Battery Components Manufacturers Interactive Datasets. 2021.

AT THE END OF 2021

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. June 6, 2022.

TAKEAWAYS *China is leading anode manufacturing. Graphite is the primary anode, though Silicon-blends have been increasing in usage.*

Cathode

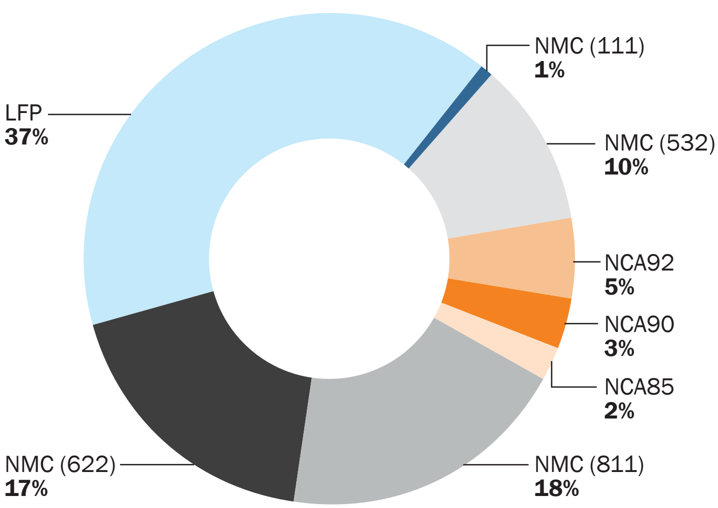
Country	2019 Cathode Manufacturing* (3 M metric tons)	2021 Cathode Manufacturing (8.3 M metric tons)
United States	—	<0.1%
China	42%	85.9%
Rest of Asia	48%	10%
Europe	—	4%
Rest of World	—	<0.1%

*As reported in the National Blueprint for Lithium Batteries 2021–2030.

Sources: BloombergNEF, Battery Components Manufacturing Asset Map. 2019. BloombergNEF, Battery Components Manufacturers Interactive Datasets. 2021.

AT THE END OF 2021

2021 Cathode Production Mix



Source: BloombergNEF, Long-Term Electric Vehicle Outlook 2022—Data: Evolution of cathode chemistry across all passenger electric vehicle segments, June 6, 2022.

Cathode Materials

NMC: Lithium Nickel Manganese Cobalt Oxide

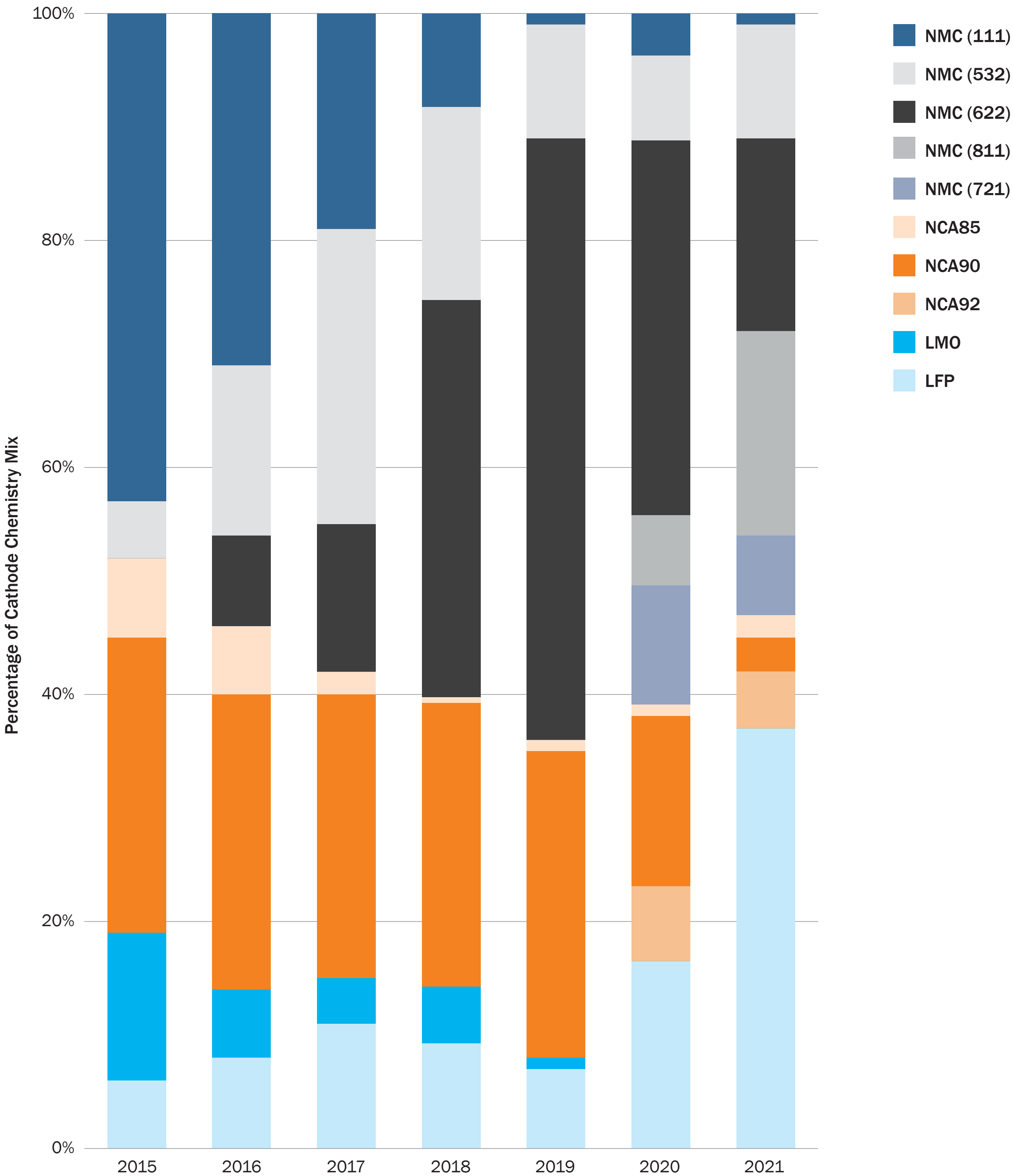
NCA: Lithium Nickel Cobalt Aluminum Oxide

LMO: Lithium Manganese Oxide

LFP: Lithium Iron Phosphate

TAKEAWAYS *China leads cathode manufacturing. Cathode chemistry mix has changed over time, with Lithium Iron Phosphate (LFP) accounting for over 50% of cathode production, mostly of Chinese production.*

EV Cathode Chemistry Mix Over Time



Source: BloombergNEF, Long-Term Electric Vehicle Outlook 2022 —Data: Evolution of cathode chemistry across all passenger electric vehicle segments, June 6, 2022.

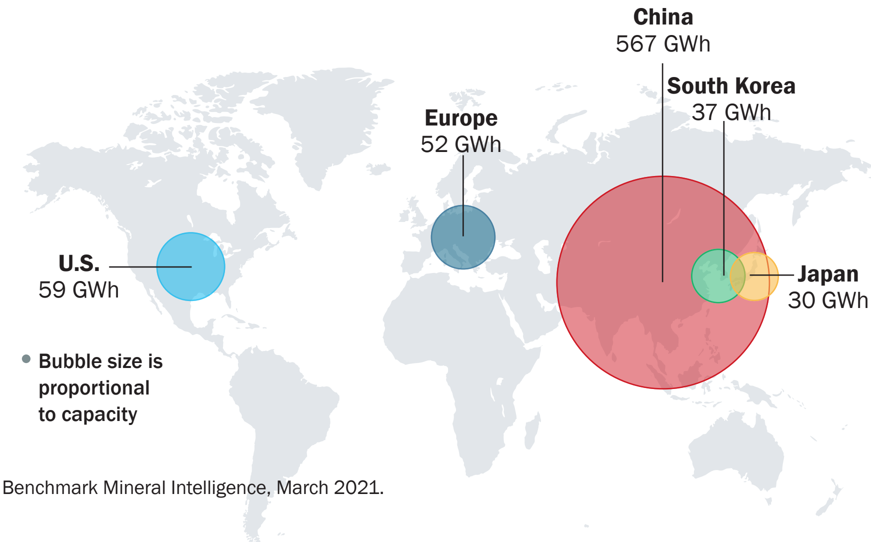
GOAL 3

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

Cell Production

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

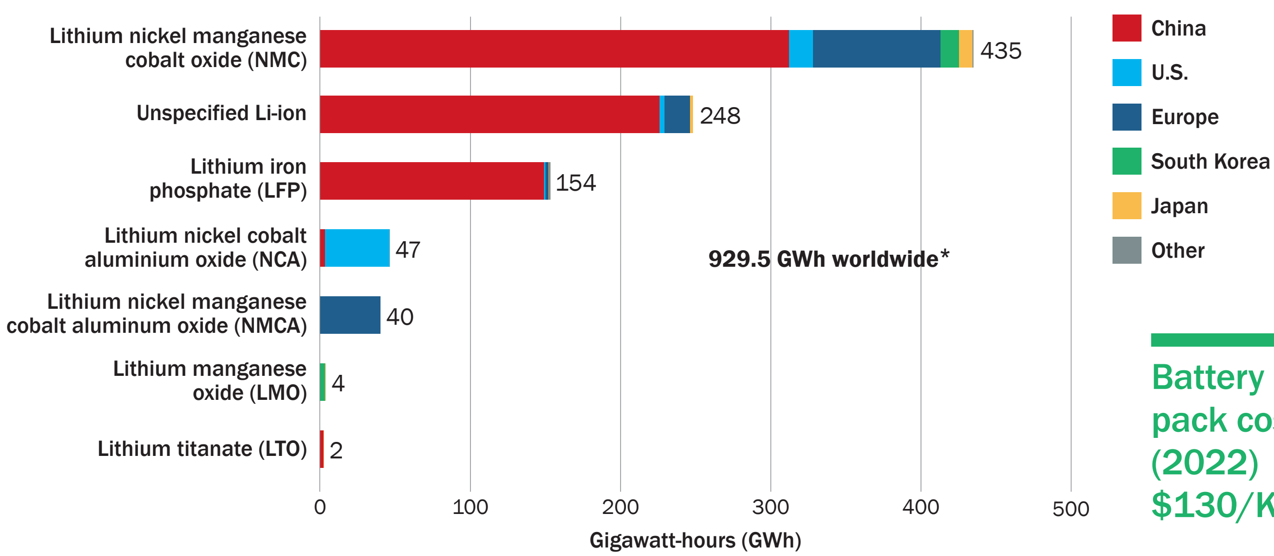
Cell Manufacturing Capacity by Country or Region



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

IN MAY 2022

Utilized Battery Capacity by Chemistry



Battery R&D pack cost (2022) $130/KWh[5]

*This data represents the most up to date information available. Differences with cell production data reporting on page 4 are attributable to updates in dataset occurring between the access dates.

Source: BloombergNEF, Battery Component Manufacturers Interactive Dataset, October 18, 2022. Includes facilities commissioned up to May 2022.

TAKEAWAYS *U.S. cell production is increasing and diversifying.*

[5] 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 November 4, 2022.

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:

Using **recycled materials*** from spent batteries has potential to **decrease**:

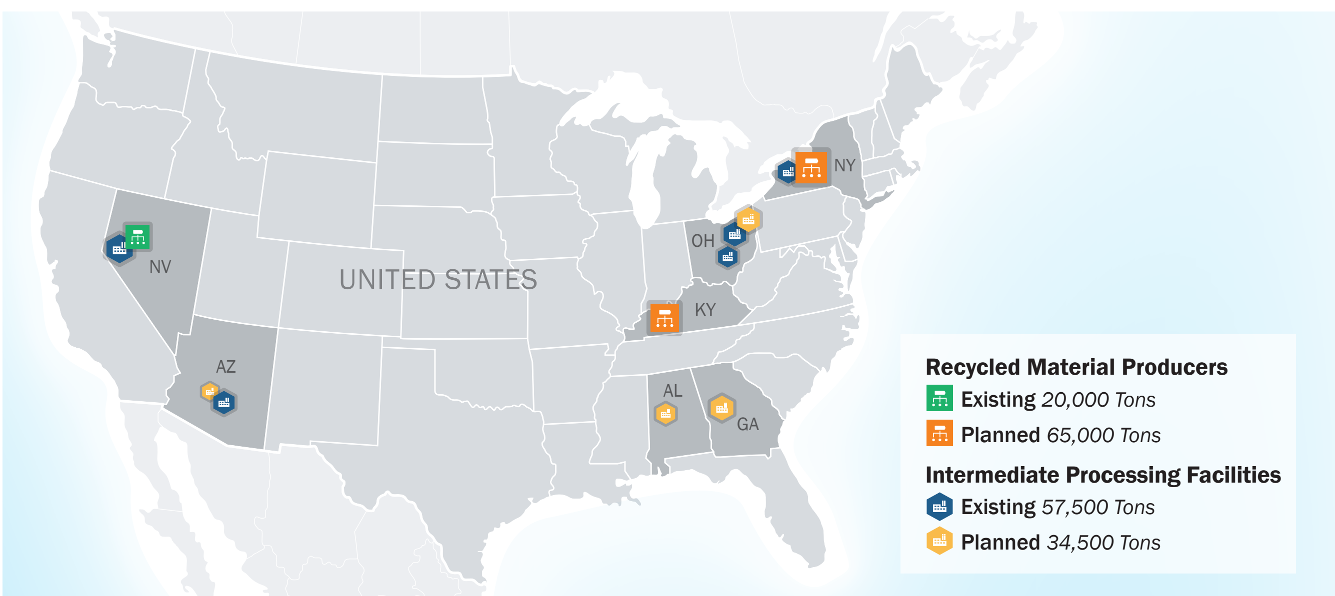
- Costs by **40%**
- Energy use by **82%**
- Water use by **77%**
- SO_x emissions by **91%**

*Assumes a direct recycling method

Source: Data from Argonne National Laboratory's ReCell Center, 2019.[6]

AT THE END OF FY2023

Domestic Battery Recyclers Potential Capacity, 2022–2023



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

[6] 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

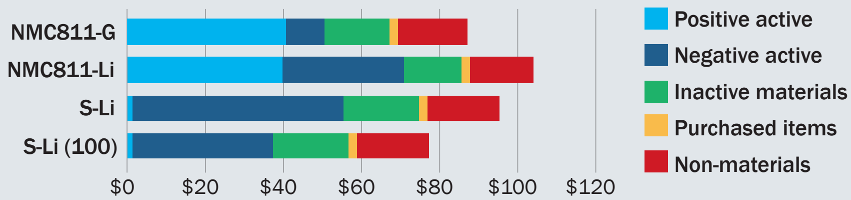
Develop Next-Generation Batteries Using Lithium as the Negative Electrode

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	28	28	3	3
Anode Price, $/kg	10	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, BatPaC 5.0 [2022], doi: 10.2172/1877590

Battery500 (Li/high-Ni NMC)

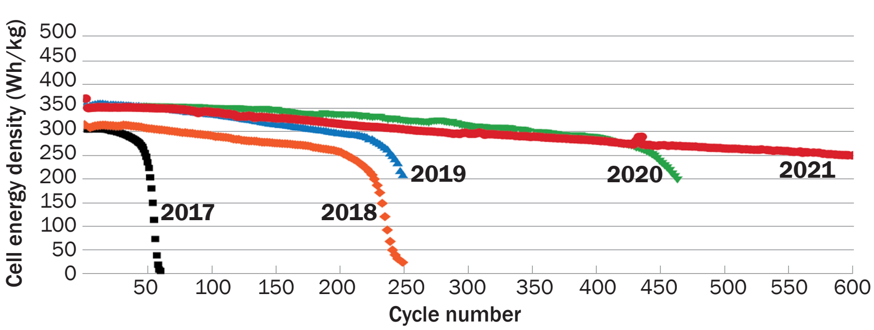
146 publications (**34** were designated as highly cited)

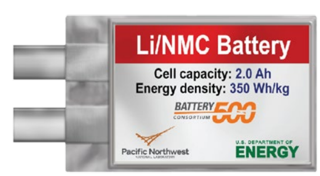
26 Intellectual Property (IP) claims, including **15** patents and applications

10 invention reports, **1** copyright

Software patents licensed to **9** companies and institutions

Steady Increase in Cycle Life in 2 Ampere hours (Ah) Li Metal Pouch Cells





FY21
600 cycles
350 Wh/kg
C/10 charge
C/3 discharge

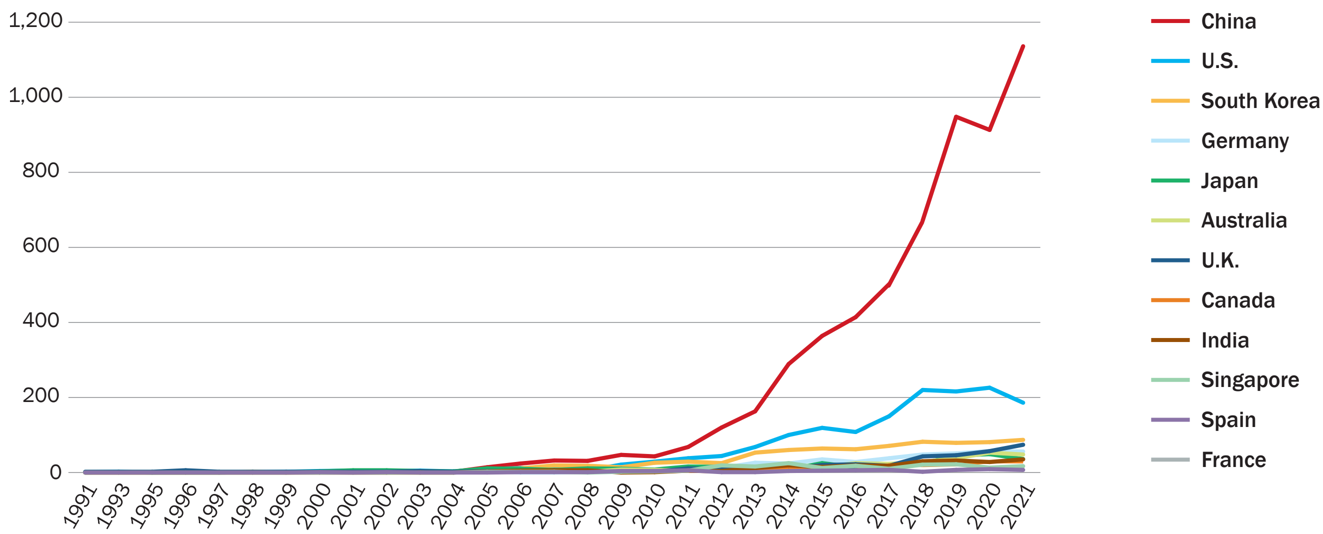
Source: Liu, J. (2022, June 21–23). *Progress and Status of Battery500 Consortium Phase II* [PowerPoint presentation]. 2022 DOE VTO Annual Merit Review, Washington DC, United States. https://www1.eere.energy.gov/vehiclesandfuels/downloads/2022_AMR/bat317_liu_2022_o_5-1_134pm_ML.pdf and Xiao, J, (2022, June 21–23). *High-energy Rechargeable Lithium Metal Cells: Design, Fabrication and Testing* [PowerPoint presentation]. 2022 DOE VTO Annual Merit Review. Washington DC, United States. https://www1.eere.energy.gov/vehiclesandfuels/downloads/2022_AMR/bat369_xiao_2022_o_4-30_1126am_ML.pdf.

Publications

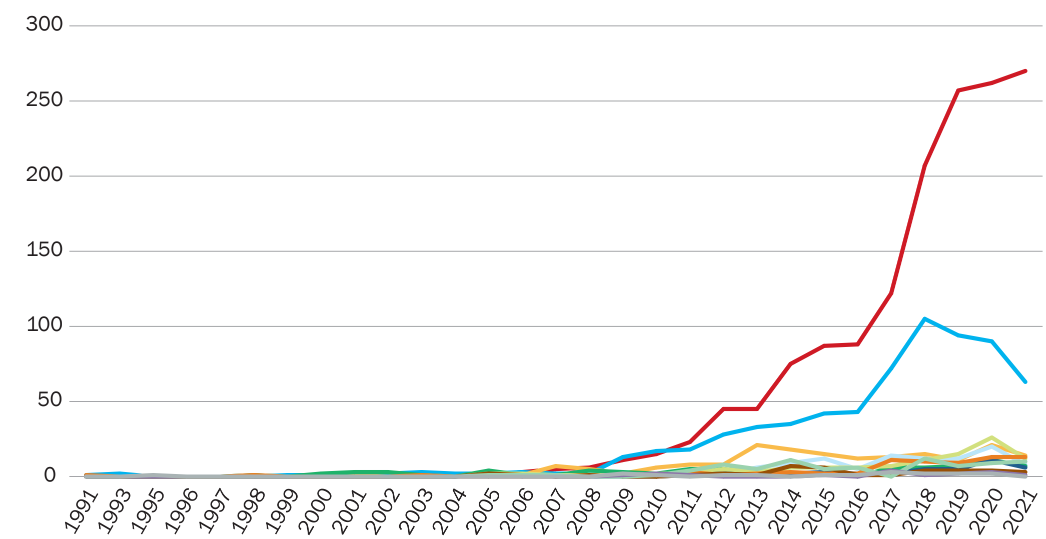
Objective: Retrospective analysis to quantify U.S. investment in battery technologies

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 *China leads in total publications on advanced Li metal cell technologies. United States on par with the top 10% of cited publications on Lithium metal.*

FEDERAL CONSORTIUM FOR ADVANCED BATTERIES

DOE/MESC-0106
www.energy.gov/mesc/federal-consortium-advanced-batteries-fcab