SELECTUSA

Industry Guide

Advanced Battery Industry

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Overview

The United States is entering a new era of activity and opportunities related to manufacturing of advanced batteries. The COVID-19 pandemic and supply chain disruptions of 2020 and 2021 have brought to the fore the importance of the production of key goods, including highly technical products like advanced batteries. Advanced batteries generally are comprised of lithium-ion batteries under HS 85076000 and are applied to myriad uses such as electric vehicles (EVs), stationary energy storage applications, and consumer goods.

The NAATBatt International (NAATBatt) envisions a future in which the U.S. battery industry is globally competitive and supplies a greater share of domestic needs onshore or with proximate geopolitical partners. That could mean securing a long-term supply of battery materials through 2050, increasing technological advances through direct and indirect investments in companies, creating tax incentives for production and consumption of battery technology, developing significant labor intelligence and skills related to the battery industry, and supporting a robust recycling and secondary life ecosystem. Coupling these factors alongside the dramatic demand signals for battery technology over the next 10 to 20 years makes for a rare and compelling investment opportunity in the United States.

The purpose of this document is to lay out the state of the advanced battery industry in the United States. We at NAATBatt, in cooperation with SelectUSA, aim to give investors a greater understanding of the industry to facilitate greenfield investment in the United States. As part of SelectUSA's efforts to highlight significant trends to international operators and investors, this chapter will survey the current North American battery supply chain, noting most of the active companies and the areas ripe for growth.

Introduction

The global advanced battery industry has recently seen some long-predicted dramatic growth trends, forcing some analysts to revise their forecasts upward. Bloomberg New Energy Finance (BNEF) now forecasts global EV demand in 2040 to be 677 million vehicles as compared to a projection of 495 million vehicles in its 2019 report, a sharp 37 percent increase. [1] Similarly, the International Energy Agency (IEA) raised 2030 electric vehicle (EV) forecasts by 7 percent since 2019, and OPEC has raised 2040 projections of alternative powertrains by 11 percent. [2]

Generally, lithium-ion batteries are the most widely utilized advanced battery, used in various growth sectors such as consumer electronics.[3] Large format lithium-ion batteries represent the most significant growth opportunities in two distinct segments.[4] EV and stationary energy storage. Of the two, consumer demand is anticipated to drive EV growth while utility demand drives the stationary storage applications, though both are highly influenced by state and federal government subsidies and regulations. Lithium-ion batteries are also widely utilized in industrial applications (e.g., fork trucks, golf carts, and other traditional lead-acid applications), and national defense applications.

Specific to the EV segment, BNEF projects that EVs will represent nearly 30 percent of all vehicle sales by 2030, with battery-electric drivetrains becoming the majority powertrain solution sold globally by 2032.[5] The World Bank has predicted that a 500 percent increase in battery metals will be needed by 2050 to meet this demand.[6] Indeed, EVs are beginning to gain traction through several recently announced prominent original equipment manufacturer (OEM) funding commitments (e.g., GM, Volkswagen, Honda, Jaguar, Volvo, and Ford have announced international combustion engine (ICE) phase-outs.[7] This leads to a projected supply and demand

[1] Bloomberg New Energy Finance, "Zero-Emission Vehicles Factbook." Accessed February 8, 2022. https://assets.bbhub.io/professional/sites/24/BNEF-Zero-Emission-Vehicles-Factbook_FINAL.pdf

[2] International Energy Agency, "Energy Storage." Accessed February 8, 2022. https://www.iea.org/reports/energy-storage

[3] International Energy Agency, "Energy Storage." Accessed February 8, 2022. https://www.iea.org/reports/energy-storage

[4] U.S. Department of Energy, "Energy Storage Grand Challenge: Energy Storage Market Report." Accessed March 3, 2022. https://www.energy.gov/sites/prod/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf

[5] Bloomberg New Energy Finance, "Electric Vehicle Outlook 2021." Accessed February 24, 2022. https://about.bnef.com/electric-vehicle-outlook/

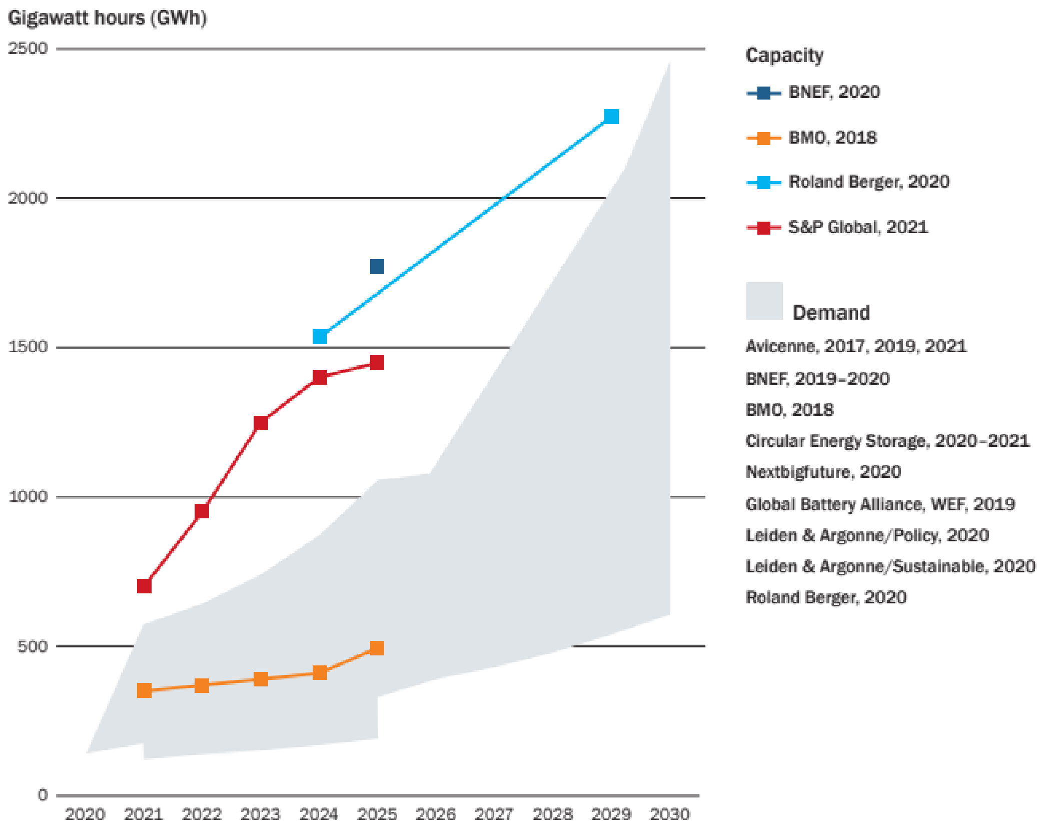
[6] The World Bank, "Mineral Production to Soar as Demand for Clean Energy Increases." Accessed March 3, 2022. https://www.worldbank.org/en/news/press-release/2020/05/11/mineral-production-to-soar-as-demand-for-clean-energy-increases

[7] As examples, Reuters, "Jaguar cars to go all-electric by 2025 as JLR plans full range of e-models by 2030," Accessed February 14, 2022. https://www.reuters.com/article/us-tata-motors-jlr/jaguar-cars-to-go-all-electric-by-2025-as-jlr-plans-full-range-of-e-models-by-2030-idUSKBN2AF0TJ; Ford Media Center, "Ford Goes All-In On EVs On Road to Sustainability." Accessed February 14, 2021. https://media.ford.com/content/fordmedia/feu/en/news/2021/02/17/ford-europe-goes-all-in-on-evs-on-road-to-sustainable-profitabil.html; Bloomberg New Energy Finance, "Electric Vehicle Outlook 2021." Accessed February 24, 2022. https://about.bnef.com/electric-vehicle-outlook/

imbalance, though projections vary as to the extent of the imbalance. Figure 1 shows the global lithium-ion EV battery capacity and demand projections from multiple sources.

In addition to the growing EV market, grid storage uses of advanced batteries are also anticipated to grow, with Bloomberg projecting total global deployment to reach over 1,095 GW by 2040, a substantial increase from 9 GW in 2018.[8] This projected increase is expected because the global power sector is migrating away from large, centralized generation plants to a cleaner, more modern electric infrastructure based on distributed generation and storage.

Figure 1: Global Lithium-Ion EV Battery Capacity and Demand Projects



Source: Federal Consortium of Batteries / Argonne National Laboratory ANL/ESD-21/3

Advanced Batteries in the United States

Migration away from a centralized model is a particularly important trend in the United States, where some analysts admit that integration of renewable generation and firming assets is

[8] Bloomberg New Energy Finance, "Energy Storage Investments Boom as Battery Costs Halve in the Next Decade." Accessed February 8, 2022. https://about.bnef.com/blog/energy-storage-investments-boom-battery-costs-halve-next-decade/

increasing and project increasing adoption as the anticipated infrastructure bill may encourage such activity.[9]

Overall, Bloomberg NEF ranks the United States second in the world on its Global Lithium-Ion Battery Supply Chain Ranking.[10] In terms of raw numbers, the United States has the second-largest EV market compared to all other countries. The U.S. again comes in second in the world in terms of global domestic demand for lithium-ion batteries thanks to strong performance in EV sales and a burgeoning stationary battery market. The report also points out that the U.S. has long been a leader in technological development and boasts some of the world's most cutting-edge startups.

The current momentum of stationary energy storage investments at the wholesale and retail levels suggests that the next two decades will create significant opportunities in stationary energy storage deployments in grid applications, both behind and in front of the meter. As a result, the Energy Storage Association (ESA) has determined that the deployment of 100 GW of new energy storage in the United States by the end of the decade is both desirable and increasingly likely.[11] Further enabling the ongoing clean energy transformation of the electricity grid requires capital-efficient assets, modern electricity planning, regulatory reforms, and policy standardization across the United States. Some analysts point to the Biden administration's movements to prioritize clean energy as a significant investment opportunity for investment in this exciting sector.[12]

Even now, there is significant opportunity to develop the U.S. manufacturing capacity and capabilities in renewable energy. Efforts at both the federal and state government levels are working to enable a cleaner energy future.[13] While lithium-ion batteries from various international suppliers dominate the current global landscape, several dynamics foreshadow a different eventuality. As forementioned, the United States is a major source of demand for lithium-ion batteries.[14] No less, the Federal Consortium for Advanced Batteries (FCAB), a joint initiative of the Departments of Energy, Commerce, State, and Defense is dedicated to bringing

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[9] JD Supra, "Bipartisan Infrastructure Bill Could Revolutionize the Energy Industry." Accessed February 24, 2022. https://www.jdsupra.com/legalnews/bipartisan-infrastructure-bill-could-4807359/

[10] Bloomberg New Energy Finance, "U.S. Narrows Gap with China in Race to Dominate Battery Value Chain." Accessed February 2, 2022. https://about.bnef.com/blog/u-s-narrows-gap-with-china-in-race-to-dominate-battery-value-chain/

[11] Energy Storage Association, "Enabling the Clean Power Transformation." Accessed February 8, 2022. https://energystorage.org/wp/wp-content/uploads/2020/08/100x30-Empowering-Clean-Power-Transformation-ESA-Vision.pdf

[12] Ibid

[13] The White House, "President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability." Accessed February 24, 2022. https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/#:~:text=With%20the%20scope%20and%20scale,a%20carbon%20pollution%2Dfree%20electricity

[14] Energy Storage Association, "Enabling the Clean Power Transformation." Accessed February 8, 2022. https://energystorage.org/wp/wp-content/uploads/2020/08/100x30-Empowering-Clean-Power-Transformation-ESA-Vision.pdf

together federal agencies to ensure a domestic supply of lithium batteries.[15] Additional efforts by trade associations are also designed to help address the issue. For instance, NAATBatt International recently partnered with the National Renewable Energy Laboratory to develop a map of the North American advanced battery supply chain to identify opportunities for the growth and development of a complete continental supply chain ecosystem.[16]

Battery development and production are strategically crucial for the United States, both as part of the transition to a clean-energy economy and a vital element of the automotive industry's competitiveness. Automotive manufacturing drives $1.1 trillion into the economy each year through the sales and servicing of vehicles.[17] A 2017 estimate suggested that approximately 10 million U.S. jobs are directly associated with the automobile industry, and 5 percent of all U.S. jobs depend on the automotive sector, which, according to BNEF, has historically contributed 3.5 percent of the total United States gross domestic product.[18]

While challenges certainly remain, NAATBatt sees the United States full of opportunities for investment for a cleaner future.

Current Global Position

Supply Chain Overview

The life cycle of batteries from earliest material extraction to end of life encompasses many processes potentially lasting decades with myriad actors. Figure 2 presents the lithium-based battery supply chain.

Each stage requires complex technical competencies, including—but certainly not limited to—chemistry, physics, materials science and engineering, and data scientists. The United States is a top country for technical knowledge—it is the top country in research and development in

[15] U.S. Department of Energy, "Federal Consortium for Advanced Batteries." Accessed February 8, 2022. https://www.energy.gov/eere/vehicles/federal-consortium-advanced-batteries-fcab

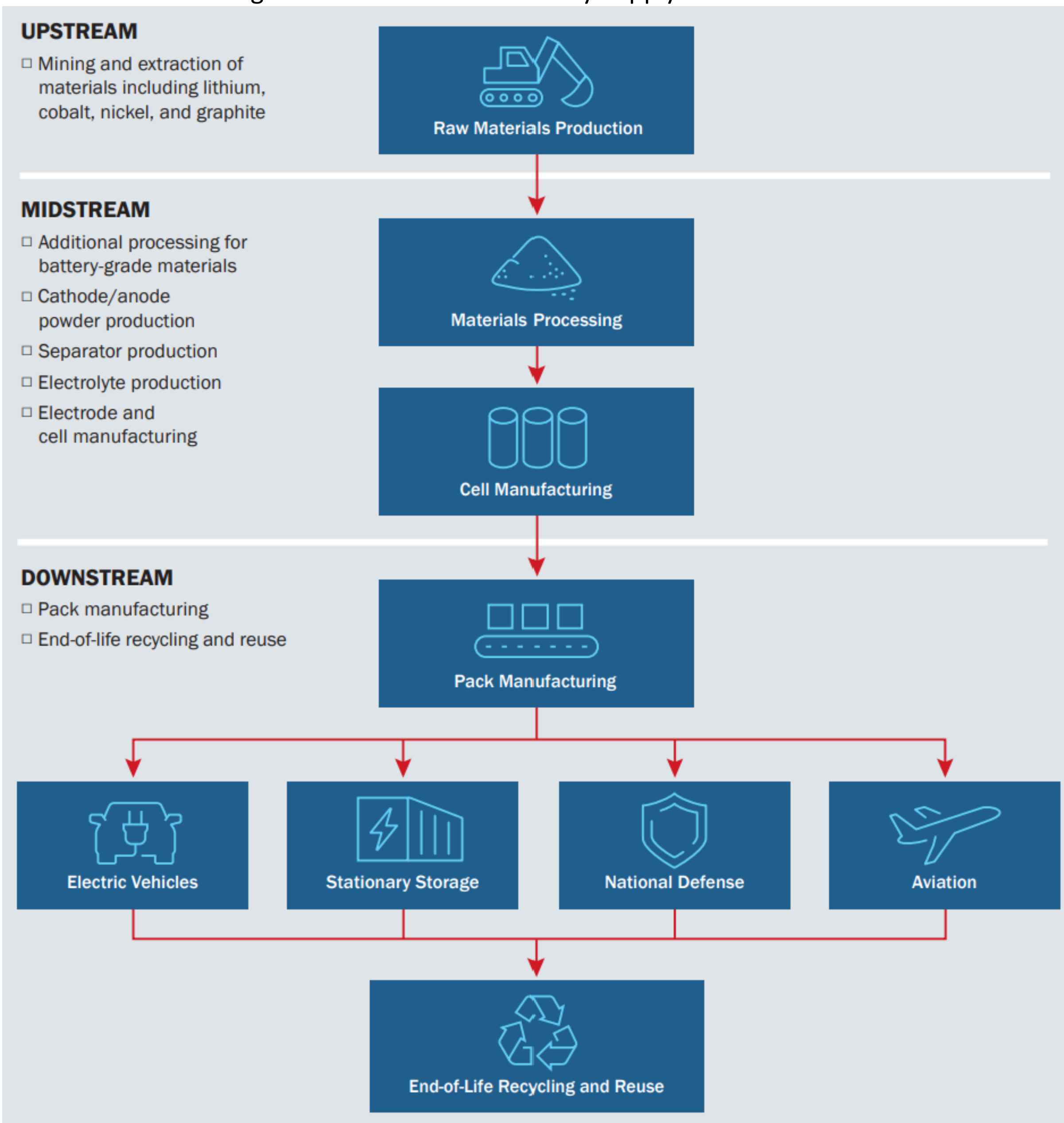
[16] NAATBatt International, "NAATBatt Publishes Database of the North American Lithium-Ion Supply Chain." Accessed February 8, 2022. https://naatbatt.org/naatbatt-publishes-database-of-the-north-american-lithium-ion-supply-chain/

[17] Alliance for Automotive Innovation, "Driving the U.S. Economy." Accessed February 8, 2022. https://www.autosinnovate.org/initiatives/the-industry#:~:text=Auto%20manufacturing%20drives%20%241.1%20trillion,business%20to%20revenue%20for%20government.

[18] Center for Automotive Research, "Contribution of the Automotive Industry to the Economies of All Fifty States and the United States." Accessed February 8, 2022. https://www.cargroup.org/wp-content/uploads/2017/02/CONTRIBUTION-OF-THE-AUTOMOTIVE-INDUSTRY-TO-THE-ECONOMIES-OF-ALL-FIFTY-STATES-AND-THE-UNITED-STATES.pdf

science and engineering, performing 27 percent of global research and development in 2019, and continues an upward trend in investing both publicly and privately.[19]

Figure 2: Lithium-Based Battery Supply Chain Outline



Source: Federal Consortium of Batteries

[19] National Science Board, "The State of U.S. Science and Engineering 2022." Referenced February 2, 2022. https://ncses.nsf.gov/pubs/nsb20221/executive-summary

Raw Materials

Lithium-ion batteries are encountering unprecedented global demand. The industry is expected to grow by a factor of 5 to 10 in the next decade.[20] Today's lithium-ion batteries include several critical materials, including lithium, cobalt, nickel, manganese, and graphite. Each of these materials is crucial for meeting the needs of next-generation battery technology.[21] All the significant materials needed for advanced batteries are imported from foreign countries, and some of them are imported at 100 percent rates, including graphite, rare earth minerals, manganese, and yttrium.[22] Figure 3 presents the United States' net import reliance in 2020.

To meet increasing demand, new domestic sources of critical materials should be identified to increase supply chain diversity and reduce the dependence and associated vulnerability to disruptions. As it stands, the United States is currently behind the rest of the world in securing such strategic access and reserves[23] and faces challenges in securing strategic access to and reserves of materials.

Many countries across the world have taken steps to secure raw material sources, increase production capabilities, sign long-term strategic partnerships, and catalyzed end-user demand through incentives and regulation.[24] The United States now faces a competitive global materials landscape. Of all the investment segments in the North American supply chain, raw material extraction may be the least saturated with only two major global players headquartered in the United States.[25]

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[20] Federal Consortium for Advanced Batteries, "National Blueprint for Lithium Batteries." Accessed March 3, 2022. https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf

[21] National Renewable Energy Laboratory, "Supply Chain of Raw Materials Used in the Manufacturing of Light-Duty Vehicle Lithium-Ion Batteries." Accessed March 3, 2022. https://www.nrel.gov/docs/fy19osti/73374.pdf

[22] United States Geological Survey, "Mineral Commodity Summaries 2020." Accessed March 3, 2022. https://pubs.usgs.gov/periodicals/mcs2020/mcs2020.pdf

[23] National Renewable Energy Laboratory, "Supply Chain of Raw Materials Used in the Manufacturing of Light-Duty Vehicle Lithium-Ion Batteries." Accessed March 3, 2022. https://www.nrel.gov/docs/fy19osti/73374.pdf

[24] See, e.g., Reuters, "Germany to extend electric car subsidies to 2025 – sources." Accessed March 3, 2022. https://www.reuters.com/article/uk-germany-autos-subsidy/germany-to-extend-electric-car-subsidies-to-2025-sources-idUKKBN27W2FT

[25] These companies include Albemarle and Westwater Resources

Figure 3: United States' Net Import Reliance in 2020

Commodity	Percent	Major import sources (2016–19)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, Vietnam, China, South Africa
GALLIUM	100	China, United Kingdom, Germany
GRAPHITE (NATURAL)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, India
NEPHELINE SYENITE	100	Canada
NIOBIUM (COLUMBIUM)	100	Brazil, Canada, Germany, Russia
RARE EARTHS,[3] compounds and metal	100	China, Estonia, Japan, Malaysia
RUBIDIUM	100	Canada
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
YTTRIUM	100	China, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
VANADIUM	96	Brazil, South Africa, Austria, Canada
TELLURIUM	>95	Canada, China, Germany, Philippines
BISMUTH	94	China, Republic of Korea, Mexico, Belgium
POTASH	90	Canada, Belarus, Russia
TITANIUM MINERAL CONCENTRATES	88	South Africa, Australia, Madagascar, Mozambique
DIAMOND (INDUSTRIAL), stones	84	South Africa, India, Botswana, Congo (Kinshasa)
ZINC, refined	83	Canada, Mexico, Peru, Spain
ANTIMONY, metal and oxide	81	China, Belgium, Thailand, India
SILVER	80	Mexico, Canada, Peru, Poland
PLATINUM	79	South Africa, Germany, Italy, Switzerland
STONE (DIMENSION)	79	China, Brazil, Italy, India
COBALT	76	Norway, Canada, Japan, Finland
PEAT	76	Canada
RHENIUM	76	Chile, Germany, Canada, Kazakhstan
ABRASIVES, crude fused aluminum oxide	>75	China, France, Canada, Russia
ABRASIVES, crude silicon carbide	>75	China, Netherlands, South Africa
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Guyana, Australia, Brazil
IRON OXIDE PIGMENTS, natural and synthetic	>75	China, Germany, Brazil
CHROMIUM	75	South Africa, Kazakhstan, Mexico, Russia
TIN, refined	75	Indonesia, Malaysia, Peru, Bolivia
MAGNESIUM COMPOUNDS	54	China, Israel, Brazil, Netherlands
GOLD	52	Mexico, Canada, Peru, Colombia
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
LITHIUM	>50	Argentina, Chile, China, Russia
TITANIUM, sponge	>50	Japan, Kazakhstan, Ukraine
TUNGSTEN	>50	China, Bolivia, Germany, Austria
NICKEL	50	Canada, Norway, Finland, Russia
CADMIUM	<50	Australia, China, Canada, Germany
MAGNESIUM METAL	<50	Canada, Israel, Mexico, Russia
SELENIUM	<50	China, Philippines, Mexico, Germany
ALUMINA	49	Brazil, Australia, Jamaica, Canada
GARNET (INDUISTRIAL)	48	South Africa, India, China, Australia
DIAMOND (INDUSTRIAL), dust, grit, and powder	47	China, Ireland, Republic of Korea, Russia
PALLADIUM	40	Russia, South Africa, Germany, United Kingdom
SILICON, metal and ferrosilicon	38	Brazil, Russia, Canada
COPPER, refined	37	Chile, Canada, Mexico
MICA (NATURAL), scrap and flake	31	Canada, China, India, Finland
PERLITE	28	Greece, China, Mexico, Turkey
SALT	27	Chile, Canada, Mexico, Egypt
BROMINE	<25	Israel, Jordan, China
ZIRCONIUM, ores and concentrates	<25	South Africa, Senegal, Australia, Russia
LEAD, refined	24	Canada, Republic of Korea, Mexico, India
VERMICULITE	20	South Africa, Brazil, Zimbabwe, Kenya

Source: United States Geological Survey

However, raw critical materials do exist in the United States and across North America. Spodumene deposits can be found in California, South Dakota, and North Carolina.[26] While some chemistries are moving away from cobalt, Minnesota, Alaska, California, Idaho, Michigan, Missouri, Montana, Oregon, and Pennsylvania all have some cobalt levels, and areas of Canada have more significant cobalt deposits available.[27] Manganese remains essential to the production of advanced batteries, and to date, 100 percent of the U.S. supply is imported, and the major import sources are South Africa, Gabon, Australia, and Georgia.[28] Reports of manganese deposits in Tennessee and Virginia, among other locations, remain largely undeveloped.[29] Nickel can be found in several locations, including the Upper Peninsula of Michigan.[30] Figure 4 shows the location of raw material operations and relative size in North America.

Figure 4: Map of North American Raw Materials Companies

Source: Data from NREL North American Database, 2021 and NAATBatt

[26] U.S. Department of the Interior, "Lithium Resources of North America." Accessed March 3, 2022. https://pubs.usgs.gov/bul/1027g/report.pdf
[27] United States Geological Survey, "Cobalt." Accessed March 3, 2022. https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-cobalt.pdf
[28] United States Geological Survey, "Mineral Commodity Summaries 2020." Accessed March 3, 2022. https://pubs.usgs.gov/periodicals/mcs2020/mcs2020.pdf
[29] GeoScience World, "New insight into the origin of manganese oxide ore deposits in the Appalachian Valley and Ridge of Northeastern Tennessee and northern Virginia, USA." Accessed March 3, 2022. https://pubs.geoscienceworld.org/gsa/gsabulletin/article-abstract/129/9-10/1158/207612/New-insight-into-the-origin-of-manganese-oxide-ore?redirectedFrom=fulltext
[30] United States Geological Survey, "Nickel." Accessed March 3, 2022. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-nickel.pdf

Material Processing

Once the raw materials are extracted, manufacturing lithium-ion batteries depends on the complex physical and chemical processing of critical materials like graphite, cobalt, manganese, and nickel. In 2019, China produced 64 percent of the world's graphite, having 24 percent of the world's reserves.[31] In other rare earth metals, China has only 1 percent of the world's cobalt reserves, but it dominates in processing raw cobalt, according to the Institute for Energy Research.[32] Furthermore, China owns eight of the 14 largest cobalt mines in the Democratic Republic of Congo, and they account for about half of the country's output.[33] China mines only 6 percent of the world's manganese but refined 93 percent of it in 2019.[34] Most manganese supply is concentrated in South Africa, followed by Australia and Gabon.[35]

In contrast, North America produced and processed zero manganese.[36] Ukraine has a small operation, but it cannot produce sufficient feedstock for the battery supply chain. Unlike the other minerals, the nickel mining industry is relatively evenly spread worldwide, and 35 percent of the chemical processing is outside of China, leaving 65 percent control in China.[37] Electric vehicles account for about 7 percent of overall nickel consumption today.[38]

While the United States does not have many material processing companies, several materials companies are actively developing new or improved materials in battery production.[39,40] Figure 5 illustrates the distribution of material processing companies across North America.

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[31] Institute for Energy Research, "China Dominates the Global Lithium Battery Market." Accessed February 8, 2022. https://www.instituteforenergyresearch.org/renewable/china-dominates-the-global-lithium-battery-market/#:~:text=In%202019%2C%20China%20produced%2064,the%20processing%20of%20raw%20cobalt.
[32] Ibid
[33] Ibid
[34] Ibid
[35] Ibid
[36] Ibid
[37] Ibid
[38] Ibid
[39] These companies include Alabama Graphite Products, Amsted Graphite Materials, BASF Toda America, Battery Resources, Borman Specialty Materials, Enevate, Group14 Technologies, Livent Corporation, Nanotech Energy, Paraclete Energy, Piedmont Lithium, Pyrotek - Metaullics Systems Division, Sila Nanotechnologies, Superior Graphite, Ten-Nine Technologies, and Unifrax.
[40] This list and those developed throughout the chapter are the result of a year-long study by NAATBatt in conjunction with the National Renewable Energy Laboratory (NREL). While every effort has been made to create comprehensive lists, the encompassing nature is effective as of the time of the study's conclusion in September 2021.; National Renewable Energy Laboratory, "NAATBatt Lithium-Ion Battery Supply Chain Database." Accessed February 24, 2022. https://www.nrel.gov/transportation/li-ion-battery-supply-chain-database.html

Figure 5: Map of North American Material Processing Companies

Source: Data from NREL North American Database, 2021 and NAATBatt

In addition to materials processing related to anodes and cathodes, several other material companies are developing next-generation components of the battery cells or systems.[41],[42] While some of these companies are larger, there remain vast opportunities for investment in and creation of battery materials processing and materials development companies in the United States.

Cell Manufacturing

As the basic building blocks of any usable battery system, the cell itself represents a complex set of steps that includes receipt of all the processed materials, creating proprietary slurries, coating electrodes typically on copper or aluminum foils, a series of post-coating processes, cutting or trimming into desired electrode form, and stacking, folding, or winding into the battery's final shape. Historically, the primary manufacturers of advanced battery cells were military or satellite customers, such as Yardney and EaglePicher Technologies (which became a single company in 2014).[43] However, the great enthusiasm around EVs in the late 2000s combined with the ARRA stimulus package of 2009 provided capital infusion to increase domestic manufacturing capacity, with the largest recipients being Johnson Controls ($299.2 million), A123 ($249.1 million), Dow

[41] These companies include including Arkema, Black Diamond Structures, Cabot, Celgard, Daikin America, DuPont, Entek, Forge Nano, Halocarbon, Honeywell International, Huntsman Petrochemical, Lyten, Microvast, Parker LORD, and The Chemours Company.

[42] This list and those developed throughout the chapter are the result of a year-long study by NAATBatt in conjunction with the National Renewable Energy Laboratory (NREL). While every effort has been made to create comprehensive lists, the encompassing nature is effective as of the time of the study's conclusion in September 2021.

[43] PR Newswire, "OM Group Completes Acquisition of Yardney." Accessed February 24, 2022. https://www.prnewswire.com/news-releases/om-group-completes-acquisition-of-yardney-300001317.html

Kokam ($161.0 million), LG Chem ($151.4 million), and EnerDel ($118.5 million).[44] Unfortunately, none of these companies reached their projections within the timeframes initially set because of slow consumer adoption and no corresponding government demand-side participation.[45] Consequently, all but LG Chem underwent some sale of assets or significant restructuring.

The Biden administration has taken some actions to encourage domestic cell manufacturing. In June 2021, the Department of Energy released the National Blueprint for Lithium Batteries 2021 to 2030, which included Goal #3: Stimulate the U.S. electrode, cell, and pack manufacturing sectors.[46] Further, the administration has also committed to strengthen requirements related to procuring batteries from American-made sources.[47] Finally, the infrastructure bill passed in November 2021 includes several encouraging provisions that commit a total of $30.7 billion for EV deployment and Charging Infrastructure Funding[48], broken down as:

- $7.7 billion directed to deployment of EVs and related infrastructure;
- $12.7 billion supporting deployment of other clean vehicles and fueling infrastructure; and
- $10.3 billion for grid modernization and battery-related investments.

Of this amount, $7.5 billion is allocated to EV charging infrastructure, split between two programs: The Charging and Refueling Grant Program and the EV Charging Formula Program. The first program, funded at $2.5 billion, will be led by the Department of Transportation and is aimed investing along Alternative Fuel Corridors that states have already designated and will complement state efforts to promote publicly accessible alternative fuel charging infrastructure. The second program is funded at $5 billion and establishes a National Electric Vehicle Formula Program at the Department of Transportation. These funds can be used by states to acquire, install, operate, and maintain EV charging infrastructure.

The bill also allocates $5 billion for clean school buses whereby state and local governments, eligible contractors, and nonprofit school transportation associations will have access to at least $2.5 billion for electric buses. The other $2.5 billion is available for any clean fuel technologies, including electric powertrains.

The infrastructure legislation also provides $140 million for Department of Energy to establish a rare earth material demonstration facility that will include a full-scale integrated rare earth

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[44] Seeking Alpha, "Obama Announces List of Grant Recipients, Recognizing Significance of Hybrid Markets," Accessed February 24, 2022. https://seekingalpha.com/article/154152-obama-announces-list-of-grant-recipients-recognizing-significance-of-hybrid-markets

[45] The Motley Fool, "Have DOE Subsidies Failed the Energy Industry," Accessed February 24, 2022. https://www.fool.com/investing/general/2012/04/03/have-doe-subsidies-failed-the-energy-industry.aspx

[46] Federal Consortium for Advanced Batteries, "National Blueprint for Lithium Batteries 2021-2030." Accessed February 8, 2022. https://www.energy.gov/eere/vehicles/articles/national-blueprint-lithium-batteries

[47] Ibid

[48] Great Plains Institute, "Electric Vehicle Programs in the Bipartisan Infrastructure Bill." Accessed February 8, 2022. https://betterenergy.org/blog/electric-vehicle-programs-in-the-bipartisan-infrastructure-bill/

element extraction and separation facility and refinery. It also gives agencies direction to evaluate and adhere to permitting timelines for critical mineral projects. Processing these materials will be supported by $3 billion in the infrastructure funding for a Battery Material Processing Grant Program that will be administered by the Department of Energy. Funding here will support demonstration projects and construction of battery material processing facilities. These resources will promote the domestic material extraction and processing of core minerals needed for advanced battery production.

Finally, another $3 billion is authorized in the infrastructure legislation will be focused on new advanced battery manufacturing and recycling grants.[49] These grants are designed to support battery manufacturing and recycling by funding demonstration projects and facility construction. These signals and commitments foretell a bright future for cell and pack manufacturers based in America.

Currently, manufacturers are binomially distributed in one of two categories of scale: low volume (i.e., largely experimental or low-rate initial production (LRIP) capacity), or an immense "gigafactory" scale. Several new gigafactory commitments have been announced, including two by GM and LG Energy Solutions in Ohio and Tennessee; three by BlueOvalSK (the joint venture by Ford Motors and SK Innovation), two of which are in Kentucky and one in Tennessee; one by SK Battery America in Georgia; and a forthcoming one by Rivian (in partnership with their existing supplier, Samsung SDI). However, the largest gigafactories operating at or near capacity remain the Tesla gigafactory in Nevada, and the Nissan-affiliated Envision AESC plant in Tennessee. Furthermore, while growing companies aspire for their gigafactories, there remains an exciting opportunity in the market for medium-scale production facilities appropriate for validating mass-production worthiness of new technologies and campus-style groups of manufacturers that can take advantage of shared supply chain dynamics and other resources.

Figure 6 shows the current map of manufacturers of cells in the United States, with an understanding that early-stage startup entities develop frequently and nearly all cataloging efforts are incomplete.[50]

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[49] U.S. Department of Energy Announcement accessed February 15, 2022. https://www.energy.gov/articles/biden-administration-doe-invest-3-billion-strengthen-us-supply-chain-advanced-batteries

[50] The map includes 24M, A123, Aesir, Altair Nanotechnologies, American Battery Factory, American Lithium Energy, Ateios, BrightVolt, Clarios, Cymbet, EaglePicher, Electrochem Solutions, EnerDel, Enersys, Envision AESC (Nissan), Forge Nano, Imperium3 New York, Kore Power, LG Energy Solutions (announced), Lithion Battery, Lyten, Microvast, Navitas Systems, NexTech Batteries, Quantumscape, Samsung SDI America, SK Innovation (announced), Tesla / Panasonic, Xalt Energy, Xerion Advanced Battery, and ZAF.

Figure 6: Map of North American Material Processing Companies

Source: Data from NREL North American Database, 2021 and NAATBatt

Pack Manufacturing

Module and pack design, assembly, and integration remain the largest segment in the United States, as bespoke configurations develop for nearly every end-user without widespread standardization. In general, module and pack manufacturers have come from a diversity of backgrounds and perspectives. They include traditional OEMs (e.g., Nissan), startup OEMs (e.g., Lucid), powertrain developers (e.g., BAE Systems), historic ICE manufacturers (e.g., Cummins), cell manufacturers (e.g., XALT), and others.

This diversity of historic strengths can continue to drive iterative improvements across the market and create confusion in the marketplace as competitors stress one or a few performance characteristics while ignoring others during the sales process. As a result, the intended application specifications drive the careful selection of a module or pack supplier, and often the ability of the supplier to be flexible in working with the final integrator can outweigh pure performance specifications. This opens this space as an opportunity for investment and consolidation shortly, with OEMs showing growing openness to vertical integration or investment in their suppliers. Consolidation is becoming more likely as safety and quality concerns continue to receive high-level attention by media, and as such, incidents increase the liability exposure to smaller companies. Figure 7 shows the current map of most of the module and pack suppliers, again acknowledging smaller or startup entities may not be captured, as with the cell manufacturers.[51]

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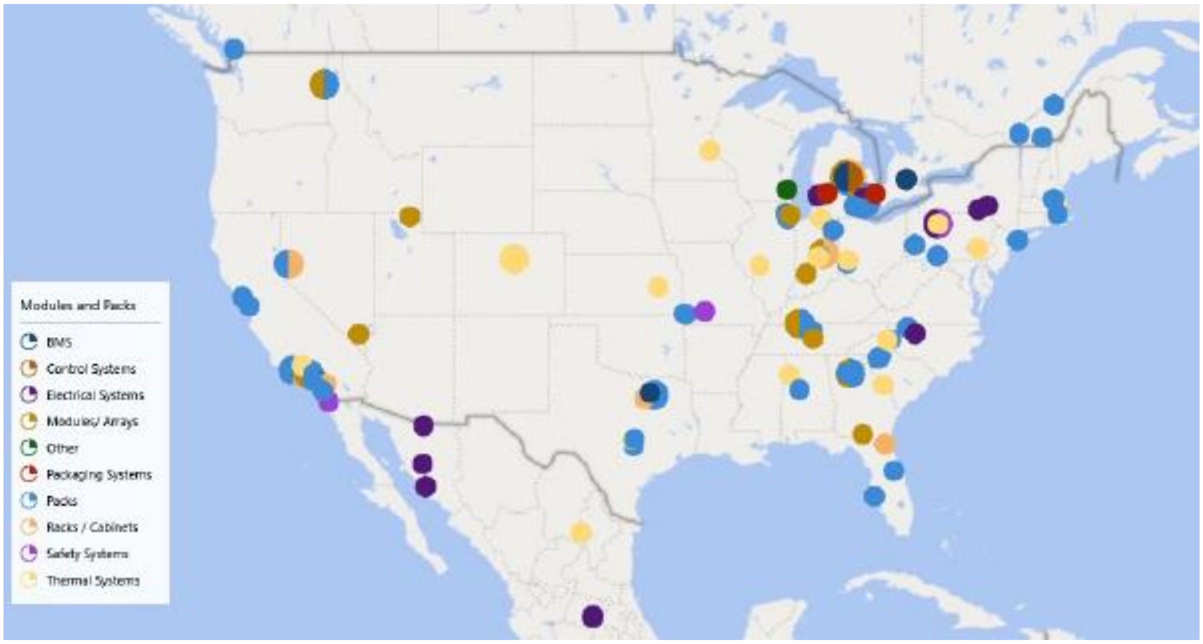
[51] The map derives from the aforemented NAATBatt and NREL study. Companies listed on the map include: 3M, A123, AA Portable Power, ADA Technologies, Advanced Powering Services, AEsir, Alion Science and Technology, AllCell Technology, Altair Nanotechnologies, Allison Transmissions, American Battery Solutions, American Lithium Energy, Amphenol, Arkema Battery Specialties, BAE Systems, BorgWarner, Braille Battery, Canoo, CAVU Group, Cell-Con, Clairos, CSM Products, Custom Power, Cummins, Dantona Industries, Eaglepicher Technologies, Electric Power Systems, EnerDel, EnerSys, Enovate Medical, Exponential Power, Faraday Future, Fisker, Flex-N-Gate, Ford

Figure 7: Map of North American Battery Module and Pack Manufacturing Companies



Source: Data from NREL North American Database, 2021 and NAATBatt

Secondary Uses and Recycling

Since the beginning of mass production of advanced battery chemistries for general use, questions have persisted around how to track, recover, transport, store, screen or sort, repair, remanufacture, refurbish, repurpose, and eventually recycle or otherwise dispose of batteries. The promise of advanced batteries supporting clean energy and a "green" solution compared to other energy solutions can only be realized as the complete life cycle is addressed. Early leaders in these considerations, such as Spiers New Technologies, Indi Powers Systems, and Retriev Technologies, each having leaders active in this aspect of the industry for well over 12 years, have been joined more recently by a collection of companies intent on helping drive advanced battery chemistries to the target of lead-acid batteries. That is, lead-acid batteries have set the bar by evolving into a completely closed-loop cycle where nearly 100 percent of the battery is recycled, and at roughly 98 percent recycling rate by consumers, lead-acid batteries are the most-recycled consumer product.[52]

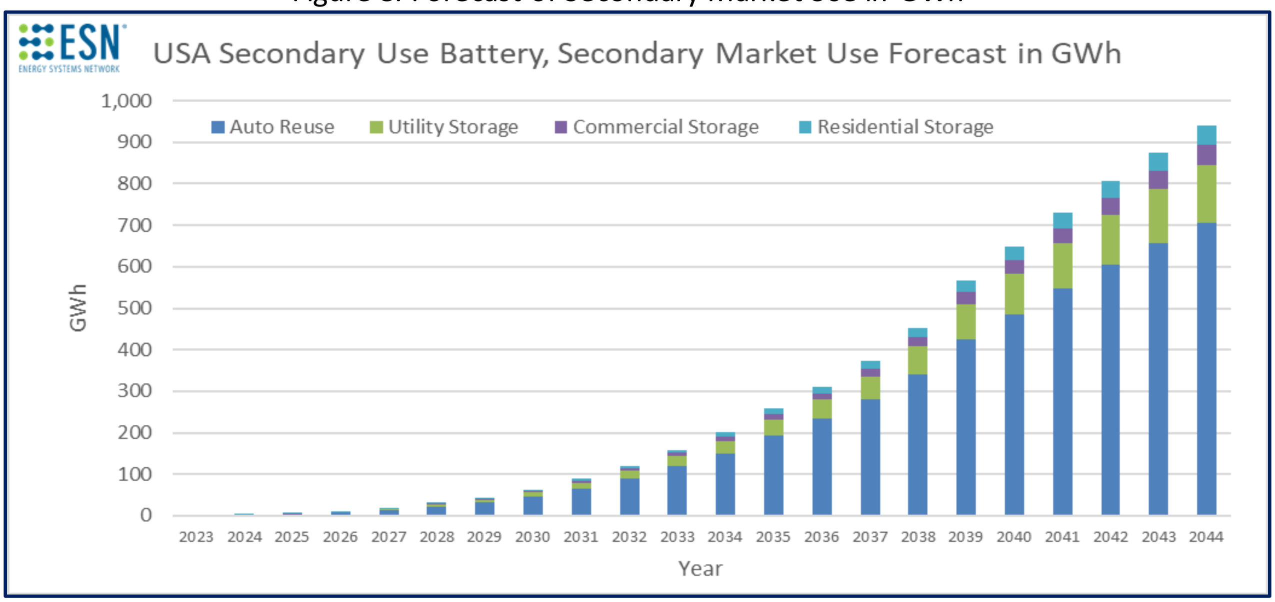
Motors, Global Battery Solutions, General Motors, Honda, HYLIION, Indie Power Systems, Integer Holdings, Inventus Power, Lithion Battery, LithiumWerks, Lockheed Martin, Lucid, Magna International, Microvast, Nanoramic Laboratories, Navitas Systems, Nissan North America, Nuvation Engineering, Paladin Power, ParkerLORD, ProTechnologies, Proterra, Romeo Power, Samsung SDI America, Senior Flexonics, Simpliphi Power, TE Connectivity, Tenergy, Tesla Motors, Toyota, TNR Technical, Triton, Wabtec, XALT Energy, Xos, Yotta Energy, ZAF, and Zeus Battery Products.

[52] The Royal Society Publishing, "Lead Acid Battery Recycling for the Twenty-First Century." Accessed February 24, 2022. https://royalsocietypublishing.org/doi/10.1098/rsos.171368

In aiming to recycle lithium-ion batteries, the four guiding principles are the "Four R's": repair, remanufacture, refurbish, and repurpose or reuse.[53] In most battery modules or packs, repair options are limited and can typically only be performed safely by the original manufacturer. At the module level, only a few battery designs (e.g., EnerDel) utilize mechanical joining methods at the cell level to enable repair and service cell by cell. Remanufacturing is the step in which functional components are reassembled into a product equal to or better than "as new" and reintroduced to the original intended application. By contrast, refurbishment refers to extending the life of a battery by replacing any required components such that the battery can be used in a second-life application distinct from the initial purpose. Finally, repurposing a battery refers to the use of the battery in a second life application with limited or no modification to the battery itself, although the battery system interface may be completely different or newly designed.

Figure 8 shows the projected amount and potential applications of batteries after their first or original use case.

Figure 8: Forecast of Secondary Market Use in GWh



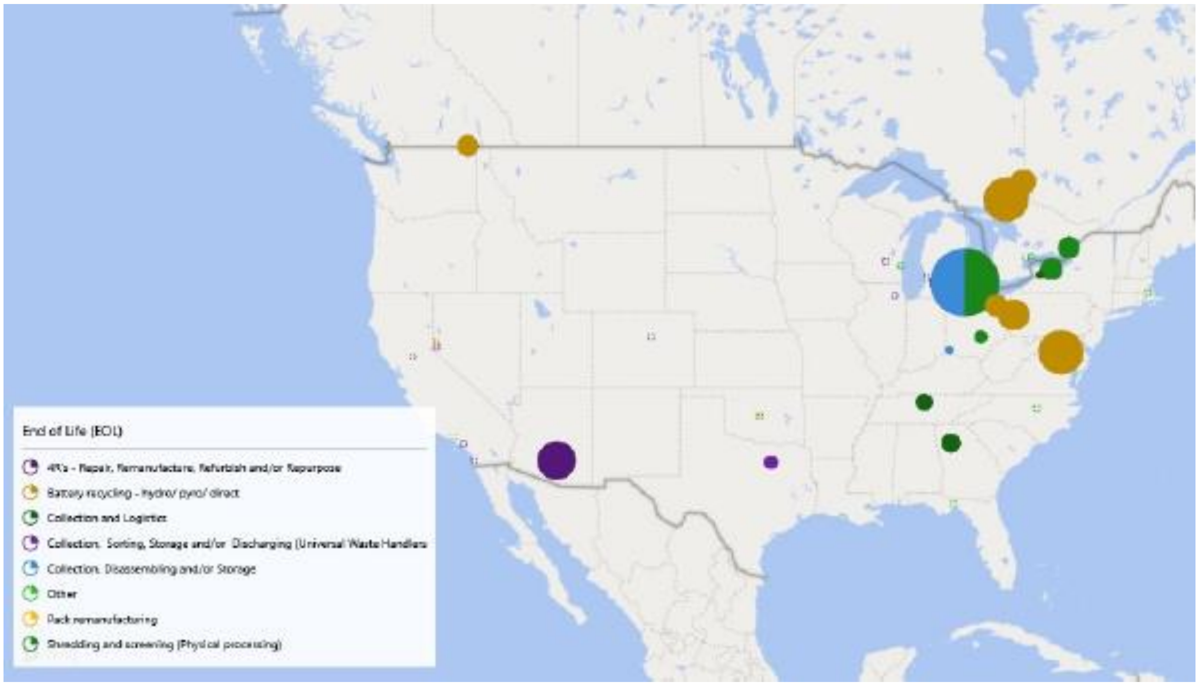
Source: Energy Systems Network, 2021

In terms of the companies involved in this aspect of the market, Figure 9 shows a map of the developing landscape of industry participants in the secondary life and recycling segment of the advanced battery industry.[54]

[53] Nissan Motor Corporation, "Battery Secondary-Use 4R Business." Accessed February 24, 2022. https://www.nissan-global.com/EN/ZEROEMISSION/APPROACH/COMPREHENSIVE/4RBUSINESS/

[54] The map derives from the aforemented NAATBatt and NREL study. Companies listed on the map include: Agmet, American Battery Technology, ATC Drivetrain, B2U Storage Solutions, Battery M.D., Battery Resources, Battery Solutions, Blue Star Recyclers, Call2Recycle, Clean Earth, Evergreen Environmental, Gem Southwest, Global Battery Solutions, GlobalTech Environmental, Heritage Battery Recycling, INMETCO, Interstate Battery Recycling, IT Asset Partners (ITAP), IT eCycling Solutions, Recycling Coordinators, Redwood Materials, Retriev Technologies, Secure E-Waste Solutions, Spiers New Technologies (SNT), Sybesma's Electronics, Veolia Environmental Services, and WeRecycleBatteries.com.

Figure 9: Map of North American Secondary Use Companies



Source: Data from NREL North American Database, 2021 and NAATBatt

Future Investment and Global Position

The United States offers a significant investment opportunity with potentially high returns. We at NAATBatt see following factors validate and bolster these opportunities:

- The current Congress has authorized a variety of new direct and indirect spending that will inject large amounts of money into the battery sector, such as the United States Innovation and Competitiveness Act (USICA), which incorporates both an incremental $100 billion into the National Science Foundation and $10 billion for the Regional Tech Hub programs.

- The appetite for significant infrastructure investments provides stability, and long-term yields that return more than Treasuries has only grown in the United States over the last twenty years.[55] Most of the investment opportunities are in downstream assets ranging from production and cell manufacturing facilities to best-in-class research and development universities. Sovereign wealth funds are a prime target and beneficiary of investment opportunities in applied research, with global capital chasing attractive yields.

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[55] Organization for Economic Co-operation and Development, "Infrastructure Financing Instruments and Incentives." Accessed February 24, 2022. https://www.oecd.org/finance/private-pensions/Infrastructure-Financing-Instruments-and-Incentives.pdf

- The United States is moving toward decentralizing electricity assets and eventually a "Bleeding Edge" grid, including islanding capabilities, distributed generation, vehicle-to-grid technology, and general backup service.[56]

- Domestic OEMs have all published plans to transition away from ICEs yet are likely to continue traditional models by retooling existing plants in the deep South and Midwest and making "bolt-on" investments when appropriate.[57] In addition, the transition may also present opportunities to invest in the supply chain partners to those OEMs.

- There are developing STEM education models for talent pipelines and demand for in-career trained battery supply chain workforce to ensure sufficient availability of talent for the growing sector.[58]

The U.S. advanced battery industry is still in a semi-nascent stage—allowing some challenges and greater opportunities as it develops in a competitive global landscape. The United States has undeniable advantages as the world's largest economy. The trajectory of the U.S. advanced battery industry is trending upwards, suggesting the next twenty years will see significant opportunities in stationary energy storage.

Disclaimer

This chapter was prepared by David Roberts, Tim O'Hara, and Ashley Gordon Schaefer with NAATBatt. Views expressed in this chapter are the author's own, not that of the International Trade Administration. This chapter does not constitute legal advice. Readers interested in investing in the United States should consult legal counsel.

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[56] U.S. Department of Energy, "Grid Modernization and the Smart Grid." Accessed February 24, 2022. https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid

[57] See, e.g., Detroit News, "GM, LG Chem to Build Battery-Cell Plant in Northeast Ohio." Accessed February 24, 2022. https://www.detroitnews.com/story/business/autos/general-motors/2019/12/05/gm-lg-chem-build-battery-cell-plant-northeast-ohio/2617316001/

[58] BIC Indiana, "The Energy Storage Short Course." Accessed February 24, 2022. https://bicindiana.com/educational-series/; Weber State University, "Division of Online & Continuing Education." Accessed February 24, 2022. https://continue.weber.edu/professional/programs/evtraining/