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NPS BATTERY WORKFORCE DEVELOPMENT
PHASE I – STRATEGIC ROADMAP

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ABSTRACT

The U.S. is highly reliant on foreign battery materials imports and processing. Fortifying national security through enhancement of the U.S. battery value chain will require nearly 3.5 million workers by 2030. Existing skills gaps will likely result in over 2 million of those jobs going unfilled. This systemic deficiency in skills and knowledge ranges from mineral discovery, extraction, and refining to manufacturing, battery pack assembly, and reuse or recycling of waste products of both production and application. Each of these gaps has the potential to become a national security vulnerability. Therefore, the creation of a domestic battery supply chain requires national commitment to achieve the needed scientific advances and to develop an adequate manufacturing base capable of supporting American battery sufficiency and national security.

To support the U.S. domestic battery workforce by identifying and filling gaps between existing programs, organizations, and policies, this study is being accomplished in two distinct phases. This paper is the culminating work of Phase I, which examined battery workforce efforts currently underway by federal and state governments, academia, and industry. Using capability-based planning, Phase I resulted in the creation of a Strategic Roadmap with seven proposed Courses of Action for filling discovered gaps in coordination and communication, education and training program creation and access, recruitment into both education and the professions represented within the battery industry, and establishment of required occupational skills. In Phase II, selected courses of action, including transition plans, will be implemented.

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EXECUTIVE SUMMARY

The United States' lack of expertise within the battery value chain is a national security vulnerability. In the next decade, it is estimated that the U.S. will need 3.5 million battery sector workers, yet the current skills gaps will result in over 2 million of those jobs going unfilled (Harris, 2020). This systemic deficiency in skills and knowledge ranges from mining through manufacturing and even to the recycling of waste products. Therefore, reinvigorating the domestic battery supply chain requires a national commitment to achieve the requisite scientific breakthroughs, and to encourage both skilled and unskilled workers into the battery workforce, so that the nation might develop and solidify a manufacturing base.

NPS Energy Academic Group's (EAG) Battery Workforce Development (BWD) research began with this central question: what actions are necessary to fill the gaps in the national effort to increase and improve all sectors of the domestic battery supply chain workforce to a level that supports effective self-sufficiency and enhances national security in accordance with goals established at the federal level?

Many programs, organizations, and policies were established and resourced through unprecedented levels of federal funding, to support a national effort to attract and train/educate a battery workforce. This paper is a Strategic Roadmap, which seeks to identify and mitigate gaps between these programs, toward greater sufficiency.

Using a phased capability approach, the Strategic Roadmap presents seven proposals, each consisting of multiple Courses of Action (COAs) that must be implemented to fill gaps between those programs, organizations, or policies already established and funded to support the building of a domestic battery workforce. These COAs focus on coordination and communication, education and training program creation and access, recruitment into both education and the professions represented within the battery industry, and establishment of required occupational skills.

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GLOSSARY

AWP. Available Workforce Personnel. Individual people able to participate in the workforce of a given region, regardless of their current training status.

BIL. Bipartisan Infrastructure Law. The BIL authorizes $62 billion for the DOE to invest in the domestic manufacturing of clean energy technologies.

BWAG. Battery Workforce Advisory Group. The advisory body formed to consult on this report and other battery workforce matters, offering perspective and advice.

BWD. Battery Workforce Development. The NPS program, within EAG, that is responsible for the creation of this report and the administration of the Battery Workforce project.

BWI. Battery Workforce Initiative. The DOE and DOL's collaborative national strategy for developing a skilled battery workforce.

C2. Coordination & Communication. This report refers to C2 in the context of increasing Coordination and Communication between different actors (employers, educational institutions, unions, government, nonprofits) in the battery value chain to enhance synergies and efficiency.

Capability Sector. Capability Sectors refer to the three functionally-designated sectors of the battery value chain: Upstream (mining and mineral extraction), Midstream (materials processing, manufacture of battery cells), and Downstream (assembly of battery packs, recycling of spent batteries).

CEWD. Center for Energy Workforce Development. A nonprofit consortium of over 120 energy stakeholders working to ensure a continuing supply of qualified workers for the energy industry.

CMGE. Center for Manufacturing a Green Economy. An organization created by the United Auto Workers (UAW) to develop and empower a well-trained, mission-driven green workforce as the United States ramps up 21st century domestic manufacturing.

DOD. Department of Defense. The federal agency responsible for defense and oversight of the United States Armed Forces.

DOE. Department of Energy. The federal agency responsible for national energy policy, production, and research and development.

DOL. Department of Labor. The federal agency responsible for oversight of labor health and safety guidelines, labor policy, unemployment, and reemployment.

Downstream. The capability sector that manages assembly of cells into battery packs, electric vehicle assembly and integration, and recycling of spent batteries and battery materials.

FCAB. Federal Consortium for Advanced Batteries. A consortium uniting federal agencies to ensure coordination of efforts for the numerous projects relating to the domestic lithium battery supply chain.

FTE. Full Time Equivalent. A unit of employee measurement equating to the work of one full time employee; typically, 40 hours per week or 2,080 hours per year.

HCD. Human Capital Development. The process of improving and refining the skills, capabilities, and overall knowledge of the individuals in an organization or nation's workforce.

IBAS. Industrial Base Analysis and Sustainment program. A DOD program aimed at ensuring the readiness and success of the U.S. industrial base and supply chains.

IIJA. Infrastructure Investment and Jobs Act. See BIL.

IRA. Inflation Reduction Act. Legislature enacted in 2022 by President Biden to promote investment and job creation in the field of clean energy.

Li-Bridge. Run through the Argonne National Laboratory, Li-Bridge is a public-private partnership formed to develop and ensure a robust domestic supply chain for lithium batteries.

LFP. A lithium-ion battery that uses lithium iron phosphate as the cathode material. LFP batteries are low cost, high safety, low toxicity, and have a long cycle life. LFP batteries do not use cobalt.

LOE. Lines of Effort. The areas within each capability sector where effort is needed to effect meaningful change on the workforce landscape, i.e., retention of current workforce, recruitment of new workers.

Midstream. The capability sector that deals with processing raw battery materials into usable forms and manufacturing those materials into cells.

NAATBatt. National Alliance for Advanced Transportation Batteries. An advocacy organization formed to promote the development and commercialization of chemical battery technology and manufacturing in North America.

NABWC. National Advanced Battery Workforce Council. Composed of stakeholders from academia, government, and industry, NABWC is a public-private partnership formed to promote the American battery workforce. NABWC is a more formal name for Li-Bridge Committee #5 Workforce and Communities and meets jointly with the NAATBatt Education Committee.

NENY. New Energy New York. A regional initiative, housed at Binghamton University, to create a battery development and manufacturing hub in New York State.

NREL. National Renewable Energy Laboratory. A federally funded research laboratory focused on R&D for renewables, energy systems, clean transport, and energy efficiency; sponsored by DOE.

NY-BEST. New York Battery and Energy Storage Consortium. A regional consortium whose goal is to advance the use of battery energy storage technologies and support their commercialization.

R2. **Recruitment & Retention.** This report refers to R2 in the context of recruiting and retaining workforce personnel for various capability sectors.

ROS. Required Occupational Skills. The minimum necessary skills required for an employee to operate effectively in a given role.

SME. Society for Mining, Metallurgy and Exploration. An industry association offering research, resources, education, and professional development for the fields of mining, metallurgy, and underground construction.

Upstream. The capability sector that deals with raw materials production: mineral exploration, mining, and extraction.

I. INTRODUCTION

Energy storage technologies in general, and batteries specifically, have moved to the forefront of many operational energy conversations. This newfound prominence is seated in the global energy sector's transition from systems of energy production and consumption based on fossil fuels to those based on renewable energy sources and their requisite power storage solutions. The demand for Lithium-ion batteries has increased in all facets of modern life and national security, due to their potential to mitigate many of the shortcomings of intermittent renewable energy sources. The availability of batteries is a vital military operational consideration, as well, which allows commanders mission flexibility and efficiency in an environment in which the United States must compete with great power and near-peer adversaries.

Large volumes of minerals, usually rare earth or strategic minerals must be extracted from subterranean mines or repositories and refined to meet the requirements of battery manufacturing. The application and recycling of batteries are also fields in need of consistent effort and investment to keep up with the pace of growing demand. Due to an excessive reliance on imported materials and manufacturing processes that spans the entire battery value chain, there is a lack of expertise in all sectors of the U.S. domestic industry. Batteries have not captured the imagination of industry in the past, as the U.S. was well supplied in materials and labor from cheaper sources overseas. Manufacturers, including those throughout the battery supply chain, are competing with other sectors for skilled labor. Yet manufacturing ranks low among prospective job candidates as a preferred career option (Manufacturing Institute, 2022, p. 3). This leads to systemic deficiencies which persist in occupational skills and employee availability from extraction through refinement, field application, and recycling byproducts of production and use. The U.S. has not worked toward greater self-sufficiency in this field in the past; now there is a perceived need. Any of the limitations inherent in the current U.S. domestic battery supply chain could become detrimental to U.S. national security.

Recent reports have clearly highlighted the need for the U.S. to build and maintain a domestic labor force for the battery industry. These reports include the President's

Day Supply Chain Review and the Department of Energy's (DOE) Supply Chain Review for the Energy Sector Industrial Base. In 2022, the Federal Consortium for Advanced Batteries published the National Blueprint for Lithium Batteries 2021–2030, which requires that by 2030, the U.S. and its trading partners should create a secure supply chain for battery materials, production, and technology. The creation of a domestic battery supply chain requires both a national commitment to achieving the requisite scientific breakthroughs, and to the re-creation of a national manufacturing base. U.S. Secretary of Energy Jennifer Granholm noted that, "investment in battery production and recycling will give our domestic supply chain the jolt it needs to become more secure and less reliant on other nations" (DOE, 2022, para. 20).

The Naval Postgraduate School (NPS) Battery Workforce Development (BWD) program relies on both new and ongoing initiatives within the NPS Energy Academic Group's (EAG) work in curriculum development, research, and training related to DOD energy security. To support federal mandates at the center of an anticipated 30% annual growth of the lithium-ion (Li-ion) battery chain through 2030 (Fleischmann et al., 2023), this paper extends the EAG's efforts beyond NPS throughout a wide and growing network of government, academic, and industry partners.

A. PURPOSE OF THE RESEARCH

The research began with this central question: **What actions are necessary to fill gaps in the national effort to increase and improve all sectors of the domestic battery supply chain workforce to a level that supports effective self-sufficiency and enhances national security in accordance with goals established at the federal level?** The response to this question demanded urgency, establishment of a wide network, and the willingness and ability to translate empirical data into action.

The BWD team's proposal for responding to this question consisted of two distinct phases as illustrated in Figure 1. In Phase I, the BWD team identified gaps in the national effort to attract, train or educate, and retain individuals in the battery workforce. This effort, which is represented by this paper, resulted in a strategic roadmap that answered questions about *what* must be done to develop the workforce to optimal levels, and *why*. Phase I culminated in the production of seven proposals, each with Courses of Action (COAs) necessitating varying levels of effort and expenditure. Once COAs are selected for implementation, Phase II will begin.

In Phase II, the research team will devise and begin execution of an actionable mitigation strategy. The second phase will answer questions about *how* the gaps are to be filled to better equip the battery workforce to discover, mine, refine, deploy, and recycle strategic minerals, and produce battery cells and packs, domestically, as well as to enact advanced research and development in accordance with national goals.

Figure 1. BWD Research Roadmap

B. PHASE I(A) RESEARCH CONCEPT AND OBJECTIVE

As the existing battery supply chain is international and complex, with many stakeholders from across the global economy, interwoven interests and overlapping strategies even within the U.S. are to be expected. Further, recent federal incentivization of the battery industry has led to diverse actors within the supply chain taking measures that most closely align to their self-interest as well as national security. These actions have not been consistently differentiated or systematically tracked for impact. Therefore, in Phase I(a) of this research, the NPS team conducted a preliminary assessment to discover similar or redundant projects in the battery workforce development space. This Phase I(a) effort was designed to identify existing efforts through a high-level overview of the sector, with a report entitled, "Summary of Ongoing Efforts and Activities" (Dupuy & Sims, 2023). This report informed the current Phase I(b) report, which builds on the work of Phase I(a) to produce a strategic roadmap for battery workforce development and courses of action that strengthen the domestic battery supply chain.

While there are varying definitions of which activities are within which sector, for purposes of this research, we define the sectors as illustrated in Figure 2.

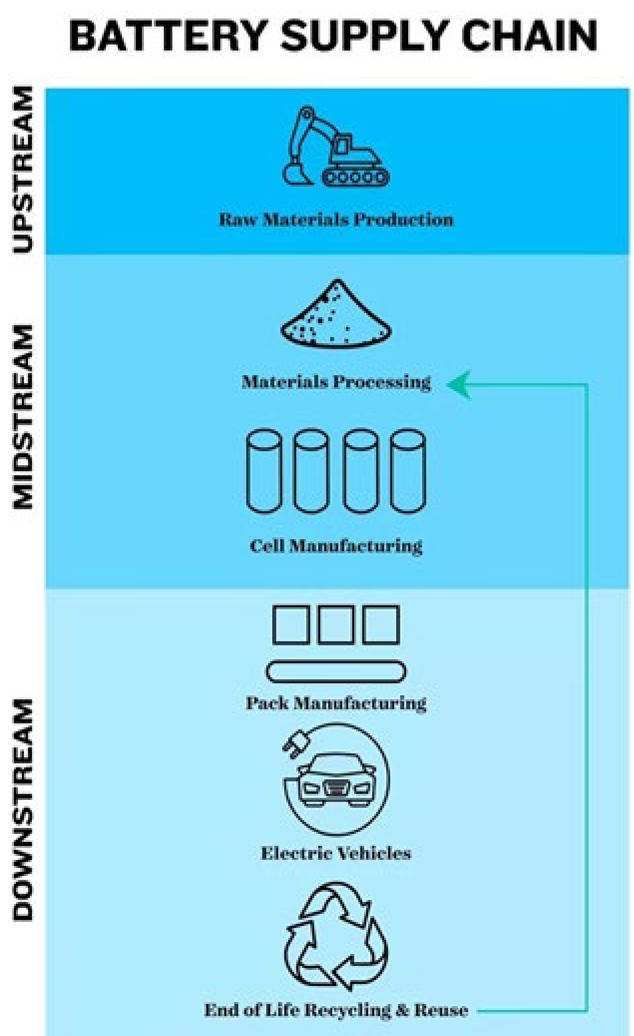


Figure 2. Battery Supply Chain Phases. Source: FCAB (2021)

<u>Upstream capability sector</u> – mineral exploration and extraction

<u>Midstream capability sector</u> – materials processing and synthesizing, cell and component manufacturing

<u>Downstream capability sector</u> – battery pack manufacturing, applications, second life, end-of-life, and recycling

C. PHASE I(B) RESEARCH CONCEPT AND OBJECTIVE

Phase I(b) identified stakeholder groups of greatest relevance, desired outcomes by stakeholder group, success metrics, and a program timeline, ensuring as little overlap as possible with the ongoing work identified in Phase I(a).

The strategic roadmap created in this study articulates *what* changes need to occur and in what sequence, *why* they need to occur, *who* is needed *when* and *where* to make the changes enduring, and *how* the battery workforce and supply chain will benefit from it.

Seven proposals, which each include several courses of action, are presented to meet the objectives of the strategic roadmap, and to allow selection based on available resources and future planning.

D. PHASE II RESEARCH CONCEPT AND OBJECTIVE

Phase II of the research will focus on execution—on *how* the strategic roadmap is to be implemented—through the creation of a Plan of Action and Milestones (POAM) that delineates how each COA selected for implementation will be executed. This phase will also encompass the implementation of selected COAs and enduring transition plans.

II. LITERATURE REVIEW OF KEY DOCUMENTS

The purpose of this Literature Review is to synthesize information on relevant and timely topics pertaining to the domestic battery workforce. Using quotes and articles, the review will cover legislation, the battery belt, strategic minerals, supply chain and manufacturing, recycling, DOD-specific challenges, education and training, recruitment and retention, and coordination and communication.

A. BATTERY GOALS AND LEGISLATION

The reliance on lithium batteries is a commonality among U.S. economic power, national security, and climate goals, all of which are vital to the country's health and well-being (Arora et al., 2023). Energy storage systems on the electrical grid, electric vehicles (EVs), military equipment and much of our modern lives are powered by lithium batteries, which may rightly be called one of the major technologies influencing the twenty-first century (Arora et al., 2023).

Despite the essential nature of the lithium battery, their supply chain is neither reliable nor secure in the U.S. As a result, only 30% of the value-added in lithium batteries that are consumed in the United States is captured by the nation, which is import-dependent. This has negative effects on the nation's economy that go far beyond the battery industry; other battery-dependent industries like electric cars, consumer electronics, and medical devices suffer similar setbacks. Similarly, U.S. reliance on foreign supply chains for lithium battery materials and components puts the country at risk and jeopardizes critical security requirements and sustainability goals (Arora et al., 2023).

For instance, the U.S. military does not currently have direct domestic access to the most advanced lithium batteries and chemical processes needed to power its armored vehicles, installations, and weaponry; the supply chain for those batteries, particularly the upstream and midstream sectors, is controlled by foreign nations, including foreign entities of concern (Arora et al., 2023). To alleviate these shortcomings and reduce the risks, several legislative acts and national-level initiatives have been enacted to devise strategies for a sustainable lithium battery supply chain for the United States. The three main legislative acts passed by Congress in support of development of a domestic battery workforce are the Infrastructure Investment and Jobs Act (IIJA), the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act, and the Inflation Reduction Act (IRA). Discussion of some key legislative acts and corresponding initiatives are expounded upon in the following sub-sections, with a focus on those impacting lithium battery supply.

1. The Bipartisan Infrastructure Law

A crucial component of President Biden's "Build Back Better" plan, the Bipartisan Infrastructure Law (BIL) gives the U.S. Department of Energy (DOE) over $62 billion to invest in domestic energy manufacturing (U.S. Department of Energy, 2021).

According to a White House statement regarding the effectiveness of the Act, "these investments help build an economy powered by clean energy… resilient to climate change, while creating good paying union jobs and rebuilding our domestic manufacturing base" (The White House, 2023). The goal of this significant investment in clean energy infrastructure was to modernize the U.S. power grid, weatherize and upgrade residences, workplaces, schools, and communities to make them more affordable and environmentally friendly, and finance new initiatives to support the creation, testing, and implementation of innovative clean energy technologies (The White House, 2023).

2. Investing in American Manufacturing and Workers

Reviving domestic supply chains and enhancing American manufacturing leadership are two of the Bipartisan Infrastructure Law's (BIL) main objectives. By encouraging domestic energy technologies, its investments in clean energy technology supply chains will enhance U.S. competitiveness in a global market predicted to reach $23 trillion by 2030 (U.S. Department of Energy, 2021).

The Department of Energy notes that the BIL will:

- Invest more than $7 billion in the supply chain for batteries…This will also include producing critical minerals, sourcing materials for manufacturing, and recycling critical materials without new extraction/mining.

- Provide an additional $1.5 billion for clean hydrogen manufacturing and advancing recycling RD&D.
- Create a new $750 million grant program to support advanced energy technology manufacturing projects in coal communities.
- Expand the authority of DOE's Loan Program Office (LPO) to invest in projects that increase the domestic supply of critical minerals and expand LPO programs that invest in manufacturing zero-carbon technologies for medium- and heavy-duty vehicles, trains, aircraft, and marine transportation. (para 4)

3. Li-Bridge Initiative

Two critical initiatives were implemented in June 2021. First, under Executive Order 14017, the White House published its 100-day Supply Chain Review Report, outlining the necessity of a national strategy for the lithium battery supply chain in the United States (Arora et al., 2023, p. 5). Second, the National Blueprint for Lithium Batteries—a national strategy for forging a resilient and domestic lithium battery supply chain—was released by the Federal Consortium for Advanced Batteries (FCAB), an alliance of all federal agencies with an interest in lithium batteries (Arora et al., 2023, p. 5). The DOE asked Argonne National Laboratory (ANL) and three U.S. trade associations—National Alliance for Advanced Transportation Batteries International (NAATBatt), New York Battery and Energy Storage Technology Consortium (NY-BEST), and New Energy Nexus, as leading experts in lithium battery technology—to advise the U.S. government. This project is called the Li-Bridge initiative (Arora et al., 2023, p. 5).

"The purpose of Li-Bridge is to develop a strategy for establishing a robust and sustainable supply chain for lithium battery technology in North America" (Arora et al., 2023, p. 3). This initiative resulted in the identification of 26 specific actions that could address the deficiency in domestic battery manufacturing and technology (Arora et al., 2023, p. 3). These recommendations fall within five broad objectives (Arora et al., 2023):

Improve investment attractiveness of U.S.-based lithium battery technology and material production through expanded and better designed supply- and demand-side incentives

Support research, enable product and business model innovation, and accelerate pathways to commercialization through investments in R&D and validation and scaling capabilities

Help U.S. companies secure access to critical minerals, energy material supplies (virgin and recycled, domestic-and foreign-sourced) and low-carbon infrastructure

Address know-how gaps by investing in workforce training

Establish an enduring U.S. public-private partnership to support the development of a robust and sustainable lithium battery supply chain in North America. (p. 3)

4. National Blueprint for Lithium Batteries

The *National Blueprint for Lithium Batteries* was produced by the Federal Consortium for Advanced Batteries (FCAB) in 2021 in response to the Biden Administration's agenda "to address the climate crisis and build a clean and equitable energy economy that achieves net-zero emissions," outlines a vision for the U.S. lithium battery supply chain (FCAB, 2021, p. 3). It states: "By 2030, the United States and its partners will establish a secure battery materials and technology supply chain that supports long-term U.S. economic competitiveness and equitable job creation, enables decarbonization, advances social justice, and meets national security requirements" (FCAB, 2021, p. 5).

The National Blueprint for Lithium Batteries seeks to direct funding toward the development and sustainment of a domestic supply chain for lithium battery manufacturing. It identifies five goals that may help the U.S. reduce its battery supply chain's dependence on foreign resources:

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

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

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

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

Maintain and advance U.S. battery technology leadership by strongly supporting scientific R&D, STEM education, and workforce development (FCAB, 2021, p. 6).

5. The Inflation Reduction Act

The Inflation Reduction Act (IRA), passed in August 2022, seeks to address the climate crisis and improve the security of American energy (The White House, 2021). The Act focuses on decreasing household energy costs, reducing pollution, and advancing environmental justice. Importantly for battery workforce, it also works toward the creation of millions of well-paying jobs for American workers in manufacturing (The White House, 2021).

The IRA has been a particular contributor to the battery industry, with over $70 billion dedicated to the U.S. battery supply chain. This investment has been particularly focused on the midstream sector and the construction of gigafactories.

B. THE "BATTERY BELT"

A "Battery Belt" is forming for reasons largely attributable to the Inflation Reduction Act and to the expenses associated with safely transporting lithium batteries. Such a geographical centralization of domestic manufacturing capabilities is an important step in the process of ensuring the U.S. achieves its economic power, national security, and climate goals. However, there is no similar coalescence around other sectors necessary to the supply chain, such as the upstream mineral mining sector and the downstream recycling sector.

The "Battery Belt" is being recognized as a region of newly-focused manufacturing, where batteries used to power electric vehicles will be produced alongside the vehicles that use them (Lauer, 2022). The region encompasses the eight states of Michigan, Indiana, Ohio, Kentucky, Tennessee, North Carolina, South Carolina, and Georgia. It has seen more than $90 billion of investments in batteries through federal investment such as the IRA, which in turn have resulted in about 70,000 manufacturing jobs (Tracy & Novak, 2023).

Federal Reserve experts expect these new investments, as well as future ones, to significantly increase U.S. production of lithium-ion batteries (Lewis, 2022). Since 2021, more than 15 new U.S. lithium-ion gigafactories or expansions have been announced in the Battery Belt (Lewis, 2022). All but one gigafactory exceed ten GWh of capacity, and the largest will exceed forty GWh (Lewis, 2022). The gigafactories are mostly clustered in the Midwest and South, and near Tesla facilities in California and Texas (see Figure 3; Lewis, 2022).

As explained in the *New York Times,* the federal government has "allocated nearly $400B over 10 years to encourage the clean energy transition and the growth of factories" (Lauer, 2022, para. 4). Through incentivization measures such as the IRA that led automakers to build batteries and electric vehicles within the U.S. in greater numbers, not only have job opportunities increased, but it is expected that the cost of EVs will decrease—with the overall result being a decreased dependence on China (Lauer, 2022).

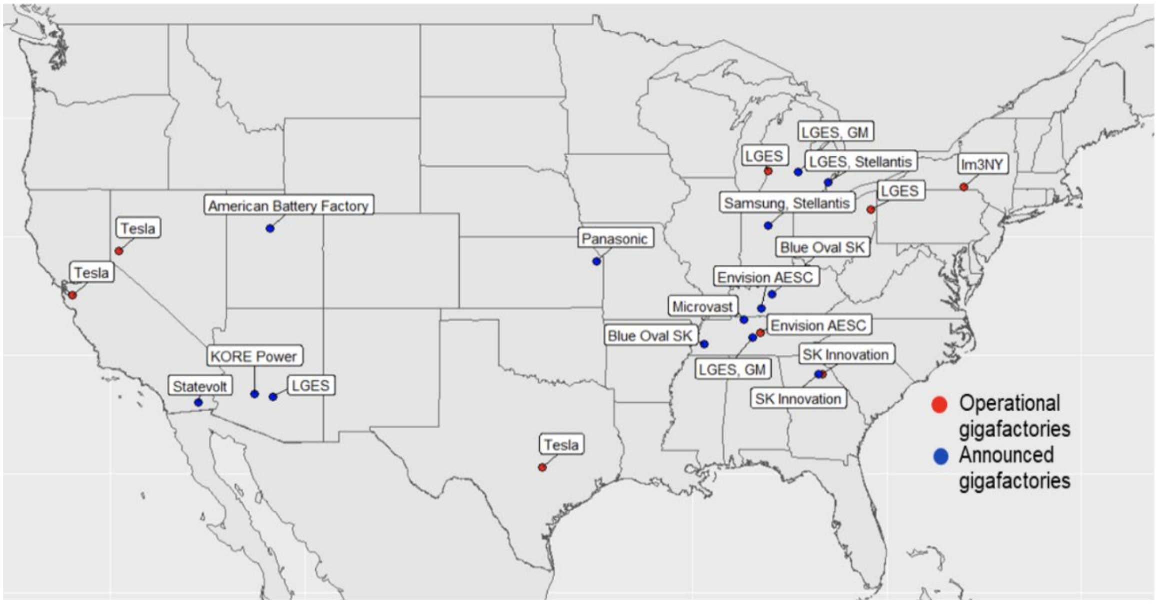


Figure 3. New Gigafactories Cluster in the Midwest, South, and Near Tesla Facilities. Source: Lewis (2022)

The transport of large quantities of lithium batteries is expensive, as they are subject to strict safety regulations. From a supply chain perspective, this is another reason that domestic manufacturing of EV batteries within the Battery Belt is a strategic decision for the U.S. (Lewis, 2022).

Another advantage of the Battery Belt is "its proximity to ports and transportation corridors, utility connections, water availability, sites prime for development and ease of permitting" (Udavant, 2023, para. 2). This leads to greater investment and higher rates of local employment.

"Alongside the rise in manufacturing investment, is a need for talent to fill the factories being built" (Udavant, 2023, para. 3). As the number of battery manufacturers in the Battery Belt rises, high schools, universities, trade schools, state governments, and manufacturers are launching a variety of initiatives to meet the increased demand for a skilled workforce.

C. UPSTREAM SECTOR OF THE BATTERY SUPPLY CHAIN – MINING AND CRITICAL MINERALS

In terms of ability to source and process minerals critical to lithium battery manufacturing, including rare earths, lithium, cobalt, graphite, manganese, and nickel, the U.S. is currently behind China and it appears this will continue for the immediate future (IER, 2020). As China intensifies its global control over the supply of these minerals, the U.S. continues to rely on them—weakening U.S. ability to achieve economic power, national security, and climate goals. To correct this negative trend, the U.S. can implement corrective actions, including:

Enter into international agreements that encourage responsible mining

Incentivize the upstream sector to expand mineral exploration capabilities

Improve upon industrial policies to streamline the governance, funding, and fast tracking of activities involving upstream activities, and

Incentivize both the downstream sector to expand its recycling and reuse capabilities and the upstream sector to shoulder more of the recycling and reuse burden.

The U.S. can also address the workforce shortage by introducing legislation that promotes support for mining and mineral engineering programs and mineral literacy organizations.

As EV demand rises, the majority will likely be manufactured using Chinese lithium-ion batteries (IER, 2020). Figure 4 indicates the key minerals in electric vehicle lithium-ion batteries: "The cells in the average lithium-ion battery with a 60 kilowatt hour (kWh) capacity contain around 185kg of minerals" (Bhutada, 2022, para. 4).

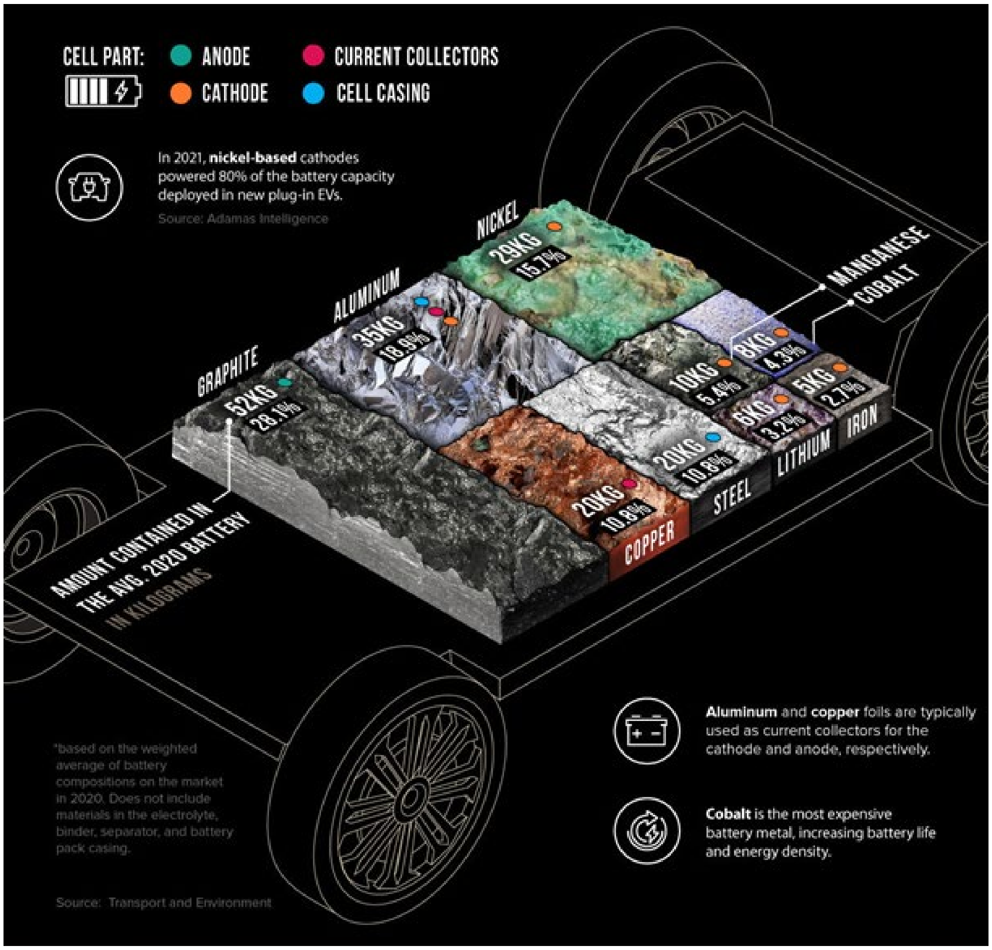


Figure 4. The Key Minerals in an EV Battery. Source: Bhutada (2022)

Chinese chemical companies account for approximately 80% of the world's total output of raw materials for advanced batteries. Lithium-ion battery manufacturing depends on key materials like graphite, cobalt, manganese, and nickel (IER, 2020). In 2019, China produced 64% of the world's graphite and held 24% of global reserves; China has only 1% of the world's cobalt reserves, but it dominates in the processing of raw cobalt (IER, 2020).

Over two thirds of the world's cobalt comes from the Democratic Republic of Congo (DRC), yet China holds over 80% control of the cobalt refining industry (IER, 2020). And China owns eight of the 14 largest cobalt mines in the DRC, and these mines account for about half of the country's output (IER, 2020). A U.S. company previously owned the largest mine in the DRC, but in 2016 its owners sold it to China Molybdenum (IER, 2020).

Although China is one of the top five countries with the highest concentration of lithium resources, it has been purchasing shares in mining operations in Australia and South America, which contain the majority of the world's lithium reserves (IER, 2020).

China mines only 6% of the global supply of manganese, with most manganese supply concentrated in South Africa, followed by Australia and Gabon, yet China refined 93% of it in 2019 (IER, 2020). Neither the U.S. nor any North American source produces manganese (IER, 2020).

The nickel mining industry is more evenly distributed throughout the globe than other minerals. Thirty-five percent of nickel processing occurs outside of China (IER, 2020). Electric vehicles account for about 7% of overall nickel consumption, but that percentage "would skyrocket under plans to electrify vehicles as proposed by [President] Biden" (IER, 2020).

China controls 65% of the worldwide mining industry overall. "Its consistent focus on building capacity throughout all sectors of the global battery supply chain has resulted in China controlling almost all critical mineral processing" (IER, 2020, para. 8). Chinese domination of the industry is significant, not only in creating global reliance on Chinese resources, but also that it is not necessary for a country to own a majority or even a significant amount of the raw materials to control the global flow of trade in the supply chain (IER, 2020). This effect and its distribution are illustrated in Figure 5.

If the U.S. continues working to achieve current federal energy goals, the U.S. will be dependent on China for key minerals (IER, 2020). It could take 20 to 30 years or more for the U.S. to catch up with China (IER, 2020). Current production goals would also necessitate the development of new mines in the U.S., "which have historically been opposed by the same environmental groups and politicians who have urged the U.S. to electrify its vehicle fleet" (IER, 2020, para. 8). There are those who believe "that electrification of the U.S. economy and its transportation system will mean the 'Chinafication' of these important parts of our economy" (IER, 2020, para. 8).

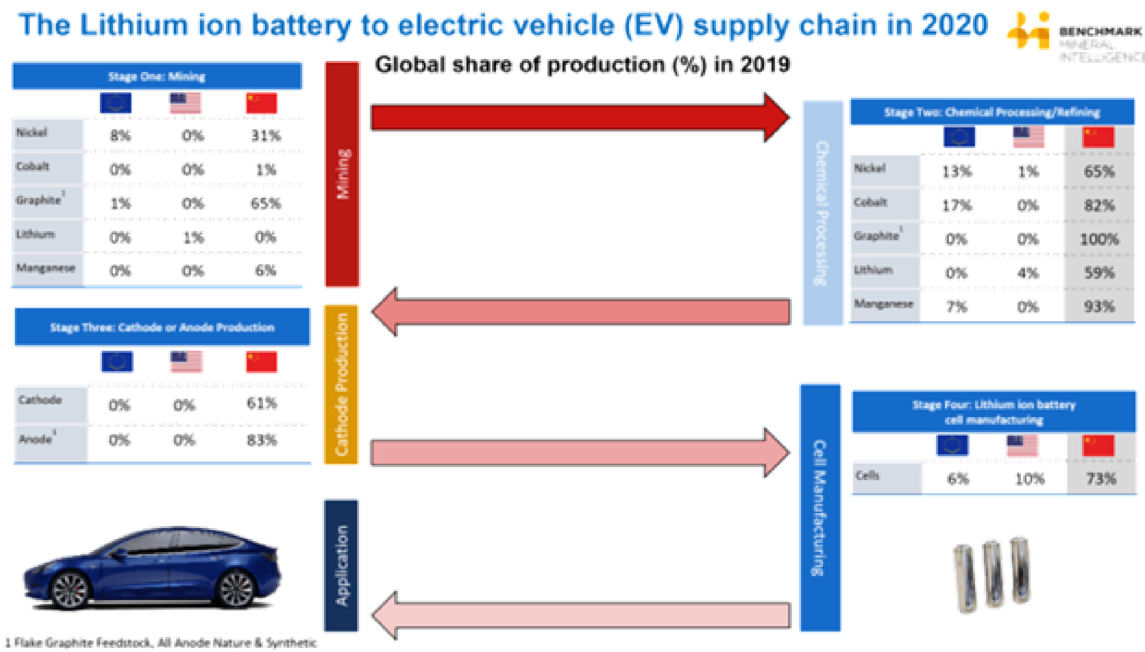


Figure 5. The Lithium Ion Battery to EV Supply Chain – 2020. Source: Els (2020).

1. Shortages of Critical Minerals for Military Technology

A consistent theme throughout the literature is that American dependence on imports is a concern to the U.S. government (Lee & Bazilian, 2021). Natural disasters, civil unrest, trade disputes and business failures can all disrupt any supply chain and the many products that depend upon it. This has led to critical minerals becoming a national security priority (Lee & Bazilian, 2021).

The U.S. recently increased its federal investment in reliable supply chains, yet its mining and recycling of critical minerals remains minimal (Lee & Bazilian, 2021). "This is due in part to how environmentally destructive and polluting many mining and processing operations can be, but also because policy measures are only recently being explored and funded" (Lee & Bazilian, 2021, para. 4).

The number of critical minerals for which the U.S. is 100% reliant on other countries is twice what it was 60 years ago (Lee & Bazilian, 2021). Twenty-eight of the 35 critical minerals identified by the U.S. are at least 50% imported (Lee & Bazilian, 2021). However, the U.S. is implementing measures which will improve these statistics. In 2022, for instance, the U.S. generated more than $98 billion in nonfuel mineral commodities. Figure 6 illustrates the U.S. states ranked by the value of their mineral production.

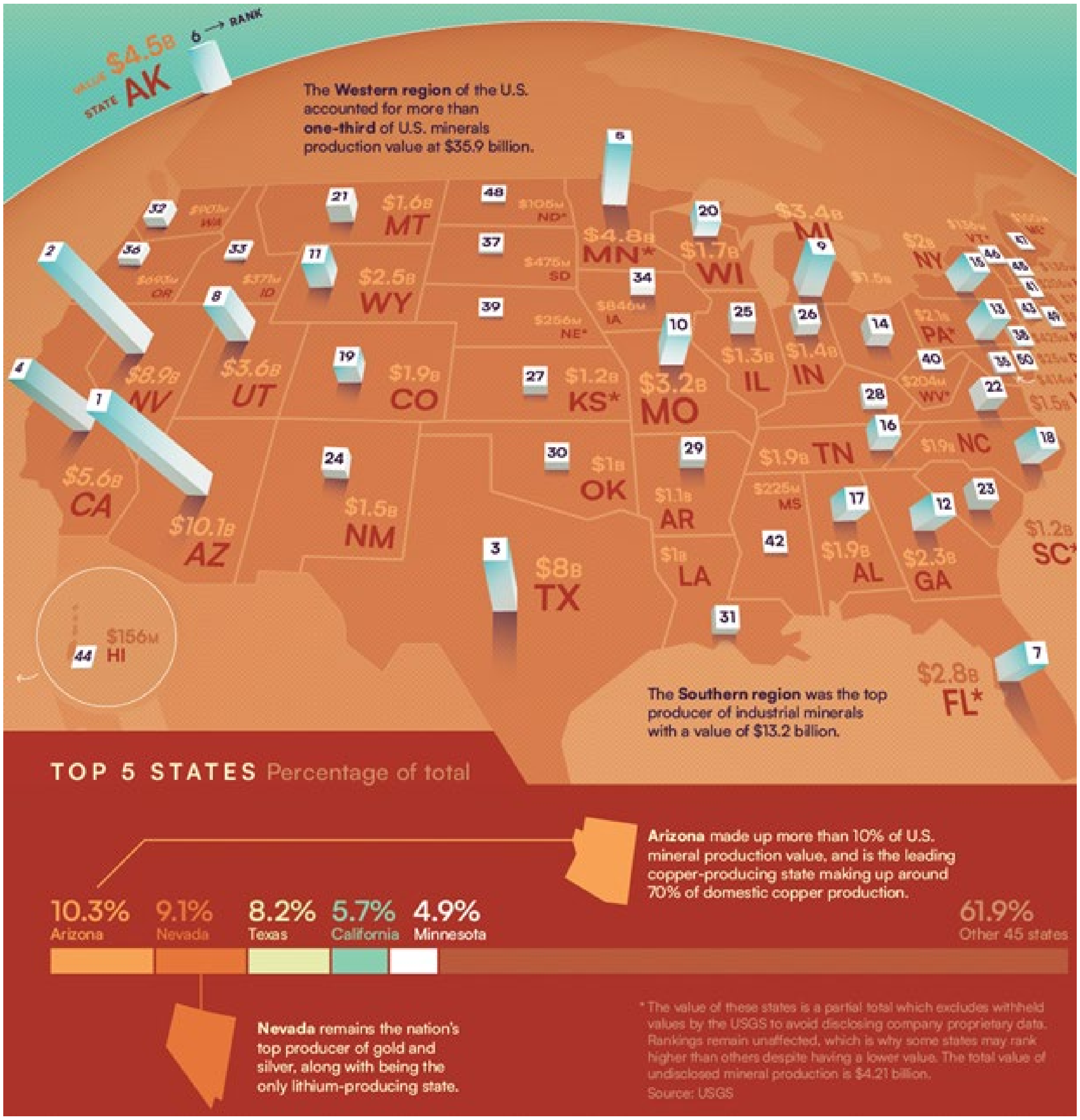


Figure 6. U.S. Mineral Production Value by State in 2022. Source: Conte (2023).

The minerals that are now deemed critical, such as lithium and rare earth elements, highlight the vital role that electric vehicles, renewable energy, and advanced defense technologies play in the American economy (Lee & Bazilian, 2021). These minerals not only contribute to the manufacture of electric motors and batteries, but also satellites, communications equipment, and missile guidance systems (Lee & Bazilian, 2021).

Consequently, the DOD has been a strong supporter of a more resilient supply chain (Lee & Bazilian, 2021). “In the last few years, [the DOD] has been proactive about strengthening domestic production, especially for rare earth elements” (Lee & Bazilian, 2021, para. 10). This focus has resulted in new working relationships with mining and manufacturing operations in California, Nebraska, and Texas (Lee & Bazilian, 2021). The Defense Logistics Agency (DLA) has stockpiled 42 commodities with a market value of $1.1 billion, at six different U.S. locations (Lee & Bazilian, 2021) as a hedge against future shortages, but the stockpile can only supply the public need for a limited time:

> The amounts of lithium, cobalt, graphene, indium and other critical minerals needed for low-carbon technologies alone are expected to increase anywhere from 100% to 1,000% by 2050…these estimates are concerning on their own, but when combined with military needs, industrial needs and the decline of U.S. mining, it paints a troubling picture for U.S. supply shortages. (Lee & Bazilian, 2021, para. 12–13)

Although the DRC is responsible for producing more than 70% of the world’s cobalt, it is not a particularly desirable trading partner for the U.S. due, in part, to reports of its having financed armed conflict with mineral sales (Lee & Bazilian, 2021). As the U.S. is reticent to get involved with “risky” nations, it remains reliant on nations that are less risk averse.

Exacerbating matters are the “major workforce gap and talent crunch” the upstream sector has begun to experience (Hale, 2023, para. 2). Most of the U.S. mining workforce will have retired by the end of the decade—a workforce that will be difficult to replace. U.S. universities have decreasing numbers not only of mining and mineral engineering workforce graduates but also mining and mineral engineering workforce programs as well.

To help remedy the approaching workforce shortage, Hale (2023) recommends the U.S. conduct three courses of action:

> **1) ensure younger generations receive instruction in natural resources and sustainability;**

2) develop and administer mineral security curricula/training for government employees and international affairs programs; and

3) increase public awareness through "mineral literacy." (paras 7-9)

2. How to Strengthen U.S. Critical Supply Chains

The U.S. has a number of options which might prevent it experiencing mineral shortages, further ensuring a successful energy transition (Lee & Bazilian, 2021, para. 16). "The U.S. has lots of room to improve its support for critical mineral markets and trade agreements. Biden's 100-day review of the critical mineral supply chains is a good start" (Lee & Bazilian, 2021, para. 18).

The expansion, recycling, and reuse of critical minerals would go a long way toward increasing sustainability, thereby making minerals more readily available for U.S. domestic use. For instance, moving responsibility for recycling programs from "waste managers" to major producers, like Apple or Tesla, might result in faster increases in recycling technology and more consistent use (Lee & Bazilian, 2021, para. 19). Furthermore, international agreements can also be written such that responsible mining is a requirement of the agreement's funding and employment (Lee & Bazilian, 2021). "U.S. companies can do more to ensure that they aren't purchasing from unsustainable sources or supporting practices that encourage the abuse and exploitation of developing economies" (Lee & Bazilian, 2021, para. 20).

Critical mineral exploration is beginning to intensify within the United States. Rio Tinto, a global mining company, has established plans for a new plant to extract tellurium, a critical mineral used in solar panels, from its copper refining operations in Utah (Lee & Bazilian, 2021). California lithium mining has started to attract investors, as have rare earth projects in Colorado and Nevada (Lee & Bazilian, 2021).

Industrial policy should form the backbone of any discussion of clean energy technologies. These policies include the permitting process, processing plant funding, and research into advanced manufacturing. "How the U.S. shapes the path for critical minerals will have important consequences for everything from the environment to national security" (Lee & Bazilian, 2021, para. 22).

D. MIDSTREAM SECTOR OF THE BATTERY SUPPLY CHAIN – MANUFACTURING

The U.S. has not established a healthy supply chain robust enough to withstand demands from the industrial base or from world-wide competition. Battery manufacturing within the U.S. cannot support the U.S. goal of 100% zero-emissions of new car sales by 2040. More investment is needed in U.S. battery gigafactories to keep pace with China and become less dependent on imports. The U.S. is a world leader in battery research, yet it lacks a domestic supply chain to manufacture cutting edge batteries. Additionally, the current U.S. workforce is not aligned to the needs of EV and battery manufacturing. Current manufacturing skillsets emphasize mechanical engineering and machining capabilities, instead of knowledge of battery chemistries, electronics, and industrial engineering which are at the center of current workforce needs.

This applies equally to the civilian and military sectors: "The Department of Defense requires healthy, resilient, diverse, and secure supply chains to ensure the development and sustainment of capabilities critical to national security and to build enduring Joint Force advantages" (DOD, 2023b, para. 1). The DOD should continue work with interagency, foreign, and industry partners to better understand supply chain risks and to stimulate supply chains in the defense industrial base.

1. Manufacturing Policies and Regulations

The U.S. battery industry needs better industrial policies and federal funding, as well as coordination among federal, state, and local governments and industry (Wilkinson & Rengarajan, 2021, para. 9; see also DOD, 2023b, para. 1; NREL, 2021, para. 21).

Wilkinson and Rengarajan (2021) advise that "to make the kind of investments required, automakers need some kind of guarantee that a sizable domestic EV market will develop, and as we've seen in China and Europe, subsidies and regulation can help provide that" (para. 9).

But it's not enough to focus primarily on building cars; the U.S. must develop the physical and regulatory infrastructure to support the burgeoning industry. Vehicle manufacturers and investors should support innovative efforts to commercialize cutting-edge technologies (Wilkinson & Rengarajan, 2021).

The largest producer of EVs is China which also has the most substantial consumer market for EVs as a result of years of investment in the automotive and battery industries and consistent consumer demand (Wilkinson & Rengarajan, 2021). Europe is also striving to generate its own EV market through regulatory measures that make it very costly to drive internal combustion vehicles and disincentivizing or even prohibiting sales of new non-electric or hybrid vehicles (Wilkinson & Rengarajan, 2021). Investment largely in the form of federal subsidies is beginning to move toward increasing domestic battery production capacity, including processing raw materials and recycling.

2. Investments in Battery Production Alongside EVs

Industry Today states that "to realize the full economic potential from electric vehicles requires investing over $100 billion in the domestic battery industry" (Wilkinson & Rengarajan, 2021, pref.). Federal goals include that 50% of new vehicle sales in the U.S. should be zero-emission by 2030. As a result, the two largest U.S. automakers pledged at a UN meeting that by 2040, 100% of their new car sales would be zero-emission. Yet, for the U.S. to realize the full benefit of all the financial and climate opportunities these new production goals represent, "we really need to be asking where all the batteries for those cars [will be] coming from" (Wilkinson & Rengarajan, 2021, para. 1). Referencing Figure 7, Wilkinson and Rengarajan (2021) project that new, domestic EV sales are expected to increase more than ten times over the next decade: "The key to dominance in EV production is the battery because it accounts for as much as 50 percent of an EV's total value" (Wilkinson & Rengarajan, 2021, para. 2). Nations which do not have domestic battery supply chains may not realize the economic contributions possible from an EV industry, "including the new, good-paying jobs related to the propulsion systems of electric vehicles" (Wilkinson & Rengarajan, 2021, para. 2).

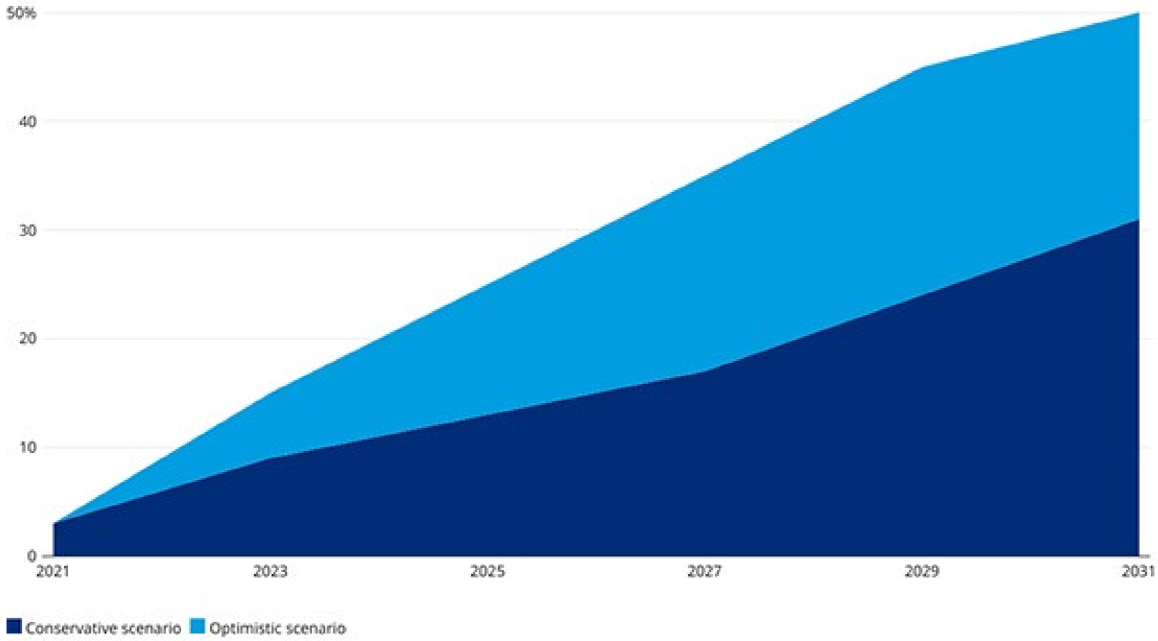


Figure 7. Projected EV Sales in the US: 2021–2031. Source: Wilkinson & Rengarajan (2021).

While U.S. auto manufacturers may offer up to 240 EV models by 2030, there may not be enough battery production in the U.S. to support them (Wilkinson & Rengarajan, 2021). To reach federals goals and guarantee that the EVs sold in the U.S. are truly "Made in the USA," the nation would require more than 1,000 gigawatt-hours (GWh) battery production annually. Currently, the U.S. has 59 GWh of cell production capacity annually, with the majority of the required components and raw materials being imported from Asia (Wilkinson & Rengarajan, 2021). Figure 8 shows the current geographical distribution of battery cell manufacturing facilities in the U.S. (Anson Resources, 2022).

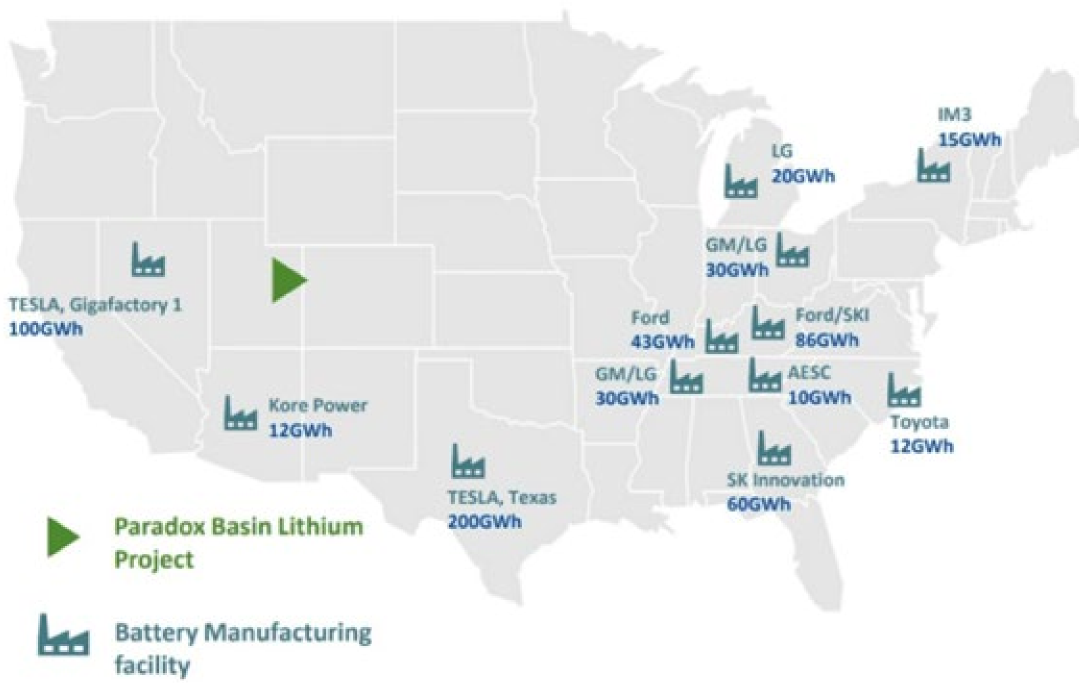


Figure 8. U.S. Battery Cell Manufacturing. Source: Anson Resources (2022).

3. More Gigafactories Are Needed

As much as $100 billion must be invested in the building, equipping, and manning of battery gigafactories before 2030 for the U.S. to have sufficient domestic capacity. Billions more are needed to develop a supply chain capable of supporting those gigafactories (Wilkinson & Rengarajan, 2021).

Wilkinson and Rengarajan (2021) state further that "[f]ailure to create a domestic battery manufacturing infrastructure would leave the entire EV industry dependent on imports and thus vulnerable to trade conflicts and supply shortages like those we are currently seeing in semiconductors — another key EV component" (para. 5). Trans-global shipping of battery cells and materials also creates a large carbon footprint, which also hazards the integrity of the industry, due to regulations surrounding decarbonization (Wilkinson & Rengarajan, 2021).

4. Coordination and Collaboration

Prudence dictates that the U.S. should also consider collaboration with non-U.S. but friendly entities throughout the battery supply chain (Wilkinson & Rengarajan, 2021): "Securing long-term raw material supplies—especially for critical minerals like lithium, nickel, and cobalt—will require upstream partnerships created today" (Wilkinson & Rengarajan, 2021, para. 12). For instance, the U.S. could establish agreements with Canada, which mines many of the metals used in batteries and has recently invested in developing lithium production (Wilkinson & Rengarajan, 2021). Extremely limited U.S. battery material production capacity requires raw materials be shipped from overseas to support production and manufacturing efforts (Wilkinson & Rengarajan, 2021).

5. Manufacturing Workforce Development and Labor Shortages

Another significant challenge faced by the U.S. and Europe is a shortage of skilled labor (Wilkinson & Rengarajan, 2021). Legacy automotive workforces offer skillsets that emphasize mechanical engineering and machining capabilities, instead of knowledge in battery chemistries, electronics, and industrial engineering needed for EVs and battery manufacturing (Wilkinson & Rengarajan, 2021). Currently, the industry and government are not sufficiently addressing what may become a potential obstacle to growth (Wilkinson & Rengarajan, 2021).

"What makes this scenario so tragic is the fact that much of the best early-stage battery research in the world is being done by U.S. universities and national labs through federal grants" (Wilkinson & Rengarajan, 2021, para. 6). While the pace and scale of innovation in the U.S. should provide manufacturing a technological edge over international competitors, EV industries in both China and Europe are heavily subsidized, which has worked to level the playing field (Wilkinson & Rengarajan, 2021).

E. DOWNSTREAM SECTOR OF THE BATTERY SUPPLY CHAIN – RECYCLING

The literature indicates the U.S. has not established an end-of-life recycling process for lithium-ion batteries. The current life cycle for lithium-ion batteries is linear, not circular, as batteries are often disposed of as waste. Circular battery energy storage systems create U.S. market opportunities, stabilize the supply chain, reduce environmental impacts, and alleviate resource constraints. Battery materials must be reused, recycled, or refurbished. The U.S. lags in establishing the technology, infrastructure, processes, workforce, and regulations for an economy based on circular battery production.

1. Circular Economy

The demand for lithium-ion batteries is rising for energy storage and EV applications, a trend expected to grow further due to anticipated technological advancements and decreasing costs. (NREL, 2021). According to a National Renewable Energy Laboratory (NREL) study, "like most U.S. consumer products, the life cycle of lithium-ion batteries is based on a linear model in which batteries are made, consumed, and disposed of without much consideration for end-of-life management strategies, including opportunities to reuse or recycle" (NREL, 2021, para. 2). This challenge of the downstream sector of the battery supply chain is noteworthy, as according to some estimates, "waste from decommissioned EV lithium-ion batteries alone could total 4 million tons annually by 2040, which is the weight about 22,000 Boeing 747s" (NREL, 2021, para. 2).

The NREL study also states that "a new vision is needed for the production, consumption, and retirement of lithium-ion batteries" (NREL, 2021, para. 3). To begin identifying possible pathways for a circular economy—one of NREL's key research objectives—NREL analysts examined the state of reuse and recycling of large-format lithium-ion batteries used in EVs and battery energy storage through a literature review and interviews with battery energy storage experts (NREL, 2021). New recycling processes that economically extract raw materials from used batteries have been developed (Wilkinson & Rengarajan, 2021). NREL analysts found reusing and recycling lithium-ion batteries could create and expand U.S. market opportunities, stabilize the supply chain, reduce environmental impacts, and alleviate resource constraints (NREL, 2021): "However, only one U.S. lithium-ion battery recycling facility exists today. The complete findings are published in an NREL technical report" (NREL, 2021, para. 4).

The benefits of a circular economy include recapturing a portion of the initial investment out of battery energy storage systems through critical mineral and material reutilization, recycling, and refurbishment for additional life cycles, all while reducing waste and the materials would be reused, recycled, or refurbished for multiple lifetimes, rather than one lifetime that depletes limited resources and creates waste (NREL, 2021).

2. Drivers of Lithium-ion Battery Circular Economy

Additional benefits of creating a circular economy for lithium-ion batteries are that manufacturing costs could be decreased, additional revenue streams could be created, and tax benefits could be offered (NREL, 2021). Alongside additional revenue streams, new and expanded markets could also create jobs (NREL, 2021).

According to the NREL study, a circular economy could enhance market competitiveness by increasing a business's reputation and consumer trust through environmentally friendly practices. The broader environmental benefits could include reducing waste, energy usage, and greenhouse gas emissions, as well as preserving raw materials (NREL, 2021).

Such factors could drive U.S. federal, state, and local investment in a circular economy, as well private investment in product, service, and process innovation for the reuse and recovery of materials (NREL, 2021).

Currently, barriers to a circular economy are technology, infrastructure, and processes (NREL, 2021). For instance, variability in lithium-ion battery design and composition makes it difficult to design a standardized process to cost-effectively reuse or recover valuable materials, requiring costly manual processes (NREL, 2021).

The NREL study found that there is limited reliable, publicly available information on the state or volume of retired lithium-ion batteries, or the cost to recondition them for other uses (NREL, 2021). NREL analysts recommend government-funded research, development, analysis, and incentives, as well as information exchanges, to increase knowledge and increase private investment (NREL, 2021).

3. Regulations Applicable to Lithium-ion Battery Reuse

Regulations play an important role in consumer product safety, reliable electricity service, and the safe handling, storage, treatment, reuse, recycling, and disposal of lithium-ion batteries (NREL, 2021). Yet, current regulations, codes, and standards for lithium-ion batteries are unclear, complex, and vary by jurisdiction (NREL, 2021).

NREL analysts highlight existing regulations that could impact the installation and grid interconnection of repurposed lithium-ion batteries (NREL, 2021). They cite, for example, how state and local regulations may govern (1) battery energy storage systems connected to the electric grid, (2) the design, materials, and quality of buildings and structures that house or connect to the systems, (3) system electrical components for grid-tied applications, and (4) industry certification standards to determine the safety and reliability of the systems (NREL, 2021). NREL analysts note that these regulations could also impact secondary uses for lithium-ion batteries (NREL, 2021).

NREL analysts further point out that some states, such as California or New York, are revising their regulations to ensure requirements for connecting to the grid specifically apply to battery energy storage systems (NREL, 2021). The NREL report suggests that this is a significant development, given that interconnection regulations were not developed with these types of systems in mind (NREL, 2021).

4. Regulations Applicable to Lithium-ion Battery Recycling

Currently, it's unclear how decommissioned lithium-ion batteries are classified as waste under the law (NREL, 2021). No federal policy in the United States as of July 2020 specifically addressed the decommissioning of battery energy storage systems or required or encouraged the reuse or recovery of lithium-ion batteries (NREL, 2021). Most often, decommissioned lithium-ion batteries are disposed of as universal waste or hazardous waste, each with their own set of rules; jurisdiction-specific regulations also differ, and penalties for noncompliance exist (NREL, 2021).

For instance, the creation, handling, storage, treatment, transportation (domestic or international), and disposal of hazardous wastes are governed by the strictest federal hazardous waste laws and regulations, which may apply to lithium-ion batteries that are gathered, stored, or treated prior to recycling (NREL, 2021).

F. DEPARTMENT OF DEFENSE – SPECIFIC CHALLENGES

Due to legislation concerning salary caps and depth of experience required prior to hiring, DOD faces challenges competing to hire top talent and retain high performing employees. Regardless, a reliable domestic battery supply chain is required for military operations, and it must receive the attention of the best and brightest minds. A shortage of batteries due to an inadequate supply chain and workforce would result in serious implications for operational capability throughout the services. The literature indicates that climate change in itself is not a specific motivating force for DOD. However, when battery power allows the military to respond to security concerns while simultaneously reducing the armed services carbon footprint, those measures are being viewed favorably.

1. Improve Recruitment and Retention of the Civilian Workforce

A recent Department of Defense (DOD) action plan report, titled "Shape an Appropriately Skilled and Ready Future Workforce: Improve Recruitment and Retention of the Civilian Workforce" (Speight & Hester, 2023) reveals that the DOD "continues to fall short on its ability to assess technical qualifications in its candidates and to shorten the time it takes to hire and onboard new talent" (Speight & Hester, 2023). The shortfall in assessing competencies required and lengthy onboarding process impacts the "Department's ability to deliver relevant and timely talent." Effective and skill-targeted workforce planning is key in the DOD's effort to achieve a competitive advantage over its adversaries while meeting national security strategy objectives.

The Department had set a goal to maximize use of direct hiring authorities up to 100% for eligible hiring actions and staff hard-to-fill positions by September 30, 2023 in an effort to improve recruitment and retention of diverse talent, create three technical hiring assessments for use during the candidate screening process, increase its use of assessments as part of the candidate screening process, improve hiring manager satisfaction incrementally up to 10% or higher, and reduce time-to-hire gradually from 74 days to 65 days (Speight & Hester, 2023). As of this writing, it is yet to be determined if the DOD will be able to accomplish this goal. However, the methodologies used are instructive toward the building of a workforce in the battery sector.

Recruitment and retention are major challenges in the DOD's civilian sector. The report advises that the DOD must strategically position itself to attract and secure top-tier talent (Speight & Hester, 2023). In order to replace critical skills and requisite experience, the DOD must enhance ways to identify, recruit, onboard and train a high performing workforce with a timely and efficient process. The challenge is further complicated by the DOD falling short on its ability to assess technical qualifications in possible candidates and to lessen the time it takes to hire and onboard new talent.

One reason recruitment and retention remain a challenge for the DOD is that "while DOD has several authorities that streamline hiring processes for certain skills and occupations, they are not routinely used in conjunction with other flexibilities, such as targeted recruiting and anticipatory hiring based on predictive analytics" (Speight & Hester, 2023, p. 2). This failure to take advantage of all available flexibilities often results in processes that are less efficient than they could be (Speight & Hester, 2023). It is essential to forecast competency requirements to recruit, develop and retain the appropriate talent for DOD operational requirements.

The DOD action plan report cautions that inefficient or arduous hiring processes may result in the loss of prime talent to the private sector and less qualified talent pools (Speight & Hester, 2023). In addition, lengthy vacancies compound the challenges to meet requirements as managers are left to operate with inadequate resources, further straining existing resources and jeopardizing the mission: "If used appropriately the combination of marketing and branding, modernized assessments tools, and streamlined hiring are very effective in meeting requirements for quality, timeliness, and retention" (Speight & Hester, 2023, pp. 2–3).

DOD recruitment and retention goals and the strategies to achieve those goals are highlighted in the action plan (Speight & Hester, 2023):

- Increase awareness of DOD's civilian employment opportunities to attract targeted candidates.
- DOD is continuing efforts to make use of all allowable recruitment capabilities beyond traditional job websites (providing required

links to satisfy public notice requirements) given the rapid access to and adoption of digital means for recruitment and outreach to the public and educational institutions.

- Expand recruitment assessment practices, to include conducting a pilot with digital talent stakeholders to better assess candidates' technical skills.
- DOD is evaluating assessment tools and creating talent team strategies to more effectively assess candidates for competitive service positions. In FY 2022, the Department allocated approximately $3.5 million for this effort to provide DOD's Human Resources practitioners licensing of USA Hire, expand USA Hire assessments, and employ contractual support to provide program and technical oversight of development and deployment efforts.
- DOD will pilot a program within the Joint Artificial Intelligence Center, the Defense Digital Service, and at least one activity per military department under which certain applicants for technical positions within the Department will be evaluated, in part, based on electronic portfolios of the applicant's work.
- Improve recruitment and outreach strategies to attract digital skills and competencies.
- DOD is planning for additional targeted, virtual hiring events, including increasing outreach to students in underrepresented demographic groups (p. 6).

2. Climate Change and China's Dominance on the Lithium-Ion Battery Supply Chain

While lithium-ion battery technology is often considered central to electrification and the future of the auto industry (i.e., EVs), battery technology applications are also critical components of military systems, "from handheld radios to unmanned submersibles and to future capabilities like lasers, directed energy weapons, and hybrid electric tactical vehicles" (Hicks, 2021, para. 23). With thousands of battery applications across the DOD, having a robust supply chain without reliance on foreign resources and technology is a prime consideration for the DOD.

At Wayne State University in Detroit, Deputy Secretary of Defense Dr. Kathleen Hicks, provided an address on climate change while summarizing the importance of America needing to lead the world, especially when it comes to batteries (Hicks, 2021). Dr. Hicks emphasized innovation, with particular emphasis on manufacturing – to ensure the U.S. has healthy supply chains to get what it needs, when needed (Hicks, 2021): "The problem, however, is that China presently dominates that supply chain" (Hicks, 2021, para. 24). The decision to address climate change and innovation in Detroit was strategic. Dr. Hicks (2021) emphasized that

> Detroit is a city that brings together leaders in the automotive industry, government partners like the Department of Defense, and academic institutions. It's a vibrant ecosystem that tracks and leverages some of the best talent in America, and it will be vital to combating the challenge of a changing climate. (para. 28)

Dr. Hicks's remarks at the address discussed strategic threats and challenges faced by the U.S., particularly with the emergence of climate change (Hicks, 2021). Her focus was on climate change as a national security challenge, and on outlining how innovations in the automotive industry can help the U.S. address the current climate crisis (Hicks, 2021).

The DOD continues to seek a well-defined strategy to account for risks associated with climate change while reducing the armed forces operational impacts on the climate (Hicks, 2021). To do so, the DOD is looking to partner with the automotive industry to help the U.S. "rise to the challenges posed by climate change and other environmental concerns" (Hicks, 2021, para. 4). In her commentary, Dr. Hicks stated, the Department of Defense injected $6.8 billion into Michigan's economy in Fiscal Year 2020 alone. Additionally, the department maintains strong collaborative ties with numerous academic institutions across the state, including Wayne State (Hicks, 2021). Education creates a foundation for talent growth in the battery workforce. During her address, Dr. Hicks underscored the importance of STEM skills, saying these skills are "critical to a strong defense industrial base" (Hicks, 2021, para. 16).

Noteworthy commentary from the address included data on the Arctic, citing the effects of climate change on polar ice melt. The changes in climate are presenting new environmental challenges, in addition to challenges from other nations like China and Russia (Hicks, 2021): "due to rising sea levels and low elevation, areas like the Marshall Islands, home to critical defense assets like the Ronald Reagan Ballistic Missile Defense Test Site, are increasingly at risk of disappearing or becoming uninhabitable" (Hicks, 2021, para. 19).

Climate change was cited as creating drastic weather occurrences that elevate the demands on the U.S. military while concurrently impeding its ability to respond as needed. (Hicks, 2021). To address President Biden's Executive Order, entitled "Tackling the Climate Crisis at Home and Abroad," the Department of Defense recently released two plans (Hicks, 2021):

> The first is the DOD Climate Adaptation Plan. It provides a roadmap to ensuring the department maintains the ability to operate under changing climate conditions. It sets a path to a lighter, leaner, more survivable and agile force that is trained and equipped to operate in all climatic conditions. The second plan, the DOD Climate Risk Analysis is focused on the geo-strategic and mission implications of climate change. It is the framework for shared department wide understanding of climate change and its effects. (Hicks, 2021, para. 20)

In the address, Dr. Hicks (2021) emphasized that the plans are meant to guide the department on how to account and take steps to combat climate change given the administration's goal to reach net zero greenhouse gas emissions no later than 2050. The DOD is committed to solving this challenge by amplifying investments in clean energy technology and instituting significant alterations in its energy consumption practices and creating a sustainable blueprint to align with climate objectives, aiming to approach net-zero emissions by 2050 (Hicks, 2021). The sustainability plan will delineate strategies for reducing greenhouse gas emissions, enhancing sustainable procurement within the supply chain, and boosting efficiency in energy, water, and waste management. Additionally, there will be a dedicated focus on establishing a fleet of non-tactical, zero-emission vehicles as part of the sustainability initiative (Hicks, 2021).

Hicks asserts that electrifying tactical vehicles—first using hybrid electric technology—may not only significantly improve operational capability but also potentially cut greenhouse gas emissions (Hicks, 2021). A significant portion of the address focused on the importance of electric vehicles and their potential to give an edge on the battlefield (Hicks, 2021). Collaboration between the DOD and industry to enhance supply chain resilience plays a pivotal role in fortifying the nation's industrial base (Hicks, 2021).

> Electric vehicles are quiet. They have a low heat signature, and incredible torch, and because they tend to be low maintenance with fewer moving parts. They have the potential to reduce logistics requirements, all with these attributes can help give our troops an edge on the battlefield. But we need partners to help capitalize on this potential and Detroit, the heart of America's automotive industry, is going to be fundamental to achieving these goals. We can't do it without you and without America's private sector. As an example, currently the Department of Defense has about 170,000 non-tactical vehicles. The cars and trucks we use on our bases. That's the largest fleet in the Federal government, next to the U.S. Postal Service. Our success in transitioning this massive fleet to zero emissions, most of which will be electric, will depend on America's auto industry and autoworkers right here in Detroit. (Hicks, 2021, para. 21)

The same is true of the U.S. military's tactical vehicles. Citing field visits to General Motors Defense Tech Center and the Army's Ground Vehicles Systems Center, Hicks highlighted how advancements in electric vehicle technology within the commercial sector can be leveraged to enhance military capabilities like the Army vehicle centric micro-grid that will enhance power applications for future combat capabilities (Hicks, 2021).

The lithium-ion battery supply chain investments are nearing $1 trillion, however, a common theme mentioned several times throughout the literature review, is that China's dominance in the lithium-ion supply chain (Hicks, 2021). Dr. Hicks suggests enhancing the competitive standing of the U.S. will stimulate resilience within the domestic supply chain, "and this will bring jobs to America and ensure our national security" (Hicks, 2021, para. 23).

With this objective in mind, the DOD has become a member of the Federal Consortium for Advanced Batteries, which focuses on securing a domestic supply of lithium batteries and accelerating the establishment of a resilient and secure domestic industrial base. As a part of this consortium, a national blueprint for lithium batteries has been unveiled, outlining the DOD's strategies to ensure a sustainable lithium battery supply chain (Hicks, 2021).

Although the DOD constitutes a significant consumer of lithium batteries, it is widely recognized that the primary impetus for investment in supply chains will ultimately come from the U.S. private sector (Hicks, 2021). Thus, it can be understood that coordination and communication between government and industry are key to drive innovation. And especially more so to maintain a resilient, domestic supply of lithium batteries, which in turn will drive a resilient domestic industrial foundation. Along these lines, Hicks (2021) emphasized that the presence of a successful commercial electric vehicle industry is imperative for reinvigorating supply chain investment within the United States. Specific challenges identified by the DOD include potential customer difficulty with intricate requirements and bureaucratic contracting procedures (Hicks, 2021).

G. BATTERY EDUCATION AND TRAINING

There are several positive examples of programs designed to educate and train a future battery workforce, but more effort is required. First, industry recruitment must expand and be promoted, as workers are in short supply. To support this objective, there must be greater focus on educational opportunities. More students in educational programs leading to future careers in the battery industry will necessitate the identification and recruitment of faculty with the appropriate skills and experience to educate the growing body of battery workers.

The Battery Workforce Initiative is a DOE program designed to align classroom education with on-the-job training. The Center for Energy Workforce Development and New Energy New York are examples of how academia is creating educational programs at the undergraduate and high school levels to support workforce requirements. Universities, community colleges, trade schools, and high schools in the Battery Belt and beyond are incorporating programs in support of battery initiatives. Georgia Quick Start is another example of a state community college system redesigning its programs to align with industry and manufacturing. On the training front, manufacturing workers' unions and building trades have thousands of training centers across the country, including strong, mature apprenticeship programs.

1. Battery Workforce Initiative

The DOE's Battery Workforce Initiative (BWI) seeks to attract fresh talent to the battery manufacturing industry. By collaborating with industry leaders, the initiative aims to pinpoint the essential competencies required for battery manufacturing roles. Insights gathered from experts will inform the standardization of national training for workforce development initiatives to meet skill requirements while addressing gaps in battery manufacturing (Udavant, 2023).

Research on the topic indicates that "while many programs already exist to train workers for battery manufacturing, there is a significant mismatch between the skills attained through classroom or lab training and the skills required on the job" (Jones, as cited in Udavant, 2023, para. 6). Under the Battery Workforce Initiative, training battery manufacturing workers will be comprised of classroom instruction as well as opportunities for hands-on learning experiences, supplemented by mentorship opportunities (Udavant, 2023).

2. Georgia Quick Start

The state of Georgia launched a "Georgia Quick Start" initiative that offers free, tailored workforce training programs for companies that qualify and operate in the state (Udavant, 2023). Quick Start is notable for designing training regimens intended to meet the specific needs of the employer, according to employer specifications. The objective of the program is to deliver timely simulated and hands-on training to expedite getting talent on the production line (Udavant, 2023).

3. Role of Educational Institutes

Research suggests that several battery manufacturing companies choose the location(s) for their respective gigafactories based on proximity to nearby universities. For example, Freyr Battery selected Georgia as the site for its gigafactory as it had easy access to the institutions of Georgia Tech, the University of Georgia, Auburn University and a the technical college system across Georgia (Udavant, 2023). The business-university proximal relationship enabled Freyr to pursue curricula and certification programs at West Georgia Technical College that support future talent pools and training pipelines for battery manufacturing. They were able to work together to explore curriculum and certificate programs to assist in building a future candidate pipeline for the battery manufacturer (Udavant, 2023).

Other various educational institutions developed new programs tailored to meet the demands of battery manufacturing as well. For instance, Clemson University in South Carolina will introduce the nation's inaugural Bachelor of Science degree program in automotive engineering. In this degree program students will combine classroom and lab work alongside industry exposure to address current issues in the automotive industry (Udavant, 2023).

The Clemson International Center for Automotive Research provides master's and PhD programs in automotive engineering, granting students the flexibility to engage in either specialized coursework or research focused on electric powertrains and/or electric vehicle (EV) and battery manufacturing. A minor is also available on electric applications in transportation including battery engineering courses (Udavant, 2023).

Additional programs at Battery Belt institutions are partnering to address future workforce requirements. Greenville Technical College, Trident Technical College, and Spartanburg Community College established a consortium titled, "Revolutionizing Electric Vehicle Education," resourced by the National Science Foundation dedicated to advance and explore the utilization of virtual reality (VR) and augmented reality (AR) educational resources to bolster electric vehicle and battery manufacturing (Udavant, 2023). "With the aid of several state and federal government programs, South Carolina continues to invest heavily in its 16 technical colleges to prepare the local workforce" (Clayton, as cited in Udavant, 2023, para. 21).

4. Energy Storage Systems Campus to Build Domestic Capacity

The Office of the Assistant Secretary of Defense for Industrial Base Policy allocated $30 million project to establish an energy storage systems campus. The 3-year project aims to shift from reliance on constrained materials critical and facilitate rapid scaling to next generation battery technology (NDTA, 2023).

Led by the University of Texas at Dallas, a diverse consortium comprising multiple universities, several businesses, and four national laboratories secured the energy storage system campus. Not only does the campus play a crucial role in the DOD's Scaling Capacity and Accelerating Local Enterprises (SCALE) initiative, "which stimulates commercial investment and builds robust, sustainable markets in technologies that are essential to national security" (NDTA, 2023, para. 2), it also serves as a cornerstone of various new MCEIP programs. These new programs will help emerging domestic organizations by removing previously identified barriers and allowing expansion of production to assist national security stakeholders (NDTA, 2023).

Assistant Secretary of Defense for Industrial Base Policy, Dr. Laura Taylor-Kale, explains that the describes how the "SCALE initiative is built on robust research that indicates market pull is needed to transition innovative technologies into new domestic industrial base capability and capacity" (NDTA, 2023, para. 3). The strategy of consolidating demand across both national security and commercial sectors is anticipated to create market momentum, significantly shortening timelines, allowing for the adoption and expansion of emerging technologies (NDTA, 2023).

The energy storage systems campus will utilize $200 million in private investment to achieve three interconnected goals: enhancing performance of existing lithium-ion batteries, expediting the advancement and manufacturing of next-generation batteries, and addressing necessary raw materials for battery manufacturing. What sets this campus apart is its integration of workforce development as a fundamental component, uniting universities, vocational schools, and the private sector to foster employment expansion while enhancing the domestic workforce skill base (NDTA, 2023).

H. BATTERY WORKFORCE RECRUITMENT AND RETENTION

In an August 2022 survey, the National Association of Manufacturers (NAM) , asked members about obstacles they faced with over 75% responding that "attracting and retaining a quality workforce is among their top problems" (Magill, 2022b, para. 1). According to federal data, as of September 2022, over 800,000 job vacancies exist in the manufacturing industry and economists predict the number could increase to 2.1 million by 2030 if left unaddressed (Magill, 2022b). A Deloitte survey of 100 industry leaders found that talent recruitment and retention remain key priorities in manufacturing : "Over 70 percent said finding and keeping the right talent was a top challenge in managing the production workforce" (Magill,, 2022b, para. 3).

"The biggest challenge is in filling entry-level production positions, which includes roles such as miscellaneous assemblers and fabricators and production worker assistants" (Gold, as cited in Magill, 2022b, para. 6). Still, companies continue to draw in entry level personnel by offering increased wages (Magill, 2022b). Paul Wellener, Vice Chair of Deloitte's Industrial Products and Construction Practice, argues that there is a pressing need to accelerate wage growth. This urgency arises as manufacturers find themselves in competition not just with each other but also with other industries like warehousing and retail, which appeal to the same pool of workers (Wellener, as cited in Magill, 2022b, para 8).

Alongside higher wages, businesses are battling the idea that manufacturing is an outdated industry (Magill, 2022b): "A primary way companies are attempting to make manufacturing a more attractive career option is by offering upskilling and reskilling programs" (Magill, 2022b, para. 12). As an illustration, the Manufacturing Institute approximated that in 2019, manufacturers invested a minimum of $26 billion in training programs, both internal and external, for their employees (Magill, 2022b).

Some companies are exploring flexible work as a means of widening the talent pool. "The pivot is meant to entice a more diverse workforce, such as younger workers, women, veterans and those with disabilities" (Magill, 2022b, para. 14). Some businesses are now offering ways to enhance culture through alternate shift schedules, reduced overtime, and expanding childcare for employees (Magill, 2022b). Manufacturing often requires in-person positions, a challenge to hybrid work, and companies are experimenting with scheduling to increase options for employees (Magill, 2022b).

1. How Manufacturing Companies Need to Pivot to Attract Gen Z

The median age of manufacturing employees stands at 44 years old; therefore, manufacturing is increasingly looking to "Gen Z" as a potential solution to their labor shortage challenges (Magill, 2022a). This presents a problem however, as a 2021 demographic survey revealed that only 8% of the manufacturing workforce was between the ages of 16- to 24-years-old (Magill, 2022a).

Further exacerbating the manufacturing workforce shortage is that "in a competitive labor market, Gen Z workers are demanding strong wages, more flexibility and clear upward mobility, pushing companies to adjust their job offerings and opportunities to meet young people where they're at" (Magill, 2022a, para. 4). One of the biggest hurdles for manufacturers, when aiming to appeal to younger workers, is demonstrating clear career progression paths to Gen Z recruits (Magill, 2022a).

Patrick O'Rahilly, Founder of Factory Fix, has said that

> I think the biggest thing is you have to sell them on the potential career path and what can come next, versus the actual job that they start in, because usually the actual job is not going to be super glamorous or super impactful. Manufacturing is one of those industries where you have a slow growth curve. (Magill, 2022a, para. 7)

O'Rahilly indicates a company must clearly demonstrate to potential employees there is a distinct path for upward mobility from entry level positions to management, particularly to be competitive with competition offering higher wages and flexible work (Magill, 2022a).

O'Rahilly further advises that

> The one place [the manufacturing industry] truly can compete [in] are the career tracks that exist within the industry. There's a pretty clear path to a

> six-figure career if you can be disciplined about getting better in your trade...that's really the thing manufacturers have to lean into more. (Magill, 2022a, para. 9)

2. Creating an Ideal Environment for Young Workers

Flexibility in the work environment is a prevalent priority among Gen Z talent (Magill, 2022a). Remote and hybrid work in manufacturing remains a challenge for the industry due to its reliance on in-person tasks (Magill, 2022a).

Despite this obstacle, employers have numerous strategies at their disposal to address the issue and provide alternative forms of flexibility. Employers are increasingly seeking input from employees regarding the types of flexibility they prioritize. This may involve offering options such as shift schedules tailored to better align with education requirements, providing additional compensation for time off for medical appointments, or even implementing a four-day workweek (Magill, 2022a). A study by the Deloitte and Manufacturing Institute revealed that executives were progressively providing choices such as shift exchanges, part-time positions, and shorter contractual arrangements (Magill, 2022a).

A standout finding in this area is that Gen Z "employees aren't just looking for a boss, they want a mentor" (Magill, 2022a, para. 21). Thus, it seems that a key aspect necessary for recruiting and retaining Gen Z employees is to cultivate such an environment in which supervisors are both a coach and a mentor, to capture hearts and minds and engender loyalty from an employee base that seeks friendship and family-type relationships in the workplace, otherwise "you're going to lose them" (Magill, 2022a, para. 22).

3. Battery Workforce Initiative

In 2022, the DOE gathered a group of specialists and stakeholders from the advanced battery sector "to rapidly develop training and materials for key occupations (as defined by industry) in a manner that complements ongoing workforce development efforts" (BWI, 2022). This effort, referred to in literature as the Battery Workforce Initiative (BWI), was coordinated between the U.S. Department of Labor (DOL) and the

DOE. The initiative additionally encompassed manufacturers, technical specialists, employers, workforce trainers, and labor unions (Grzelewski, 2022).

The goal of the BWI is to accelerate the creation of training and education opportunities to address the workforce requirements of the advanced battery manufacturing sector (Grzelewski, 2022). U.S. Energy Secretary, Jennifer Granholm, and other officials from the Biden administration conducted a visit in 2022 to the state of Michigan promoting the BWI, which targets strengthening the workforce for electric vehicle and grid storage battery sectors in the United States (Grzelewski, 2022). The intent of the BWI is "to speed up the development of high-quality training, starting with existing examples to develop consensus on core training needs, and then develop training for use by companies and local training providers" (BWI, 2022). The initiative's objectives include (BWI, 2022):

- Convene battery industry organizations to cooperate in the development of training by sharing non-proprietary requirements for high-demand occupations.
- Engage training experts from manufacturers, labor, education, government, and other organizations to participate in facilitated workshops that quickly distill common skills and abilities needed in each industry segment and accelerate decision making.
- Translate those needs into educational and on-the-job training requirements, forming the basis for training materials and guides.

The BWI encompasses employer-driven testing and validation programs designed to evaluate the efficacy of preliminary training for key job positions and responsibilities identified through the initiative (NETL, 2022a). The outcome will be a roadmap of training needed for each evaluated position and refined upon employer testing and validation which can be used to create standardized DOL credentialing shared across the community of practice (NETL, 2022a).

The DOE announced a $2.5 billion loan to Ultium Cells LLC, a partnership between General Motors Co. and LG Energy Solution, to help in the building of several lithium-ion battery cell manufacturing plants across 3 states: Michigan, Ohio, and

Tennessee (Grzelewski, 2022). Provided by the DOE's Loan Programs Office and augmented from the IRA, the loan was the first exclusive resourcing for a battery cell manufacturing project (Grzelewski, 2022).

Also noteworthy is that the investment across three plants in Michigan, Ohio, and Tennessee will be able to produce 130 gigawatt hours (GWh) of cell capacity allowing General Motors in its pursuit to sell 1 million EVs each year by 2050 (Grzelewski, 2022). This is significant if the U.S. plans to reach the target of 1,000 GWh of battery production annually (Wilkinson & Rengarajan, 2021).

Secretary Granholm claimed the U.S. would have as many as 10 battery manufacturing plants operating by 2025 (Grzelewski, 2022). With three GM plants opening in the battery belt, adding 130 additional GWh of battery cell capacity to the current 59 GWh available, the authors contend that it is fair to assume that the U.S. will be tracking towards that objective of reaching net zero greenhouse gas emissions by 2050, increasing manufacturing jobs, and improving supply chain resiliency and reliance within in the U.S. (Grzelewski, 2022).

I. BATTERY INDUSTRY COORDINATION AND COMMUNICATION

The literature indicates that the United States is collaborating on 15 projects aimed at securing critical mineral supplies such as lithium and rare earth metals. Consequently, forging partnerships in free trade agreements will be essential for the United States. Additionally, the U.S. government created the National Advanced Battery Workforce Council (NABWC), an emerging public-private partnership comprised of industry, government, community organizations, academia, and workforce/labor intermediaries. NABWC is a more formal name for Li-Bridge Committee #5 Workforce and Communities and meets jointly with the NAATBatt Education Committee. This coalition aims to coordinate and achieve national objectives for the battery workforce. This is a new organization, and it is too early to determine if the NABWC is successful. So far, New York State is the sole model for private industry participation, facilitated by an alliance of NAATBatt, NY-BEST, and New Energy Nexus. However, additional partnerships with private industry are needed.

1. U.S., U.K., and partners working on 15 critical minerals projects

In order to address the energy goals established by the Biden Administration, the U.S., along with its partners, is actively engaged in 15 initiatives aimed at securing critical mineral supplies essential for electric vehicles and the transition towards renewable energy (Onstad, 2023). In 2022, 14 separate governments established The Minerals Security Partnership (MSP) in hopes to guarantee sufficient mineral reserves, including lithium and rare earth elements, to fulfill zero-carbon objectives (Onstad, 2023).

Jose Fernandez, Undersecretary for Economic Growth, Energy, and the Environment, recently stated that the U.S. is "looking at 15 projects on five continents, ranging from extraction to processing…It's our intent to get some deals done in the next few months" (Fernandez, as cited in Onstad, 2023, para. 4). The MSP seeks to streamline agreements between private enterprises and assist in financing, which may involve trade banks like the U.S. government's Export-Import Bank (EXIM) (Onstad, 2023). One of the initiatives resides in the U.K. and other MSP members include the European Union, Canada, Australia, France, Germany, Italy, Sweden, Finland, Norway, Japan, India and South Korea (Onstad, 2023).

According to Fernandez, the United States is intending "to seal an agreement to allow critical minerals mined or processed in Britain to qualify for U.S. clean vehicle tax breaks" (Onstad, 2023, para. 9). Furthermore, the U.S. agreed to a minerals deal with Japan in 2023 and is looking to come to terms with the EU (Onstad, 2023). The U.S. Inflation Reduction Act provided an incentive for U.S. EV purchases, up to $7,500 in tax credit, provided that a specific proportion of minerals used in the production were sourced from the U.S. or a free trade partner (Onstad, 2023). As such, U.S. partnerships with free trade partners, such as those in the MSP, are critical.

2. The National Advanced Battery Workforce Council

The National Advanced Battery Workforce Council (NABWC) is an emerging public-private partnership made up of industry, government, academia, community organizations, and workforce/labor intermediaries (NABWC, 2023). Its goal is to catalyze, coordinate and execute national battery workforce objectives (NABWC, 2023). "NABWC is a public service, non-profit, brand neutral, volunteer-based organization dedicated to the success of the U.S. battery industry" (NABWC, 2023, para. 1).

The formation of the NABWC was a key recommendation of the Li-Bridge Workforce and Communities Committee (NABWC, 2023). Li-Bridge is a public-private partnership tasked with developing a national strategy to address and create a sustainable and robust U.S. supply chain for battery technology. Argonne National Labs serves as facilitator between private industry and the federal agencies and departments (NABWC, 2023). Private industry participation is facilitated by an alliance of NAATBatt, NY-BEST, and New Energy Nexus (NABWC, 2023).

According to the NABWC (2023), the need for a major battery industry training and education effort is an essential factor in building a broad, strong and vibrant U.S. battery industry. "Doing that successfully and expeditiously is crucial to U.S. national security and economic vitality" (NABWC, 2023, para. 3). NABWC is working towards these objectives by aiming to accomplish the following in 2023 (NABWC, 2023):

Update and expand the 2022 survey of battery industry workforce needs

Reach out to battery training and education providers in the U.S. and allied nations – including trade and apprenticeship schools, community colleges and universities – to build a comprehensive database of existing battery and battery-related training and education offerings

Organize and catalog the available training and education

Develop a central "one stop" internet platform where all interested organizations and individuals may conveniently and efficiently access the cataloged information

Compare the results of numbers 1 and 2 above to determine gaps in available battery training and education

Strongly encourage training and education content providers to create courses which will fill those gaps

Promote careers in battery manufacturing and maintenance to students and other potential workforce participants. (para. 4)

III. METHOD

Phase I(b) of this project flowed from the central research question and was conducted in multiple stages as described in Figure 9. Each stage was conducted in terms of the capability sectors within it, and each sector was in turn examined through four lines of effort. For instance, within Capability Sector 1, the upstream sector of the battery supply chain, *required occupational skills (ROS)*, was examined for the new workforce, current workforce, coordination and communications, and transition planning. Subsequently, the same four lines of effort were examined in terms of *available workforce personnel (AWP).* Once all four lines of effort were examined for each of the six stages within Capability Sector 1, then the focus moved to Capability Sector 2, and Capability Sector 3, and the same four-dimensional analysis of each stage within each of those sectors.

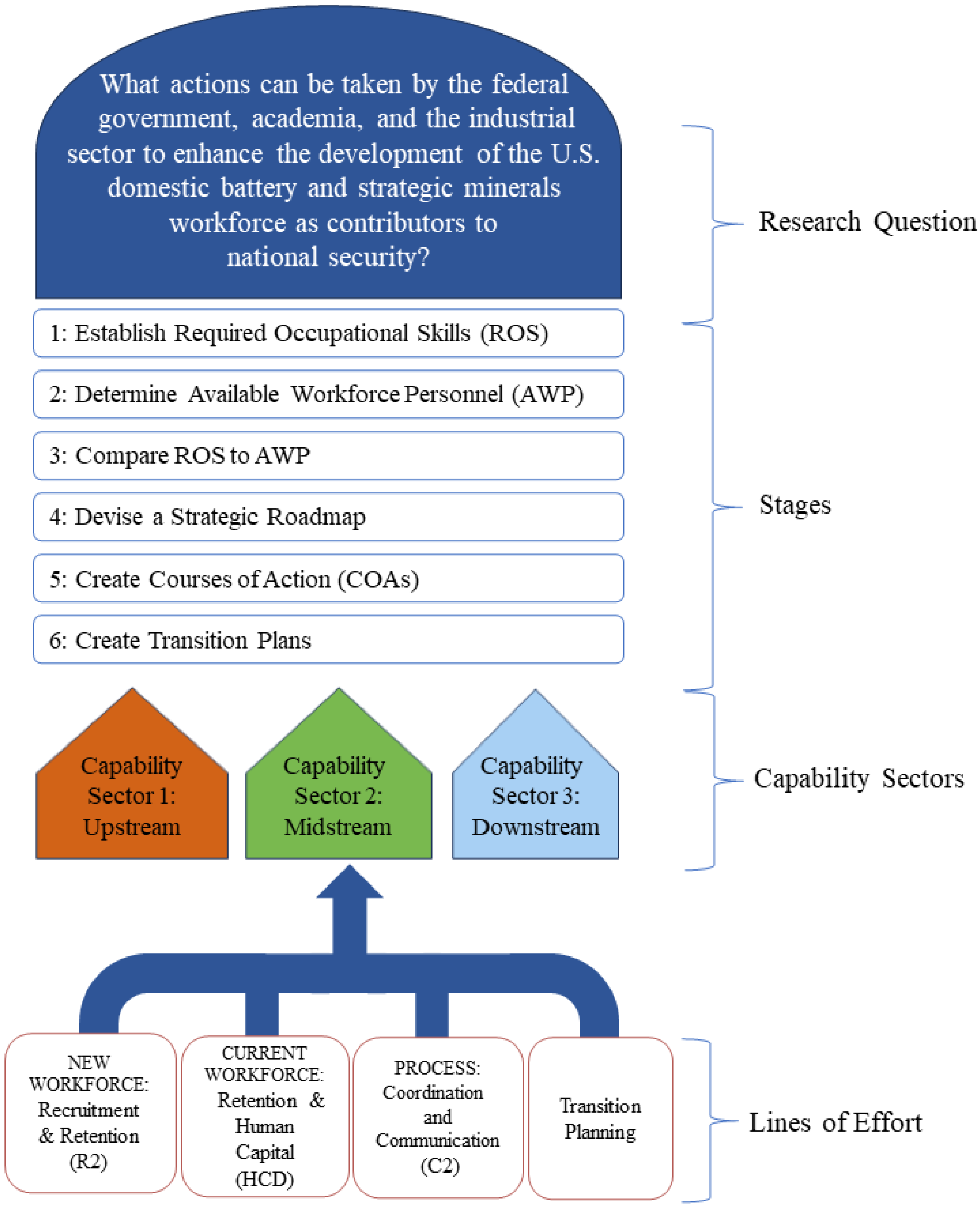


Figure 9. Overall Design of NPS Battery Workforce Development Study.

A. STUDY DESIGN

Phase I(b) builds upon the results of Phase I(a) by creating a plan to guide the multi-year effort that is Phase II. While the objective of Phase I(a) was to understand the current state of the battery workforce, the objective of Phase I(b) was to identify skill gaps and determine a path toward closing them.

The work was divided into the six stages of discrete effort illustrated in Figure 9 and discussed further in Table 1.

Table 1. Stages of Study Design

STAGE	OBJECTIVE
Stage 1: Establish required occupational skills (ROS).	Through primary and secondary means, determine the need for battery workforce occupational skills research.
Stage 2: Determine available workforce personnel (AWP).	Through primary and secondary means, establish the current availability of research into the availability of appropriately skilled and available workforce personnel.
Stage 3: Compare ROS to AWP.	Determine the gaps in manning as a function of the difference between required occupational skills and available workforce personnel.
Stage 4: Devise a strategic roadmap.	Map out a plan that will close the gaps discovered in Stage 3.
Stage 5: Create courses of action (COAs).	Based on the strategic roadmap, propose multiple courses of action (COA) at varying levels of effort and cost, to work toward a fully developed battery workforce.
Stage 6: Create transition plans.	Ensure the longevity and scalability of the battery workforce development initiative by proposing transition plans based on each COA.

B. RESEARCH METHODS

1. Stage 1: Establish Required Occupational Skills (ROS)

a. Collaboration

1. The researchers worked to establish partnerships with battery manufacturers, research institutions, and trade associations. This was accomplished primarily by tapping into an expanding network of subject matter experts, cold-calling organizations of interest, and attendance at symposia, where further contacts were generated.
2. The project team held meetings and interviews with industry and government stakeholders and researchers and participated in seminars and symposia to assess existing workforce skills and future needs.

b. Skills Mapping

1. The project team sought a comprehensive skills framework that outlined the specific competencies required for different roles within the battery sector. This was accomplished through online and in-person meetings and interviews. The team also utilized secondary on- and off-line resources to assess the state of occupational skills mapping and job identification within the battery supply chain.
2. Emerging technologies and trends, as reported in popular media, were discussed at symposia and studied to anticipate future skill requirements.

c. Labor Market Analysis

1. The project team analyzed labor market trends, job postings, and publicly available workforce demographics to identify areas with the most significant skill shortages.
2. Using primary and secondary sources, the team developed an understanding of regional variations in skill demands and used that understanding in formulating courses of action.

2. Stage 2: Determine Available Workforce Personnel (AWP)

a. The project team utilized primary and secondary sources throughout industry, as well as government and academic research, to discover the state of the current workforce throughout the battery supply chain.
b. Through discussions with industry personnel at symposia, during site visits, and through stakeholder connections, the project team worked to discover the deficiencies in the workforce, and their proximate causes. Through primary and secondary means, the researchers considered educational quality or availability challenges, and if they were discovered, the reason for the deficiency.
c. Demographic profiles publicly available were used to study geographic variations.

3. Stage 3: Compare ROS to AWP

a. The project team compared the framework of required occupational skills, as identified by primary and secondary sources, to the personnel currently employed within the battery supply chain to determine whether the perceived need for workforce personnel was being filled by the available population in adequate numbers.
b. The researchers also conducted a literature review to determine how any mismatch in skills and workforce was affecting the stated outcomes of the battery industry or goals set by Federal entities.
c. The project team collected feedback from symposia participants, industry partners, labor organizations, academic institutions, and battery supply chain employers to identify areas for improvement, and then sought to discover through secondary research whether participant insights were generalizable, or regional, or true only for their organizations.
d. BWD research and active programs in place or planned were studied to evaluate the impact that they would have, and whether that impact would result in workforce gaps.

4. Stage 4: Devise a Strategic Roadmap

a. The researchers used the Stage 3 results to create a strategy to fill the identified gaps, based on the resources considered most applicable and available.
b. The researchers examined the goals of the various Federal agencies as they applied to each of the lines of effort in this project and integrated into the strategy for filling the gaps.

5. Stage 5: Create Courses of Action

a. The project team devised several courses of action that would ensure complete coverage of the supply chain, U.S. geography, the various battery technologies, and the diverse set of end-users.
b. The following themes ran throughout stakeholder and subject matter expert interaction:
    1. Partnership Expansion: Forging new partnerships with and between government agencies, public/private organizations, industry, and academia. Capitalizing on these partnerships with battery manufacturers to provide trainees with practical experience.
    2. Regional Expansion: Extending training and education programs to new regions or in new ways, tailoring them to local workforce needs and opportunities, and the needs of the supply chain.
    3. Research and Development: Investing in research projects that address long-term workforce challenges, such as emerging battery technologies and automation.
    4. Policy Advocacy: Advocating for policies that promote workforce development and incentivize industry engagement in skill-building initiatives.
    5. Curriculum Adaptation: Updating training and education curricula to incorporate the latest technological advancements and industry trends. Offering in-person, online, and hybrid training formats.

6. Flexible Learning Formats and Chunk Learning: Collaborating with industry partners and educational institutions to develop modular training and education curricula aligned with the required occupational skills framework. Offering in-person, online, and hybrid training formats to accommodate diverse learning preferences and geographical locations.
7. Multi-level Programs: Creating programs for unskilled labor, technicians, engineers, researchers, and management professionals at entry level and more senior positions.
8. Industry Certifications: Working with industry associations to develop accredited certifications that validate the skills acquired through the training programs.
9. Impact Assessment: Measuring the success of the courses of action by tracking participants' career progression, job placements, and skills acquired.

C. PARTICIPANTS

1. Stakeholder Group

The intent of this research was to involve the triad of government, academia, and industry in all aspects of study design and execution. The primary stakeholder participants consulted are noted in Table 2.

Table 2. Stakeholder Group Participation

Government	Academia	Industry
Department of the Navy	New York University (Incl Tandon School of Engineering)	New Energy New York (NENY)
Department of Labor		AFL-CIO
Li-Bridge related National Advanced Battery Workforce Council (NABWC)	Stanford University (Incl Doerr School of Sustainability)	NY State Energy Research & Development Authority (NYSERDA)
Department of Transportation	Binghamton University	Bren-Tronics
Department of Energy	Naval Postgraduate School	
DEVCOM Army Research Directorate	Colorado School of Mines (Incl Payne Institute)	Int'l Federation of Professional & Technical Engineers (IFPTE)
Center for Energy Workforce Development (CEWD)	Cornell University (Incl Cornell Program in Infrastructure Policy)	National Mining Association
		New Energy Nexus
	Calhoun Community College	The Labor-Management Cooperation Committee of CA, IBEW-NECA
	University of Michigan	
	Columbia University	Dragonfly Energy
	Colombia Business School	Think Policy Consulting
	Harvard Business School	International Union, United Automobile, Aerospace and Agricultural Implement Workers of America (UAW)
	University of Connecticut	
	University of California, Berkeley	
	SUNY Stony Brook University	

2. Battery Workforce Advisory Group (BWAG)

To provide the research team with advice and perspective in creating the strategic roadmap, the project team formed a Battery Workforce Advisory Group (BWAG). This body will remain in place throughout this project.

The members of the BWAG were chosen with respect to their impact and potential contribution to the project:

1. National Advanced Battery Workforce Council (NABWC). This organization was selected due to its mission and vision being closely aligned to that of the NPS BWD project, providing an opportunity to capitalize on synergies. NABWC forms a "public-private partnership comprised of industry, government, community organizations, academia, and workforce/labor intermediaries to catalyze, coordinate and execute national battery workforce objectives. NABWC is a public service, non-profit, brand neutral, volunteer-based organization dedicated to the success of the U.S. battery industry" (NABWC, 2023, para. 1).

NABWC completed its assessment of battery workforce employers during the period of this report and it was a significant input, along with data sourced by the project team, in formulating courses of action.

2. International Federation of Professional & Technical Engineers (IFPTE). IFPTE is the union for professional employees, representing over 80,000 highly educated and skilled members across the U.S. and Canada. Their access to battery workforce employers and employees at the senior levels is unique, in that the majority of the industry's focus is on the unskilled or hourly workforce. Their insights and the reach of their network provided the research team invaluable perspective.
3. New Energy New York (NENY). With the engagement of Nobel Laureate Stan Whittingham, Binghamton University's NENY is one of the most productive centers of battery innovation, manufacturing, and workforce development in the nation. The research team was able to capitalize on NENY's extensive network with industry as well as a new and unique supply chain database. Additionally, the NENY Battery Academy is one of the first of its kind in the U.S., and the lessons learned during creation of the Battery Academy and many of NENY's

other initiatives were invaluable to the research team in planning and proposing courses of action.

D. PROCEDURE

The project team employed a capability-based method to examine the battery workforce. The translation of the research question into a strategic roadmap was done in a structured manner, which ensured clear linkage of the outcomes back to the research question.

Capability-based planning, which has its origins in military and defense planning, recognizes that goals and objectives evolve over time, so the most effective way to achieve them is to build and maintain a strong foundation of capabilities that can be leveraged in a variety of contexts. This type of planning, "enables organizations to become more agile in the face of changing circumstances, internal and external" (Theseira, 2023, para. 4). The first five steps of a standard eight-step capability model apply to Phase I of this research, as indicated in Figure 10. Phase II will discuss steps 6 through 8, which have to do with implementation, tracking, and transition.

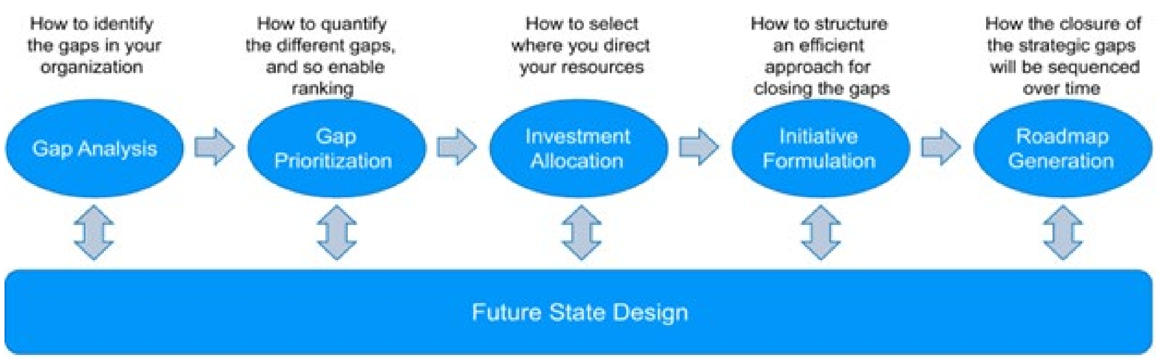


Figure 10. Steps 1–5 of the Capability Plan. Source: Rekhi & Van Dijk (2022).

The *three capabilities* being examined in this study are efficient and effective workforces in each of the three streams of the battery supply chain: up-, mid-, and downstream. Although each capability is multi-dimensional, this study focuses on four lines of effort within each capability: people – new workforce (recruitment); people – current workforce (retention and human capital development); process (communication and coordination); and transition planning. This project architecture is illustrated in Figure 11.

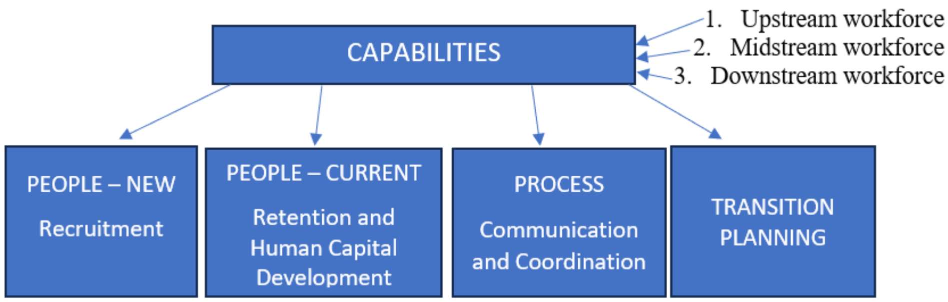


Figure 11. Project Architecture (Capability Tree).

The project team's planning took a holistic view of the battery ecosystem to ensure coverage and understanding of the areas of change. It enabled an understanding of the current strength and composition of each capability's lines of effort; what changes to capabilities are required in the future to meet the strategic vision; and the priority of any changes. The changes identified form the outcomes or initiatives that appear on the strategic roadmap and are the foundation for the recommendations contained within the courses of action.

This capability-based analysis provided structure for this study and was used to create the project's "Battery Workforce Gap Analysis," as described in Chapter V.

E. PHASE 1(B) TIMELINE

The Phase I(b) POA&M is listed below. It began with the approval of the Phase I(a) Summary Report in August 2023, runs through its culminating report, the Strategic Roadmap, in April 2024, and is completed with selection of courses of action to implement by June 2024.

1. 01 Aug 23 – Phase I(a) Summary Report approved and Phase I(b) began
2. 01 Apr 2024 – Submitted Phase I - Strategic Roadmap and Proposed Courses of Action
3. Jun 2024 – Approval of report and selection of COAs, to inform Phase II.

Figure 12 illustrates the timeline for the full duration of the project.

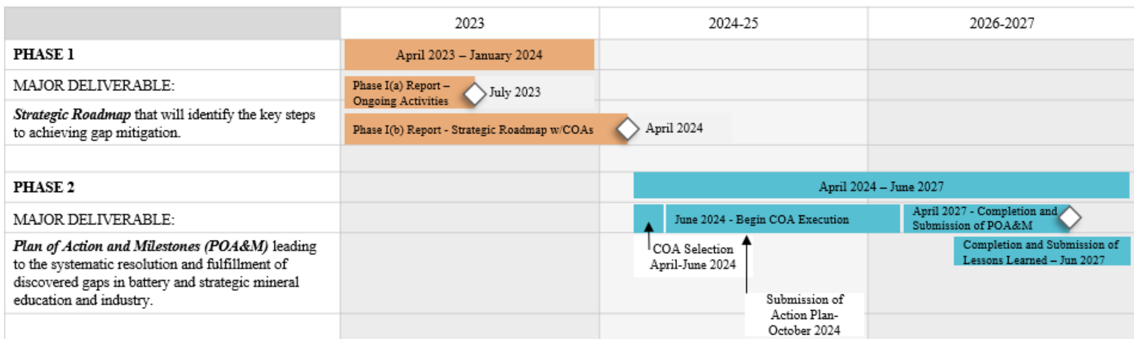


Figure 12. Project Timeline.

F. NEXT STEPS

The observations and courses of action indicated by this Strategic Roadmap will be leveraged to the benefit of Phase II and the final Plan of Action and Milestones (POAM). The initial Action Plan will be due 90 days after COA selection, and the final POAM is due in April 2027, although actions indicated by the Strategic Roadmap's courses of action will already be in progress. The project concludes with transition plans implemented no later than June 2027, where possible. Where it is not possible, a clear plan for their execution will be contained in the POAM.

IV. A CAPABILITY-BASED PLAN

Business capabilities describe what a business does and needs to do in response to a defined strategy. They help to close the gap between strategy ("how") and execution ("what"). The planning process for capability-based change is depicted in Figure 10. This process enables the design of a future state that involves and informs all participants within the other four stages. For instance, closing a gap may call for too costly an investment, requiring a revision of which gaps are in scope. Even the final stage of creating a roadmap may reveal that a particular timeline is unacceptable. The future design is continuously refined in parallel with steps 1 through 5 to inform decision making at all levels.

Each of the six stages of research, as described under *Study Design*, was pursued sequentially as much as possible. Within each stage, the three capability sectors under consideration focused on the effectiveness and sufficiency of the workforce in each stream of the supply chain:

- Capability Sector 1 – Upstream
- Capability Sector 2 – Midstream
- Capability Sector 3 – Downstream

Within each capability sector, four lines of effort (LOEs) were examined:

1. People – current workforce (retention)
2. People – new workforce (recruitment)
3. People – human capital development
4. Process – coordination and communication (C2).

To begin planning around and finding gaps within the capabilities of the battery workforce and the intentions of funded programs in place, the project team first had to understand those capabilities and intentions. That meant accurately defining the four lines of effort within the current capability sectors, ascertaining whether those LOEs met the need for that capability sector, and determining whether they were being maintained and matured. For the purposes of this research, planned programs are considered "current and in place" unless otherwise noted.

A. CAPABILITY SECTOR 1: UPSTREAM (STAGES 1 AND 2)

1. Stage 1: Required Occupational Skills (ROS)

More than half the current domestic mining workforce will retire by 2029 (roughly 221,000 workers) (Hale, 2023). Yet, in 2020 only 327 degrees were awarded in mining and mineral engineering, resulting in a 39% net drop in graduations in the U.S. since 2016 (DataUSA, n.d.-a). University programs that have traditionally educated students to engage in the upstream workforce capability have also been decreasing, with the number of mining and mineral engineering programs in the U.S. dropping from 25 in 1982 to 15 in 2023 (Hale, 2023). Young adults are not enrolling in programs leading to careers in the mining industry at rates that would sustain the industry, let alone allow it to meet growth targets. Most mining companies in the U.S. say their expansion and growth plans could come under pressure if current hiring trends continue, especially for high-skilled roles such as engineers, exploration geologists, and data analysts (Khan, 2023).

The NPS research team compiled an initial list of 641 U.S.-based public universities. From this list, schools in Washington, Michigan, Kentucky, and Georgia were identified due to the high level of battery activity in those areas. Accredited mining engineering schools were also added to the list resulting from those four states, totaling 83 public universities. As research programs were discovered for schools and universities outside this flagged list, they were added as well. The search through each university focused on areas of engineering and science specifically applicable to the battery supply chain and related activities, such as chemical engineering, mechanical engineering, electrical engineering, robotics and automation, and electric vehicles. Key terms used to find programs in battery-focused/related topics included: solid-state energy, energy storage, batteries, power systems, energy systems, electrochemical engineering, electric vehicles, and automation. In this manner, 36 schools were added to a growing database that included programs such as those listed above with electives and research foci in areas outlined by the key terms of the search. While these programs were not definitively determined to be battery-focused, they do have enough elements to be considered battery-related STEM programs.

Most undergraduate and graduate degrees reviewed in battery-related fields do not explicitly describe batteries as a focus of the program. Many engineering disciplines consider areas of study that are necessary for the development of future and advanced batteries, but most programs use general topic areas to describe electives and focus tracks within their degrees. Institutes and Centers for Research are much more explicit in using language specific to battery development.

An example of the combination of programs and centers/institutes may be found at the Colorado School of Mines. Not only does the school offer degrees in Chemical, Mining, Electrical, and Mechanical Engineering, they also have graduate programs focused on energy systems. The school also has several institutes that focus on issues directly affecting batteries, such as the Center for Hydrate Research and the Critical Minerals Institute. The combination of these options indicates that the school is focused on education and research within the fields necessary for the battery industry and the advancement of the workforce.

The process used to find technical, community college, and general workforce training courses differed from that of the bachelor's and graduate degree programs due to the volume of material eligible for review. Select community colleges and technical programs were flagged in the first round of research from a list of over 890 schools and programs. Targeted web searches were also used to find schools focused on training. The primary search terms used to find these programs included the following: battery workforce training, battery storage training, battery training, and battery training programs. Based on this search, 12 schools and training programs were initially added to the database with battery-focused programs. Battery-related training was not included in the database for this level due to the number of options available.

Programs discovered through this research fall predominantly within the EV industry. While some programs, such as those created and administered through New Energy New York, are more generally focused on the batteries themselves and on advancement of technical skills in working with them directly, most of the programs identified were related to automotive technical degrees or training. In contrast to battery-related programs in traditional 4-year and graduate degree programs, training and technical degrees tend to state their focus much more explicitly as being battery-specific.

Private industry appears to be taking the initiative to develop the skills and abilities of their local communities as well. NOVONIX, for example, has created an Institute of Advanced Battery Technology to foster learning at the high school level around Chattanooga, TN, where they manufacture battery components (NOVONIX, n.d.). Toyota is creating similar opportunities in Greensboro, NC, at the 2-year degree level (Byrd, 2023).

Organizations such as NENY, NYSERDA, and CEWD are also developing training and education for the battery workforce, while labor unions have thousands of training centers and apprenticeship programs across the country. While these are strong and evolving programs, they are disconnected from one another and there is no vehicle for reviewing all available programs from one online or live location. This will be discussed in some detail later in this study.

Due to the relatively short timeline and targeted intent of the present study, the database of educational programs compiled as reference material cannot be considered a comprehensive list of battery-specific programs, and it doesn't begin to address the full scope of battery-related programs. More work must be done in this area with significant priority to ascertain the actual state of domestic educational programming availability, from traditional academic institutions, through industry, and through cooperative programs and apprenticeships. But it does indicate that technical schools and professional development organizations are beginning to create programs to fill the present need. It also demonstrates how industry is beginning to plan for its future workforce in areas surrounding its planned factories.

The Bureau of Labor Statistics (DataUSA, n.d.-a) notes that Mining and Mineral Engineering majors need many skills, but most especially Reading Comprehension, which is not generally pursued as a Science, Technology, Engineering, and Mathematics (STEM) skill. As shown in Figure 13, mining and mineral engineering majors need more than the average amount of many skills that are not typically considered STEM: Management of Financial, Material, and Personnel Resources; Negotiation; Persuasion; Coordination; Time Management; Complex Problem Solving; Judgment and Decision Making; Instructing; Persuasion; Monitoring; Active Learning; Writing; Social Perceptiveness; Service Orientation; Critical Thinking; Learning Strategies; Speaking; and Active Listening. As might be anticipated, they also require skills that are considered STEM: Mathematics; Science; Systems Analysis; Systems Evaluation; Operations Analysis; and Repairing. In Figure 13, the closer the orange line comes to the circumference of the circle, the more important that skill is.

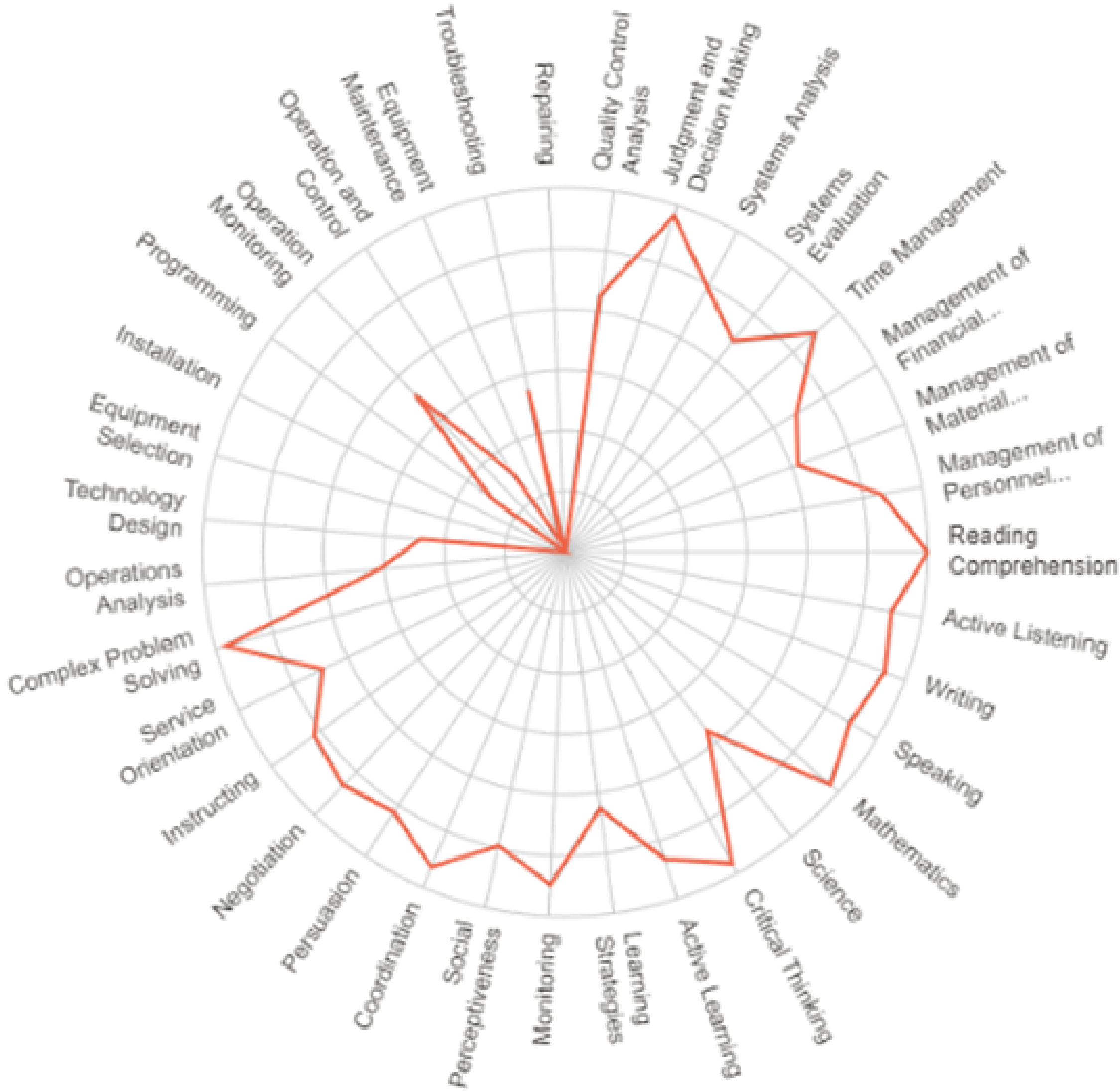


Figure 13. Radar Distribution of Skills Required for those in the Mining and Mineral Engineering Fields. Source: DataUSA (N.D.-a).

2. Stage 2: Available Workforce Personnel (AWP)

The demographics of the areas surrounding mining activities, largely (but not exclusively) focused in the western U.S., play an essential role in the mining sector. A balanced workforce can enhance safety, adaptability, operational efficiency, and effectiveness, but the statistics show that demographics surrounding the rural locations of most mines do not always provide the economic and social advantages that such a balance of diversity of experience, education, gender, and background might provide (Akamboe et al., 2023). There are also unique challenges for infrastructure, housing, and regional economic development.

The U.S. Bureau of Labor Statistics data show that the mining workforce is on a downward trajectory from 797,200 in 2012 to an expected 545,400 by 2032 (USBLS, 2023a). While this is an alarming decrease of 32%, more unexpected is that nearly all the total increase, all but the final 1%, occurred in the first half that period, from 2012 to 2022. While these data do not filter coal mining, which is not directly pertinent to this study, it is still indicative of the state of the mining workforce.

While the predictions are dire, the actual U.S. mining industry figures are even worse—the mining industry employed only 512,000 people in 2021, a decrease of more than 100,000 compared to 2019 (Statista, 2023). This indicates that not only are new employees not joining the industry, but also that mining employees are leaving the industry, whether due to mine closures, retirements, or through obtaining other employment.

Much of this occupational egress is the result of U.S. deindustrialization. The U.S. has been able to rely on foreign supply chains to fill its battery requirements for several decades, and at a lower cost than might result from domestic production. But new climate goals and shifting mores make the need for reshore our battery industry, an imperative. Figure 14 shows the battery production landscape as it currently stands. Some materials travel up to 50,000 miles before reaching an end user as finished battery cells (Chen, 2021). The waste inherent in such processes is obvious, and runs directly counter to federal climate goals to reduce U.S. greenhouse gas emissions 50–52% below 2005 levels in 2030, to reach 100% carbon pollution-free electricity by 2035, and to achieve a net-zero emissions economy by 2050 (The White House, 2021).

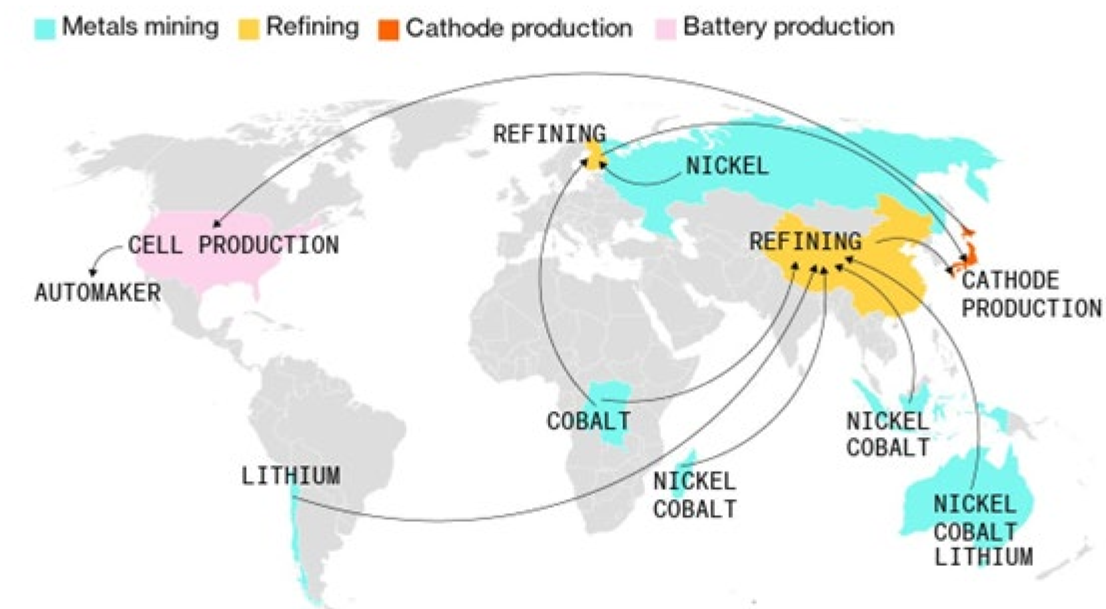


Figure 14. Battery Materials Supply Chain Flow.
Source: Chen (2021).

Figure 15 shows the countries that provided 30% or more of the U.S. supply of a critical mineral in 2020. It shows that the U.S. is most heavily dependent upon China and Canada for critical minerals. Natural disasters, poor governance, civil unrest, trade disputes, and company failures can all have catastrophic consequences on a supply chain so completely rooted outside U.S. control, particularly if it is controlled by potentially adversarial suppliers.

Figure 15. Providers of Battery Minerals to the U.S.
Source: USGS (2021).

The upstream battery workforce capability sector is supported domestically by mines primarily in the western part of the U.S., as shown in Figure 16. Centers of mining include Nevada for lithium, Idaho for cobalt and rare earth elements, and other ranges in Arizona, Texas, and Utah for copper, all of which come with environmental, political, and cultural conflicts that are beyond the scope of this study yet impact the workforce willing to associate with sometimes socially contentious mining operations. This effect is explored more fully in Chapter V.

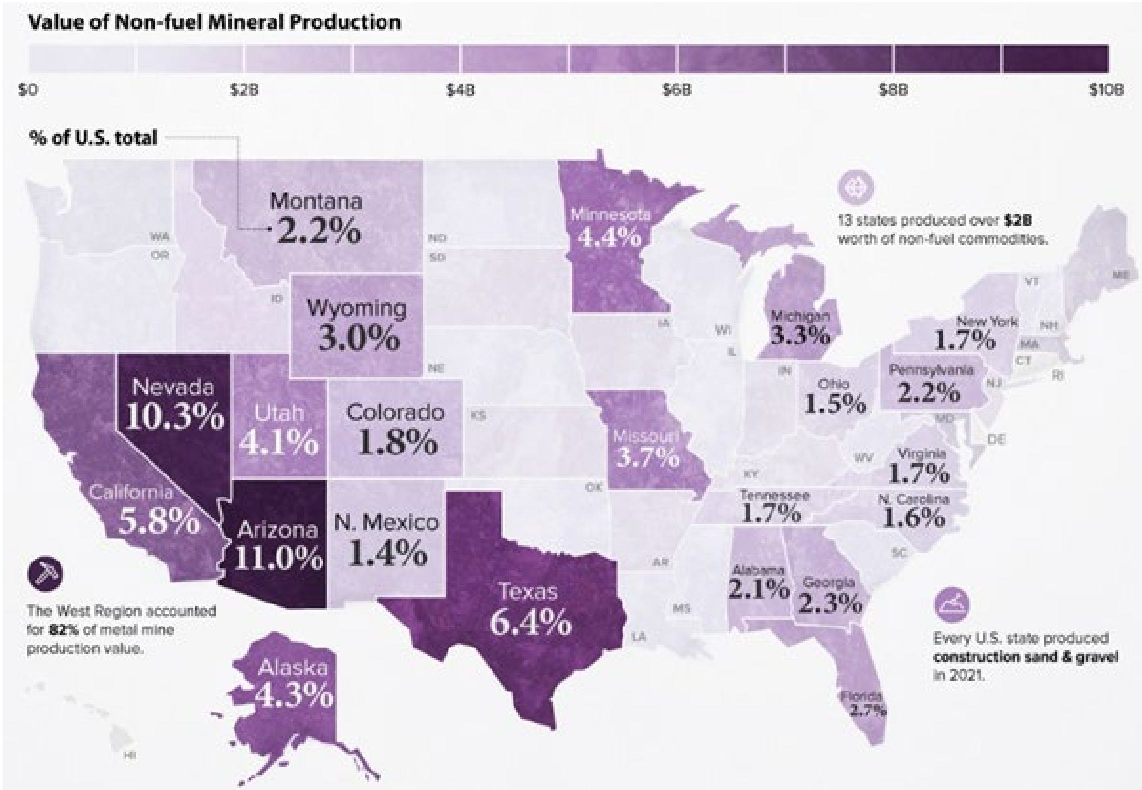


Figure 16. Mineral Production by State, 2021.
Source: Bhutada (2022).

Despite representing less than 1% of all current U.S. mining, metals such as lithium and cobalt are becoming increasingly important to the U.S. economy and U.S. national security as the nation moves toward greener sources of energy. Industrial metals, however, such as copper, nickel, and manganese, at 6.6% of all U.S. mining (Venditti, 2023), are also essential. Figure 17 illustrates the metals mined in the U.S.

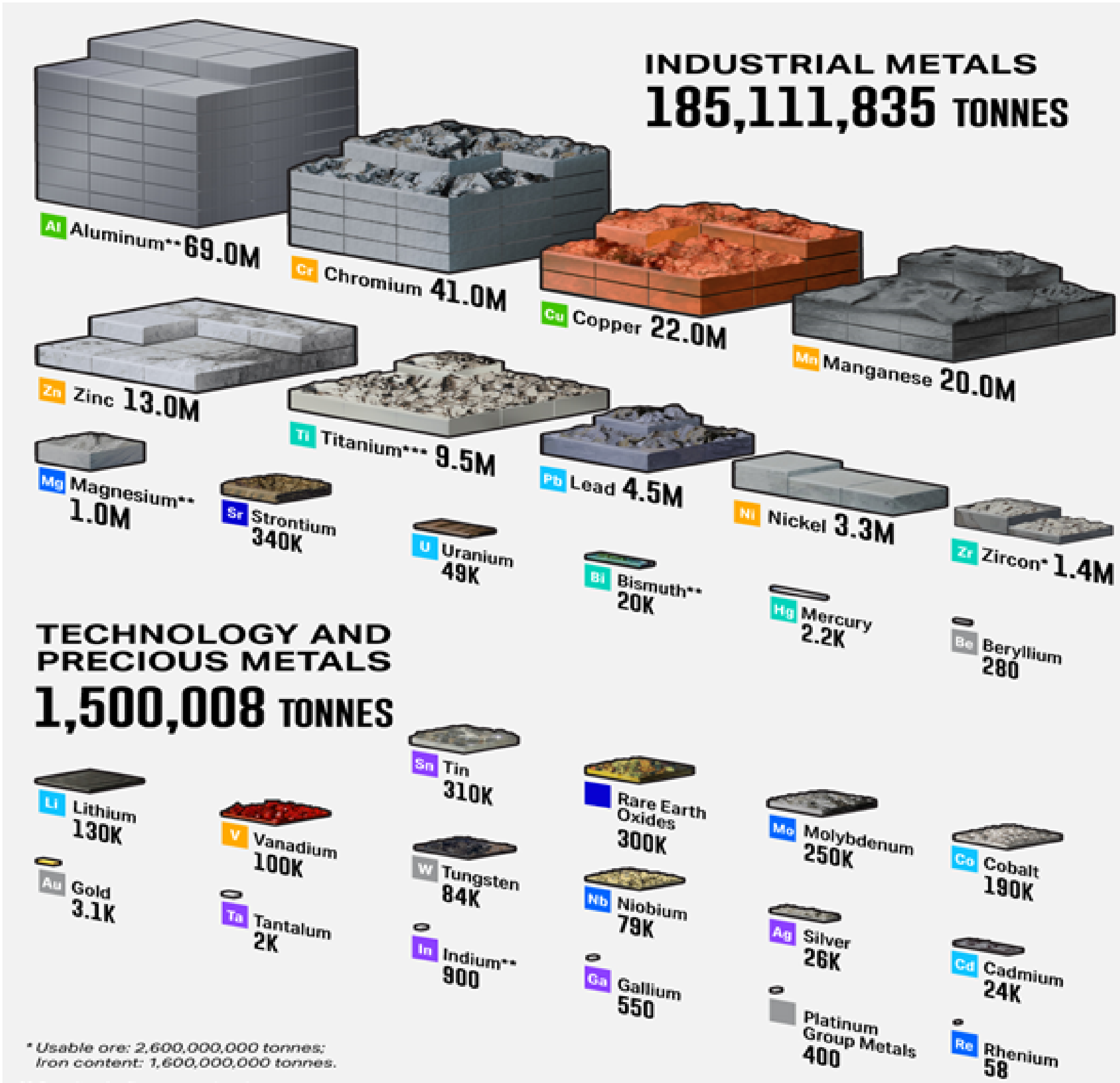


Figure 17. All the Metals Mined in the U.S. (Except Iron Ore).
Source: Venditti (2023).

Mining is expected to be one of a handful of sectors that will add jobs at a fairly constant rate (11,000 to 13,000 per year) over the next 20 years, driven by the retirement of the current workforce and projected increase in demand for resource production (Oregon Group, 2023; SME, 2014). The increase in demand will result in new jobs that will tend to be well-paying and relatively long-term. However, the U.S. does not presently have the skilled labor or educational base to meet the current resource demand of the upstream capability sector in the burgeoning battery industry. The skilled labor that does exist may well be lured to places promising higher wages (Australia, Canada, etc.), or industries that are traditionally more well-supported and therefore seen as more stable (SME, 2014).

The mining industry historically has been male-dominated with a reliance on manual labor, transient lifestyles, and cultural biases (Akamboe et al., 2023; Mao, 2021). However, with the shift toward technology-driven skills, opportunities for women have opened, leading to a slow but positive increase in female participation (Akamboe et al., 2023). Organizations like Women in Mining (WIM) actively promote gender diversity in the industry and try to prevent what many see as an exodus of female participation in mining due to "feeling that work is no longer intellectually challenging and having the perception that there are fewer advancement opportunities [for women] than there are for their male colleagues" (Ellix et al., 2021, para. 9). International Women in Mining (IWiM) and major corporations like Rio Tinto and BHP are working to create a more inclusive environment through mentorship, scholarships, and flexible work arrangements. This is encouraging in an environment where there have been many claims of unhealthy work environments, and dozens of resultant firings from major mining corporations (Mao, 2021). Websites of these multi-national corporations are now full of images of women working at job sites, emphasizing their efforts at increasing cultural awareness (see Rio Tinto; BHP).

The availability of both individuals who are appropriately skilled and those who are interested in being so is a significant problem for the domestic mining industry. Without an adequate workforce available and trained or educated in mining trades and related fields, the foundation of the battery supply chain crumbles. However, it is unlikely that there will be sufficient skilled mine labor to satisfy this demand over the next 20 years without radical action. By 2029, more than half the current workforce will be retired and replaced (~221,000 workers) (SME, 2014), creating a skill and knowledge gap the industry will be challenged to accommodate. Finding and retaining skilled labor is likely to be a lasting problem for mining companies, particularly as demand is expected to increase exponentially in response to legislation, incentives, and consequent increasing demand for electric vehicles and other consumer goods.

Of interest, these dire statistics contrast with those of the U.S. Bureau of Labor Statistics, which show an overall gain in the size of the workforce over the last few years in non-gas non-oil mining, as shown in Figure 18 (USBLS, 2024). However, this gain includes coal, which has actually increased the size of its workforce. While this may reflect a population that could enter mineral mining at the expense of other mining industries, it does not reflect the reality of the mineral mining workforce.

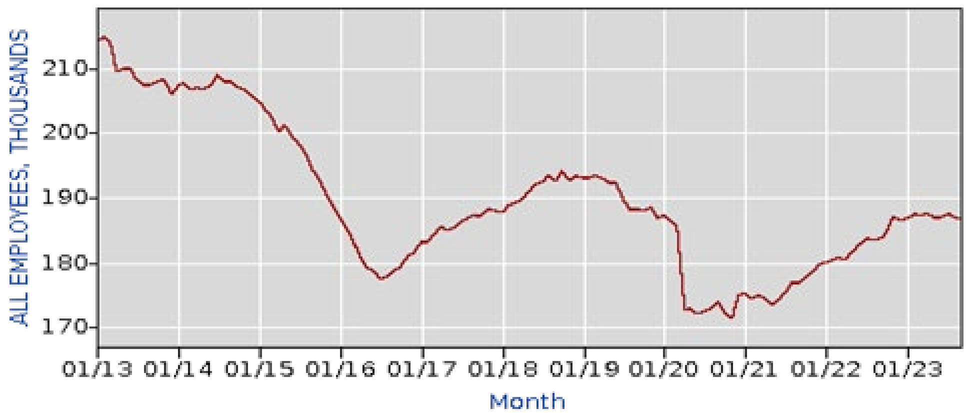


Figure 18. Current Employment in Mining (Except Oil and Gas) from the Current Employment Statistics Survey (National).
Source: USBLS (2024).

The reasons for the decline in the mineral mining workforce may be attributed to three global trends: "First, the nature of work itself is evolving, with an increasing focus on automation, algorithms, and a growing need to be digital savvy—resulting in an estimated one in 16 (more than 100 million) workers globally needing to find a different occupation by 2030" (Abenov et al., 2023, para. 1). Second, the needs and desires of workers are evolving. Following the COVID-19 pandemic, 40% of employees said they were likely to leave their jobs in the next 6 months, prompted by various factors that included changes in life priorities (De Smet et al., 2021). Finally, ways of working are also evolving: a recent McKinsey Global Institute report (Lund et al., 2021) indicated that 72% of executives say their organizations have started adopting permanent remote-working models. These are issues that will need to be addressed directly in building the upstream capability sector of the battery workforce.

On top of the general workforce issues in the mining industry, there has been a decline in the number of mining and mineral engineering programs at U.S. colleges and universities from a high of 25 in 1982 to 18 in 2021. There has also been a corresponding decline in U.S. mining faculty (~120 in 1984 to ~70 in 2014) in these programs as well as a shortage of qualified candidates to fill these faculty vacancies (SME, 2014). There were 314 mining and mineral engineering degree completions in the U.S. in 2021, as illustrated in Figure 19. This is down 42% from 533 in 2016 (DataUSA, n.d.-a). It is doubtful that U.S. schools, as they are currently staffed, will be able to meet a future demand for qualified graduates that is likely to outstrip supply.

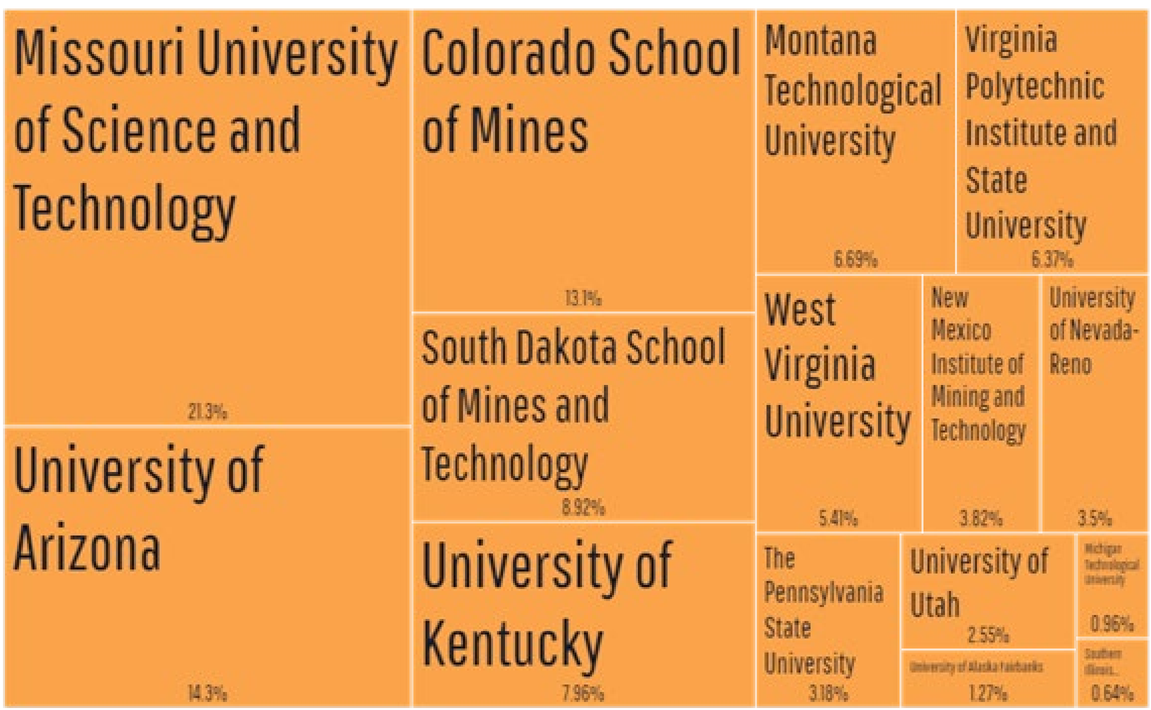


Figure 19. Institutions Awarding the Most Degrees in Mining & Mineral Engineering. Source: DataUSA (N.D.-a).

Despite these workforce challenges, the mineral mines in the upstream sector are not accelerating their level of activity in recruitment and training in the manner being seen in the midstream sector. The primary reason for this seeming business-as-usual approach is that the licensing and permitting of a new mine is fraught with political and legal challenges that keep the pace of growth within the mining industry at a crawl. For mines that require only state permitting, one might get approved in only 3 years (i.e., Cactus Mine in Arizona) to 7 years (i.e., Eagle Mine in Michigan). Reviews of the employment websites of those mines indicate that as of this writing there are no open positions remaining. Other mines that require federal permission to operate as they are on federal lands, or become embroiled in litigation, may take much longer. As of October 2023, PolyMet's NorthMet Mining Project in Minnesota is in year 19 of its federal permitting request. In response to these permitting challenges, some equipment manufacturers have begun "to vertically integrate to directly source critical minerals and de-risk mining operations" (Mehdi & Moerenhout, 2023, p. 7; see also EIU, 2023).

While the permitting process is beyond the scope of this study, the relevant point is that new mines often do not need a workforce for many years, so any lack of recruitment activity in this capability sector should not be interpreted as a lack of need. As one leader within the industry noted, "A mine having to worry about its workforce is a good problem to have" (R. Sistad, Personal Interview, October 19, 2023).

B. CAPABILITY SECTOR 2: MIDSTREAM (STAGES 1 AND 2)

1. Stage 1: Required Occupational Skills (ROS)

The number of new workers needed in the midstream capability sector of the battery supply chain is vast. In 2019, there were only two gigafactories operating in the U.S., and another two under construction. As of this writing, there are 30 gigafactories either planned, under construction, or operational in the U.S. (Bellan, 2023). Figure 20 shows the locations of currently operational or planned gigafactories as of November 2023.

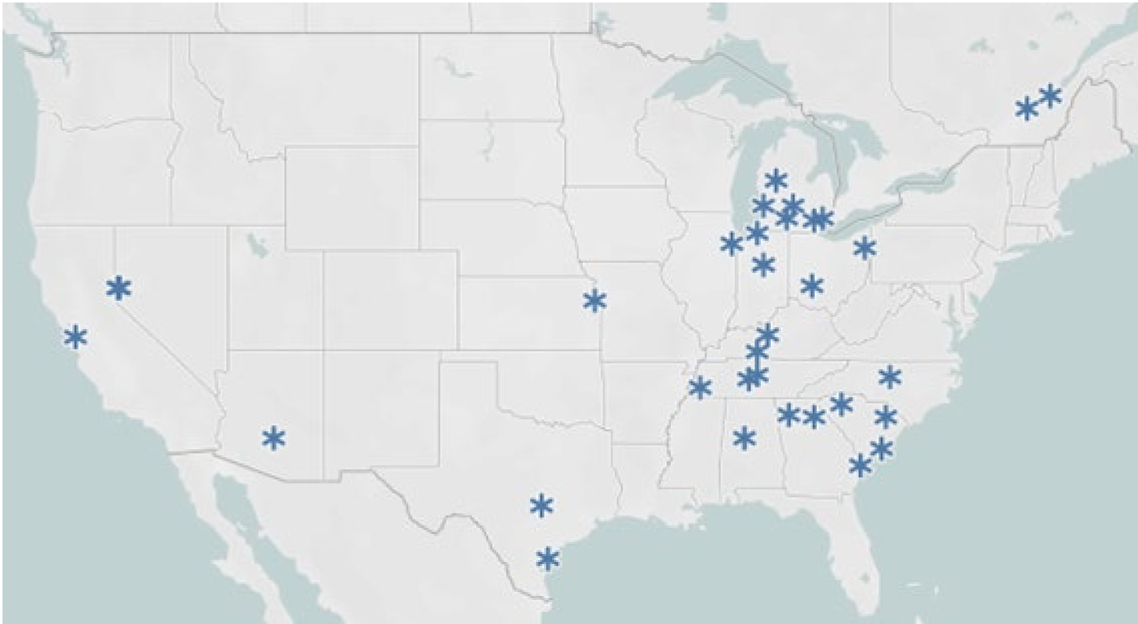


Figure 20. Locations of Currently Operational or Planned Gigafactories as of Nov 2023. Source: Halpern (2023).

Each gigafactory might employ a few thousand to many tens of thousands of employees, many being pulled from local communities. For instance, as of September 2023, Tesla Inc. employed nearly 20,000 people at its manufacturing plant near Austin, Texas, having added more than 7,700 employees to its January starting strength of 12,200. It began production in 2021 with 3,500 employees and is expected to increase its workforce at that plant to 60,000 (Killelea, 2023; Figure 21). New Carlisle, Indiana, is to be the site of a gigafactory resulting from a partnership between General Motors and Samsung. It will be built in 2026 and is expected to employ at least 1,700 in that area (Korosec, 2023).

Figure 21. Employees at Tesla's Factory in Austin, Texas Pose with the First Cybertruck to be Built at That Gigafactory. Source: Killelea (2023).

As automakers increase capacity for production of electric cars and trucks, new manufacturing plants will continue to be built to meet the equally rising demand for EV batteries. Census data show that employment in the industry group *NAICS 3359: Other Electrical Equipment and Component Manufacturing*, which includes both EV batteries and battery chargers, is projected to increase 17.0% over the 2021−31 decade, making it one of the fastest growing manufacturing industries in the economy (U.S. Census Bureau, 2021).

New battery plants will result in a wide variety of new jobs, from the production technicians assembling and testing batteries, to their supervisors, quality control, and many others. Many more skilled employees, currently experienced in the trades, as well as many thousands of unskilled employees, will also be needed. While the Bureau of Labor Statistics shows that virtually all manufacturing, manufacturing-related, and many non-manufacturing jobs are represented within the NAICS 3359 career group, the largest occupational groups in this field through 2030 are electrical engineers, electronic engineers, electromechanical assemblers, and miscellaneous assemblers, and fabricators.

Combined, these occupations represented over 30% of industry employment in 2021. But on an occupational list that includes jobs as oddly specific as alligator hunter and bagel baker, there are no occupations that specifically include the word "battery," as in "battery engineer" or "battery pack tester," anywhere in the handbook. Instead, any search for battery results in routing to "assemblers and fabricators" as the only offered occupation (USBLS, 2023d).

There is a clear explosion in need for midstream capability sector employees at all levels of education and experience. In common with the upstream capability sector, however, there is not a comprehensive listing of the jobs required in this sector. Fortunately, work is underway by the Department of Energy's (DoE's) Battery Workforce Initiative (BWI) to make inroads on that gap (BWI, 2022), and they have completed work on a midstream sector analysis, with an upstream analysis having commenced in early March 2024. To identify skill requirements for key occupations, the Battery Workforce Initiative brought together "advanced battery manufacturers, companies introducing new battery technology, the advocates of work-based learning and quality apprenticeship, and community-based organizations and unions trusted by thousands of workers interested in high-skill, quality jobs" (National Energy Technology Laboratory, 2023, p. 2). This effort has established a team of experts and stakeholders from the advanced battery industry to develop training and materials for key, industry-defined occupations: "The purpose of this industry-driven, government-facilitated initiative is to speed up the development of high-quality training, starting with existing examples to develop consensus on core training needs, and then develop training for use by companies and local training providers" (National Energy Technology Laboratory, 2023, p. 2).

While the work of DOE's BWI is tremendously valuable to the success of various workforce initiatives, there is still scope for expansion. The focus of those efforts has been on understanding and supporting just a few positions within each sector to ensure a breadth of industry reach and a depth of understanding in those occupations; there is yet much work to be done in understanding the full volume of need.

2. Stage 2: Available Workforce Personnel

The battery supply chain's midstream sector is profoundly impacted by recent legislation affecting EVs and climate goals. The U.S. is expected to double its manufacturing capacity by 2025, with more than 10 new battery manufacturing plants expected to be operational in the next 5 years (National Energy Technology Laboratory, 2023). The current locations of gigafactories in the U.S., and the battery workforce that populates the midstream and downstream workforce capabilities, are largely centered on the "Battery Belt," a trending term used to describe the high level of battery manufacturing activity in eight states: Michigan, Indiana, Ohio, Kentucky, Tennessee, North Carolina, South Carolina, and Georgia (Lewis, 2023), as seen in Figure 22.

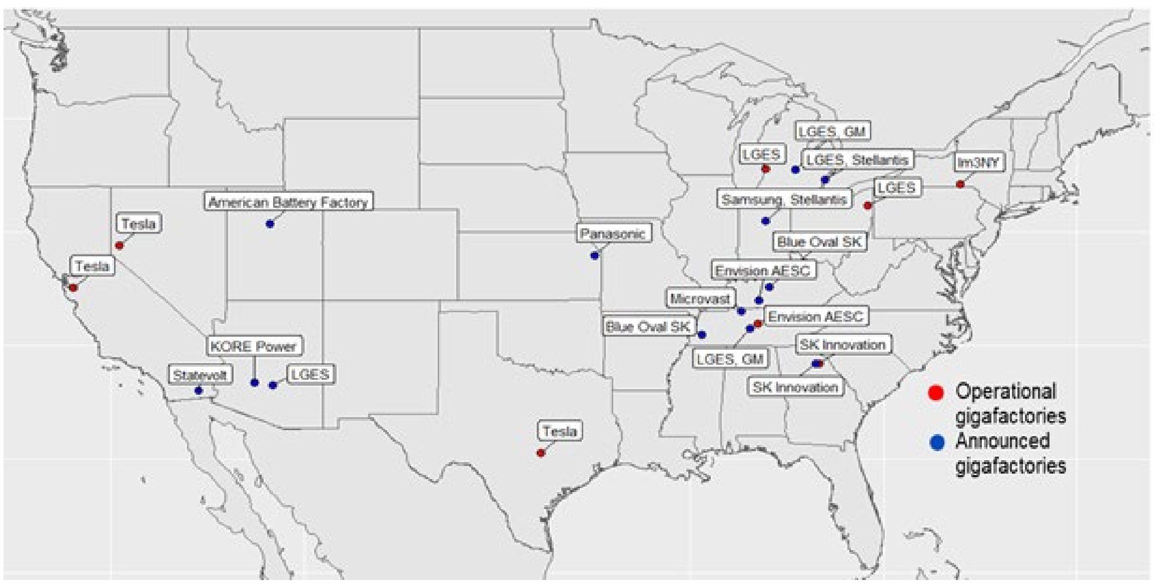


Figure 22. Operational and Announced Gigafactories. Source: Lewis (2022).

It is expected that by 2032, North America will have enough gigafactories available to satisfy cell demand, but the U.S. will not have a domestic supply of cathodes and anodes to construct those cells (Mehdi & Moerenhout, 2023). If this situation occurs, then the U.S. will remain dependent on imports to meet federal goals.

Figure 23 shows the numbers, by state, of those employed as electrical, electronic, and electromechanical assemblers, who might be employed in a future battery industry. While there is a high to medium-high concentration of these skills throughout most of the battery belt, there are also concentrations on the west coast, as well as in Texas and Florida, indicating the suitability of those states for the locating of gigafactories. Some companies, like Tesla, have already understood the value of those locations more remote from the Battery Belt, and have located their factories accordingly (Gigafactory, n.d.).

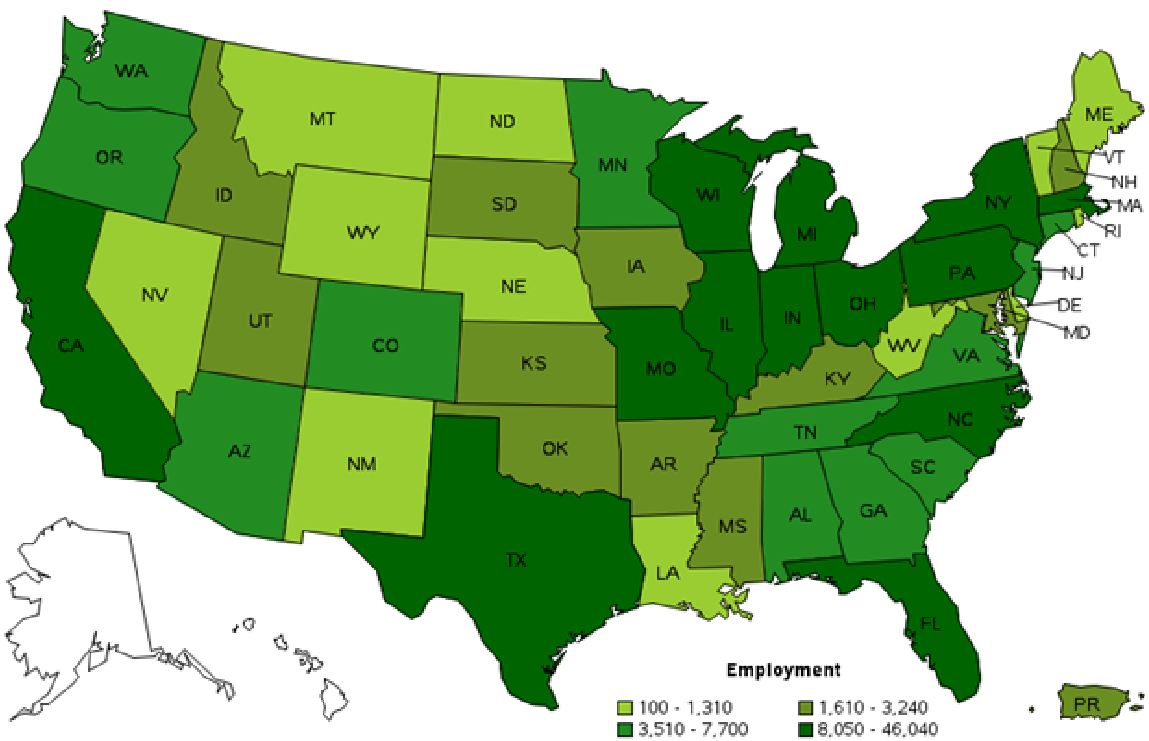


Figure 23. Employment of Electrical, Electronic, and Electromechanical Assemblers, May 2022. Source: USBLS (2023c).

The Battery Belt region is facing a unique challenge in terms of workforce development for its growing battery manufacturing industry. The region's population is aging, with an average age of 45 years or older in Michigan (PolicyMap, n.d.-a), for example. This aging workforce is coupled with a population density that ranges from a high of 192 people per square mile in states like Michigan, Ohio, and Georgia to a low of

12 people per square mile in states like Indiana and Tennessee (PolicyMap, n.d.-a). These demographic factors present challenges in recruiting and retaining a skilled workforce for the battery industry because older workers are typically less likely actively to seek reskilling or upskilling to the needed functions of the battery industry.

The Battery Belt states are also grappling with high unemployment rates in certain pockets. Michigan, for instance, has county-level unemployment rates that rival those of California, New Mexico, and Oregon, hovering around 19% (PolicyMap, n.d.-a). The potential pool of unemployed workers in the Battery Belt region is significant, with Michigan leading the pack, followed by North Carolina, South Carolina, Indiana, Kentucky, and Tennessee. Georgia enjoys notably lower unemployment rates (PolicyMap, n.d.-a).

Poverty rates across the Battery Belt states also vary, ranging from a low of 9.5% in Ohio and Michigan to a high of 19.3% in Georgia, Tennessee, North Carolina, South Carolina, Indiana, and Kentucky (PolicyMap, n.d.-a). These poverty rates underscore the need for targeted workforce development programs that can provide training and upskilling opportunities for individuals from low-income backgrounds, enabling them to participate in the growing battery manufacturing sector and improve their economic prospects with family-supporting occupations.

The Battery Belt does have some variations in its foreign-born population, green card holders, and English proficiency levels. Kentucky, Ohio, and Indiana have the lowest foreign-born populations, ranging from 1.2% to 1.9%, while Michigan, North Carolina, South Carolina, and Tennessee have higher proportions, ranging from 4.6% to 6.9% (PolicyMap, n.d.-a). This diversity in foreign-born populations presents opportunities for tapping into a broader talent pool for the battery industry, but also necessitates consideration of language barriers and cultural integration. Georgia, Michigan, and Ohio have the highest proportions of green card holders, ranging from 1.6% to 1.9%, while Kentucky and Indiana have lower percentages, ranging from 0.2% to 0.3% (PolicyMap, n.d.-a). Variation in green card status could influence the ability to attract and retain foreign-born workers in the battery industry, as green card holders have greater employment flexibility and pathways to permanent residency compared to non-green card holders.

The ability to communicate in English is another important consideration for workforce development in the Battery Belt region. The proportion of non-English speakers ranges from a low of 0.6% to 1.2% in Michigan, Kentucky, Ohio, and Indiana, to a fairly significant high of 3.2% to 4.6% in North Carolina, South Carolina, and Georgia (PolicyMap, n.d.-a). These variations in English proficiency levels suggest the need for targeted language training and support programs to ensure that all workers have the necessary language skills to participate effectively in the battery industry.

There are considerable variations in incomes throughout the battery belt, as well as housing affordability and household composition. Kentucky, Georgia, South Carolina, Indiana, Tennessee, and East Michigan have the lowest IRS (Internal Revenue Service) incomes, ranging from $46,000 to $67,000 (PolicyMap, n.d.-a). Lower incomes can impact the ability of individuals and families to afford living expenses and may limit their access to educational and professional opportunities. These lower incomes in Kentucky, Georgia, South Carolina, Indiana, Tennessee, and East Michigan could also make it more challenging for individuals and families to afford the cost of living in these areas. This could make it difficult to attract and retain workers in the battery manufacturing industry, which could in turn limit the growth of the industry in these states. Additionally, lower incomes could also limit the demand for housing and other services in these areas, which could have a ripple effect on the overall economy.

Renter housing costs as a percentage of income range from 24% in Indiana, Ohio, and Tennessee to 30% in Michigan, North Carolina, South Carolina, and Georgia (PolicyMap, n.d.-b), suggesting that housing costs may pose a challenge for some households in the region. The higher housing costs in Michigan, North Carolina, South Carolina, and Georgia could make it more expensive for workers in the battery manufacturing industry to afford to live in these areas. This could again make it difficult to attract and retain workers in the industry, and it could also limit the disposable income of workers, which could make it difficult for them to purchase goods and services from local businesses.

Household sizes also differ across the Battery Belt states. The proportion of households with four or more persons per household varies from 16% in Northeast Michigan to 23% in Georgia, Tennessee, South Carolina, North Carolina, Indiana, Kentucky, and Tennessee (PolicyMap, n.d.-a). The percentage of one-person households also varies across the Battery Belt states, ranging from 24% in Ohio, Southwest Michigan, and Indiana to 32% in Georgia, North Carolina, and South Carolina (PolicyMap, n.d.-a). These variations could reflect factors such as age demographics, marital status, and living preferences in distinct parts of the region, and may influence the demand for housing and the types of services and resources needed in different communities. The larger households in Georgia, Tennessee, South Carolina, North Carolina, Indiana, Kentucky, and Tennessee could create a demand for larger homes, which could in turn drive up housing costs in these areas. Additionally, the larger households could also create a demand for more services, such as education and childcare, which could put a strain on local resources.

Household growth rates vary throughout the region. Michigan has experienced a negative household growth rate of -3.3%, while Ohio, Indiana, Tennessee, North Carolina, South Carolina, and Kentucky have seen growth rates ranging from 0.2% to 4.0% (PolicyMap, n.d.-a). These trends suggest that some states in the region are attracting new residents and experiencing population growth, while others are facing declining population levels. The negative household growth rate in Michigan could indicate that the state is losing population, which could make it difficult to find workers for the battery manufacturing industry. Conversely, the positive household growth rates in Ohio, Indiana, Tennessee, North Carolina, South Carolina, and Kentucky could indicate that these states are gaining population, which could create a larger pool of potential workers for the battery manufacturing industry. However, it is important to note that household growth rates are not necessarily indicative of economic growth rates. Also household growth rates may not be as significant as the magnitude of the pool of unemployed workers such as in Michigan, for instance, (noted earlier) which has county-level unemployment rates that rival those of

California, New Mexico, and Oregon, hovering around 19% (PolicyMap, n.d.-a). The potential pool of unemployed workers in the Battery Belt region is significant, with Michigan leading the pack.

Travel commute times and distances in the Battery Belt Zone suggest that workers are not heavy commuters. The average commute ranges from 15 to 25 miles, with travel times of 20 to 30 minutes (PolicyMap, n.d.-a). This implies that workers are likely to reside in communities close to battery manufacturing facilities, reducing transportation barriers and commuting costs.

The distribution of Qualified Low-Income Community (QLIC) home construction projects favors Ohio, Indiana, and Georgia compared to North Carolina, South Carolina, Michigan, and Tennessee. This suggests that these states are prioritizing affordable housing options for low-income individuals and families, potentially creating a more inclusive and equitable workforce for the battery industry.

The proportion of owner-occupied homes with more than 1.5 occupants per room is low across the Battery Belt states. In Georgia and Kentucky, the percentage ranges from 0.01% to 0.02%, while in Michigan, Georgia, Ohio, North Carolina, South Carolina, Tennessee, and Indiana, it ranges from 0.1% to 0.5% (PolicyMap, n.d.-b). This indicates that overcrowding is not a widespread issue in the region, which could have positive implications for the health and well-being of battery industry workers and their families.

HUD-subsidized housing benefits are more prevalent in the eastern half of the United States compared to the continental United States as a whole (PolicyMap, n.d.-b). This suggests that there may be a higher concentration of low-income individuals and families in the eastern Battery Belt states, who could benefit from targeted workforce development programs and affordable housing options.

Housing vacancy rates in the Battery Belt states exhibit mixed trends. Michigan, Ohio, North Carolina, and South Carolina have experienced vacancy rate declines over the past decade of up to 14% (PolicyMap, n.d.-b), suggesting a tightening housing market. Conversely, Georgia, Kentucky, and Indiana have seen vacancy rate increases of up to 15%

(PolicyMap, n.d.-b), indicating a more available housing supply. These variations could impact the ability of battery manufacturers to attract and retain workers in certain areas. Median home prices in the Battery Belt region are lower in East Michigan, Georgia, Indiana, South Carolina, and Kentucky compared to other parts of the country (PolicyMap, n.d.-b). This could make it more affordable for battery industry workers to purchase homes in these areas, potentially increasing their financial stability and overall well-being.

Indiana, Michigan, Georgia, Tennessee, and Kentucky have lower internet availability by county compared to other parts of the country (FCC, 2018), which could work to hinder access to online education and job search resources. For instance, in 2018, Michigan had a broadband availability rate of 73.8%, while the national average was 89.9% (PolicyMap, n.d.-c). These states share some common characteristics that may contribute to their lower internet availability. One factor is their location. Indiana, Michigan, Tennessee, and Kentucky are all located in the Midwestern and Southeastern regions of the United States, which are generally less densely populated than coastal areas. This can make it more expensive and challenging to build and maintain broadband infrastructure in these areas. Another common factor is the presence of rural areas. All five states have a significant proportion of rural residents. Rural areas are often more difficult and expensive to serve with broadband than urban areas, due to factors such as geographic dispersion and the cost of running cable or fiber optic lines over long distances. Finally, these states all have relatively low median incomes. This can make it more difficult for residents to afford broadband service, as monthly fees can be a significant expense.

High school graduation rates in the Battery Belt states, as illustrated in Figure 24, range from 82% to 93% (PolicyMap, n.d.-a), as compared to a national average of 87% in 2020 (NCES, 2023). While the 4-year college graduation rate in the Battery Belt is encouraging, with rates ranging from 79% to 90% (NCES, 2023; PolicyMap, n.d.-a), there is still room for improvement in STEM (Science, Technology, Engineering and Mathematics) education and degree attainment. The percentage of individuals aged 25 and older with a bachelor's degree in engineering or science is lower in the Battery Belt compared to states like California, Texas, Florida, and the U.S. East Coast (PolicyMap, n.d.-a). The percentage of individuals aged 23 and older enrolled in college ranges from 2.2% to 5.2% in the Battery Belt, falling well below the national average of 33.4% (PolicyMap, n.d.-a) and those of states like California, Puerto Rico, Texas, and most of the East Coast (PolicyMap, n.d.-a). This indicates that there are likely to be fewer graduate degrees-holders in this region.

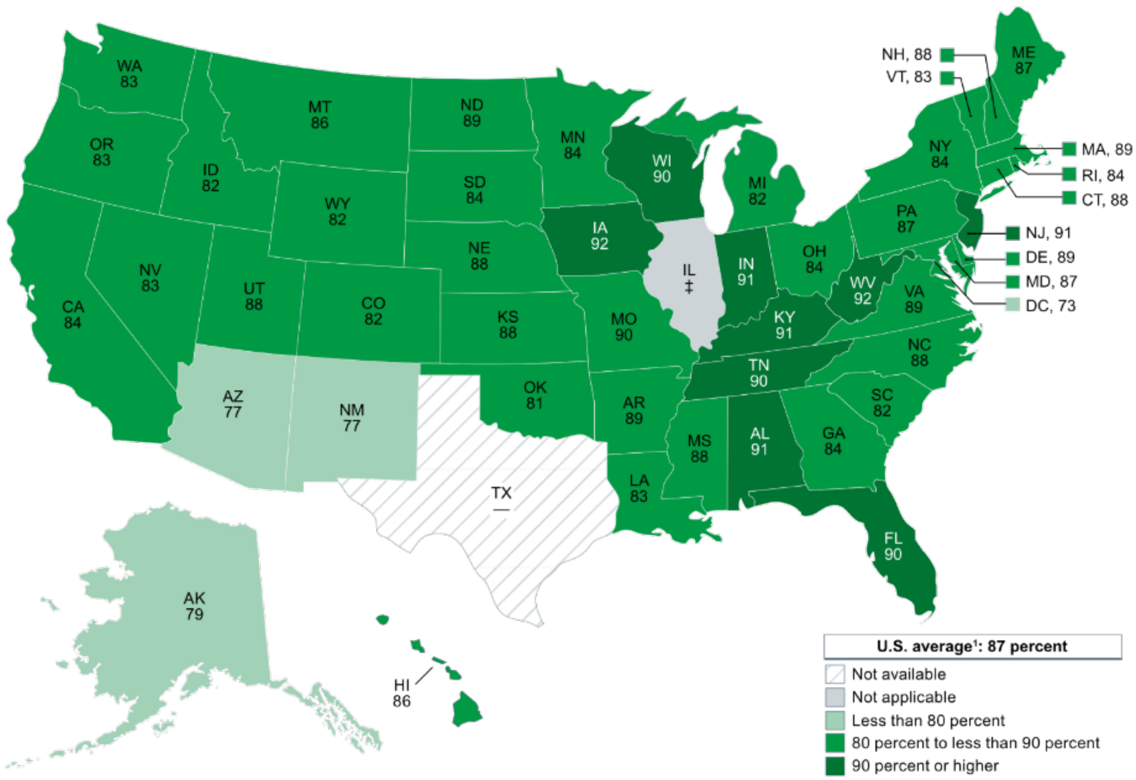


Figure 24. Graduation Rate for Public High School Students by State: 2019–2020. Source: NCES (2023).

The Battery Belt states have a higher proportion of community, junior, and 2-year colleges compared to 4-year institutions (PolicyMap, n.d.-a). This emphasis on 2-year degrees can be beneficial in providing individuals with trade and vocational skills that are in high demand in the battery manufacturing industry. However, it is important to ensure that these 2-year programs offer quality, targeted education and training that prepare graduates for successful careers in the battery industry.

Master’s degree attainment in the Battery Belt states varies, with rates ranging from 4.7% to 10.9% (PolicyMap, n.d.-a). While these rates are lower than the national average of 13.7% (Abbasi, 2022) illustrated in Figure 25, it is encouraging to see that some states in the region, such as North Carolina, South Carolina, Georgia, and Indiana, have higher proportions of individuals with master’s degrees. Promoting graduate education and research opportunities can help attract and retain highly skilled talent.

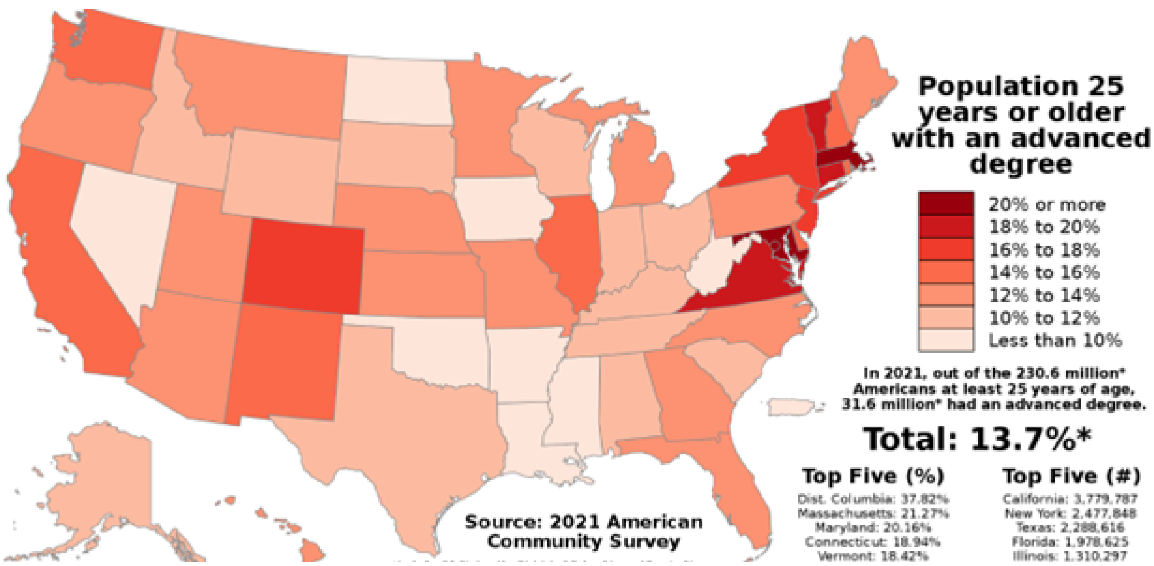


Figure 25. Population 25 Years or Older With an Advanced Degree.
Source: Abbasi (2022).

In 2023, only 38% of U.S. adults said that patriotism was important to them, compared to 70% in 1998 (Blackburn, 2023). While this statistic may not seem to have immediate application to the battery workforce, the element of patriotism is an increasingly prominent element of the appeal of manufacturing, and of the battery industry in particular. The “existential importance of our nation’s productive capabilities in a world of transnational peril…[is] the indispensable basis of our national security, our social stability, and hence our persistence as a polity” (Hockett, 2023, para. 2). Examination of some of the indicators of the presence or absence of this patriotism in the population of interest is warranted.

In 2020, Indiana, Kentucky, Tennessee, and South Carolina had voter turnout rates of around 63%, while Michigan, North Carolina, Georgia, and Ohio had higher turnout rates of around 73% (PolicyMap, n.d.-a), as compared to the national average for the 18–45 demographic of 56.3% (PolicyMap, n.d.-a). Further, the percentage of living veterans in the Battery Belt states, who might be presumed to have a patriotic perspective, ranges from 6% to 9.8% (PolicyMap, n.d.-a), with most states having 7%-8.5% of their population composed of veterans. Seven of the eight battery belt states are in the top 20% of numbers of veterans, with four of those in the top 10% (WiseVoter, 2023). Veterans can bring valuable skills and experience to the workforce, including technical expertise, leadership, loyalty, strong work ethic, and teamwork. Leveraging the veteran community can help address the workforce shortage in the battery manufacturing industry and provide veterans with meaningful employment opportunities.

Although there is no stereotypical employee, the demographics of the battery belt allow us to draw some conclusions. For ease of use, these are summarized in Table 3.

Table 3. Summary of Demographics

Characteristic	**Description**
Location	Midwestern and Southeastern regions of the United States
Population density	Relatively low
Rural areas	Significant proportion
Median income	Relatively low
Poverty rate	High
Agricultural presence	Strong
High school education	High likelihood
University education	Medium likelihood
Active citizenship	High

However, the "typical" hourly employee varies in each area; for sake of comparison, the worker who resides in the vicinity of the Eagle Mine in North Michigan may be compared to a resident in the area of Kings Mountain Mine in North Carolina in key dimensions.

Areas of Difference in the two sample communities

- Eagle Mine (North Michigan)
    - The Eagle Mine is located in a rural area of North Michigan, and many of the employees are from the local community. This potential pool of employees tends to live in small towns or on farms. They may have family members who have worked at the mine for generations.
    - Michigan's cost of living is 8% below the national average. Housing costs are 10% below the national average, and the majority of residents rent. This means that the average resident's average salary of $59,462 per year or $29 per hour will stretch further, and residents will be less tied to particular locations due to lack of home ownership.
    - There are approximately 47,573K people eligible to work in Michigan, including both those who are working and those who are unemployed but seeking work. (Data from Economic Research Institute, 2023)
- Proposed Kings Mountain Mine (North Carolina)
    - The Kings Mountain Mine is located in a more urban area of North Carolina, and the employees may come from a wider range of backgrounds. They may live in a variety of housing options, including apartments, houses, and condos. They may have moved to the area from other parts of the country or even from other countries.
    - The cost of living in Kings Mountain, NC is 14% below the national average, so less costly than in north Michigan, but at $57,797 annually and $28 hourly, the average salary is also lower. State tax is much higher in NC (18th highest in the U.S. vs. 25th highest in MI).
    - There is a smaller workforce available at 45,415K. (Data from Economic Research Institute, 2023)

Common Experiences and Challenges

- Both mines are located in rural or semi-rural areas, and the employees may have to commute long distances.
- Both mines are important sources of employment in their communities, and the employees play a vital role in the local economy.

These are the factors that battery manufacturers need to consider when seeking a workforce from the local community, which is generally a company's surest way of obtaining approval to build.

C. CAPABILITY SECTOR 3: DOWNSTREAM (STAGES 1 AND 2)

1. Stage 1: Required Occupational Skills (ROS)

The downstream battery supply chain is currently controlled and regulated by China, which accounted for about 73.3% of global lithium battery manufacturing capacity as of May 2023, as evidenced by Figure 26. The U.S. accounted for only about 6.7% of the market (Economist Intelligence, 2023).

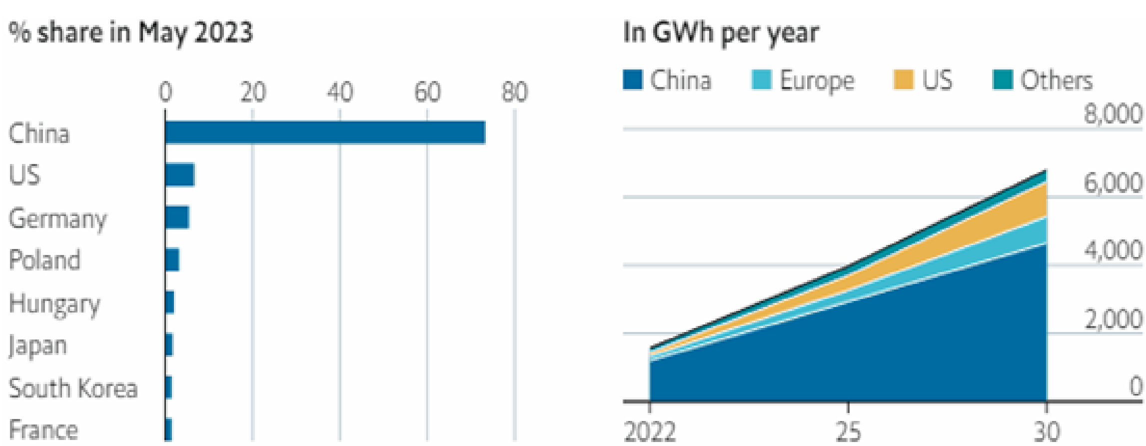


Figure 26. Share of Lithium-Ion Battery-Making Capacity.
Source: Economist Intelligence (2023).

Enacted in 2022, The U.S. Inflation Reduction Act (IRA) encourages clean energy investments, with just over $70 billion earmarked for the U.S. battery supply chain

(Moerenhout, 2023). A feature of the IRA has been the acceleration of joint ventures between manufacturers and cell makers, a model pioneered in the U.S. market by Tesla and Panasonic (Mehdi & Moerenhout, 2023). The IRA mandates that by 2029, all battery components must be produced in North America (Hafshejani, 2022). Despite bold initiatives such as IRA, China will continue to account for the majority of the battery supply chain through 2030: "For example, 70% of battery production capacity announced for the period to 2030 is in China" (IEA, 2022, p. 3). Figure 27 illustrates China's dominance of the entire downstream battery supply chain (Mehdi & Moerenhout, 2023).

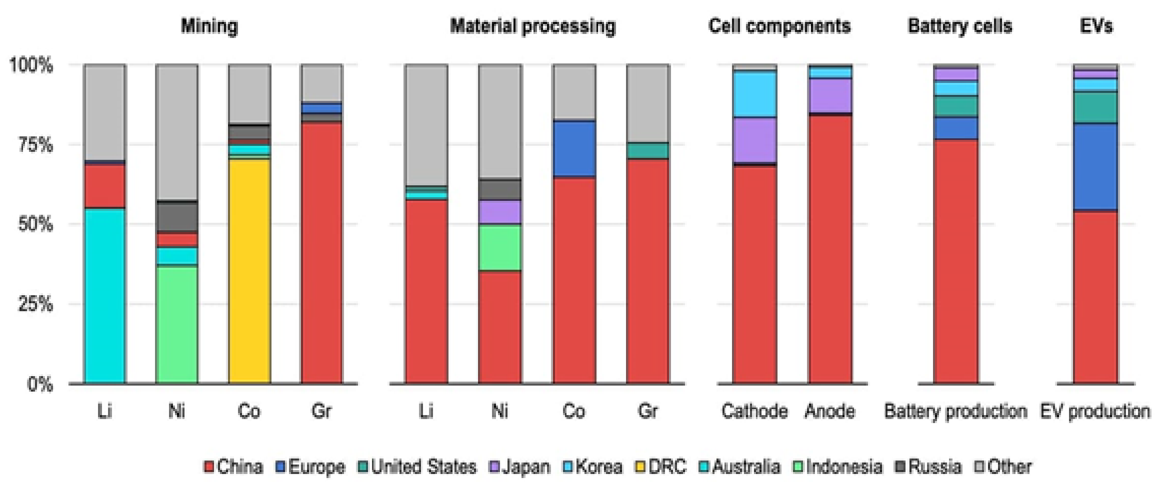


Figure 27. Geographical Distribution of the Global EV Battery Supply Chain.
Source: St. John (2023).

One of the clearest gaps in this sector is in worker expertise. The need is for technicians, engineers, and specialists who can work on battery-powered systems in assembly, integration, and maintenance. Standardization and certification, however, are also missing throughout the sector; this can lead to inconsistencies in workforce quality and safety practices. Development of industry-recognized certifications could help mitigate this gap.

2. Stage 2: Available Workforce Personnel (AWP)

The need for workforce in the downstream capability sector is largely regulated by the supply of cells from the midstream capability sector. As that is the case, and as an increasing trend toward vertical integration is at play, there is likely less of a demand for personnel in this capability sector than others, although the situation will be just as severe when the other sectors' workforces are fully formed and when their production matches their capacity. Additionally, as end-of-life processes mature, that too will require not only an increase in the workforce, but potentially a re-education of parts of the existing workforce.

Beyond that, very little information, other than anecdotal, is available on the status of the downstream capability sector workforce. More primary research is required into this area, which will remain a knowledge gap in this study, and readily lends itself to further work.

D. ALL CAPABILITY SECTORS: C2 THROUGHOUT THE BATTERY SUPPLY CHAIN

Communications channels within and between the three supply chain capabilities are not currently adequate to support the level of anticipated growth. Developing a highly skilled battery workforce surpasses any single organization's capacity for enterprise (NETL, 2022b), necessitating multiple channels of coordination and communication (C2). These channels, which should run between industry, government, academia, and all relevant stakeholders, are a necessity for the efficiency of the industry. But more than that, it is expected by stakeholders in part due to the rise of the internet and social media persuading users to expect a broader and more extensive range of information; "merely pushing information out is no longer enough to ensure that communications have taken place" (IFC, 2013, p. 4). This failure to communicate has tangible effects: "In the field of lithium-based batteries, there is often a substantial divide between academic research and industrial market needs" (Frith et al., 2023, p. 1). Researchers are not focusing on industry-relevant topics. This is partly due to the scarcity of peer-reviewed publications from industry and partly because there is no coordinating body or effective communication mechanisms among organizations.

Throughout the period of research for this study, the research team heard repeatedly from industry, government, and the academy that they would value not only a means of coordinating communication at a central point, but also a central clearinghouse of opportunities, whether funding, workforce driven, or facilities based. Further, many would value a forum for engaging in a secure, non-proprietary venue on best practices around the workforce and legislation. The stakeholders involved in this project would particularly value a direct conduit in policy discussions throughout the supply chain.

There is a gap in how industrial communications programs are conducted at corporate levels, and how local and corporate communications impact one another (IFC, 2013). Although the performance indicators of communications are intertwined with many other factors and difficult to evaluate, this study's stakeholder representation of all capability streams of the battery supply chain agree that more alignment within the industry is needed. There is no evidence, beyond the creation of reporting bodies, of a serious focus on creating that alignment where so much of the supply chain traditionally occurred outside the U.S.

1. C2 in the Upstream Capability Sector

In the upstream sector, the mining industry functions under a collective reputation often viewed as the lowest common standard. Establishing industrial coordination and fostering peer-to-peer collaboration would provide valuable, timely insights. Industry communications could have a significantly greater impact if companies unite together on key issues and collaborate to enhance skills and knowledge through training for media, civil society, academia, employees, and partners.

A 2013 survey of mining executives, which predated much of the legislation affecting the current environment, discovered that preserving a social license ranked as the second most critical risk confronting the mining and metals sector (Ernst & Young, n.d.). Research by the International Council on Mining and Metals, in cooperation alongside the International Finance Corporation, found that "surprisingly little has been written publicly about how mining companies utilize communications strategically across functions to further overall business aims" (IFC, 2013, p. 4). Further, they struggled to find the individuals responsible for communications within the organizations they surveyed, noting that when they did identify such individuals, they generally had multiple responsibilities and no consistent line of reporting within the organization (IFC, 2013).

Some companies have made inroads, however. The Eagle Mine, for example, owned by Lundin Mining on Michigan's Upper Peninsula, developed a "Community Scorecard," which leverages an interactive format enabling the community to rate the company's performance, even allowing the company a chance to respond (IFC, 2014). This demonstrated a responsiveness and transparency that contributed to the building of trust within the operational environment.

The Community Scorecard, as useful as it was for local communications, did not, however, facilitate communications or coordination within or across the supply chain or its stakeholders; that gap remains: "Collaborations and partnerships between raw material suppliers, battery producers, automakers, research facilities, and recycling facilities are necessary for the global EV battery supply chain" (Biliti Electric, 2022), as well as throughout the supply chain for all types of batteries. There is wide recognition that "to meet the expectations of their stakeholders, companies need to communicate with a unified message and voice" (IFC, 2013, p. 12). But without coordinating mechanisms or standardized communications channels, they are not able to create a unified voice, and may miss opportunities to support their strategic aims and greater efficiency throughout the supply chain with proactive communications.

To communicate with international aid organizations, governments, and civil society groups more effectively, mining organizations are working to discuss challenges related to mining and impact on communities where their operations take place. This emerging trend presents both opportunities as well as risks. Safety, health, and environmental concerns offer expanded collaboration as their management necessitates actions extending beyond the parameters of individual companies.

But the most significant developments toward integration in the upstream sector are instead working to keep the sector even more divided. Major players in the automotive and battery manufacturing market are making ambitious moves to control the extraction of raw materials and their processing, for eventual use in their end products. Automotive giant General Motors, for instance, recently announced an investment of more than $650 million in the world's third largest lithium mine, located in Nevada, to ensure that it is the only customer of the mine, "with the aim of guaranteeing its supply while reinforcing its competitiveness with respect to other producers" (Informaciòn, 2023). BMW is investing in Argentinian mines (Aja, 2023; Hyatt, 2021), and Tesla is operating its own mines in Nevada (Aja, 2023; Fuentes, 2020). But this vertical integration works to ensure an insularity of supply and communication within what results in many mini-supply chains throughout the industry. The present study does not consider further the business decisions of these companies, but only their impact on the workforce and ramifications for coordination and communications.

These effects result in one of the most significant gaps in the upstream capability sector overall, which is coordination and communications integration throughout the sector. This lack contributes to further gaps in the strategic mineral ecosystem, from legislative support to skilled and unskilled workers, to education and training programs, which might support the rest of the ecosystem.

2. C2 in the Midstream Capability Sector

From the point where critical minerals are extracted to the initial battery manufacturing is known as battery midstream production. While United States industries have primarily concentrated on automotive battery manufacturing markets, the midstream production sector has been predominantly led throughout the Asia-Pacific region, but this capability sector is expanding, due to green legislation providing incentives such as the Advanced Manufacturing Production Credit, though it cannot be managed in the manner it is currently.

Like the upstream capability, the midstream suffers from a lack of integrative activity. The establishment of a coordinating mechanism across the sector would provide a means to prioritize focus and would consider the sector's susceptibility to the potential impacts of the expected battery delivery speed. (Nicholson et al., 2023).

There are successes in coordination across this capability. For instance, the lithium-ion battery manufacturer "Sparkz" in conjunction with the United Mine Workers is working to attract 350 workers as well as train them for a new, 482,000 square foot West Virginia facility (Engel, 2022; Raby, 2022). "An agreement with the United Mine Workers union was announced in May [2023] to recruit and train dislocated miners to be the factory's first production workers" (Raby, 2022, para. 4). But this type of integration across the capability is the exception, rather than the norm. There are federal- and state-level incentives along with fledgling training programs, but there is yet much work to be done.

3. C2 in the Downstream Capability Sector

Most of the integrative activity in the downstream battery sector is focused on recycling and second life (Aja, 2023), and there is much competition between original equipment manufacturers to give a second life to batteries or reuse recycled materials to lower costs and remain in compliance with social expectations. While much of the literature notes the importance of a large cross-industry effort and coordination in achieving the full potential of a circular value chain (Fleischmann et al., 2023), the industry is not moving in that direction.

Circularity within the downstream sector of the battery supply chain, however, will remain key to reducing the gaps in mineral production in the upstream sector, as it reduces the long-term need for new raw materials, lowers costs, reduces emissions, and increases the resiliency of the supply chain overall: "As EV adoption and the potential feedstock of end-of-life battery materials increase, circularity will be one of the United States' most important strategies for building a resilient domestic supply chain that is also more sustainable and helps reduce dependence on extractive industry over the long term" (Aggarwal et al., 2023, p. 19). Inherent in circularity is a feedback loop, where those within the industry coordinate their activities in terms of how much recycled material can be used, the destinations for second life materials, etc.

While the downstream sector suffers the same lack of integrative activity seen in the up- and midstream capability sectors, there is less of a gap in manpower and education in existing functionality, primarily as a result of the Inflation Reduction Act (IRA). The law offers generous support to the nation's lithium-ion EV battery and energy storage value chain, and provides tax incentives to clean energy initiatives. The IRA led to significant investment activity, in less than one year after it passed into law, with specific impacts to the downstream capability of the battery supply chain (Mehdi & Moerenhout, 2023).

Despite successful advancements made by the U.S. in the downstream capability, the sector remains dependent upon the cells being provided by the midstream capability sector. And in the midstream sector, by 2032, even if the U.S. can establish the necessary number of gigafactories available to satisfy cell demand, it lacks an adequate supply of cathodes and anodes to manufacture the cells (Mehdi & Moerenhout, 2023), which will cause the U.S. to remain dependent on imported resources and foreign supply chains.

As the upstream capability builds its capacity to supply minerals at the rate required, keeping the gigafactories fully employed, then the downstream sector may have a larger workforce problem. As technology surrounding circularity and second life improves, this sector will again feel the strain. The battery recycling and disposal process is not as well-established as other parts of the supply chain, thus there is the opportunity to grow the workforce along with the industry; the other sectors are building their capacity, so this is the ideal time to create a plan for building downstream capability. However, without some means of coordination across the supply chain, the information signals do not travel between sectors, with potentially detrimental impact to national security.

E. ALL CAPABILITY SECTORS: DEMOGRAPHIC COMPARISON OF REQUIRED OCCUPATIONAL SKILLS (ROS) TO AVAILABLE WORKFORCE PERSONNEL (AWP)

1. Capability Sector 1: Upstream Population

There are five main minerals needed for lithium battery production: lithium, nickel, cobalt, magnesium, and graphite (Kemp, 2023). While these minerals are being mined within the U.S., or could be, that has not happened at the level required in the next two decades.

Nevada is being called the "Silicon Valley of lithium" (Northey & Cama, 2023) due to the nation's only significant, operational lithium mine in the town of Silver Peak. In the summer of 2023, a new and massive lithium deposit was reported in a volcano along the Nevada/Oregon Border (Solis, 2023), solidifying that area's status as the lithium capitol of the nation.

Silver Peak, Nevada, has a 2023 population of 195, which has declined nearly 10% over the past three years. Incomes have increased 14%. At 4.41 inches of precipitation per year, it is dry and often hot. The population in the vicinity of Silver Peak is almost entirely U.S. born, and non-Hispanic. The median age is 54.2, so beyond the usual age for entry-level or hourly mine workers. Most of the large veteran personnel in the area served in Vietnam. Thirty-five percent of the workforce is engaged in mining, quarrying, and oil and gas extraction. Approximately 23% of the population has a high school education or equivalent, with nearly 13% continuing to a bachelor's degree (all data on Silver Peak, Nevada from DataUSA, n.d.-c). This population, although small, is well-suited to employment in the mines, though it is insufficient to run the mine without support from surrounding communities. Also, the significant decline in population shows that the mine would need to position itself as attractive to young workers to achieve any significant local employment.

Also in the western region is the nation's only significant permitted cobalt mine (Siegler, 2022). The Jervois mine, which is fully permitted but currently sitting idle due to unfavorable cobalt spot prices, is located near Salmon, Idaho, a city of over 3,000 residents, which is slowly declining in population despite a 20% increase in income. The median property value, at $140,300, is higher than that of most mining towns, and although most people commuted only 10 minutes to work, slightly higher than Silver Peak's nine minutes, average car ownership in Salmon was two cars per household, exceeding the usual one-car average in Silver Peak.

Salmon has a large population of veterans who served in Vietnam, but a nearly equivalent number who served in the second Gulf War. This, combined with the heavily Republican nature of the area, indicates a younger, potentially conservative and patriotic population. The largest sector of workers in the area, at over 18%, is currently engaged in retail trade. The education level of this area is very similar to that of Silver Peak (all data on Salmon, Idaho from DataUSA, n.d.-b).

These demographics indicate a population well-suited for employment in the mine, and one which might be reached by emphasizing the national security aspect of mining operations at the current juncture in history. Due to relatively higher incomes and property values, they would likely need to see strong packages of compensation, and family-oriented policies.

The only nickel mine in the U.S., Eagle Mine, is in the Upper Peninsula region of Michigan. This mine's tremendously rural surroundings are sparsely populated, with an ageing workforce. Although Michigan has one of the denser populations in the Battery Belt, that is not the case in the Upper Peninsula, which is more rural than the lower peninsula. Unemployment rates are higher than the U.S. average on the Upper Peninsula (Anderson, 2023). The state suffers from some of the lowest incomes in the Battery Belt, yet some of the highest housing costs, which might lead mines to consider their provision of family housing as part of an employee's benefit package. Since the data show that population is declining in Michigan, it could be that potential employees are tending to seek higher pay and more economical housing outside Michigan and would certainly need enticement to stay.

Those who do stay are less likely to attend university than those on the coasts, but if they do go, while they tend to finish they do not study STEM subjects. On the other hand, as they have greater access to community colleges and technical schools due to there being a higher proportion of these types of schools in the battery belt and in Michigan in particular, the people of Michigan are well-placed to obtain exactly the type of education that is being considered most appropriate for much of this capability sector (PolicyMap, n.d.-a). Importantly, Michiganders vote at high proportions, and per capita, are more likely to be veterans than in many other states (PolicyMap, n.d.-a). While these statistics are not unexpected in an older population, this might appeal to the call to service for career-changers, in protection of national security and global leadership. The younger members of this voting population, to whom work increasingly must have a meaning beyond its own productivity, might also respond to service-based messaging.

The U.S. produces only a small amount of low-grade Manganese at the Abernathy Manganese Mine in McCormick, South Carolina (Diggings, n.d.; EPA, 2023). It is unlikely to be a significant player in the upstream capability sector during the period of this study, as the U.S. has positive relationships with the primary suppliers in Gabon, South Africa, Mexico, and Brazil (EPA, 2023; OEC, 2023).

While the U.S. has not produced graphite in any significant quantities since the 1950s, the U.S. Department of Defense has offered incentives and a $37.5 million grant for graphite mining in Nome, Alaska and processing in Washington state (Rogerson, 2023; Rosen, 2023). Nome has a 2023 population just under 3,500, of whom 2,585 are adults of working age, with an approximately equal split between men and women, although there are more women in the workforce employed at poverty wages. There is a strong native American presence in Nome. Over 33% of all adults are high school graduates, with just under 15% completing a bachelor's degree. Residents of Nome are likely to be married, with incomes in the mid-$100K. The veteran presence in Nome is likely to have served in the Vietnam War (46%) with the first Gulf War a close second (38%), indicating a veteran population approaching full maturity and retirement. Seventy-four percent of the eligible labor force is employed, and nearly 80% of the population was born in Alaska. The overall population is expected to continue declining by approximately 1.34% per year through 2030 (all data from World Population Review, 2022).

These data indicate that an appeal to the local population that provides consistent, family-supporting employment is likely to be viewed favorably. Expectations would be high for income levels, but there is a patriotic population to which a national security approach would appeal. Measures that speak to the Native population, particularly, are likely to be most successful as that sector is more likely to be in poverty, at 11.43% below the poverty level, as opposed to the white and Hispanic populations, which are 1.41% and 2.72%, respectively.

This capability sector's available workforce personnel cannot be compared to the needed required occupational skills, as there is not a reliable ROS from which to draw. So that, in itself, becomes a gap of interest. But what is known about the AWP is that industry struggles to find workers at all levels, particularly from the areas surrounding the mines, and that potential students would struggle to find educational opportunities within a reasonable distance due not to the unavailability of schools, but to the absence of relevant education and training programs along with the faculty qualified to teach them. The need for both will only grow.

2. Capability Sectors 2 and 3: Midstream and Downstream Populations

The U.S. currently has the capacity to produce 72 Gwh of battery capacity per year: "The United States is currently not a midstream leader; however, its midstream capacity is growing quickly, driven in part by the Advanced Manufacturing Production Credit (45X) which offers up to $45 per KWh of battery capacity and has the potential to strengthen the U.S. midstream sector" (Carreon, 2023, para. 67). Also, as previously noted, the IRA will continue to assist. The IRA stipulates that to qualify for any vehicle tax credits, an increasing proportion of an EV's battery metal value must undergo extraction or processing in the U.S. or a partnering country within a Free Trade Agreement, like Australia, Japan, or Mexico.

But there remain concerns over the very limited cathode active material production in North America, and that "even by 2030, announced domestic facility investments will meet only half of the projected demand from the private passenger vehicle segment"

(Mohanty, 2023, para. 12). NAATBatt estimates that existing and announced midstream battery facilities will result in the creation of over 170,000 jobs, improving U.S. ability to meet domestic demand and increasing certainty about the future of EVs, thereby encouraging investment and adoption (NREL, 2024).

Most of the Battery Belt states are strongly conservative and republican, yet they are funding the projects that are shifting public attitudes about climate change. Georgia, in fact, is leading the nation in clean energy investments since the IRA, yet, "Along with the governor, most state lawmakers rarely mention 'climate change' — or the emissions reductions and environmental benefits of switching to electric vehicles" (Osaka, 2023, para 8).

Billions of dollars are also being invested in battery plants and EV manufacturing facilities in other Battery Belt states like South Carolina, Tennessee, and Kentucky (Osaka, 2023). It is expected that the competition for talent in these states will be fierce, which is why corporations turn to operations like Georgia's "Quick Start," a program affiliated with the Technical College System of Georgia that quickly tailors training programs for workforce requirements at newer factories.

The Battery Belt is pioneering a novel, yet traditionally-based and proven, economic development model wherein possessing a degree may not be the definitive qualification for employment: "It's more geographically diverse, with different economic and infrastructure needs than the prior era that was so heavily influenced by Silicon Valley" (Sen, 2023, para. 2). The most important feature for battery manufacturing sites in the midstream capability are large parcels of land close to appropriate infrastructure and population hubs. Next on the list of priorities is a less tangible desirability: appropriate workforce, or a local workforce of the right quality, size, and cost, with proximity to future customers.

"While the Battery Belt will need a trained workforce, it won't be as reliant on workers with elite educations as the Silicon Valley economy was" (Sen, 2022, para. 7). In Georgia's Jackson, Bartow, Coweta and Bryan counties, there are plants in operation or being built where the population of adults with a minimum of a bachelor's degree education ranges from 19.8% to 33.3% compared to 50% for Fulton and DeKalb counties in Atlanta (USDA, 2023). Although it is still early in this movement, and a majority of the gigafactories are early in construction or planned, it appears that the economic focal point is pivoting. Originally centered in communities with a high density of college graduates, it is now expanding as the U.S. endeavors to develop the industrial economy of the future.

The median age in the Battery Belt is about 38.8, closely matching the nationwide figure of 39 but also squarely in the middle of the average working life (Census Reporter, 2023). Per capita and median incomes are about 90% of the average throughout the U.S. The 2.5 person household average, with half the population married, indicates families who need reliable employment. The population is slightly more mobile than the national average in this region, indicating that they may be willing to relocate for employment purposes, particularly as 80% of those who moved crossed state or county lines or even came from abroad. High school graduation rates are within half a percent of the national average, while advanced education is less widespread than throughout other parts of the country. Notably, the veteran population is 20% higher than the U.S. average, with most having served in Vietnam, followed by the second Gulf War, and then the first Gulf War (all data from Census Reporter, 2023). These are demographics well-suited to the need for both hourly and skilled workers in battery manufacturing.

The supply chain's downstream (battery module and pack assembly) has also received significant consideration (Mohanty, 2023, para. 8): "New battery plants will result in a wide variety of new jobs, from the production technicians assembling and testing batteries, to their supervisors, quality control, and many others" (Chalmers, 2023, para. 2). The largest occupations employed in battery manufacturing, according to the Bureau of Labor Statistics, are electrical engineers, electronic engineers, electromechanical assemblers, and miscellaneous assemblers and fabricators (Colato & Ice, 2023), as seen in Table 4.

Table 4. Employment Projections 2021–2031 for Select EV-Related Occupations. Sources: Colato & Ice (2023), USBLS (2023c).

Occupation title	Employment 2021 (thousands)	Employment 2031 (thousands)	Employment change, 2021–31 (thousands)	Employment change %, 2021–31	Occupation openings, 2021–31 annual avg (thousands)	Median annual wage, 2021	Typical education needed for entry
Total, all occupations	158,134.7	166,452.1	8,317.4	5.3	19,532.5	$45,760	
Electrical, electronic, electromechanical assemblers	279.5	285.5	6.0	2.2	32.8	$37,460	High school diploma/ equivalent
Miscellaneous assemblers and fabricators	1,367.1	1,270.7	-96.4	-7.1	142.7	$36,590	High school diploma/ equivalent

V. MINDING THE GAPS: BATTERY WORKFORCE GAP ANALYSIS

Upon understanding the current dynamic within the battery workforce and the skills it requires, and comparing that to the available workforce personnel, the direction of travel required for improvement begins to reveal itself. What remains is to consider a list of the capabilities that would most readily benefit from investment at the current stage in the development of the battery workforce.

To do this, the desired states of each capability must be modeled, and initiatives formulated to attain those states based on which measures will contribute the most to overall strategic goals as promulgated by Li-Bridge and the federal government. It is important, at this stage, to ensure that decision-making processes are driven by the strongest business cases, and not "decibel-driven." It is also important to maintain coherence between the proposed initiatives, so that they stay aligned toward greater progress overall. This is where the capability model is most useful, by focusing on outcomes that can be described, designed, and realized, providing a useful bridge between strategy and execution.

A 2021 NAATBatt survey indicated that supporting the anticipated 2030 demand for Lithium-based batteries in the U.S. would require a ten-fold workforce increase of over 200,000 new jobs (Green Car Congress, 2023): "High amongst the priorities to strengthen the U.S. battery supply chain is an investment in workforce training and updated applied educational curriculum needed to upskill/reskill in emerging clean energy technologies" (Gangi, 2023, para 7). The NAATBatt survey revealed that hiring across all education levels was expected throughout 2022, with the greatest hiring challenge at the 4-year degree and post-graduate levels (McQuilling, 2021): "The big challenge for the (battery) industry will be establishing a reliable supply chain and building the human capacity to make these factories hum" (Nigro, as cited in Clifford, 2023, para. 13). At present, there is a stark difference in the federal support provided to development of the battery workforce

($5 million) and federal funding of improvements to infrastructure and production (over $135 billion) (Brochot & Vitos, 2023).

Strengthening the domestic battery supply chain is crucial for enhancing energy security, fostering economic growth, and promoting sustainability. To achieve these goals, resources should be directed to several key areas in each capability area. Although there are potentially endless avenues for resource allocation, in a resource-limited environment, the closing of gaps must be sequenced and prioritized to ensure the most efficient expenditure of resources throughout the range of capabilities, to result in the greatest impact. This chapter begins with a discussion of work in progress to discover gaps in workforce programs and continues to explore gaps that are the most in need of closing in each capability sector, by capability and line of effort, along with possible mitigations.

A. FUNDED RESEARCH PROGRAMS ESTABLISHED TO EXPLORE GAPS

Occupational skills and jobs requisite for developing the domestic battery supply chain workforce are being studied as indicated in Appendix D. The NPS research team identified these programs by electronically word searching with Google.com, 22 federal government and 18 national laboratory websites identified by USA.gov, and the websites of the 146 "R1" and 133 "R2" doctoral universities assessed in the 2021 update of the Carnegie Classification of Institutions of Higher Education. Key words searched included various combinations of the following: "battery," "workforce," "training," "initiative," "development," "mining," "gigafactory," and "supply chain."

At the unit of analysis involving the federal government, there are at least six major efforts:

1. Battery Workforce Initiative (Battery Workforce Initiative, 2022)
2. U.S. Department of Energy Lithium-Battery Workforce Initiative (DOE Announces $5 Million to Launch Lithium-Battery Workforce Initiative, 2022)
3. Li-Bridge related National Advanced Battery Workforce Council (National Advanced Battery Workforce Council, 2023)

4. National Renewable Energy Laboratory Study by Truitt et al. (State-Level Employment Predictions for Four Clean Energy Technologies in 2025 and 2030, 2022)
5. National Renewable Energy Laboratory Study by Moe and Turner (Clean Energy Education and Training Resources and Opportunities in New York's Southern Tier Region, 2022)
6. National Science Foundation grant (NSF Award Search: Award # 1501883, 2015)

Other units of analysis examining required occupational skills and jobs include at least one business league and four universities:

1. NAATBatt Education Committee (Survey on Gap Analysis in Workforce Skills and Policies in the Battery Industry, 2021)
2. University of Texas at Dallas (UT Dallas to Lead $30 Million Battery Technology Initiative, 2023)
3. Michigan Defense Resiliency Consortium (Department of Defense Approves $30 Million in Grants under Defense Manufacturing Community, 2023a)
4. University of California, Santa Cruz (Lithium Battery Electric Supply Chain: Workforce Analysis – UCSC Institute for Social Transformation, 2022)
5. SUNY Broome (Workforce Development Component of New Energy New York's "1 Billion Build Back Better Regional Challenge" Initiative, 2022)

Although the collective aim of these efforts is to accelerate the development of the domestic battery supply chain workforce, each emphasizes different facets of its development. Pockets of highly focused work on developing a national strategy for the battery industry is underway, but efforts are sparse and regionalized. For example, both Moe and Turner (2022) and SUNY Broome focus their analyses on the southern tier region of New York. The effort funded by the National Science Foundation grant targets workforce development in Pennsylvania. The University of Texas at Dallas plans to develop relationships with north Texas community colleges. The University of California, Santa Cruz has set its sights on inland southern California as the setting in which to expand workforce development.

Although regionalization is itself evidence of substantial progress being made in achieving our nation's objective, it is not the full answer to the U.S. domestic battery workforce dilemma, as demonstrated by 44% of battery industry employers indicating that they had been unable to hire locally sourced talent (McQuilling, 2021).

There is evidence of the building of more comprehensive strategies, however. The Center for Manufacturing a Green Economy (CMGE), an organization created by the United Auto Workers (UAW) is creating a workforce training program for Sparkz, an LFP battery manufacturer in California. CMGE seeks to build recruitment from local communities, provide foundational job skills training as well as wraparound services to support cohorts, and to create a skills-based apprenticeship for production workers.

Another example of contribution to future strategies is the National Advanced Battery Workforce Council effort to create "a comprehensive database of existing battery and battery-related training and education offerings" that will allow potential employees nationwide to determine where and how to acquire the education and training required to enter the battery workforce (NABWC, 2023, para. 4). While this effort will contribute significantly to recruitment goals within the battery supply chain and is a necessity, as of this writing the program has not been funded.

These programs will make significant contributions once funding is allocated to them. But very little U.S. federal funding is being spent on battery workforce or technology in relation to the total funding recently approved by the U.S. government via the Infrastructure Investment and Jobs Act ($1.2T), the CHIPS and Science Act ($280B), and the Inflation Reduction Act ($891B) (U.C. Berkeley Labor Center, 2023). U.S. government messaging says that large investments are occurring to make manufacturing jobs and workforce transition programs available in the clean energy industry. While this is occurring in pockets, often with federal funding, there is little to no evidence that this is occurring on a large scale, or with any coordination, across the U.S.

The IIJA, for instance, has invested only 2% of its budget on EV battery-specific or battery-related programs. IRA has invested 6.5% of the total budget on EV battery-specific or battery-related programs (Gabriel, 2023). And the CHIPS and Science Act has invested approximately 20% of its total budget on chip manufacturing and semiconductor technology and another 30% of the total budget goes to the National Science Foundation (AAAS, n.d.). The greatest contribution by the CHIPS and Science Act to battery programs is the investment in overall technology and in education and research, which will have a positive impact on the overall improvement of battery technology.

Most available U.S. funding for battery programs is for matching funds or incentives to the commercial manufacturing industry, investing in low-income areas within the U.S., support to colleges and universities involved in specific research, increasing agency budgets (i.e., doubling the National Science Foundation budget), or funding infrastructure and facility improvements at U.S. national laboratories.

The best examples of coordinated efforts supporting battery programs have been occurring at the state level in Georgia, South Carolina, and New York. These states have community college systems that are coordinating directly with manufacturing and commercial industry to adapt their trade courses to ensure the future workforce is ready and matches the new demand in battery technology. In addition, these states have sought and obtained grants and other funding aggressively to create economic zones and "Regional Innovation Engines" that welcome battery-specific programs.

New York, in particular, benefits from the fulsome efforts of the coalition between New Energy New York (NENY) and Binghamton University. Both the University, through the invigorated leadership of a campus which includes the labs of Nobel laureate M. Stanley Whittingham, as well as NENY itself, are developing coordinated and innovative programs for K-12 and pre-professional programs throughout the regions that they support. In common with CMGE, NENY puts a particular emphasis on collaborating with community-based organizations to address and secure support that pulls down barriers, such as obtaining secure housing, providing childcare, and organizing transportation.

These types of measures have proven effective in both attracting the needed workforce, and in retaining them.

B. CAPABILITY SECTOR 1: UPSTREAM WORKFORCE GAPS

As indicated in Appendices D and E, while many projects are underway to investigate and improve conditions within the battery workforce, Capability Sector 1, while benefitting from a greater proportion of IRA funds that the other sectors, has had the least attention overall. This would tend to indicate that there is perhaps less need in Capability Sector 1 for the type of focused support provided in both other capability sectors. However, discussions with industry representation indicate that this is not the case.

1. Line of Effort 1: People – New Workforce (Recruitment)

No comprehensive list of required occupational skills (ROS) exists. A more thorough and widespread understanding of ROS would allow formulation of educational and/or training programs sufficient to keep the industry operating at full capacity. It would also provide for identification of those occupations most in need of filling, whether skilled, unskilled, or mining-related vs. mining specific. Various generalizations are available, such as the radar wheel of skills needed by those seeking careers in mining and mineral engineering published by DataUSA (n.d.-a) and shown in Figure 13, but these do not fill the need for a fulsome and usable list of ROS, around which programs of study or training might be devised.

No work is currently being done to create a listing of the ROS in the upstream capability sector.

There are not enough education/training programs at appropriate levels to fulfill even current needs, and certainly not enough to fulfill future needs. However, without a good understanding of ROS, there can be no assurance of the need. A comprehensive survey of all education and training programs available to this sector, such as that indicated by the second pillar of the NABWC Charter, should be conducted, with the end result a working and accessible database of nationwide programs. Upon identification of ROS, this would allow identification of gaps in educational programs with greater specificity, toward the creation or modification of programs as required. This work, although planned by NABWC, is neither funded nor underway. Until this work is completed, the evidence of the various employers and representative organizations must be taken at face value and cannot be verified.

This represents two significant gaps:

1) The need for a comprehensive understanding and record of existing training and education programs, which may lead to a need for the creation or modification of programs to fill the gap, particularly for advanced professionals.

2) A comparison of required skills to available programs to determine the extent and character of need for further or modified education and training programs.

Students are not enrolling in existing programs of education that might lead to careers in mining. As shown in Figure 28, enrollment has been declining steadily and steeply, approximately 45%, from a 30-year high in 2015 (SME, 2022). While there have been previous declines, the current decline is occurring during a period of exponential growth in the industry, so it is even more dramatic.

Figure 28. B.S./M.S. Mining Engineering Program Degrees Conferred, by Year. Source: SME (2022).

Clearly, this capability needs talent. Eighty-six percent of mining executives surveyed in a study by McKinsey (Abenov et al., 2023) note more difficulty in recruiting and retaining needed talent over the last few years. Mining is not currently considered an aspirational industry, despite high wages, positive social climate, and long-term career potential, as evidenced by a 39% decline in graduations from U.S. mining programs since 2016 (Abenov et al., 2023; DataUSA, n.d.-a). Mining has traditionally used its financial incentives to attract young miners to the trade, but with Gen Z expecting high technology solutions, larger purpose, and a friendly work environment, mining is positioned well to capitalize on its other benefits.

This talent gap must be treated as more than a human relations problem. It is a strategic consideration, alongside safety, production, and cost (Abenov et al., 2023). Resources must be expended not only on attracting employees to the trades, but also on focusing on what matters to them as is being done by CMGE and NENY. Capital might be invested in infrastructure, for instance, as these worksite gaps are immediate detractors for young employees and low investment to fix. And the capability sector should seek to get ahead on understanding what the next generation of talent values most, to embrace those changes in time to attract new workers at every level.

There is voluminous evidence supporting a recruitment challenge in this capability sector. Mining jobs that were closed during Q1 2022 had been online for an average of 10 days when they were taken offline. This was an increase compared to the equivalent figure a year earlier, indicating that the required skillset for these roles has become harder to find in just the past year (GlobalData, 2022). While this was still a shorter than average posting time as compared to most industries, it indicated a worrying trend for mining in particular.

Some mining companies have tried to reach technology workers through graduate programs and other incentives, but the sector has struggled to bring in the necessary talent. Fifty-seven percent of the companies surveyed by the World Economic Forum (WEF) said they see the inability to attract specialized talent as the biggest barrier to the adoption of new technology ("Future of Jobs," WEF, 2020). An even more formidable problem may be the availability of such workers, as discussed in Chapter IV. Seventy-three percent of the companies surveyed by the WEF named skills gaps in the local labor market as the biggest barrier to adopting new technology. With many mine sites operating in remote locations, successful retraining of local workers is likely to be critical.

"Companies that mine copper, lithium and other metals—viewed as a critical part of the supply chain to produce green energy—say they are struggling to find enough young workers to support the transition" (Khan, 2023, para. 4). Particular challenges have been reported in recruiting high-skilled roles such as engineers, exploration geologists, and data analysts (Khan, 2023). In the U.S., the job vacancy rate for mining and logging was 5.1% going into the third quarter of FY2023, up from 3.6% five years ago, according to Bureau of Labor Statistics data. Of particular concern are the positions most difficult to fill, which industry and industrial research (Abenov et al., 2023; GlobalData, 2022; Khan, 2023) have indicated are:

Data Analysts	Diesel Mechanics	Electricians – Field
Electricians – Repair	Exploration Geologists	Machinists
Maintenance Mechanics	Metallurgical Engineers	Welders – Standard

Recruitment for these positions must be a priority in Capability Sector 1.

There are currently isolated programs of recruitment to mining education and training, but many of those are at the unskilled level and occur post-hiring: "Today, automation, digitization, and AI are core elements of any mining operation, and require skilled workers who are often hard for miners to attract" (Bermack et al., 2023, p. 13). Organizations such as the Society for Mining, Metallurgy and Exploration's Mineral Education Coalition offers resources such as literature, videos, information databases, and outreach, but there is no evidence of direct recruitment into coordinated programs of education and training that might result in an increase in the battery workforce. Commercial companies such as Brunel or Georgia Quick Start recruit employees into specific jobs for pre-determined clients, but there is no program of recruitment that seeks to bring the general population into mining.

There are no nationwide programs of worker recruitment into the industry, or recruitment into education for the industry, coordinated across all aspects of the upstream capability sector.

Universities and technical schools that offer mining programs, and the faculty who are qualified to teach in those programs, are in short supply. Twelve schools have closed their mining programs since 1985 due to lack of demand: University of California Berkeley; Southern Illinois University, Carbondale (SIU-C); Ohio State; University of Minnesota; University of Alabama; University of Idaho; Columbia University; University of Pittsburgh; Texas A&M; University of Washington; University of Wisconsin, Madison; and the University of Wyoming (SME, 2022, p. 3). Declining enrollment has meant fewer faculty members. There has been a corresponding decline in U.S.-qualified faculty in these programs as well as a shortage of qualified candidates to fill faculty vacancies.

Part of attracting new talent is developing the education and training that are required to prepare new employees to contribute within the sector, as well as being able to assure the incumbent workforce of opportunities for further education and training. The demand for both mining technicians and mining professionals is growing due to the retirement of baby-boom employees and the growth in the industry, so a lot of expertise is being lost. According to the Bureau of Labor Statistics, most jobs across the full spectrum of industries in the 21st century require some education beyond high school, but not necessarily a 4-year degree. The same holds true for the energy and mining industries (National Research Council, 2013). But these specialized education and training programs, which would rapidly prepare workers to enter the workforce at all levels, do not yet exist in great numbers.

Similarly, programs are needed to give advanced professionals, such as lawyers, accountants, and public affairs professionals, the specialized knowledge they need to pursue their professions within the battery industry. In order to represent a mine through the permitting process, for instance, the legal professional must have some level of knowledge of the mining industry. These types of just-in-time education and training programs for professionals are completely lacking outside sparse on-the-job training programs.

There are no programs of specialized recruitment for faculty into mining programs, or into programs that incentivize the establishment and maintenance of programs of education in mining and minerals.

Development of sufficient numbers of education and training programs, as well as creation of programs for advanced professionals, is a Capability Sector 1 priority.

2. Line of Effort 2: People – Current Workforce (Human Capital Development)

Seventy-one percent of mining leaders are finding that a pervasive talent shortage is holding them back from delivering on production targets and strategic objectives (Abenov et al., 2023). Eighty-six percent of mining executives note that it is harder to both recruit and increasingly, retain, the talent they need versus two years ago, "particularly in specialized fields such as mine planning, process engineering, and digital (data science and automation). We expect this trend to continue" (Abenov et al., 2023, para. 5). Some mine workers lack confidence that their current employers are training them in the use of new technologies. Thirty-eight percent of workers at metals and mining companies said that they're concerned about not getting sufficient training in digital and technology skills from their employer (Bermack et al., 2023). Talent retention continues to be a major challenge for mining and metals companies. Individual mines are deploying a range of solutions, including upskilling internal candidates as well as considering digital solutions. But above all, the development of attractive career pathways will help inspire workers to see their future in mining and improve retention rates. Building a stronger work culture and mining brand, including highlighting mining's role in the energy transition, will also help (Mitchell, 2022).

The mining industry is facing a severe retention problem. Although work is being done in some areas, there is no national program of branding, career pathway

advertising, or consistent incentivizing that reaches future workers where they are and curtails the migration of the workforce into other industries.

Only 19% of business executives and 23% of workers say work is best structured through jobs (Cantrell et al., 2024)*; the unit of measure within an organization is most efficiently the skillset versus the job jar*. A skills-based approach to managing work and workers delivers greater agility and worker autonomy by enabling skill mastery and work performance beyond formal job boundaries. Focusing on skills helps alleviate talent shortages by providing a more expansive view of the work people are able to "do," instead of artificially limiting the talent pool to people with specific backgrounds and job histories. This also allows organizations to mitigate talent shortages by plugging gaps with internal resources instead of hiring from outside. Further, a skills-based approach helps promote diversity and equity in the workplace, for which there is a solid case in the mining industry (Bermack et al., 2023; Cantrell et al., 2024).

In a skills-based organization survey, 75% of executives say hiring, promoting, and deploying people based on skills (versus tenure, job history, or network) can help democratize and improve access to opportunities (Cantrell et al., 2024). Merck and IBM, for example, are part of a coalition called OneTen that is committed to hiring, upskilling, reskilling, and promoting 1 million people without 4-year degrees by shifting to a skills-first approach (Cantrell et al., 2024). This is a solid step in the right direction, but it is limited to individual companies and mines.

There is no comprehensive, national strategy to enable greater development of mine workers at any level.

3. Line of Effort 3: Process – Coordination and Communication (C2)

The mining industry involves prospecting, planning and permitting a mine, extraction of raw minerals via surface mining and/or underground mining techniques, processing and mineral dressing, and the restoration or reclamation of the mine at the end of its economic life cycle (Flyability, n.d.). Effective communication and collaboration among the various stakeholders involved in these activities are essential for the successful support of the battery industry. Additionally, coordination with the other capability sectors within the battery industry is important to the success of all. The volume of minerals that refineries are capable of processing will strongly determine the useful output of the mineral mining sector. Further, both the upstream and midstream sectors are dependent upon the downstream sector's ability to assemble and install the battery packs. The waste products produced in the downstream sector may be subject to reuse, recycling, or second life that will again affect the needed output of the upstream capability sector. In the absence of C2, all parties are functioning in a vacuum.

Improvements in this area would allow Capability Sector 1 to transfer expertise more efficiently into the battery industry, between sectors of the battery industry, or within a sector of the battery industry. Coordination within the sector would provide for the creation of a knowledge bank or listing of occupational skills and/or jobs that are required to be filled, more readily enabling the creation of education and training that is fit for purpose. It would also allow potential employees of the upstream capability to understand more fully what is available to them in this sector, which would go a long way to dispelling the myth of hazardous, shirtless, pickaxe mining.

This type of C2 is not currently in place within the battery supply chain's upstream capability sector, nor between sectors, to the detriment of all sectors.

Improvement of communications and coordination within Capability Sector 1 and between all the capability sectors is a priority.

C. CAPABILITY SECTOR 2: MIDSTREAM WORKFORCE GAPS

The midstream capability of the battery supply chain suffers from a lack of coordination that would enable it to utilize a limited pool of human and other resources more effectively. Through the Inflation Reduction Act (IRA), the federal government is working to localize production within the U.S., as supported by North and South American free trade agreements, and the Department of Energy has awarded significant sums to many companies across at least 12 states operating in the domestic battery supply chain (Nicholson et al., 2023). All this activity has resulted in a hiring boom that is pocketed and sporadic. It is led by industry, which is appropriate, but often in an environment of secrecy and suspicion. An alliance across the sector would require a clear view and ability to prioritize focus but would also provide for the alignment of a technology roadmap, ensure an environmental, social, and governance (ESG) focus, and realize common goals such as common delivery of waste products to recycling hubs to drive circularity.

Absent from Capability Sector 2 is a federally funded, nationwide battery communication and coordination network that could collaborate with the DOE, DOL, DOD, and DOT and unify those areas of government with existing workforce strategies (Brochot & Vitos, 2023, para. 8). Further, there is no venue for determining future need due to lack of a coordinating capability.

C2 is an area of priority development for Capability Sector 2.

Myriad, largely industry-driven programs are being created within the midstream capability to attract potential employees to the gigafactories, which are being planned and built across the Battery Belt and elsewhere. Where manufacturers see a lack of training sources, they are taking things into their own hands. Tesla, for instance, is opening a new facility in Reno, and simultaneously investing $37.5 million in the state's K-12 education system (Hull, 2015), because "local colleges don't graduate enough students with the technical skills to fill the gigafactory's expected 6,500 permanent positions" (Smith, 2015, para. 5).

The Biden administration's historic investments are primarily dedicated to boosting manufacturing, production, and processing of batteries, as opposed to workforce development. The need for talent is not being overlooked, however. Accredited technical courses and private-public partnerships at the state and federal levels are emerging, such as the partnership between the state and the Georgia Department of Education that resulted in Georgia Quick Start. The department has created a career pathway program for high school students interested in EVs in response to an upcoming Rivian plant. Additionally, the Department of Energy and industry partners announced a $5 million lithium-battery workforce initiative and a 3-year college student competition. But more will be needed to avoid a talent shortage and subsequent supply chain disruptions.

So, the need, in this sector, is equally recruitment for employment and recruitment to education—as success in the latter will lead to success in the former. Students must be made aware of the opportunities of education—what education or training is required to enter the industry, why they should educate themselves for the battery industry, and where to obtain the appropriate education or training.

Recruitment to education is a priority area for Capability Sector 2

Further to the goal of making potential entrants into the workforce aware of education and training available to them is ensuring that enough of the right type of education and training are actually available. Particularly for those companies that are already supplying their own training programs to fill a perceived lack, standardized courses will become increasingly relevant where in-house training gets too time and cost intensive or special external knowledge is needed (i.e., on digital skills or certain academic topics that might require more intensive cooperation with universities or the transfer of skills to an increasing number of "next generation" staff) (Thielmann et al., 2021). The curricula at universities are often adapted to the needs of the local environment or nearby industries, but do not always cover the most current needs of those industries, as education, an industry guided by tradition and peer-reviewed bodies of knowledge, is often averse to responding to what might be interpreted as trends. As the requirements of the battery industry evolve, new needs will emerge or become more concrete. The curricula, courses, or seminars being offered need to be adapted to emerging requirements.

While PhD and master's level education currently offered is a good beginning and is often targeted toward battery-specific chemistries and technologies, the situation is different with professional and vocational education. The main challenge in professional education is to reskill and upskill personnel along the value chain, especially in the automotive industry. Large companies typically face this challenge by offering in-house training or on-the-job training. Online courses are available in some cases, but they primarily provide a basic level of knowledge on relevant topics and are not specific enough to lead directly to employment. Programs available for vocational education are generally limited across the nation and very localized. This might be because industry is often training the staff in-house. Future programs for vocational education will thus have to be practically and locally relevant with an emphasis on skills directly related to the desired job (i.e., battery production, integration, operation, safety, machine operators and repairpersons, material handlers).

Capability Sector 2 requires more widespread and targeted programs of education for the current and prospective workforce.

D. CAPABILITY SECTOR 3: DOWNSTREAM WORKFORCE GAPS

The downstream sector of the battery industry involves the assembly, integration, and application of batteries into various products and systems. As the battery industry continues to grow, there are a number of gaps and challenges in the downstream workforce that need to be addressed.

In common with the other two capability sectors, the downstream sector also lacks coordinating collaboration and communication between stakeholders, such as battery manufacturers, integrators, and end-users, which are essential for the successful deployment and operation of battery systems. Effective communication and collaboration among different stakeholders are essential for the successful deployment and operation of battery systems.

The workforce must be adept at coordinating efforts among all the participants in this sector, including educational institutions and governments, toward the development and maintenance of industry standards and a proactive approach to staying current with technology and safety best practices. The lack of standardized training and certification programs for battery professionals can lead to inconsistencies in workforce quality and safety practices. Developing industry-recognized certifications can help mitigate this gap, which can help ensure the continued growth and sustainability of the battery industry.

The absence of effective C2 throughout Capability Sector 3 is a gap.

There is a shortage of skilled workers with expertise in battery assembly, integration, and maintenance in capability sector 3. This includes technicians, engineers, and specialists who can work on battery-powered systems, such as electric vehicles (EVs), energy storage systems, and portable electronic devices. As batteries are integrated into various applications, there's a further need for professionals who understand how to optimize battery systems for specific uses, whether in transportation, grid storage, or consumer electronics. This includes electrical engineers, system integrators, and software developers. Also, understanding and complying with regional and international regulations related to batteries, including safety standards and environmental requirements, is crucial. Workforce gaps in regulatory expertise can result in compliance issues and potential legal challenges.

Capability Sector 3 requires the recruitment of talent and experience throughout the sector, but particularly at the highly educated professional levels.

As seen elsewhere throughout the battery value chain, while employees are in demand, so is the education and training that would increase their value to the industry. Particularly as battery technologies evolve rapidly, the workforce must stay up-to-date with the latest developments. This requires continuous training and education to keep workers informed about new battery chemistries, safety protocols, and integration techniques. There are programs in existence to train workers for battery manufacturing, but the skills that the workers obtain in the classroom or lab are not always the ones they need on the job site (Udavant, 2023).

Working with high-capacity batteries can be hazardous if not handled correctly. Workforce training on safety measures, emergency response procedures, and the proper handling of high voltages and hazardous materials is crucial to ensure safe handling of hazardous battery materials to preserve a reputation of safety for the industry.

Capability Sector 3 lacks widespread, standardized training for on-board work forces that would allow employees to up- or cross-skill, as well as to provide safety, and emergency response.

The battery recycling and disposal process is not as well-established as other parts of the supply chain. Proper disposal and recycling are essential to reducing environmental impact, recovering valuable materials, and addressing concerns about battery waste.

Enhancing this part of the downstream capability would strengthen the upstream capability, as greater recycling equates to a lesser requirement for minerals and new mining. Recycling, reuse, and disposal or thus becoming national security issues in their own right.

All aspects of the recycling and disposal sector of the downstream capability sector are in need of strengthening, from technology, to manpower, through training, transportation, and management.

While this is an area sorely in need of attention, the issues of technology and government/industrial will are yet to be solidified, making it beyond the scope of this workforce study. It is not infeasible that it could become an issue of concern prior to complete implementation of the present project, but recycling, second life, and circularity are not yet at a state where planning for workforce gap resource application would be appropriate.

VI. STRATEGIC ROADMAP AND COURSES OF ACTION

Section A below contains the proposed Strategic Roadmap and describes the actions to be taken in each of the three lines of effort of People – Current (Retention and Human Capital Development), People – New (Recruitment), and Process (Communications and Coordination). Each line of effort is considered for each of the three Capability Sectors (upstream, midstream, and downstream). At the points where the lines of effort intersect with the Capability Sectors are the recommendations for further action. Each recommendation is based on the findings of the present study and has one or more sub-task recommendations that might be accomplished to effect the change or complete the task identified.

Following Table 5*,* the BWD Strategic Roadmap, is a full explanation of each recommended task and subtask.

Section B encompasses the courses of action derived from the sequencing and alignment of the items indicated on the Roadmap. Section C illustrates the prioritization of recommendations.

A. STRATEGIC ROADMAP

Figure 29 is the strategic roadmap that has been derived from the research conducted throughout Phase I of the NPS/EAG Battery Workforce Development study. It cross-references the Capability Sectors with the Lines of Effort and indicates actions that might be taken to fill the gaps between existing programs in the current battery workforce.

Of note, the strategic roadmap does not respond to those items that are essential to the creation and maintenance of a workforce, *and are already being addressed by existing programs*, many of which are noted in Appendices D-H. This roadmap indicates the means through which the *gaps* in the battery workforce, current and prospective, might be filled. Some sectors have similar gaps, and some very different, but they all lack any structure within Line of Effort 3: Process (Communications and Coordination). All sectors also need to consider programs in recruitment, but at varying levels. And education is a common theme throughout Line of Effort 1: People – Current (Retention and HCD).

Each gap is discussed throughout this section, along with proposals as to how the gap might be filled. These proposals would provide a strong starting point for closing the gap, but as work progresses on each, it is highly likely that there will be other proposals generated as a part of the final Plan of Action and Milestones that marks the end of Phase II.

It should be noted that transition planning is not addressed in the Strategic Roadmap, as transition plans depend upon the courses of action selected and implemented.

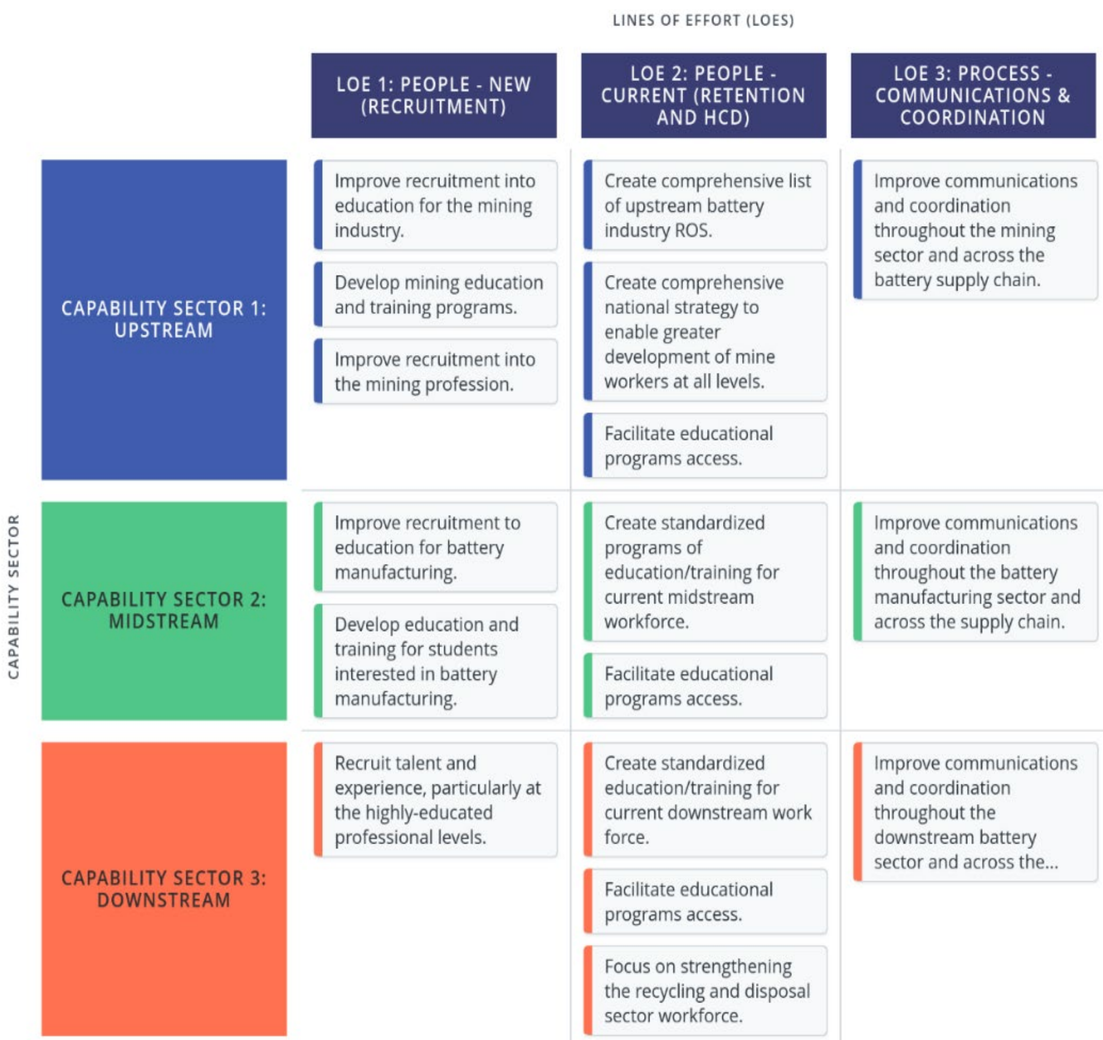


Figure 29. BWD Capability Sector Strategic Roadmap.

1. Capability Sector 1: Upstream

a. Line of Effort 1: People – Current (Retention and Human Capital Development)

Create a comprehensive and coordinated national strategy to enable greater development of mine workers at all levels.

There is no comprehensive, national strategy to enable greater development of mine workers. The proposal is to create such a strategy that would allow those employed in the mining industry to stay current in technical expertise as well as remain alert and mindful of areas that affect them such as safety, or legislation.

<u>PROPOSALS</u>

SKILL BLOCKS – Create and promulgate "Skill Blocks" that each carry with them specific sets of occupational *skills* that are common to the jobs within the block. These blocks are based on skills, and not on jobs, so may have individuals of varying levels of seniority and experience. This allows for passive (example-setting) and active mentoring of less experienced employees.

TECHNICAL REFRESHER TRAINING – Create technical refresher training for each skill block on the skills which form the coherent basis of the block. Have the more experienced workforce train the more junior workforce on a formal, recurring basis.

"GREAT" – Create a program of online General Readiness Education and Training, or GREAT programming, with an annual requirement of completion for all employees at all levels, that carries with it an incentive in terms of pay or bonuses, time off, a coupon or point program, or other appropriately valuable incentives. Training will cover safety, culture, interpersonal communication, and other skills determined to be universally applicable.

SCHOLARSHIPS – Establish federally funded scholarships with time off for those within the battery workforce to obtain higher education and create expertise, upon a commitment by the employee to return to the workforce in a more senior and/or more advanced position (commitment may be incentivized with guarantees of promotability, financially, etc.). Establish years of service and other criteria required prior to application eligibility.

Facilitate educational programs access through a comprehensive record/database of existing training and education programs.

There is a need for a comprehensive understanding and record of existing training and education programs, which may lead to a need for the creation or modification of programs to fill the gap, particularly for advanced professionals.

PROPOSALS

U.S. DOMESTIC EDUCATION & TRAINING SURVEY – Survey and engage with all U.S. domestic education and training providers who provide or might provide education or training that would lead to involvement in the Upstream Capability Sector of the U.S. domestic supply chain.

ALLIED EDUCATION & TRAINING SURVEY – Survey and engage with all English-based Allied education and training providers who provide or might provide education or training that would lead to involvement in the Upstream Capability Sector of the U.S. domestic supply chain.

EDUCATION & TRAINING DATABASE – Create a publicly accessible database of education and training programs that will lead to careers in mining.

Create a comprehensive list of upstream battery industry ROS.

No comprehensive list of required occupational skills (ROS) exists. A more thorough and widespread understanding of ROS would allow formulation of educational and/or training programs sufficient to keep the industry operating at full capacity. It would also provide for identification of those occupations most in need of filling, whether skilled, unskilled, or mining-related vs. mining specific.

PROPOSALS

ROS SURVEYS – Survey and engage with industry and union personnel to develop a comprehensive list of ROS. While the primary resource on this project is likely to be industry, the work should reflect and be influenced by the DoE/BWI, NAATBatt, and NABWC surveys to ensure that all the findings of their respective bodies of work are considered and incorporated.

ROS DATABASE – Produce a publicly accessible database of the mining industry's ROS, for use by educational institutions and the public, in seeking out opportunities in the mining industry and gaining information more specific than that which is currently published in generalized form at state and federal levels.

b. Line of Effort 2: People – New (Recruitment)

Create a nationwide program of worker recruitment into education for the mining industry.

There are currently isolated programs of recruitment to mining education and training, but many of those are at the unskilled level and occur post-hiring.

PROPOSALS

BRANDING/EDUCATION PATHWAYS – Create a new, highly-publicized, and federally-funded/endorsed marketing campaign to attract potential students where they are most likely to be found—in high schools and in other industries. Ensure that the campaign takes full advantage of social media devices such as Instagram, Reddit, Quora, Twitter, Hootsuite, etc., as well as Facebook and LinkedIn for more mature employees. Publicize the practical aspects of research widely, through venues previously unconsidered, such as the Superbowl or Comedy Conventions.

ROADSHOWS – Create a federally funded campaign of junior high and high school roadshows, calling on the interests and patriotism of tweens and teens in

considering education for careers related to or contributing to the mining industry. Ensure consistency and comprehensiveness of messaging.

Develop sufficient numbers of mining education and training programs, as well as programs for advanced professionals, to support recruitment in adequate numbers.

Universities and technical schools that offer mining programs, and the faculty who are qualified to teach in those programs, are few and far between.

PROPOSALS

EDUCATION & TRAINING PROGRAMS – Based on the work planned by DoE and completed by NAATBatt on ROS, as well as the ROS study recommended in this report, create education and training programs that will fill current gaps as noted in this report and the surveys of its stakeholder groups to support the needs of the next 20 years. Devote federal resource to the creation of programs that include all forms of education and training, such as degree programs, short programs, competency-based education, online and on-site courses, and credentialling that involves the stacking of the foregoing into degrees. Ensure match of content to delivery method to student and employer need.

FACULTY PROGRAMS – In addition to a lack of students and educational programs, there are too few faculty to teach the numbers of students that the industry requires. Universities could be federally incentivized to create and prioritize recruiting for programs of education that would lead to employment in mining industry higher education, and then there could be federal programs of incentivization for those new faculty to stay within the mining industry.

Create a nationwide program of worker recruitment into professions within the mining industry.

There are currently isolated programs of recruitment into the mining profession, but they are not sufficient to fill the need. The U.S. does not have a national, comprehensive workforce education system. Current programs lack the proper focus, are small in scale, and siloed from each other. “The Department of Labor’s training programs don’t reach the oncoming higher technical skills or help incumbent workers acquire them. In turn, the Department of Education’s programs tend to target college, not workforce education, and don’t mesh with the Labor programs” (Bonvillian & Sarma, 2021). In many states, the vocational education system in high schools has largely been dismantled. Community colleges, which could provide advanced training in emerging fields, often report being underfunded, and a scan of their catalogs reveals much more opportunity for community engagement on the needs and benefits of the battery workforce.

PROPOSALS

BRANDING/CAREER PATHWAYS – Create a new, highly-publicized, and federally-funded/endorsed marketing campaign to attract potential employees where they are most likely to be found—in high schools, community colleges, undergraduate universities, and in other industries. Ensure that the campaign takes full advantage of social media devices such as Instagram, Reddit, Quora, Twitter, Hootsuite, etc., as well as Facebook and LinkedIn for more mature employees. Publicize the practical aspects of research widely, through venues previously unexplored (Superbowl?).

JOB FAIRS AND SKILL GROUPS – Ensure participation in mass hiring events, using the skills groups. Individuals can be hired into a skill group, and master all the jobs within it throughout a career so promotability is built in. Or there is the possibility to transfer to a new skill group if the current ROS does not suit the individual, so flexibility is also available throughout a career. These, along with a call to service (“America First”) could be finessed into talking points and released as a campaign for federally represented, hard-to-fill occupations at job fairs.

APPLICATION PLATFORM – Create a centralized platform for applying to positions within the mining industry, so that mines and mine-support organizations can, in effect, bid on an employee in the database, or at least contact them individually to use text-recruiting or other modern and individualized recruiting strategies.

c. Line of Effort 3: Process – Communications and Coordination

Improve C2 throughout the mining sector and across the battery supply chain.

Communications and coordination (C2) within the upstream capability sector would provide for the creation of a knowledge bank or listing of occupational skills and/or jobs that are required to be filled, as well as the status of fulfillment of required occupational skills, more readily enabling the creation of education and training that is fit for purpose. It would also allow potential employees of the upstream capability to understand more fully what is available to them in this sector, afford coordination on legislative matters, and increase the general understanding of requirements and challenges throughout the supply chain.

This type of C2 is not currently in place within the battery supply chain's upstream capability sector, nor between sectors, to the detriment of all parties.

<u>PROPOSALS</u>

CONSORTIUM – Create a consortium of state-level stakeholders in government, industry, and academia to exchange information and encourage coordination of activities and policies at the state level. Invite participants with decision-making authority and capacity, and devote resources to ensuring that there is consistent, significant tasking assigned. Form an upstream subcommittee.

OVERSIGHT OFFICE – Create a Battery Supply Chain Oversight office at the federal level. This office would be empowered to propose legislation initiated by the Consortium, manage consortia at federal and state levels, control the flow of discretionary federal funding into the upstream capability sector, create and manage workforce, research, and implementation programs, provide industry liaison, serve as a point of entry into the supply chain for Allied nations, etc.

2. Capability Sector 2: Midstream

a. Line of Effort 1: People – Current (Retention and Human Capital Development)

Create standardized programs of education/training for current midstream workforce.

PROPOSALS

SKILLS BLOCKS – Create and promulgate "Skill Blocks" that each carry with them specific sets of occupational *skills* that are common to the jobs within the block. These blocks are based on skills, and not on jobs, so may have individuals of varying levels of seniority and experience. This allows for passive (example-setting) and active mentoring of less experienced employees.

TECHNICAL REFRESHER TRAINING – Create technical refresher training for each skill block on the skills which form the coherent basis of the block. Have the more experienced workforce train the more junior workforce on a formal, recurring basis.

"GREAT" – Create a program of online General Readiness Education And Training, or GREAT, with an annual requirement of completion for all employees at all levels, which carries with it an incentive in terms of pay or bonuses, time off, a coupon or point program, or other appropriately valuable incentives. GREAT will cover safety, culture, interpersonal communication, and other skills determined to be universally applicable.

SCHOLARSHIPS – Establish federally funded scholarships with time off for those within the battery workforce to obtain higher education and create expertise, upon a commitment by the employee to return to the workforce in a more senior and/or more advanced position (commitment may be incentivized with guarantees of promotability, financially, etc.). Establish years of service and other criteria required prior to application eligibility.

b. Line of Effort 2: People – New (Recruitment)

Improve recruitment to education for the battery manufacturing sector.

The need in this capability sector is less recruitment for employment as recruitment to education. Students must be made aware of the opportunities of education—what education or training is required to enter the industry, why they should educate themselves for the battery industry, and where to obtain the appropriate education or training.

PROPOSALS

INNOVATIVE MARKETING CAMPAIGN – Create a new, highly publicized, and federally funded/endorsed marketing campaign to attract potential students where they are most likely to be found—in high schools and in other industries. Ensure that the campaign takes full advantage of social media devices such as Instagram, Reddit, Quora, Twitter, Hootsuite, etc., as well as Facebook and LinkedIn for more mature employees. Publicize the practical aspects of research widely, through venues previously unconsidered.

ROADSHOWS – Create a federally funded campaign of junior high and high school roadshows, calling on the interests and patriotism of tweens and teens in considering education for careers related to or contributing to the battery manufacturing industry. Ensure consistency and comprehensiveness of messaging.

Create programs of education/training for students interested in entering the battery manufacturing sector.

PROPOSALS

CREATE EDUCATION & TRAINING PROGRAMS – Based on the work completed by both DoE and NAATBatt on ROS, as well as the ROS study recommended in this report, create education and training programs that will fill current gaps as noted in this report and the surveys of its stakeholder groups to support the needs of the next 20 years. Devote federal resources to the creation of programs that include all forms of education and training, such as degree programs, short programs, competency-based education, online and on-site courses, and

credentialling that involves the stacking of the foregoing into degrees. Ensure match of content to delivery method to student and employer need.

c. Dimension 3: Process – Communications and Coordination

Improve C2 throughout the midstream capability sector and across the battery supply chain.

Communications and coordination (C2) within the midstream capability sector would facilitate the creation of a knowledge bank or listing of occupational skills and/or jobs that are required to be filled, as well as the status of fulfillment of required occupational skills, more readily enabling the creation of education and training that is fit for purpose. It would also allow potential employees of the upstream capability to understand more fully what is available to them in this sector, afford coordination on legislative matters, and increase the general understanding of requirements and challenges throughout the supply chain.

This type of C2 is not currently in place within the battery supply chain's midstream capability sector, nor between sectors, to the detriment of all parties.

PROPOSALS

CONSORTIUM – Create a consortium of state-level stakeholders in government, industry, and academia to exchange information and encourage coordination of activities and policies at the state level. Invite participants with decision-making authority and capacity, and devote resources to ensuring that there is consistent, significant tasking assigned. Form a midstream subcommittee.

OVERSIGHT OFFICE – Create a Battery Supply Chain Oversight office at the federal level. This office would be empowered to propose legislation initiated by the Consortium, manage consortia at federal and state levels, control the flow of discretionary federal funding into the upstream capability sector, create and manage workforce, research, and implementation programs, provide industry liaison, serve as a point of entry into the supply chain for allied nations, etc.

3. Capability Sector 3: Downstream

a. Line of Effort 1: People – Current (Retention and Human Capital Development)

<u>PROPOSALS</u>

SKILLS BLOCKS – Create and promulgate "Skill Blocks" that each carry with them specific sets of occupational *skills* that are common to the jobs within the block. These blocks are based on skills, and not on jobs, so may have individuals of varying levels of seniority and experience. This allows for passive (example-setting) and active mentoring of less experienced employees.

TECHNICAL REFRESHER TRAINING – Create technical refresher training for each skill block on the skills which form the coherent basis of the block. Have the more experienced workforce train the more junior workforce on a formal, recurring basis.

"GREAT" – Create a program of online General Readiness Education And Training, or GREAT, with an annual requirement of completion for all employees at all levels, which carries with it an incentive in terms of pay or bonuses, time off, a coupon or point program, or other appropriately valuable incentives. GREAT will cover safety, culture, interpersonal communication, and other skills determined to be universally applicable.

SCHOLARSHIPS – Establish federally funded scholarships with time off for those within the battery workforce to obtain higher education and create expertise, upon a commitment by the employee to return to the workforce in a more senior and/or more advanced position (commitment may be incentivized with guarantees of promotability, financially, etc.). Establish years of service and other criteria required prior to application eligibility.

Focus on strengthening the recycling and disposal sector workforce.

When employees are a good fit for a professional field and have marketplace or company knowledge that would be difficult to replace, then the company just needs to update skills to match new systems and new capabilities. Reskilling may involve obtaining a new degree, certification, or education in a different field or area of expertise.

PROPOSALS

UPSKILL/RESKILL – In the recycling and disposal sector of the battery supply chain, there is little work being done on the needs of a potential workforce, so there is much scope for tangible impact, although it is likely to be longer term than other initiatives proposed in this Roadmap. But, certainly, the demand for skilled talent in this sector is going to continue to grow, and the skills gap will widen as technology advances. All types of continuous learning will be required to help build high-demand skills, whether an individual is trying to upskill current capabilities or s/he needs complete reskilling to build entirely new recycling or second life capabilities.

A program of upskilling/reskilling could be created to set this sector of the industry on a successful path to having an adequate workforce. It would need to be comprehensive and is largely beyond the scope of this study, as it is largely dependent upon emerging technologies. Yet it is a significant element of the success of the entire supply chain, so cannot be ignored.

b. Line of Effort 2: People – New (Recruitment)

Create a nationwide program of talent recruitment, particularly at the highly educated professional levels.

There are currently programs of recruitment for the hourly downstream workforce, but there is a lack of interest at the highly educated professional levels.

PROPOSALS

INNOVATIVE MARKETING CAMPAIGN – Create a new, highly publicized and federally funded/endorsed marketing campaign to attract potential employees where they are most likely to be found—in universities and in other industries. Ensure that the campaign takes full advantage of social media devices such as Instagram, Reddit, Quora, Twitter, Hootsuite, etc., as well as Facebook and

LinkedIn for more mature employees. Publicize the practical aspects of research widely, through venues previously unexplored.

APPLICATION PLATFORM – Create a means of applying to positions across the industry from a single point of entry. This allows the applicant to find positions, apply to them, and interact with employers from a single interface.

c. Dimension 3: Process – Communications and Coordination (C2)

Improve C2 throughout the downstream capability sector and across the battery supply chain.

Communications and coordination (C2) within the downstream capability sector would facilitate the creation of a knowledge bank or listing of occupational skills and/or jobs that are required to be filled, as well as the status of fulfillment of required occupational skills, more readily enabling the creation of education and training that is fit for purpose. It would also allow potential employees of the upstream capability to understand more fully what is available to them in this sector, afford coordination on legislative matters, and increase the general understanding of requirements and challenges throughout the supply chain.

This type of C2 is not currently in place within the battery supply chain's downstream capability sector, nor between sectors, to the detriment of all parties.

PROPOSALS

CONSORTIUM – Create a consortium of state-level stakeholders in government, industry, and academia to exchange information and encourage coordination of activities and policies at the state level. Invite participants with decision-making authority and capacity, and devote resources to ensuring that there is consistent, significant tasking assigned. Form a downstream subcommittee.

OVERSIGHT OFFICE – Create a Battery Supply Chain Oversight office at the federal level. This office would be empowered to propose legislation initiated by the Consortium, manage consortia at federal and state levels, control the flow of

discretionary federal funding into the upstream capability sector, create and manage workforce, research, and implementation programs, provide industry liaison, serve as a point of entry into the supply chain for Allied nations, etc.

B. PROPOSED COURSES OF ACTION (COA)

Each proposed COA, which has multiple subparts, is summarized in a one-page briefing in Appendix I. Some proposals must be accomplished sequentially, and some may be pursued simultaneously; these variations are indicated in each. While each course of action is created to stand alone, if multiple COAs are selected, some may benefit from the work done on others. For instance, COA 3 proposes a survey that can be reused and built upon in COA 7.

1. **COA Proposal #1 –** Improve coordination and communication throughout the battery industry.

a. Problem Statement – There is no effective and enduring means of communication and coordination across the full battery value chain, to include government, academia, and industry.

b. No Action Option ("Status Quo")

- Allow the constituents of the battery value chain to continue operating in isolation.
- Rely on current consortia (i.e., FCAB), to provide organizing impetus to the battery industry.

c. Impact of Maintaining the Status Quo

- Reduction in potential synergies, effectiveness, and opportunities for collaboration.
- As current consortia were not conceived as comprehensive and enduring bodies capable of impact and direction, they will likely remain advisory networks.

d. Proposed Solution

- Create an American Battery Coordination (ABC) Office at the federal/national level to oversee supply chain activities, coordinate execution for greatest efficiency, communicate throughout the chain, oversee regional hubs and international recruitment, and serve as executive administrator for all national battery policies and activities. This office would coordinate regional developments at the federal level, existing and new training facilities and programs, recruiting efforts, and could initiate the establishment of regional training and recruiting centers as needed.
- Establish an enduring, national level consortium of industry, government, academia, and consumers to forge relationships and share information. May consist in expanding scope of existing organization or establishing a new body. This consortium would be chartered to provide advisory direction to a Chair within the Battery Office.

  If it is determined that an existing consortium should have its charter expanded, then this work will encompass creating the process and structure of that expansion, and a revised charter.
- Create regional special-interest hubs.
- The elements of this proposal could be pursued simultaneously with a team of three or more full-time equivalents. This would reduce overall time to completion to 2+ years.

e. Financial Considerations

- Development and approval of an American Battery Coordination (ABC) Office is estimated to take 2 years x 1 FTE for a total of $1,000,000 (see Table 5).

- Establishment of a Consortium is estimated to take 1 year x 1 FTE for a total of $500,000 (see Table 5).
- Establishment of regional special-interest hubs is estimated to take 2 years x 2 FTE for a total of $2,000,000 (see Table 5).

Table 5. COA Proposal 1 Financial Considerations

	DURATION	MANPOWER	EXPENSE (K)
ABC Office	24 months	1 FTE	$ 1,000
Consortium	12 months	1 FTE	$ 500
Special Interest Hubs	24 months	2 FTE	$ 2,000

2. **COA Proposal #2 –** Develop education and training programs for the battery industry.

a. Problem Statement

Education and training programs are not available in the needed numbers or content to fulfill the needs of battery industry employers. Further, even if the programs were available, there are not sufficient faculty to teach them. CAR's recent assessment on behalf of NABWC noted that "Specialized training is essential in the areas of chemistry (encompassing materials and product development, chemical engineering, and recycling), advanced manufacturing, automation, and advanced software skills for manufacturing and battery systems management, and safety across all sectors of industry" (Krusemark et al., 2024, p.11). This specialized training is not currently available where it is needed nor in sufficient quantities to fulfill industry requirements.

b. No Action Option ("Status Quo")

- Allow students to sift through the limited programs available and apply themselves to various industries in inconsistent numbers. This is what is currently occurring.
- Rely on state programs like NENY to take the lead in producing educational programs, recognizing that few states are as active as NY.

c. Impact of Maintaining the Status Quo

- There is unlikely to be significant improvement in the nation-wide availability or appropriateness of program availability in the near term.
- Targeted education and training will be available only to those who reside in a state that takes an active interest in the battery industry, resulting in the loss of many skilled battery industry employees due to lack of access, not talent.

d. Proposed Solution

- Working closely with industry and labor, develop standardized programs of education to be offered throughout the nation, at universities, colleges, and trade schools. Offer federal incentives for providing and studying appropriate education and training.
- Develop faculty/instructor training courses that can reskill/upskill faculty to teach proposed courses as quickly as feasible. Offer federal incentives to the schools that offer the programs and hire the graduates, as well as the faculty/instructor.
- Establish four training centers across the country to serve as hubs of instruction and training, proof of concept centers for education and training, and regional hubs of workforce.
- The elements of this proposal could largely be pursued simultaneously after course content is developed, with a team of four or more full-time equivalents. This would reduce overall time to completion.

e. Financial Considerations

- Creation of standardized programs of education is estimated to take 2 years x 4 FTE for a total of $4,000,000. Initial implementation is planned for 2 years at 3 FTE for a total of $4,000.000 (see Table 6).

- Development of faculty and instructor training courses is estimated to take 2 years x 3 FTE for a total of $3,000,000. Initial implementation is planned for 2 years at 3 FTE for a total of $3,000.000 (see Table 6).

- Creation of four regional training centers across the nation is estimated to take 5 years (18 months each with some synergies) x 4 FTEs for a total of $10,000,000. Initial implementation is planned for 2 years at 4 FTEs for a total of $4,000,000 (see Table 6).

Table 6. COA Proposal 2 Financial Considerations

	DURATION	MANPOWER	EXPENSE (K)
Education Programs	24 months	4 FTE	$ 4,000
Education Programs Implementation	24 months	3 FTE	$ 4,000
Faculty Programs	24 months	3 FTE	$ 3,000
Faculty Programs Implementation	24 months	3 FTE	$ 3,000
Training Centers	60 months	4 FTE	$10,000
Training Center Implementation	24 months	4 FTE	$ 4,000

3. **COA Proposal #3 –** Facilitate access to education and training that provides for entry into the battery workforce.

a. Problem Statement

There is very limited awareness of and access to battery education and training programs by potential students and employees. Sometimes, limited access is based on limited availability, but even in these cases there is not currently any means of potential students or employees finding appropriate programs except by chance, as there is no catalog of what is “appropriate” for any given career path or skills block. Even where skills are understood, there is no centralized location where they might be accessed.

b. *No Action Option (“Status Quo”)*

- Rely on prospective students or employees to contact schools and training centers until they find useful programs. This would require potential students/employees to have the initiative, drive, and means to determine what type of training would provide them with skills appropriate to the trade or profession they wish to enter. As the skills needed, and the way they are described by the various employers, are likely to differ, this element of the status quo is likely to remain confusing and discouraging.
- New employees could be trained or educated after they have been hired, at corporate expense. While this might be a viable option which maintains financial responsibility for development of the workforce at the level of the employer, it does not provide for any consistency of quality or content across the industry, does not lead to increased numbers of programs where required, and does not provide any greater ability for students or prospective employees to educate themselves or make decisions about the various modes of training or education that might suit them best (online, in person, short courses, etc.).
- Await results of NABWC’s 2nd pillar. The North American Battery Workforce Consortium has three pillars of activity, the second of which is to create a database very similar to that which is proposed here.

c. *Impact of Maintaining the Status Quo*

- Those who seek to prepare for the battery industry may be lost to other industries due to a dearth of information on how to prepare for a career in mineral mining, battery manufacturing, or other sectors of the battery workforce.
- Current members of the battery workforce may leave the industry due to a mistaken belief that development opportunities are limited, even as those opportunities are, in actuality, increasing.

d. *Proposed Solution*

- Survey employers throughout all sectors of the battery industry to determine ROS. (NOTE: This work could incorporate and expand upon the work of COA 1).
- Using ROS inventory, survey all U.S. education and training providers available to the public to catalogue all relevant programs. This survey could incorporate either just English-language programs, or in line with reaching across the U.S. demographic, also consider programs in Spanish or other languages that might be useful to the areas surveyed. This proposal incorporates the latter option.
- Produce a Battery Education and Training Catalog (BETC) database. This would consist of creating a database structure, which could be accomplished concurrently with the other work in this course of action, and then populating it with information on the providers discovered in the previous step of this COA. This database could either connect to or incorporate the database produced in COA 1, i.e., the CEWD 'Get Into Energy Jobs' database. Their contents, though unique, are complementary.

- Devise and implement a transition plan (to include database maintenance) to ensure enduring usage of the BETC database. This plan should include where the database will reside, who will update it, who will maintain it, and how the transition plan will be funded.

e. Financial Considerations

- Conducting an employer survey is estimated to take 2 years x 3 FTE for a total of $2,700,000 (see Table 7).
- A survey of all U.S. education and training institutions is estimated to take 3 years x 3 FTE for a total of $4,000,000 (see Table 7).
- Creation and implementation of the BETC database is estimated to take 2 years x 2 FTE for a total of $1,800,000 (see Table 7).
- Transition planning and implementation is estimated to take 1 year x 1.5 FTE for a total of $1,000,000 (see Table 7).

Table 7. COA Proposal 3 Financial Considerations

	DURATION	MANPOWER	EXPENSE (K)
Employer Survey	24 months	3 FTE	$ 2,700
Education Survey	36 months	3 FTE	$ 4,000
BETC Database	24 months	2 FTE	$ 1,800
Transition	12 months	1.5 FTE	$ 1,000

4. COA Proposal #4 – Improve recruitment into education for the battery industry.

a. Problem Statement

Current literature and this team's research have revealed that there are currently isolated programs of recruitment to both mining and manufacturing education and training, but many of those are at the unskilled level and occur post-hiring. This is supported by the recent finding that 89% of the upstream capability respondents in the CAR Survey indicated difficulty in recruiting *skilled* talent (Krusemark et al., 2024).

b. *No Action Option ("Status Quo")*

- Rely on the current, disjointed mechanisms of education recruitment to mature. One or more of them may grow to close some or all of the current gaps.
- Allow CAR BIETNA survey to lead other groups to implement similar recommendations to below.

c. *Impact of Maintaining the Status Quo*

- Each capability sector is likely to continue experiencing manpower shortages, which will prevent support of other capabilities, slowing down the whole value chain.

d. *Proposed Solution*

- Establish (and fund first year of) high school programs in 25 states and territories using NENY's "New Energy Lab" blueprint. Offer federal incentives to provider and student.
- Develop and execute a program of roadshows at schools and colleges where local talent is sought (largely throughout the western U.S. for mining, and the battery belt for manufacturing). Organize the participation of representatives from all facets of the battery industry. The message of the roadshows should be one of optimism, growth, and patriotism where appropriate. Return on investment will be easy to measure, and in any case road shows are fairly quick and inexpensive to create and execute.
- Establish four mobile classrooms / labs (each in a U.S. region) that can be used for training and recruiting.

e. *Financial Considerations*

- Establishment and initial funding of high school programs is estimated to take 6 years x 6 FTE for a total of $30,000,000. Note: this proposal is scalable, i.e., initial implementation to five states to reduce outlays (see Table 8).
- Development of a roadshow is estimated to take 9 months x 2 FTE for a total of $3,000,000. Initial implementation is planned for 3 years at 2 FTE for a total of $3,000.000 (see Table 8).
- Development of mobile classrooms is expected to take 2 years x 4 FTE for a total of $4,000,000 and implementation is expected to take 2 years x 8 FTE for a total of $8,000,000 (see Table 8).

Table 8. COA Proposal 4 Financial Considerations

	DURATION	MANPOWER	EXPENSE (K)
High School Programs	72 months	6 FTE	$ 30,000
Road Show	9 months	2 FTE	$ 3,000
Road Show Implementation	36 months	2 FTE	$ 3,000
Mobile Classrooms	24 months	4 FTE	$ 4,000
Mobile Classroom Implementation	24 months	8 FTE	$ 8,000

5. COA Proposal #5 – Create a comprehensive national strategy for development of the current workforce at all levels.

a. *Problem Statement*

Despite the urgent need for employee reskilling and educational support, there is no comprehensive, national strategy in place to enable development of the current workforce at any level. Eighty percent of the respondents to the Center for Automotive Research's Assessment (Krusemark et al., 2024) report employees have outdated skills.

b. No Action Option ("Status Quo")

- Continue localized programs of instruction, often devised by mines or manufacturers, who are the experts on the training or education they need, or contractors paid by employers.
- Rely on workers to find their own upskilling resources.

c. Impact of Maintaining the Status Quo

- Battery workers may experience only inconsistent levels and types of development, as determined by individual employers. Some essential types of education or training, such as safety, may be minimized or only incompletely covered due to programs created by unqualified personnel. The programs may meet only the minimum requirements, and not address the knowledge set required to advance within a skill block.
- There is less incentive for the current workforce to remain when development does not occur. Conditions may be less safe, the workforce may be less qualified, and the perception of concern on the part of management may be less pronounced.

d. Proposed Solution

- Create, promulgate, and market Skill Blocks that each carry with them specific sets of occupational skills that are common to the occupations within the block.
- Create technical refresher training for each skill block on the skills which form the coherent basis of the block.
- Create a program of online, annual General Readiness Education and Training ("GREAT" Training) that covers safety, culture, interpersonal communication, and other skills universally applicable within the upstream capability sector.

- Establish federally-funded scholarships.
- Devise and implement a transition plan to ensure enduring usage. This plan should include how, when, and by whom the courses created will be updated and maintained, and where they will reside. It should also propose an ongoing plan of marketing for all programs within this proposal.
- Establish a national accreditation board responsible for accrediting battery-related educational programs including trainings, certificates, and degree programs. Accreditation will not only attract prospective students and faculty to the industry, but it will also ensure consistency of outcomes and skills learned across curricula.
- The elements of this proposal could largely be pursued simultaneously with a team of three or more full-time equivalents. This would reduce overall time to completion.

e. *Financial Considerations (see Table 9)*

- The creation of skills blocks is estimated to take 1 year x 1.5 FTE for a total of $1,000,000.
- The proposed technical refresher training for each skill block is estimated to take 2 years x 3 FTE for a total of $2,700,000.
- Creation and implementation of the GREAT Training is estimated to take 1.5 years x 2 FTE for a total of $1,200,000.
- The establishment of federally-funded scholarships is estimated to take 1 year x 1 FTE for a total of $500,000, exclusive of the funding of the scholarship itself.
- Transition planning and implementation is estimated to take 1 year x 1.5 FTE for a total of $750,000.

- The establishment of an accreditation board for battery programs is estimated to take 2 years x 2 FTE for a total of $2,000,000.

Table 9. COA Proposal 5 Financial Considerations

	DURATION	MANPOWER	EXPENSE (K)
Skill Blocks	12 months	1.5 FTE	$ 1,000
Refresher Training	24 months	3 FTE	$ 2,700
GREAT Training	18 months	2 FTE	$ 1,200
Scholarships	12 months	1 FTE	$ 500
Transition	12 months	1.5 FTE	$ 750
Accreditation	24 months	2 FTE	$ 2,000

6. COA Proposal #6 – Improve recruitment into the battery industry.

a. Problem Statement

There are persistent workforce shortages across the battery value chain, particularly for skilled local labor, technical and research and development roles.

b. No Action Option ("Status Quo")

- Rely on existing recruiting sources to fill the gaps—unions, colleges, job boards, etc.
- Rely on state programs like NENY to take the lead in attracting potential employees, recognizing that few states are as active as NY.

c. Impact of Maintaining the Status Quo

- There is unlikely to be improvement in the availability of employees, particularly in areas of greatest need.
- Employees will only be available for recruitment from those states that takes an active interest in the battery industry and establish state-level programs.

d. *Proposed Solution*

- Create a national marketing strategy to recruit to the battery industry, targeting the required domestic and allied demographic. Use modern, data-driven means such as targeted texting and social media searches. Effect a fresh branding of the battery industry, available educational and professional pathways, climate, and a call to national service. Engage at job fairs across the U.S.
- Establish/promulgate web-based digital bulletin board for posting of positions throughout the battery industry. Include transition planning.
- Create a streamlined process for international recruitment, to include visa, relocation, settlement, language training and onboarding.
- The elements of this proposal could largely be pursued simultaneously with a team of three or more full-time equivalents. This would reduce overall time to completion.

e. *Financial Considerations*

- Creation of a national marketing campaign is estimated to take 2 years x 3 FTE for a total of $3,500,000. Initial implementation is planned for 5 years at 3 FTE for a total of $5,000.000 (see Table 10).
- Development of a web-based digital bulletin board and transition planning is estimated to take 1 year x 2 FTE for a total of $1,000,000 (see Table 10).
- Creation of a streamlined international recruiting process is estimated to take 1 year x 1 FTE for a total of $500,000 (see Table 10).

Table 10. COA Proposal 6 Financial Considerations

	DURATION	MANPOWER	EXPENSE (K)
Marketing Campaign	24 months	3 FTE	$ 3,500
Marketing Campaign Implementation	60 months	3 FTE	$ 5,000
Digital Bulletin Board	12 months	2 FTE	$ 1,000
Streamlining of Recruitment	12 months	1 FTE	$ 500

7. COA Proposal #7 – Create an ROS inventory for all sectors of the battery industry.

a. Problem Statement

There is no listing of upstream required occupational skills (ROS), resulting in a limited ability to plan the workforce. Where ROS is available, a comparison could be made with the available workforce personnel in the local area and an early determination made as to the extent of recruiting which would be required upon establishment of a new mine, reuse of a pre-existing mine, or growth of the industry requiring increased production. In an environment poised for explosive growth, it is important that the actual needs of the industry are understood.

b. No Action Options ("Status Quo")

- Continue to use existing, generalized resources to determine workforce needs. These consist of sources such as U.S. Bureau of Labor Statistics, DataUSA, and many private sites. All of these resources reflect the mining industry, but rarely do they focus on mineral mining, and there is nothing that speaks to the needs of mining specific minerals.
- Await the study being done by the Department of Energy Battery Workforce Initiative (DOE BWI), which will likely conclude in early 2026. With its reach and resources, the BWI did an ROS study on two occupations within the midstream capability sector in 2022–2024. While the output is remarkable in its detail and utility,

it had a limited scope (two occupations) and it will likely be the same now that DoE has turned its attention to the upstream capability. Their work is indispensable, certainly, and the accuracy of it is beyond doubt.

c. *Impact of Maintaining the Status Quo*

- Programs of education and training will continue to be developed for general audiences and not the specific needs of the industry. This is the situation at present, and it is resulting in concern over how and whether the nation will be able to meet the needs of the growing battery industry in the near and mid-term.
- Recruitment will continue to be conducted piecemeal by companies as the immediate need for employees is recognized, rather than allowing prior planning and coordination within the employment chain that begins with an individual's awareness and understanding of employment options, runs through available qualified faculty or instructors and academic or training programs, to those who seek to hire. This is inefficient on all possible dimensions, but also risks mission failure in building the upstream capability sector of the battery industry to a level that can support 2030 goals.

d. *Proposed Solution*

- Survey major employers and employee providers (i.e., unions and employment programs such as "Georgia Quick Start") throughout capability sector one as to their required occupational skills and compile into skill groups. These capability-based skill groups will define the combination of ROS and capability levels that can be sensibly combined, and will be based on capabilities, or ROS, vice the more traditional grouping into categories of jobs or occupations.

- From the results of these surveys, compile a database of the results, to include ROS, skills groups, occupations, entry points, sources of education. Ensure that the database is web-based and publicly accessible, links to resources that enable preparation for employment and advice as to available employment.
- Devise and implement a transition plan to ensure enduring usage. This plan should include where the database will reside, who will maintain it (frequency, cost, location, access, etc.), how/to whom it will be marketed, and how return on investment will be assessed, monitored, and reported.
- All elements of this proposal should be pursued sequentially as indicated.

e. *Financial Considerations*

- The proposed survey is estimated to take 3 years x 2.5 FTE for a total of $3,000,000 (see Table 11).
- The proposed database is estimated to take 2.5 years x 3 FTE for a total of $2,600,000 (see Table 11).
- Transition planning and implementation is estimated to take 9 months x 1.5 FTE for a total of $400,000 (see Table 11).

Table 11. COA Proposal 7 Financial Considerations

	DURATION	MANPOWER	EXPENSE (K)
Survey	36 months	2.5 FTE	$ 3,000
Database	30 months	3 FTE	$ 2,600
Transition	9 months	1.5 FTE	$ 400

C. IMPLEMENTATION PRIORITIES

The Course of Action (COA) proposals are discussed in section B and summarized in Appendix I.

Figure 30 shows the COA validation and prioritization methodology that the NPS EAG team applied, in concert with advice and observations from the wider BWD Stakeholder Group and the BWD Advisory Group.

All proposed COAs are critical to the success of the U.S. domestic battery workforce. When both objective and subjective but balanced criteria are applied to each initiative proposed as a course of action, the prioritization of initiatives is as indicated in Figure 30.

A COA selection matrix is provided in Appendix J for convenience and clarity. Appendix J is for use by the sponsors of this work to indicate which COAs are selected for implementation.

PRIORITIZATION MATRIX

Dimensions of Analysis - 1 = low, 5 = high

Rank	Initiatives	STRATEGIC FIT		RESOURCE IMPACT		FEASIBILITY		Total Score
		Impact of Action	Enduring Solution	Cost of Solution	Time to Impact	Ease of Execution	Risk if Not Done	
1	Improve coordination and communication throughout the battery industry.	5	5	5	5	3	5	28
2	Develop education and training programs for the battery industry.	5	5	3	4	3	5	25
3	Facilitate access to educational programs across the battery workforce.	5	5	3	4	3	5	25
4	Improve recruitment into education for the battery industry.	5	4	2	4	4	5	24
5	Create national strategy for development of current workforce.	4	4	4	3	4	4	23
6	Improve recruitment into the battery industry.	5	3	3	4	4	4	23
7	Create list of ROS for mining of top five battery minerals.	4	4	3	4	4	3	22

Figure 30. Analysis of Alternatives.

LIST OF REFERENCES

Abbasi. (2022). *Americans with an advanced degree by state* [Infographic]. Wikimedia. https://commons.wikimedia.org/wiki/File:Americans_with_an_advanced_degree_by_state.svg

Abenov, T., Franklin-Hensler, M., Grabbert, T., & Larrat, T. (2023). *Has mining lost its luster? Why talent is moving elsewhere and how to bring them back.* McKinsey & Company. https://www.mckinsey.com/industries/metals-and-mining/our-insights/has-mining-lost-its-luster-why-talent-is-moving-elsewhere-and-how-to-bring-them-back#/

Aggarwal, A., Atkinson, W., Buzwani, M., Carey, L., Carreon, A.R., Clark-Sutton, K., Massey-Green, T., McNamara, M., & Mohanty, S. (2023). *Measuring Gaps in Supply and Demand for EV Battery Materials in the United States.* Rocky Mountain Institute. https://rmi.org/insight/measuring-gaps-in-supply-and-demand-for-ev-battery-materials-in-the-united-states/

Aja, I.C. (2023, February 14). The Battery Industry's New Strategy: Cross Value Chain Integration. *CIC Energi Gune*. https://cicenergigune.com/en/blog/cross-value-chain-integration-batteries

Akamboe, J., Malone, A., Amoah, M., Lange, I., Alvarez, Y.M., Manful-Sam, E., Handler, B., & Ayaburi, F. (2023). *The State of Critical Minerals Report*. The Payne Institute for Public Policy. https://miningindaba.com/getmedia/209e8ea9-b5b2-45e3-9f20-f5380ed329f0/Payne-Institute-The-State-of-Critical-Minerals-Report-2023.pdf

American Association for the Advancement of Science. (n.d.). *Breaking Down the CHIPS and Science Act.* https://www.aaas.org/programs/office-government-relations/breaking-down-chips-and-science-act

Anderson, J. (2023, September 26). Jobless rate dips, UP adds 1,900 jobs. *Escanaba Daily Press. https://www.dailypress.net/news/local-news/2023/09/jobless-rate-dips-up-adds-1900-jobs/*

Anson Resources. (2022, June 6). *Paradox Lithium Project Strategic Expansion: DFS targeting production capacity of 10,000tpa of Battery-Grade Lithium Carbonate* [press release]. https://wcsecure.weblink.com.au/pdf/ASN/02528656.pdf

Arora, A., Acker, W., Collie, B., Kennedy, D., Roberts, D., Roddy, I., Greenberger, J., Cerveny, J., Niese, N., Srinivasan, V., & Dhar, V. (2023). *Building a Robust and Resilient U.S. Lithium Battery Supply Chain.* Li-Bridge. https://www.anl.gov/sites/www/files/2023-02/Li-Bridge%20Industry%20Report_2.pdf.

Battery Workforce Initiative (BWI). (2022). Netl.doe.gov. https://netl.doe.gov/bwi.

Bellan, R. (2023, August 16). Tracking the EV battery factory construction boom across North America. *Tech Crunch*. https://techcrunch.com/2023/08/16/tracking-the-ev-battery-factory-construction-boom-across-north-america/

Bermack, L., Harris, C., Bennett, S., Mulherin, C., Peterseim, J., Levine, L., Iskander, M., Iturri, M., Syed, A., Wessels, B., & Zaragoza, N. (2023). *Mine 2023: The Era of Reinvention*. Pricewaterhouse Coopers. https://www.pwc.com/gx/en/issues/tla/content/PwC-Mine-Report-2023.pdf

Bhutada, G. (2022, May 2). *The Key Minerals in an EV Battery* [infographic]. Elements. https://elements.visualcapitalist.com/the-key-minerals-in-an-ev-battery/

Biliti Electric Inc. (2022). Electric Vehicle Battery Supply Chain. *Biliti Electric*. https://bilitielectric.com/blog/electric-vehicle-battery-supply-chain/.

Blackburn, M. (2023, June 30). *This Independence Day, We Must Restore American Patriotism.* Marcia Blackburn for U.S. Senate. https://www.blackburn.senate.gov/2023/6/this-independence-day-we-must-restore-american-patriotism#:~:text=June%2030%2C%202023,compared%20to%2070%25%20in%201998.

Bonvillian, W.B. & Sarma, S.E. (2021, March 9). *America Needs a New Workforce Education System.* MIT Open Learning. https://openlearning.mit.edu/news/america-needs-new-workforce-education-system

Brochot, A. & Vitos, A. (2023, October 25). *An EV Talent Gap Will Weaken the U.S. Battery Supply.* SupplyChainBrain. https://www.supplychainbrain.com/blogs/1-think-tank/post/38339-an-ev-talent-gap-will-weaken-the-us-battery-supply

Byrd, Z. (2023, October 2). *Toyota launches a unique hiring process in Greensboro.* Spectrum News 1. https://spectrumlocalnews.com/nc/charlotte/news/2023/10/02/toyota-greensboro-program

Cantrell, S., Commisso, C., Duda, J., Eaton, K., Flynn, J., Forsythe, J., Griffiths, M., Guziak, J., Kirby, L., Mallon, D., Marcotte, M., Poynton, S., Scoble-Williams, N., Van Durme, Y., & Zanza, M. (2024). *2024 Global Human Capital Trends*. Deloitte. https://www2.deloitte.com/content/dam/insights/articles/glob176836_global-human-capital-trends-2024/DI_Global-Human-Capital-Trends-2024.pdf

Carreon, A. R. (2023). *The EV Battery Supply Chain Explained.* RMI.org. https://rmi.org/the-ev-battery-supply-chain-explained/

CensusReporter. (2023). *South Region* [graphic data set]. https://censusreporter.org/profiles/02000US3-south-region/

Chalmers, R. (2023, March 10). How to Work Battery Workforce Development. *Battery Technology*. https://www.batterytechonline.com/industry-outlook/how-work-battery-workforce-development.

Chen, J. (2021, September 14). *A new industry for the U.S.: Battery materials*. Mining.com. https://www.mining.com/web/a-tesla-co-founder-aims-to-build-an-entire-us-battery-industry/a-new-industry-for-the-u-s-battery-materials/

Clifford, C. (2023, January 5). *These states will dominate EV battery manufacturing in 2030.* CNBC. https://www.cnbc.com/2023/01/05/map-which-states-will-build-the-most-ev-batteries-in-2030.html

Colato, J. & Ice, L. (2023). Charging into the future: the transition to electric vehicles. *Beyond The Numbers, Volume 12 (issue 4). https://www.bls.gov/opub/btn/volume-12/charging-into-the-future-the-transition-to-electric-vehicles.htm*

Conte, N. (2023, March 20). *Mapped: U.S. Mineral Production Value by State in 2022* [Infographic]. Elements. https://elements.visualcapitalist.com/mapped-u-s-mineral-production-value-by-state-in-2022/

Data USA. (n.d.-a). *Mining & Mineral Engineering* [interactive demographic data]. Datausa.io. https://datausa.io/profile/cip/mining-mineral-engineering#:~:text=The%20most%20common%20sector%2C%20by%20number%20of%20degrees%20awarded%20in,(314%20completions%20in%202021).

Data USA. (n.d.- b). *Salmon, ID* [interactive demographic data representation]. Datausa.io. https://datausa.io/profile/geo/salmon-id

Data USA. (n.d.- c). *Silver Peak, NV* [interactive demographic data representation]. Datausa.io. https://datausa.io/profile/geo/silver-peak-nv?measure=1mDIgj&groups%5B0%5D=1sy3WT%7C0&time=2021

Di Gangi, L. (2023). *The Opportunities and Challenges in Sustainable Battery Production*. PTC. https://www.ptc.com/en/blogs/plm/the-opportunities-and-challenges-in-sustainable-battery-production

Diggings. (n.d.). *Abernathy Manganese Mine*. Thediggings.com. https://thediggings.com/mines/usgs10202119

DOE Announces $5 Million to Launch Lithium-Battery Workforce Initiative. (2022). Energy.gov. https://www.energy.gov/articles/doe-announces-5-million-launch-lithium-battery-workforce-initiative.

De Smet, A., Dowling, B., Mugayar-Baldocchi, M., & Schaninger, B. (2021). *'Great Attrition' or 'Great Attraction'? The Choice is Yours.* McKinsey & Company. https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/great-attrition-or-great-attraction-the-choice-is-yours

Dupuy, A. C. & Sims, M. J. (2023). *NPS Battery Development Summary of Ongoing Efforts and Activities Phase 1(a).* Naval Postgraduate School. https://nps.edu/documents/114698888/144696361/Phase+1%28a%29+Summary+of+Ongoing+Efforts+and+Activities.pdf/a35282ce-5c01-cb01-f703-2a1ce0094c86?t=1694126927519

Economic Research Institute. (2023). *Cost of Living Data in United States* [interactive demographic data]. Erieri.com. https://www.erieri.com/cost-of-living/united-states

Economist Intelligence (EIU). (2023, August 2). Complexities of battery supply chain may slow EV adoption. https://www.eiu.com/n/complexities-of-battery-supply-chain-may-slow-ev-adoption/.

Ellix, H., Farmer, K., Kowalik, L., Little, R., Moonsamy, T., Mussacaleca, M., Ruban, P., & Zapata, G. (2021). *Why women are leaving the mining industry and what mining companies can do about it.* McKinsey & Company. https://www.mckinsey.com/industries/metals-and-mining/our-insights/why-women-are-leaving-the-mining-industry-and-what-mining-companies-can-do-about-it

Els, F. (2020, April 16). *CHART: China's stranglehold on electric car battery supply chain.* Mining.com. https://www.mining.com/chart-chinas-stranglehold-on-electric-car-battery-supply-chain/.

Engel, J. (2022, March 23). U.S. *startup to staff EV battery plant with displaced coal miners.* Power Engineering International. https://www.powerengineeringint.com/smart-grid-td/ev-infrastructure/us-startup-to-staff-ev-battery-plant-with-displaced-coal-miners/

Environmental Protection Agency (EPA). (2023). *Manganese Dioxide Supply Chain Profile*. https://www.epa.gov/system/files/documents/2023-03/Manganese%20Supply%20Chain%20Profile.pdf

Ernst & Young. (n.d.). Business risks facing mining and metals: 2012 – 2013. http://www.puertovida.org/docs/Ernst-Young_Business-risk-facing-mining-and-metals-2012-2013.pdf.

Federal Communications Commission (FCC). (2018). *2018 Broadband Deployment Report.* https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2018-broadband-deployment-report

Federal Consortium for Advanced Batteries (FCAB). (2021). *National Blueprint for Lithium Batteries 2021–2030.* https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf.

Fleischmann, J., Hanicke, M., Horetsky, E., Ibrahim, D., Jautelat, S., Linder, M., Schaufuss, P., Torscht, L., & van de Rijt, A. (2023). Battery 2030: Resilient, sustainable, and circular. In *Automotive & Assembly*. McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-2030-resilient-sustainable-and-circular.

Flyability. (n.d.). *Mining Industry: A Complete Guide*. https://www.flyability.com/mining-industry#:~:text=The%20mining%20industry%20accounts%20for,of%20its%20economic%20life%20cycle.

Frith, J., Lacey, M., & Ulissi, U. (2023). A non-academic perspective on the future of lithium-based batteries. *Nature Communications*, *14* (420). https://doi.org/10.1038/s41467-023-35933-2

Fuentes, V. (2020, September 23). *Tesla abatara costes extrayendo su proprio litio en Nevada: ya se ha echo con un enorme terreno en el desierto.* Motorpasion. https://www.motorpasion.com/tesla/tesla-abaratara-costes-extrayendo-su-propio-litio-nevada-se-ha-hecho-enorme-terreno-desierto

Gabriel, N. (2023, January 12). *$210 Billion of Announced Investments in Electric Vehicle Manufacturing Headed for the U.S.* EV Hub. https://www.atlasevhub.com/data_story/210-billion-of-announced-investments-in-electric-vehicle-manufacturing-headed-for-the-u-s/

Gigafactory Austin, TX. (n.d.) Tesla. Retrieved February 16, 2024 from https://www.tesla.com/giga-texas

GlobalData. (2022). *Mobile Hiring: the mining industry found it harder to fill mobile vacancies in Q1 2022.* https://mine.nridigital.com/mine_jul22/mobile_hiring_mining

Green Car Congress. (2023, March 25). *DOE and Stellantis launch Battery Workforce Challenge*. https://www.greencarcongress.com/2023/03/20230325-bwc.html

Grzelewski, J. (2022). Granholm uses Michigan visit to kick off battery workforce initiative. *The Detroit News.* https://www.detroitnews.com/story/business/autos/2022/12/12/granholm-uses-michigan-visit-to-kick-off-battery-workforce-initiative/69720115007/.

Hafshejani, A.A. (2022, August 16). *Implications of Inflation Reduction Act on the North American Battery Supply Chain.* S&P Global. https://www.spglobal.com/mobility/en/research-analysis/implications-of-inflation-reduction-act-on-the-north-american-.html

Hale, T. (2023, May 8). *The United States Needs More than Mining Engineers to Solve Its Critical Mineral Challenges*. Center for Strategic and International Studies. https://www.csis.org/analysis/united-states-needs-more-mining-engineers-solve-its-critical-mineral-challenges.

Halpern, M. (2023, August 7). *Where are EV batteries being produced in North America?* [interactive map]. Tableau. https://public.tableau.com/app/profile/miranda.halpern/viz/EVIRAanniversarymap/EVIRAanniversarydashboard

Harris, K. (2020, November). "Forty years of falling manufacturing employment," Beyond the Numbers: Employment & Unemployment. *U.S. Bureau of Labor Statistics*, 9(16). https://www.bls.gov/opub/btn/volume-9/forty-years-of-falling-manufacturing-employment.htm

Hicks, K. H. (2021). *Deputy Secretary of Defense Dr. Kathleen Hicks Remarks at Wayne State University, Detroit, Michigan, on Climate Change as a National Security Challenge.* Defense.gov. https://www.defense.gov/News/Transcripts/Transcript/Article/2838082/deputy-secretary-of-defense-dr-kathleen-hicks-remarks-at-wayne-state-university/.

Hockett, R. (2023, June 5). What is The New Economic Patriotism? Hint: It's About the Production. *Forbes*. https://www.forbes.com/sites/rhockett/2023/06/05/what-is-the-new-economic-patriotism-hint-its-about-the-production/?sh=148014c873e3

Hull, D. (2015, June 21). *Reno Bets Tesla Gigafactory Will Erase Image as Downmarket Vegas*. Bloomberg. https://www.bloomberg.com/news/articles/2015-06-22/reno-bets-tesla-gigafactory-will-erase-image-as-downmarket-vegas

Hyatt, K. (2021, March 31). *BMW invests big in clean lithium extraction in South America.* CNET. https://www.cnet.com/roadshow/news/bmw-invests-clean-lithium-south-america/

Informaciòn, La. (2023, January 31). *GM invertirà 650 millones de dòlares en la extracciòn de litio en Estados Unidos.* https://www.lainformacion.com/economia-negocios-y-finanzas/gm-invertira-650-millones-dolares-extraccion-litio-estados-unidos/2880632/

Institute for Energy Research (IER). (2020, September 9). *China Dominates the Global Lithium Battery Market.* https://www.instituteforenergyresearch.org/renewable/china-dominates-the-global-lithium-battery-market/.

International Energy Agency. (2022). *Global Supply Chains of EV Batteries.* https://www.iea.org/reports/global-supply-chains-of-ev-batteries

International Finance Corporation (IFC). (2013). *Changing the Game: Communications and Sustainability in the Mining Industry.* https://www.commdev.org/publications/changing-the-game-communications-and-sustainability-in-the-mining-industry/

International Finance Corporation (IFC). (2014). *A Strategic Approach to Early Stakeholder Engagement*. https://www.commdev.org/publications/a-strategic-approach-to-early-stakeholder-engagement/

Kemp, Y. (2023, May 1). *Five key minerals for EV lithium-ion batteries.* ESI Africa. https://www.esi-africa.com/energy-efficiency/five-key-minerals-for-ev-lithium-ion-batteries/

Khan, Yusuf. (2023, June 1). A 'Dirty' Job That Few Want: Mining Companies Struggle to Hire for the Energy Transition. *The Wall Street Journal*. https://www.wsj.com/articles/a-dirty-job-that-few-want-mining-companies-struggle-to-hire-for-the-energy-transition-7d62d2ae

Killelea, E. (2023, September 25). *Tesla now employs 20,000 in Austin, could triple that as it ramps up Cybertruck production.* San Antonio Express-News. https://www.expressnews.com/business/article/tesla-employs-20000-austin-cybertruck-18387363.php

Korosec, K. (2023, June 13). GM and partner Samsung SDI pick Indiana for $3B battery factory. *Tech Crunch*. https://techcrunch.com/2023/06/13/gm-and-partner-samsung-sdi-pick-indiana-for-3b-battery-factory/

Krusemark, L., Ganguly, S., Harp, T., Kulicki, A., Smith, C., & Venkatesh Prasad, K. (2024). *Battery Industry Education and Training Needs Assessment*. Center for Automotive Research.

Lauer, A. (2022, December 29). *What is the U.S. "Battery Belt"? And Where Is It Located?* InsideHook. https://www.insidehook.com/autos/battery-belt-ev-battery-manufacturing.

Lee, J. & Bazilian, M. (2021, April 13). *The U.S. is worried about shortages of critical minerals for electric vehicles, military tech.* PBS News Hour: Nation. https://www.pbs.org/newshour/nation/the-u-s-is-worried-about-shortages-of-critical-minerals-for-electric-vehicles-military-tech.

Lewis, M. (2022, October 13). *Here's where the new U.S. EV 'Battery Belt' is forming – and why*. Electrek. https://electrek.co/2022/10/13/us-ev-battery-belt/.

Lithium Battery Electric Supply Chain: Workforce Analysis – UCSC Institute for Social Transformation. (2022). University of California, Santa Cruz. UCSC Institute for Social Transformation. https://transform.ucsc.edu/work/solidarity-economics-projects/lithium/.

Lund, S., Madgavkar, A., Manyika, J., Smit, S., Ellingrud, K., & Robinson, O. (2021). *The future of work after COVID-19.* McKinsey & Company. https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-after-covid-19

Magill, K. (2022a, December 1). *Hiring Gen Z: How manufacturing companies need to pivot to attract young workers.* ManufacturingDive. https://www.manufacturingdive.com/news/gen-z-labor-hiring-talent-manufacturing/637442/.

Magill, K. (2022b, November 14). *With more than 800K unfilled jobs manufacturers strain to attract talent.* ManufacturingDive. https://www.manufacturingdive.com/news/manufacturing-labor-workforce-shortages-2023-outlook-deloitte-national-association-manufacturers/636275/.

Manufacturing Institute. (2022). *Future skill needs in manufacturing: A deep dive.* https://www.themanufacturinginstitute.org/wp-content/uploads/2022/10/NAM_Rockwell-PTC-Study.pdf

Mao, F. (2021, August 20). BHP sacked 48 over sexual harassment and assaults at Australian mines. *BBC*. https://www.bbc.com/news/world-australia-58278104

McQuilling, A. (2021). Survey on Gap Analysis in Workforce Skills and Policies in the Battery Industry. In *Overview of Results*. NaatBatt Education Committee. https://nac.naatbatt.org/wp-content/uploads/2022/12/NAATBatt-Edu-Comm-Survey-Results-Overview_Final_Dec-21-2021.pdf.

Mehdi, A. & Moerenhout, T. (2023, June 8). *The IRA and the U.S. Battery Supply Chain: Background and Key Drivers*. Center on Global Energy Policy at Columbia. https://www.energypolicy.columbia.edu/publications/the-ira-and-the-us-battery-supply-chain-background-and-key-drivers/.

Mitchell, P. (2022, October 11). *Top 10 business risks and opportunities for mining and metals in 2024.* Ernst & Young. https://www.ey.com/en_us/mining-metals/risks-opportunities

Moe, A., & Turner, S. (2022). Clean Energy Education and Training Resources and Opportunities in New York's Southern Tier Region. National Renewable Energy Laboratory https://www.nrel.gov/docs/fy23osti/83861.pdf.

Mohanty, S. (2023, September 19). *Stuck in the Middle: Strengthening the EV Battery Supply Chain's Midstream Will Be Critical to Transportation Electrification.* LinkedIn. https://www.linkedin.com/pulse/stuck-middle-strengthening-ev-battery-supply-chains-critical-mohanty/

NAATBatt International. (2021). *Overview of Results: Survey on Gap Analysis in Workforce Skills and Policies in the Battery Industry.* https://nac.naatbatt.org/wp-content/uploads/2022/12/NAATBatt-Edu-Comm-Survey-Results-Overview_Final_Dec-21-2021.pdf

National Advanced Battery Workforce Council (NABWC). (2023). Battery Innovation Center. https://nabwc.org/.

National Advanced Battery Workforce Council (NABWC). (2023). Nabwc.org. https://nabwc.org/.

National Center for Education Statistics (NCES). (2023). *Fast Facts High School Graduation Rates.* IES – NCES. https://nces.ed.gov/fastfacts/display.asp?id=805#:~:text=The%20U.S.%20Department%20of%20Education,the%20ACGR%20in%202010%E2%80%9311.&text=The%20U.S.%20average%20ACGR%20for,87%20percent%20in%202019%E2%80%9320.&text=On%20average%2C%20the%20ACGR%20increased,%E2%80%9319%20to%202019%E2%80%9320.

National Defense Transportation Association (NDTA). (2023, September 27). *DOD Launches Energy Storage Systems Campus to Build Domestic Capacity.* https://www.ndtahq.com/dod-launches-energy-storage-systems-campus-to-build-domestic-capacity/.

National Energy Technology Laboratory. (2022a). *Solid Oxide Fuel Cells Peer Review.* https://netl.doe.gov/sites/default/files/2022-04/FY22-SOFC-Peer-Review-Overview-Report_03232022.pdf.

National Energy Technology Laboratory. (2022b). *Summary of Battery Workforce Initiative Industry Roundtables (October 2022).* https://netl.doe.gov/sites/default/files/2023-01/Summary%20of%20Battery%20Workforce%20Initiative%20-%20Industry%20Roundtables%20(Oct22)_20221215%20(Web).pdf

National Energy Technology Laboratory. (2023). *Summary Of Battery Workforce Initiative Industry Round Table (December 2022).* https://netl.doe.gov/sites/default/files/2023-03/Summary%20of%20Battery%20Workforce%20Initiative%20-%20Industry%20Roundtable%20(Dec22)_20230315%20(Web).pdf

National Mining Association. (2022). *World Mining Employment for Selected Countries*. https://nma.org/2022/08/31/statistics-world-mining-employment-2020/.

National Renewable Energy Laboratory (NREL). (2024). *NAATBatt Lithium-Ion Battery Supply Chain Database* [database]. NAATBatt International. https://www.nrel.gov/transportation/li-ion-battery-supply-chain-database.html

National Renewable Energy Laboratory (NREL). (2021, February 5). *New Circular Vision for Lithium-Ion Batteries.* https://www.nrel.gov/news/program/2021/pathways-to-achieve-new-circular-vision-for-lithium-ion-batteries.html

National Research Council. (2013). *Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action.* National Academies Press. https://nap.nationalacademies.org/catalog/18250/emerging-workforce-trends-in-the-us-energy-and-mining-industries

Nicholson, J., Patel, P., & Lewis, A. (2023, May 19). *How Europe can unblock the midstream battery materials bottleneck.* Ernst & Young. https://www.ey.com/en_jp/strategy/how-europe-can-unblock-the-midstream-battery-materials-bottleneck

Northey, H. & Cama, T. (2023, March 3). *'Silicon Valley of Lithium': Nevada mine breaks ground.* E&E News. https://www.eenews.net/articles/silicon-valley-of-lithium-nevada-mine-breaks-ground/

Novonix. (n.d.). *Prepare for a Career in the Booming Battery Industry.* https://www.novonixgroup.com/niabt/

NSF Award Search: Award # 1501883 – Battery Energy Storage Systems Education and Training Initiative (BESS-ETI). (2015). Nsf.gov. https://www.nsf.gov/awardsearch/showAward?AWD_ID=1501883.

OEC. (2023). *Manganese Ore in United States* [interactive data set]. https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/usa

Onstad, E. (2023). U.S., *UK and partners working on 15 critical mineral projects.* Mining.org. https://www.mining.com/web/us-uk-and-partners-working-on-15-critical-minerals-projects/.

Oregon Group, The. (2023, October 5). The mining industry is running out of miners. https://theoregongroup.com/energy-transition/mining/the-mining-industry-is-running-out-of-miners/#:~:text=The%20mining%20industry%20is%20expected,from%2027%2C000%20the%20previous%20year.

Osaka, S. (2023, April 17). The unlikely center of America's EV battery revolution. *The Washington Post*. https://www.washingtonpost.com/climate-environment/2023/04/17/georgia-evs-battery-belt/

PolicyMap. (n.d.- a). *Interactive demographic data*. [Map based on data from Census & PolicyMap: PolicyMap calculations of data from the Census Bureau, December 2022]. http://www.policymap.com

PolicyMap. (n.d.- b). *Interactive real estate, occupancy, and home value data, between 2018–2022* [Map based on data from Census: U.S. Bureau of the Census http://www.policymap.com

PolicyMap. (n.d.- c). *Interactive telecommunications availability data, between 2018–2022* [Map based on data from Census: U.S. Bureau of the Census]. http://www.policymap.com

Raby, J. (2022, August 30). *Electric battery maker to locate factory in northern WVa.* AP. https://apnews.com/article/technology-west-virginia-climate-and-environment-a8a5ae2cc374e87771664a95397ddc91

Rekhi, J., & Van Dijk, S. (2022). *Directing Strategic Change with Capability-based Planning.* Bizzdesign. https://bizzdesign.com/blog/directing-strategic-change-with-capability-based-planning/

Rogerson, R. (2023, July 17). Department of Defense awards $37M to Graphite One mining project near Nome. *Anchorage Daily News*. https://www.adn.com/business-economy/2023/07/17/department-of-defense-awards-37m-to-graphite-one-mining-project-near-nome/

Rosen, Y. (2023, July 18). *Department of Defense, citing critical mineral needs, boosts Nome-area graphite mining project.* Alaska Public Media. https://alaskapublic.org/2023/07/18/department-of-defense-citing-critical-mineral-needs-boosts-nome-area-graphite-mining-project/

Sen, C. (2022, December 29). U.S. *'Battery Belt' Will Be a New Kind of Job Magnet*. Bloomberg. https://www.bloomberg.com/opinion/articles/2022-12-29/us-battery-belt-will-be-a-new-kind-of-job-magnet

Sen, C. (2023, January 2). Comment: Jobs in 'Battery Belt' won't depend on college degrees. *Everett Herald*. https://www.heraldnet.com/opinion/comment-jobs-in-battery-belt-wont-depend-on-college-degrees/

Siegler, K. (2022, October 8). *In Idaho, America's first, and only, cobalt mine in decades is opening.* OPB. https://www.opb.org/article/2022/10/08/in-idaho-america-s-first-and-only-cobalt-mine-in-decades-is-opening/

Smith, D. F. (2015, July 20). *'Tesla Effect' Hits Nevada Schools as Interest in STEM Surges.* EdTech. https://edtechmagazine.com/k12/article/2015/07/tesla-effect-hits-nevada-schools-interest-stem-surges

Society for Mining, Metallurgy & Exploration (SME). (2022). *Maintaining the viability of U.S. Mining education.* https://smenet.blob.core.windows.net/smecms/sme/media/smeazurestorage/about%20sme/technical%20briefings/maintainingviabilityusminingeducationfinal-07262022.pdf

Society for Mining, Metallurgy & Exploration (SME). (2014). Workforce Trends in the U.S. Mining Industry. https://www.smenet.org/What-We-Do/Technical-Briefings/Workforce-Trends-in-the-US-Mining-Industry.

Solis, J. (2023, September 22). *Report of giant lithium find underscores need for less 'sloppy' permitting, conservationist says.* Nevada Current. https://nevadacurrent.com/2023/09/22/report-of-giant-lithium-find-underscores-need-for-less-sloppy-permitting-conservationist-says/#:~:text=A%20new%20study%20published%20in,million%20metric%20tons%20in%20total.

Speight, N. A. & Hester, D. (2023). *Shape an Appropriately Skilled and Ready Future Workforce: Improve Recruitment and Retention of the Civilian Workforce*. Department of Defense. https://assets.performance.gov/APG/files/2023/april/FY2023_April_DOD_Progress_Shape_an_Appropriately_Skilled_and_Ready_Future_Workforce_Improve_recruitment_and_retention_of_the_civilian_workforce.pdf

Statista. (2023, December 22). *Total employment in the United States mining industry from 2000 to 2022. https://www.statista.com/statistics/193214/employment-in-total-us-mining-industry-since-1998/*

St. John, J. (2023, June 8). *The U.S. has big EV goals. Can the domestic EV industry meet them?* Canary Media. https://www.canarymedia.com/articles/electric-vehicles/the-us-has-big-ev-goals-can-the-domestic-ev-industry-meet-them

Theseira, D. (2023, March 29). *How to Deliver Strategic Success With Capability-Based Planning*. https://www.ardoq.com/blog/capability-based-planning#:~:text=What%20Is%20Capability%2DBased%20Planning,than%20specific%20goals%20or%20objectives.

Thielmann, A., Neef, C., Hettesheimer, T., Ahlbrecht, K., & Ebert, S. (2021). *Future Expert Needs in the Battery Sector.* EIT Raw Materials. https://eitrawmaterials.eu/wp-content/uploads/2021/03/EIT-RawMaterials-Fraunhofer-Report-Battery-Expert-Needs-March-2021.pdf

Thurston, C. W. (2021, August 17). *All eyes on Lithium: Sizing up a potential U.S.-based lithium battery supply chain.* Solar Builder. https://solarbuildermag.com/featured/all-eyes-on-lithium-sizing-up-a-potential-u-s-based-lithium-battery-supply-chain/

Tracy, B. & Novak, A. (2023). *EV battery manufacturing energizes southern communities in "Battery Belt*." CBS News. https://www.cbsnews.com/news/ev-battery-manufacturing-energizes-southern-communities-battery-belt/.

Truitt, S., Elsworth, J., Williams, J., Keyser, D., Moe, A., Sullivan, J., & Wu, K. (2022). State-Level Employment Projections for Four Clean Energy Technologies in 2025 and 2030. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy22osti/81486.pdf.

Udavant, S. (2023, August 7). *How the Southeast U.S. is Preparing a Battery Manufacturing Talent Pipeline*. Manufacturing Dive. https://www.manufacturingdive.com/news/battery-manufacturing-workforce-development-georgia-south-carolina-sk-on/688295/.

U.C. Berkeley Labor Center. (2023). *Federal Research on IIJA IRA and CHIPS.* https://sbud.senate.ca.gov/sites/sbud.senate.ca.gov/files/Federal%20Research%20on%20IIJA%20IRA%20and%20CHIPS%20Final.pdf

U.S. Bureau of Labor Statistics. (2023a). *Employment by major industry sector.* https://www.bls.gov/emp/tables/employment-by-major-industry-sector.htm

U.S. Bureau of Labor Statistics. (2024). *Industries at a Glance: Mining (except oil and gas) NAICS 212. https://www.bls.gov/iag/tgs/iag212.htm#workforce*

U.S. Bureau of Labor Statistics. (2023b). *National Industry-Specific Occupational Employment and Wage Statistics NAICS 212000.* https://www.bls.gov/oes/current/naics3_212000.htm

U.S. Bureau of Labor Statistics. (2023c). *Occupational Employment and Wages 51–2028.* https://www.bls.gov/oes/current/oes512028.htm

U.S. Bureau of Labor Statistics. (2023d). *Occupational Outlook Handbook: Assemblers and Fabricators.* https://www.bls.gov/ooh/production/assemblers-and-fabricators.htm

U.S. Census Bureau. (2021) *3359: Other electrical equipment and component manufacturing* [Interactive infographic data set]. Retrieved on Feb. 16, 2024, from https://data.census.gov/profile/3359_-_Other_electrical_equipment_and_component_manufacturing?g=010XX00US&n=3359

U.S. Department of Agriculture (USDA). (2023). *Completion rates, 2017–2021 (Completing college, adults 25 and older)* [graphic data]. USDA Economic Research Service. https://data.ers.usda.gov/reports.aspx?ID=17829&AspxAutoDetectCookieSupport=1

U.S. Department of Defense. (2023a, September 25). *Department of Defense Approves $30 Million in Grants Under Defense Manufacturing Community* [Press release]. https://www.defense.gov/News/Releases/Release/Article/3536350/department-of-defense-approves-30-million-in-grants-under-defense-manufacturing/.

U.S. Department of Defense (DOD). (2023b). *Ensure Supply Chain Resilience*. https://www.performance.gov/agencies/dod/apg/goal-1/.

U.S. Department of Energy. (2021, November 9). *DOE Factsheet: The Bipartisan Infrastructure Deal Will Deliver for American Workers, Families and Usher in the Clean Energy Future.* https://www.energy.gov/articles/doe-fact-sheet-bipartisan-infrastructure-deal-will-deliver-american-workers-families-and-0.

U.S. Department of Energy (DOE). (2022, May 4). *Secretary Granholm Visited Michigan to Announce $3.16 Billion for Domestic Battery Production and Tout Benefits of American Manufacturing*. https://www.energy.gov/articles/icymi-secretary-granholm-visited-michigan-announce-316-billion-domestic-battery-production.

U.S. Geological Survey (USGS). (2021). *Mineral Commodity Summaries 2021*. https://pubs.usgs.gov/periodicals/mcs2021/mcs2021.pdf

UT Dallas To Lead $30 Million Battery Technology Initiative. (2023). The University of Texas at Dallas. News Center. https://news.utdallas.edu/science-technology/battery-energy-storage-initiative-2023/.

Venditti, B. (2023, November 15). *All the Metals We Mined in One Visualization.* Elements. https://elements.visualcapitalist.com/all-the-metals-we-mined-in-one-visualization-2/

White House, The. (2021). National Climate Taskforce. In *President Biden's Actions to Tackle the Climate*. https://www.whitehouse.gov/climate/#:~:text=Reducing%20U.S.%20greenhouse%20gas%20emissions,zero%20emissions%20economy%20by%202050.

White House, The. (2023). Climate, Energy and the Environment. In *A Guidebook to the Bipartisan Infrastructure Law*. https://www.whitehouse.gov/build/guidebook/.

Wilkinson, A. & Rengarajan, S. (2021). *The U.S. Needs to Produce Batteries, Not Just EVS*. Industry Today. https://industrytoday.com/the-us-needs-to-produce-batteries-not-just-evs/.

WiseVoter. (2023). *Veteran Population by State 2023.* https://wisevoter.com/state-rankings/veteran-population-by-state/

Workforce Development Component of New Energy New York's "1 Billion Build Back Better Regional Challenge" Initiative. (2022). SUNY Broome. Sunybroome.edu. https://www2.sunybroome.edu/sponsoredprogs/2022/09/22/workforce-development-component-of-new-energy-new-yorks-1-billion-build-back-better-regional-challenge-initiative.

World Economic Forum (WEF). (2020). *The Future of Jobs Report*. https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf

World Population Review. (2022). *Nome, Alaska Population* [demographic data visualizer]. https://worldpopulationreview.com/us-cities/nome-ak-population

APPENDIX A. PHASE I(B) BUDGET

Budget Item	Labor*	Other	Total
FTEs	$1,012,206	$ 10,155	$1,022,361
NPS Overhead (on $1.2M)		$ 315,118	$ 315,118
Total	$1,012,206	$ 325,273	$1,337,479
Total Funds Remaining			$ (137,479)

*Based on an average loaded rate of $1.2M.

APPENDIX B. LOCATIONS OF DOMESTIC U.S. MINES

(minerals required for the battery supply chain)

STATE	COUNTY	NAME	OWNER	MINERAL(S)	MINE STATUS	CAPACITY/ ACTUAL (tons per year)
Alabama	Coosa	Coosa Graphite Mine	Westwater Resources	Graphite	In pipeline	50,000
Alaska	Nome Area	Graphite One Mine	Graphite One, Inc.	Graphite	In pipeline	51,000
California	Imperial	Hell's Kitchen 1	Controlled Thermal Resources	Lithium	In Pipeline	25,000
Georgia	Decatur	Anovion Synthetic Graphite*	Anovion Technologies	Graphite*	In Pipeline	44,000
Idaho	Lemhi	Idaho Cobalt Operations	Jervois	Cobalt	In Pipeline	2,000
Michigan	Marquette	Eagle Mine	Lundin Mining	Nickel, Copper, Cobalt	Producing	16,500 (Ni) 16,800 (Cu) 386 (Co)
Minnesota	Aitkin	Tamarack Mine	Talon Metals	Nickel	In Pipeline	Not Yet Published
Nevada	Lyon	Thacker Pass Lithium Mine	Lithium Americas	Lithium	In Pipeline	40,000
Nevada	Esmeralda	Rhyolite Ridge Mine	Ioneer	Lithium	In Pipeline	22,000
Nevada	Silver Peak	Silver Peak Mine	Albemarle Corp	Lithium	Producing	10,000
North Carolina	Gaston	Gaston Mine	Piedmont Lithium Inc.	Lithium	In Pipeline	30,000
North Carolina	York	Kings Mountain Mine	Albemarle Corp	Lithium	In Pipeline	50,000

Notes:

- Production capacity refers to the planned or permitted maximum output, while actual production may vary depending on market conditions and other factors.
- Table is not exhaustive. May not include all projects in the development stage.
- This table primarily notes the top five minerals required in lithium-ion battery production. Some mines may produce minerals relevant to batteries in lesser quantities but are not listed in the table, such as copper or manganese.

* Denotes synthetic graphite production facility. This facility does not mine graphite, but rather manufactures it from petroleum needle coke, a byproduct of petroleum refining.

RESOURCES:

- U.S. Geological Survey: U.S. Geological Survey: https://www.usgs.gov/national-minerals-information-center
- Critical Minerals Institute: Critical Minerals Institute: https://www.energy.gov/eere/ammto/articles/us-department-energy-renews-critical-materials-institute-secure-americas-clean
- Mining Association of America: https://nma.org/
- https://westwaterresources.net/projects/graphite/
- https://www.graphiteoneinc.com/wp-content/uploads/2022/10/JDS-Graphite-One-NI-43-101-PFS-20221013-compressed.pdf
- https://www.fastmarkets.com/insights/jervois-delays-ramp-up-cobalt-mine/#:~:text=The%20mine%2C%20located%20in%20the,to%20be%201%2C100%2D1%2C300%20tonnes
- https://www.desertsun.com/story/news/environment/2024/01/25/lawsuit-could-block-massive-project-near-salton-sea/72354176007/
- https://www.ioneer.com/wp-content/uploads/2022/07/300420-dfs-executive-summary-metric_final.pdf

APPENDIX C. LOCATIONS OF DOMESTIC U.S. GIGAFACTORIES

STATE	CITY	NAME	STATUS	ACTUAL/ EXPECTED
Alabama	Montgomery	Hyundai Motor Manufacturing Alabama (Battery Pack Assembly)	Operational	2024
Alabama	Woodstock	Mercedes-Benz Battery Plant	Operational	2021
Arizona	Casa Grande	Lucid Motors Casa Grande Factory	Operational	2021
Arizona	Queen Creek	LG Energy Solution Gigafactory (Battery Cell Production)	Under Construction	2025
Arizona	Tucson	American Battery Factory LFP Production Facility	Under Construction	2025
California	Fremont	Tesla Fremont Factory	Operational	2010
California	Hanford	Faraday Future Hanford (Battery Assembly)	Operational	2023
Georgia	Commerce	SK Battery America Jackson County Plant	Operational	2022
Georgia	Savannah	Hyundai Motor Group, LG Energy Solution (Battery Manufacturing)	Under Construction	2025
Georgia	Stanton Springs	Rivian Georgia (Battery Manufacturing)	Planned	N/A
Illinois	Normal	Rivian Normal (Battery Pack Assembly)	Operational	2022
Indiana	Kokomo	StarPlus Giga I Stellantis-Samsung SDI Joint Venture (Battery Cell Manufacturing)	Under Construction	2025
Indiana	Kokomo	StarPlus Giga II Stellantis-Samsung SDI Joint Venture (Battery Cell Manufacturing)	Planned	2027
Indiana	New Carlisle	Samsung – GM Joint Venture (Battery Cell Manufacturing)	Under Construction	2026
Kansas	De Soto	Panasonic Battery Cell Assembly	Under Construction	2025
Kentucky	Bowling Green	AESC Bowling Geen Gigafactory (Battery Cell Manufacturing)	Under Construction	2025
Kentucky	Glendale	Ford BlueOval SK Battery Park “Tennessee I”	Under Construction	2025

		(Battery Production and Vehicle Assembly)		
Kentucky	Glendale	Ford BlueOval SK "Tennessee II"	Planned	N/A
Michigan	Marshall	Ford BlueOval Battery Park (LFP Battery Cell Production)	Under Construction	2026
Michigan	Holland	LG Energy Solution Michigan (Battery Production)	Operational	2009
Michigan	Ypsilanti	Ford Rawsonville Components Plant (Battery Pack Assembly)	Operational	1956
Nevada	Sparks	Tesla Gigafactory 1 (Battery Cell Production)	Operational	2016
Nevada	Sparks	Panasonic Giga Nevada (Battery Cell Production)	Operational	2014
Nevada	Sparks	Redwood Materials Sparks Campus (Recycling, Cathode/Anode production)	Operational	2023
North Carolina	Greensboro	Toyota Battery Plant	Under Construction	2025
Ohio	Jeffersonville	LG Energy Solutions – Honda Joint Venture (Battery Cell Production)	Under Construction	2024
South Carolina	Florence	AESC Battery Cell Production Gigafactory	Under Construction	2026
South Carolina	Ridgeville	Redwood Materials Ridgeville Campus (Battery Recycling, Anode & Cathode Production)	Under Construction	2025
South Carolina	Woodruff	BMW Plant Woodruff (Battery Pack Assembly)	Under Construction	2026
Tennessee	Spring Hill	Ultium Cells (Battery Cell Production)	Under Construction	2024
Tennessee	Stanton	BlueOval City Ford-SK Joint Venture (EV and Battery Production)	Under Construction	2025

Figure 31. North American Gigafactories. Source: Thurston (2021).

References:

- https://www.autonews.com/cars-concepts/mercedes-alabama-plant-could-go-all-electric
- https://abc3340.com/news/local/mercedes-opens-alabama-battery-plant-adding-up-to-600-jobs-tuscaloosa-county-bibb-county-german-kay-ivey-electric-vehicle-suv-eqs-eqe
- https://lucidmotors.com/company
- https://lucidmotors.com/stories/construction-complete-on-first-lucid-motors-ev-factory
- https://electrek.co/guides/tesla-gigafactory-nevada/
- https://www.cnbc.com/2019/05/03/we-went-inside-teslas-gigafactory-heres-what-it-looked-like.html
- https://www.businessinsider.com/redwood-materials-electric-vehicle-battery-recycling-expands-2022-12
- https://www.enr.com/articles/55900-nevada-ev-battery-material-plant-expands-with-2b-us-loan
- https://dayton247now.com/news/auto-matters/inside-teslas-fremont-electric-car-plant-how-model-s-model-x-are-built-video

- https://en.wikipedia.org/wiki/Tesla_Fremont_Factory
- https://en.wikipedia.org/wiki/Gigafactory
- https://apnews.com/article/technology-nevada-south-carolina-carson-city-climate-and-environment-430b1bf8f90e40f7effccbc6248bde98
- https://www.camphall.com/news/sc-battery-recycling-plant-owner-breaks-ground-on-3-5b-lowcountry-project/#:~:text=February%202%2C%202024-,SC%20battery%2Drecycling%20plant%20owner%20breaks%20ground%20on%20%243.5B,the%20end%20of%20the%20year.
- https://www.morgancountycitizen.com/news/morgan-leaders-blindsided-by-rivian-plans-for-lithium-battery-manufacturing-facility/article_a9f53c60-66ef-11ee-9236-1f5c3a558368.html
- https://www.enr.com/articles/57899-clayco-picked-for-5b-rivian-ev-plant-in-georgia
- https://group.mercedes-benz.com/careers/about-us/locations/location-detail-page-416402.html
- https://www.stellantis.com/en/news/press-releases/2023/october/stellantis-samsung-sdi-announce-kokomo-indiana-as-site-for-second-us-starplus-energy-gigafactory?utm_source=EN-Press%20Releases&utm_medium=email&utm_campaign=A585_Stellantis%2C%20Samsung%20SDI%20Announce%20Kokomo%2C%20Indiana%20as%20Site%20for%20Second%20U.S.%20StarPlus%20Energy%20Gigafactory_11102023
- https://www.ff.com/us/press-room/Hanford-sale-leaseback/
- https://na.panasonic.com/us/news/panasonic-energy-breaks-ground-ev-battery-factory-kansas
- https://www.wdrb.com/news/business/ford-to-delay-second-of-two-ev-battery-plants-in-kentucky/article_40ff1e9e-7449-11ee-b0e2-f7ec41a405ef.html
- https://governor.alabama.gov/newsroom/2022/10/governor-ivey-announces-hyundai-mobis-plans-ev-battery-module-plant-in-montgomery-creating-400-jobs/#:~:text=Hyundai%20Mobis%20said%20construction%20on,projected%20to%20begin%20in%202024.
- https://www.bmwgroup-werke.com/spartanburg/en/our-plant.html
- https://electronsx.com/battery-gigafactories.php
- https://www.savannahnow.com/story/business/2023/02/17/hyundai-ev-plant-bryan-county-ga-larger-than-montgomery-alabama/69915046007/
- https://www.recyclingtoday.com/news/american-battery-factory-setting-up-shop-in-arizona/
- https://corporate.ford.com/operations/locations/global-plants/rawsonville-components-plant.html
- https://corporate.ford.com/operations/blue-oval-battery-park-michigan.html

APPENDIX D. RESEARCH PROGRAMS FUNDED TO EXAMINE THE DOMESTIC BATTERY WORKFORCE

Unit of Analysis	Name	Scope	Funding Source	Funding	Start	End	Findings
Federal	Battery Workforce Initiative	To accelerate the creation and distribution of non-proprietary training curricula that imparts the knowledge and skills required for working in key occupations of the domestic battery supply chain	US DOE	$5M	12/22	n/a	Occupational skills inventory in progress in late 2023. Initial population being examined is hourly, mid-stream employees.
Federal	National Advanced Battery Workforce Council (NABWC)	To stimulate, organize, and accomplish educative objectives aimed at developing the domestic battery supply chain workforce	Federal Consortium for Advanced Batteries (FCAB)		2022	n/a	
Federal	State-Level Employment Projections for Four Clean Energy Technologies in 2025 and 2030	To estimate by state the number of workers required to sustain modeled deployments of four clean energy technologies	US DOE Office of Energy Efficiency and Renewable Energy Weatherization and Intergovernmental Programs Office			3/22	Appendix A details job estimates by state
Federal	Clean Energy Education and Training Resources and Opportunities in New York's Southern Tier Region	To assess gaps in battery workforce development assets located in 11 counties of the New York Southern Tier region	US DOE Office of Energy Efficiency and Renewable Energy Building Technologies Office			10/22	There are 3 major gaps: few numbers of battery workforce development programs are available in (1) high schools, (2) community colleges, and (3) non-profit service providers
Federal	Battery Energy Storage Systems Education and Training Initiative	To create portable training curricula for use in Pennsylvanian community colleges and electrical worker training programs aimed at developing battery energy storage technicians	NSF	$550k	09/15	12/18	This research articulated the education and skills necessary for installing and maintaining battery energy storage systems

Unit of Analysis	Name	Scope	Funding Source	Funding	Start	End	Findings
Business league	NAATBatt Education Committee	To perform a gap analysis over the existing and future skills needed in the battery workforce			10/21	11/21	Survey responses indicated few applicants are available with skills requisite for working in the battery industry, and local applicant are difficult to source
University	University of Texas at Dallas	To perform a number of objectives related to the domestic battery supply chain, which includes developing its workforce	US DOD	$30M	09/23		
University	Michigan Defense Resiliency Program	To support the training needs of workers in the domestic battery supply chain	US DOD	$5M			
University	University of California, Santa Cruz	Through collaboration efforts with other institutions, to analyze workforce-related development issues in the battery supply chain					
University	SUNY Broome	To meet the training needs of the battery supply chain workforce in the Southern Tier of upstate New York	US Economic Development Administration via Binghamton University & The SUNY Research Foundation	$1.31M		09/27	

APPENDIX E. DOMESTIC BATTERY WORKFORCE PROGRAMS IN PROGRESS

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
Corning Incorporated	Corning, NY	1851	Private	OJT/Internships – semiconductor chip production	57,500		X	X
Kohler Company	Kohler, WI	1873	Private	OJT – Power and clean energy solutions	40,000		X	X
Albemarle Corporation	Charlotte, NC	1887	Private	Producers of lithium and bromine for EV batteries	7,400	X	X	X
Energizer Company	St. Louis, MO	1896	Private	OJT – Battery production	6,000		X	X
General Electric / GE Research	Niskayuna, NY	1900	Private	OJT – Electrical innovation and development	5,000		X	X
General Motors Company	Detroit, MI	1908	Private	OJT – electric vehicle production	167,000		X	X
Cummins, Inc.	Columbus, IN	1919	Private	OJT – Power generation products/engines; alternative fuel engines	73,600			X
Duracell, Inc.	Bethel, CT	1924	Private	OJT – Battery production	2,700		X	X
Tennessee Valley Authority	Knoxville, TN	1933	Private	OJT – Energy delivery	10,000		X	X
Dow Corning Corporation	Midland, MI	1943	Private	Apprenticeships/Internships – transformative transportation	12,000		X	X
Argonne National Laboratory	Lemont, IL	1946	DOE ($1.1B)	Internships – Clean energy	3,400		X	X

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
Idaho National Laboratory	Idaho Falls, ID	1949	DOE ($1.6B)	Internships (524) – Integrated energy; carbon free energy	6,123		X	
General Atomics	San Diego, CA	1955	Private	OJT/Internships – Nuclear energy, UAVs, Airborne Sensors	15,000		X	X
South Carolina Technical College System (16 colleges across the state) – readySC Program	Columbia, SC	1961	Public	Partnering with local manufacturing companies and industries to provide specific training in industrial work skills and maintenance	5,755 students			X
South Carolina Technical College System (16 colleges across the state) – Apprenticeship Carolina Program	Columbia, SC	1961	Public	Partnering with local manufacturing companies and industries to provide Apprenticeship and Pre-Apprenticeship opportunities to students in school	860 students			X
Southern Company Services	Atlanta, GA	1963	Private/DOE	OJT/Internships – Energy	4,536		X	X
West Georgia Technical College	Carrollton, GA	1966	Public	Provide training and retraining to support area economic development, technical certificates	8,913 students			X

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
Technical College System of Georgia (22 colleges across the state) – Georgia Quickstart	Atlanta, GA	1967	State Government	Customizes workforce training for new, expanding and existing businesses in Georgia	26,500			X
Workforce Development for Teachers and Scientists (WDTS)	Washington, DC,	1968	DOE	Training and supporting teachers and scientists to sustain a pipeline of STEM workers through awards, 17 x national laboratories, and 6 x Office of Science Research Program offices	30,000	X	X	X
Electric Power Research Institute	Palo Alto, CA	1972	Non-profit	Online Courses – Power generation and Delivery			X	X
Industry-University Cooperative Research Centers (IUCRC) – various centers	Alexandria, VA	1973	U.S. National Science Foundation	Foster long-term partnerships among industry, academics, and government. These partnerships support research programs of mutual interest, contribute to the nation's research infrastructure base, promote workforce development, and facilitate technology transfer	N/A		X	X
National Renewable Energy Laboratory	Golden, CO	1977	DOE	Internships – Renewable energy and energy efficient technologies	3,227		X	

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
Sabre Industries, Inc.	Alvarado, TX	1977	Private	OJT – Power, utility, and telecom infrastructure	3,000		X	X
SK Battery America, Inc.	Commerce, GA	1984	Private ($2.6B)	OJT – Battery Manufacturing	2,600		X	X
The National Center for Manufacturing Sciences (NCMS)	Ann Arbor, MI	1986	Non-profit	Technology Consortium – improving the strength of the U.S. industrial base	N/A		X	X
Concurrent Technologies Corporation	Johnstown, PA	1987	Non-profit	OJT – Conducts applied research in energy, resilience, and sustainability	1,450		X	X
Ameren Corporation	St. Louis, MO	1997	Private	Apprenticeships/Internships/OJT – Energy delivery	9,116		X	X
Exelon Corporation	Chicago, IL	2000	Public	OJT – Energy delivery	19,063		X	X
Gas Technology Institute – Energy	Des Plaines, IL	2000	Non-profit	Online Training in the natural gas industry	500			X
Tesla	Austin, TX	2003	Private	OJT – Automotive and clean energy (batteries and storage devices)	127,855		X	X
National Alliance for Advanced Transportation	Chicago, IL	2008	Non-profit/DOE ($2B)	Promotes the development of energy storage technology and advanced battery manufacturing	N/A			

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
Battery Cell Manufacture (NATTBatt)								
Eos Energy Enterprises	Turtle Creek, PA	2008	Private/DOE($500M)	OJT – Energy storage solutions	300		X	X
NextEra Energy Resources	Juno Beach, FL	2009	Private	OJT/Internships – Solar and Wind energy	5,200		X	X
24M Technologies, Inc.	Cambridge, MA	2010	Private	OJT – Lithium-ion battery cell manufacturing	200		X	X
New York Battery and Energy Storage (NY-BEST) Consortium	Albany, NY	2010	Dept of Commerce	Work with economic and workforce development programs within the energy storage industry	N/A		X	X
Navitas Systems, LLC	Ann Arbor, MI	2011	Private	OJT – Energy storage solutions	80			X
Materion Corporation	Mayfield Heights, OH	2011	Private	OJT – Advanced engineered materials for a cleaner future	3,700		X	X
Battery Innovation Center (BIC), Inc.	Newberry, IN	2012	Non-profit	Provides energy storage short courses; testing, evaluation, and certification	N/A			X
ENGIE North America, Inc.	Houston, TX	2015	Private	OJT – Renewable and low-carbon energy transition	5,000		X	X

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
Linde	Danbury, CT	2018	Private	OJT – Industrial gas for electronics manufacturing	24,461		X	X
Lockheed Martin Advanced Energy Storage, LLC	Andover, MA	2020	Private	OJT – Redux flow battery	250		X	X
Freyr Operations	Coweta, GA	2022	Private	OJT – Efficient Battery Cells	600		X	X
Li-Bridge Workforce and Communities Committee	Argonne National Laboratory, Lemont, IL	2022	DOE	To develop a strategy for establishing a robust and sustainable supply chain for lithium battery technology; investing in workforce training	TBD	X	X	X
Spruce Power Holding Corporation	Boston, MA	2022	Private	OJT – Hybrid electric vehicle technology	200		X	X
New Energy New York Storage Engine	Binghamton, NY	2022	U.S. National Science Foundation ($160M)	Establish a battery tech-based, industry-driven innovation hub; use-inspired research and development, technology translation, and workforce development	TBD		X	X
NSF Regional Innovation Engines – various locations	Alexandria, VA	2022	U.S. National Science Foundation	Advancing transdisciplinary, collaborative, use-inspired and translation research and technology development in key technology focus areas; Train and educate diverse technicians, researchers, practitioners and entrepreneurs based on regional workforce needs	TBD	X	X	X
Battery Workforce Initiative (BWI)	Washington, DC,	2022	DOE ($5M)	Support up to five pilot training programs in energy and automotive communities and advance workforce partnerships between industry and labor for the domestic lithium battery supply chain	TBD		X	X

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
Critical Mineral and Materials for Advanced Energy (CM2AE) Tech Hub	University of Missouri, Columbia, MO	2023	Dept of Commerce	Critical minerals processing	TBD	X	X	X
Nevada Lithium Batteries and Other EV Material Loop (Tech Hub)	University of Nevada, Reno, NV	2023	Dept of Commerce	Build a self-sustaining full lithium life cycle cluster, spanning extraction, processing, manufacturing, and recycling	TBD	X	X	X
Energy Program for Innovation Clusters (EPIC) – Supercharge NY	Binghamton, NY	2023	DOE	Creating a statewide energy storage hardware innovation cluster to accelerate New York's energy storage manufacturing industry, positioning it as a U.S. hub for energy storage innovation, research, development, and manufacturing	TBD		X	X
New Energy New York (NENY) Battery Tech Hub	The State University of New York (SUNY) at Binghamton, NY, and Southern Tier of New York	2023	Dept of Commerce	End-to-end battery development and manufacturing	TBD		X	X
New Energy New York Battery Academy	Binghamton, NY	2023	Dept of Commerce	Educate and build a battery workforce	TBD			X

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
The New York Semiconductor Manufacturing and Research Technology Innovation Corridor (NY SMARTI-Corridor) Tech Hub	Upstate New York (Buffalo, Rochester, Syracuse, Ithaca, Auburn, Batavia)	2023	Dept of Commerce	Semiconductor manufacturing and supply chain sustainability	TBD			X
South Carolina Nexus for Advanced Resilient Energy (Tech Hub)	South Carolina (Greenville, Anderson, Columbia, Spartanburg) and Georgia (Augusta, Richmond)	2023	Dept of Commerce	Clean energy supply chain; developing, testing, and deploying exportable electricity technologies; leverage the region's dynamic and growing manufacturing base, superior research capabilities, and demonstrated record of public-private collaboration to innovate and commercialize emerging energy storage materials and manufacturing techniques	TBD			X
Texoma Semiconductor Tech Hub	Southern Methodist University, Dallas, TX, North Central Texas, Southern Oklahoma	2023	Dept of Commerce	Semiconductor manufacturing	TBD		X	X

Organization Name / Program	Location	Year Est.	Sponsor / Source of Funding	Focused Area of Training	# Personnel Trained	SUPPLY CHAIN STREAM		
						UP	MID	DOWN
Battery Workforce Challenge	Washington, DC,	2023	DOE	3-year student hands-on competition to design, build, test, and integrate an advanced EV battery pack into a Stellantis vehicle (12 x universities partnered with a community college or trade/vocational school)	TBD		X	X
21st Century Energy Workforce Advisory Board	Washington, DC,	2023	DOE	Advising DOE and Secretary of Energy on development and support of a clean energy workforce.	TBD	X	X	X
Critical Minerals Collaborative	Washington, DC,	2023	DOE	Training leaders and workforce for critical minerals across various sectors.	TBD	X		
Center for Manufacturing a Green Economy	Rancho Cordova, CA; Imperial County, CA	2024	Private; UAW	Workforce training program, with recruitment pipeline and training center, to support lithium battery manufacturing jobs. Training includes apprenticeships, foundational job skill training, and follow up services to support cohorts.	TBD		X	X

APPENDIX F. PROGRAMS FUNDED THROUGH THE IIJA/BIL

The Infrastructure Investment and Jobs Act (IIJA), aka Bipartisan Infrastructure Bill (BIL) – 15 November 2021

Overall Funding and Purpose: $1.2T = Transportation and Infrastructure

Battery and Battery-Related Subset Funding and Purpose: $844B = Projects to rebuild our roads and bridges, deliver clean and safe water, clean up legacy pollution, expand access to high-speed internet, and build a clean energy economy

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	UPSTREAM	MIDSTREAM	DOWNSTREAM	Notes
Public Transportation Technical Assistance and Workforce Development	$27.5 million	Department of Transportation / Federal Transit Administration	Provides funding to support workforce development and transition, including in relation to zero-emission fleet conversion, and other technical assistance to support transit providers in enhancing safe, efficient, equitable, and climate-friendly public transportation			X	
EV Batteries and Critical Materials	$7 billion	Department of Energy / Energy Programs	Support to U.S. manufacturing of batteries and the extraction, refinement, and processing of the critical materials that power them		X	X	Received funding: Cirba Solutions (Lancaster, OH) – lithium-ion recycling facility, Group14 Technologies (Washington) – developing commercial-scale modular manufacturing facility that will reduce battery costs and greenhouse gas emissions

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	UPSTREAM	MIDSTREAM	DOWNSTREAM	Notes
Electric or Low-Emitting Ferry Program	$250 million	Department of Transportation / Federal Transit Administration	Establishes an Electric or Low-Emitting Ferry Pilot Program to support the transition of passenger ferries to low or zero emission technology			X	Provides competitive funding for projects supporting the purchase of electric or low-emitting ferries and the electrification of or other reduction of emissions from existing ferries
Electric Drive Vehicles Battery Recycling and 2nd Life Applications Program	$200 million	Department of Energy / Energy Programs	To expand DOE program for research, development, and demonstration of electric vehicle battery recycling and second-life applications for vehicle batteries		X	X	Recipients include institutions of higher education, national laboratories, nonprofit and for-profit private entities, state/local governments, and consortia of these entities -
Low or No Emission Vehicle Component Assessment Program	$26 million	Department of Transportation / Federal Transit Administration	To conduct testing, evaluation, and analysis of low or no emission components intended for use in low- and zero emission buses used to provide public transportation; The Low and No-Emission Component Assessment Program (LoNO-CAP) is intended to test items that are separately installed in and removable from a low- or no-emission transit bus			X	One objective is to advance the development of materials, technologies, and safer designs

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	Upstream	Midstream	Downstream	Notes
Battery Materials Processing Grants	$3 billion	Department of Energy / Office of Manufacturing and Energy Supply Chains (MESC)	To provide grants for battery materials processing to ensure the U.S. has a viable battery materials processing industry		X		Funded $2.8B across 21 projects (7 x Cathode/ Electrodes Manufacturing projects, 2 x Anode Manufacturing projects, 2 x Precursor Materials Separation projects, 9 x Materials/ Cathode/Anode Minerals Separation project, and 1 x Recycling project); Project portfolios will support new and expanded commercial-scale domestic facilities to process lithium, graphite and other battery materials, manufacture components, and demonstrate new approaches, including manufacturing components from recycled materials
Battery Manufacturing and Recycling Grants	$3 billion	Department of Energy / Office of Manufacturing and Energy Supply Chains (MESC)	To provide grants to ensure that the U.S. has a viable domestic manufacturing and recycling capability to support a North American battery supply chain		X	X	

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	UPSTREAM	MIDSTREAM	DOWNSTREAM	Notes
Advanced Energy Manufacturing and Recycling Grant Program	$750 million	Department of Energy / Energy Programs	To provide grants to small- and medium-sized manufacturers to enable them to build new or retrofit existing manufacturing and industrial facilities to produce or recycle advanced energy products in communities where coal mines or coal power plants have closed		X		DOE has released a $425 million funding for round 2 projects. This opportunity builds on a successful first round of investments in 2023, representing $275 million of federal investments across seven selected projects in seven states.
Critical Material Innovation, Efficiency, and Alternatives	$600 million	Department of Energy / Energy Programs	To conduct a program of research, development, demonstration, and commercialization to develop alternatives to critical materials, to promote their efficient production and use, and ensure a long-term secure and sustainable supply of them		X	X	Through the Office of Fossil Energy and Carbon Management
State Energy Program	$500 million	Department of Energy / Energy Programs	To support programs that help reduce carbon emissions in all sectors of the economy, including the transportation sector and accelerate the use of alternative transportation fuels and vehicle electrification			X	
Grants for Energy Efficiency and Renewable Energy Improvements at	$500 million	Department of Energy / Energy Programs	To provide competitive grants to make energy efficiency, renewable energy, and alternative fueled vehicle upgrades and improvements at public schools			X	Include consortiums of one local educational agency (LEA) with one or more schools, nonprofits, for-profits/private, or community organizations

Major Battery Investment Programs	**Funding**	**Sponsor / Funding Source**	**Purpose**	**UPSTREAM**	**MIDSTREAM**	**DOWNSTREAM**	**Notes**
Public School Facilities							
Earth Mapping Resources Initiative	$320 million	Department of the Interior / U.S. Geological Survey	To accelerate the U.S. Geological Survey mapping mission by providing integrated topographic, geologic, geochemical, and geophysical mapping; accelerating the integration and consolidation of geospatial and resource data; and providing an interpretation of both critical mineral resources still in the ground and critical mineral resources that may be reprocessed from mine wastes	X			Information acquired through the initiative could advance understanding of other economically valuable mineral resources (such as copper, zinc, gold, and industrial minerals), energy and groundwater resources, and geologic hazards
Energy and Minerals Research Facility	$167 million	Department of the Interior / U.S. Geological Survey	For design, construction and tenant build out of a facility to support energy and minerals research and associated structures, through a cooperative agreement with an academic partner	X			Establishes a center of excellence in minerals and energy science, providing opportunities for science collaboration that will leverage U.S. Geological Survey science
Industrial Research and Assessment Centers	$150 million	Department of Energy / Energy Programs	To provide funding for institutions of higher education-based industrial research and assessment centers to identify opportunities for optimizing energy efficiency and environmental performance at manufacturing and other industrial facilities		X		Supports engineers-in-training and Small- and Medium-Sized Manufacturers (SMMs) nationwide. Establishes five Regional Centers of Excellence among existing Industrial Assessment

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	Upstream	Midstream	Downstream	Notes
							Centers, creates new IACs at community colleges, trade schools, and union training programs
Long-Duration Energy Storage Demonstration Initiative and Joint Program	$150 million	Department of Energy / Energy Programs	To establish a demonstration initiative composed of demonstration projects focused on the development of long-duration energy storage technologies at different scales		X	X	Technology Developers, Industry, State and Local Governments, Tribal Organizations, Community Based Organizations, National Laboratories, Universities, and Utilities
Rare Earth Elements Demonstration Facility Program	$140 million	Department of Energy / Energy Programs	To demonstrate the feasibility of a full-scale integrated rare earth element extraction and separation facility and refinery	X			Extraction, separation and refining from unconventional feedstock materials
Rare Earth Security Activities	$127 million	Department of Energy / Energy Programs	To conduct a program of research and development to improve the security of rare earth elements, through extraction and recovery of rare earth elements	X			
Battery and Critical Mineral Recycling	$125 million	Department of Energy / Office of Manufacturing and Energy Supply Chains (MESC)	To award grants for research, development, and demonstration projects to create innovative and practical approaches to increase the reuse and recycling of batteries		X	X	Funded to enhance campaigns to increase consumer, government, and retailer participation for battery recycling programs,

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	UPSTREAM	MIDSTREAM	DOWNSTREAM	Notes
Critical Material Supply Chain Research Facility	$75 million	Department of Energy / Energy Programs	To support construction of a Critical Materials Supply Chain Research Facility to enable research, development, demonstration, and commercialization activities throughout the supply chain for critical materials		X	X	
Lithium-Ion Recycling Prize	$10 million	Department of Energy / Energy Programs	To provide a prize for recycling of lithium-ion batteries and convene a task force on battery producer requirements		X	X	
Solid Waste Infrastructure and Recycling	$275 million	Environmental Protection Agency	Support improvements to local post-consumer materials management, including municipal recycling programs, and assist local waste management authorities in making improvements to local waste management systems		X	X	Funding Opportunity for States and Territories, Communities, Tribes and Intertribal Consortia.
Battery Collection Best Practices	$10 million	Environmental Protection Agency	To develop best practices with respect to the collection of used batteries			X	EPA is developing a report to Congress on the best practices for collection of batteries to be recycled to be published in 2024
Voluntary Battery Labeling Guidelines	$15 million	Environmental Protection Agency	To develop voluntary labeling guidelines for batteries and other forms of communication materials for battery producers and consumers about the reuse and recycling of critical materials from batteries			X	Voluntary labeling guidelines for various battery chemistries and types published by 2026

APPENDIX G. PROGRAMS FUNDED THROUGH THE CHIPS AND SCIENCE ACT

The Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act – 9 August 2022

Overall Funding and Purpose: $280B = Fund American semiconductor research, development, and production in advanced manufacturing and materials; incentives to produce semiconductors in the U.S.

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	UPSTREAM	MIDSTREAM	DOWNSTREAM
Manufacturing Incentives	$39 billion	Department of Commerce	Subsidies for chip manufacturing in the U.S.		X	
Research and Development	$11 billion	Department of Commerce	Boost advanced semiconductor research and development in the U.S.		X	X
International Information Communications Technology Security and Semiconductor Supply Chain Activities	$500 million	Department of State	To coordinate with foreign-government partners on semiconductor supply chain security			X
Microelectronics Research, Fabrication, and Workforce Training	$2 billion	Department of Defense	Fund microelectronics research, fabrication, and workforce training			X
Promote and Deploy Wireless Technologies (that use open and interoperable radio access networks)	$1.5 billion	Federal Communications Commission	To enhance competitiveness of software and hardware supply chains of open 5G networks			X

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	UPSTREAM	MIDSTREAM	DOWNSTREAM
Regional Economic Growth and Development	$10 billion	Department of Commerce	Invest in regional innovation and technology hubs across the U.S., bringing together state and local governments, institutes of higher education, labor unions, businesses, and community-based organizations to create regional partnerships to develop technology, innovation, and manufacturing sectors		X	X
RECOMPETE Pilot Program at the Department of Commerce's Economic Development Administration (EDA)	$1 billion	Department of Commerce	To alleviate persistent economic distress and support long-term comprehensive economic development and job creation in the most distressed communities			X
Establishes the Directorate for Technology, Innovation, and Partnerships (TIP) within the NSF	$20 billion	National Science Foundation	Establishes the critical mission to advance critical and emerging technologies, address pressing societal and economic challenges, and accelerate the translation of research results from lab to market and society			X
National Science Foundation	$81 billion	National Science Foundation	Doubles the NSF annual budget with specific guidance for STEM education		X	X
STEM Education and Workforce Development Activities	$13 billion (within the $81B budget)	National Science Foundation	Authorizes new and expanded investments in STEM education and training from K-12 to community college, undergraduate, and graduate education; NSF increased scholarship opportunities		X	X

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	UPSTREAM	MIDSTREAM	DOWNSTREAM
Energy, Power, Control, and Networks (EPCN)	$81 billion across all NSF Programs	National Science Foundation	Encourage research on emerging technologies and applications including battery management systems; hybrid and electric vehicles			X
Research Advanced by Interdisciplinary Science and Engineering (RAISE) and Early-concept Grants for Exploratory Research (EAGER)	$81 billion across all NSF Programs	National Science Foundation	Focus areas include: Critical Materials for Clean Energy Technologies – their Recovery, Resue, and Recycling (new approaches to materials recovery and recycling; deposit discovery and characterization; fundamental research on advanced manufacturing to allow simpler recovery at end-of-use; and advancing the fundamental understanding of challenges and potential solutions to enable reuse of critical materials); Education and Workforce Development Efforts		X	X
Advanced Materials Research	$81 billion across all NSF Programs	National Science Foundation	Fundamental research to understand, design and synthesize new materials		X	X
NSF Regional Innovation Engines	$81 billion across all NSF Programs	National Science Foundation / U.S. Economic Development Administration	Foster innovation ecosystems		X	X

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	UPSTREAM	MIDSTREAM	DOWNSTREAM
Enabling Partnerships to Increase Innovation Capacity (EPIIC)	$81 billion across all NSF Programs	National Science Foundation / U.S. Economic Development Administration	Program to build capacity among minority-serving institutions, two-year institutions, undergraduate institutions, and other emerging research institutions in regional innovation ecosystem		X	X

APPENDIX H. PROGRAMS FUNDED THROUGH THE IRA

The Inflation Reduction Act (IRA) – 16 August 2022

Overall Funding and Purpose: Raise $738B = Curb inflation by reducing the federal government budget deficit (tax reform) and lowering prescription drug prices (prescription drug reform)

Overall: Spending $891B = Energy, climate change, modernize and expand the Internal Revenue Service (IRS), and Affordable Care Act subsidies (3-years)

Subset: $783B = Focuses on improving clean energy manufacturing and recycling; industrial decarbonization; critical materials processing, refining, and recycling; incentivizing domestic production; improving supply chains; and electrifying heavy-duty vehicles.

Subset: $64B = Affordable Care Act subsidies (3-years)

Subset: $44B = Changes to Medicare Part D

Subset: $80B = Modernize and expand the Internal Revenue Service (IRS)

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	Upstream	Midstream	Downstream
Advanced Technology Vehicles Manufacturing (ATVM) Direct Loan Program	$3 billion	Department of Energy / Loan Programs Office	To provide loans to support manufacturing a range of advanced technology vehicles and their components, including light-duty vehicles, medium- and heavy-duty vehicles, locomotives, maritime vessels including offshore wind vessels, aviation, and hyperloop		X	X
Clean Heavy-Duty Vehicle Program	$1 billion	Environmental Protection Agency / Office of Air and Radiation	To provide funding to offset the costs of replacing heavy-duty Class 6 and 7 commercial vehicles with zero-emission vehicles; deploying infrastructure needed to charge, fuel, or maintain these zero-emission vehicles; and developing and training the necessary workforce			X
Domestic Manufacturing Conversion Grants	$2 billion	Department of Energy / Office of Manufacturing and Energy Supply Chains	To provide cost-shared grants for domestic production of efficient hybrid, plug-in electric hybrid, plug-in electric drive, and hydrogen fuel cell electric vehicles or components for these vehicles		X	X
Advanced Manufacturing Production Credit	$30.62 billion	Department of the Treasury	Tax credit for domestic manufacturing of components along the supply chain for solar modules, wind turbines, battery cells and modules, and critical minerals processing		X	X
Clean Vehicle Tax Credit	$7,500/per vehicle	Department of the Treasury	Tax credit for consumers purchasing new qualifying clean vehicles, including battery electric, plug-in hybrid, or fuel cell electric vehicles; the battery's	X	X	X

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	Upstream	Midstream	Downstream
			components must meet certain standards for manufacturing or assembly; and the battery's critical minerals must meet certain requirements for sourcing or processing in the U.S.			
U.S. Postal Service Clean Fleets	$3 billion	U.S. Postal Service	To purchase zero-emission delivery vehicles and to purchase, design, and install the requisite infrastructure to support zero-emission delivery vehicles at U.S. Postal Service facilities			X
Energy Infrastructure Reinvestment Financing	$5 billion	Department of Energy / Loan Programs Office	Loans to projects that retool, repower, repurpose, or replace energy infrastructure that has ceased operations which could include repurposing shuttered fossil energy facilities for clean energy production, retooling infrastructure from power plants that have ceased operations for new clean energy uses, or updating operating energy infrastructure with emissions control technologies, including carbon capture, utilization, and storage		X	X
Extension and Expansion of the Advanced Energy Project Credit	$10 billion	Department of the Treasury / Department of Energy	Allocate funding to re-equip, expand, or establish an industrial or manufacturing facility for the production or recycling of a range of renewable energy and energy efficiency equipment, carbon capture equipment, and advanced vehicles; re-equip, expand, or establish an industrial		X	

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	Upstream	Midstream	Downstream
			facility for the processing, refining, or recycling of critical materials			
Fueling Aviations Sustainable Transition Technology (FAST-Tech)	$46.53 million	Department of Transportation / Federal Aviation Administration	To provide funding to design, prototype, and test discrete low emission aviation technologies; and enhance aircraft and engine technology testing and demonstration capabilities to accelerate development and demonstration of a broad range of low-emission aircraft technologies			X
Funding for Department of Energy Loan Programs Office	$3.6 billion	Department of Energy / Loan Programs Office	To support loans for innovative clean energy technologies, including critical minerals processing, manufacturing, and recycling		X	X
National Laboratory Infrastructure Improvements (National Renewable Energy Laboratory)	$150 million	Department of Energy / Office of Energy Efficiency and Renewable Energy	To support infrastructure improvements to advance solutions-driven research and innovation at the National Renewable Energy Laboratory which supports research in advanced manufacturing, energy analysis, energy storage, integrated energy solutions, materials science, etc.		X	X
National Laboratory Infrastructure Improvements (National Energy Technology Laboratory)	$150 million	Department of Energy / Office of Fossil Energy and Carbon Management	To support infrastructure improvements to advance solutions-driven research and innovation at the National Energy Technology Laboratory which supports the Battery Workforce Initiative			X

Major Battery Investment Programs	Funding	Sponsor / Funding Source	Purpose	Upstream	Midstream	Downstream
National Laboratory Infrastructure Improvements (Office of Science)	$1.55 billion	Department of Energy / Office of Science	To support infrastructure improvements and projects to advance solutions-driven research and innovation across the 10 x national laboratories supported by the Office of Science			X

APPENDIX I. PROPOSED COURSES OF ACTION

1.	Improve coordination and communication throughout the battery industry	($3,500,000 over 5 years)
2.	Develop education and training programs for the battery industry	($27,000,000 over 15 years)
3.	Facilitate access to educational programs across the battery workforce	($9,500,000 over 8 years)
4.	Improve recruitment into education for the battery industry	($48,000,000 over 13.75 years)
5.	Create national strategy for development of current workforce	($7,150,000 over 8.5 years)
6.	Improve recruitment into the battery industry	($10,000,000 over 9 years)
7.	Create ROS inventory for all sectors of the battery industry	($6,000,000 over 6.25 years)

NOTE: Durations and costs do not consider potential for simultaneous effort.

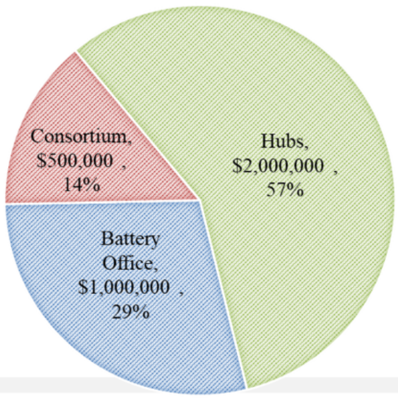
COURSE OF ACTION PROPOSAL #1

Improve coordination and communication throughout the battery industry.

Problem Statement

There is no effective and enduring means of communication and coordination across the full battery value chain, to include industry, government, and academia.

Financial Considerations



No action option

Status Quo

- ✓ Allow the constituents of the battery value chain to continue operating in isolation.
- ✓ Rely on current consortia (i.e., FCAB), to provide organizing impetus to the battery industry.

Impact

Status Quo

- ✓ Reduction in potential synergies, effectiveness, and opportunities for collaboration.
- ✓ As current consortia were not conceived as comprehensive and enduring bodies capable of impact and direction, they will likely remain advisory networks.

Proposed Solution

Proposal

1. Create an American Battery Coordination (ABC) Office at the federal/national level to oversee supply chain activities, coordinate execution for greatest efficiency, communicate throughout the chain, oversee regional hubs and int'l recruitment, and serve as executive administrator for all national battery policies and activities(2 yrs / 1 FTE) (Does not include operational funding/manning, only development).
2. Establish an enduring, national level consortium of industry, government, academia, and consumers to forge relationships and share information. May consist in expanding remit of existing organization or establishing a new one (1 yr / 1 FTE).
3. Create regional special-interest "hubs" (2 yrs / 2 FTE).

NOTES:
1 – Items are not sequential and may be pursued simultaneously with a workforce of 3 -4 FTE over 4 -5 years.

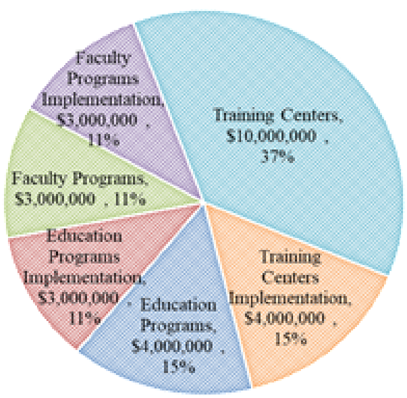
COURSE OF ACTION PROPOSAL #2

Develop education and training programs for the battery industry.

Problem Statement

Educational programs are not available in the needed numbers or content to fulfill the needs of battery industry employers.

Financial Considerations



No action option — Status Quo

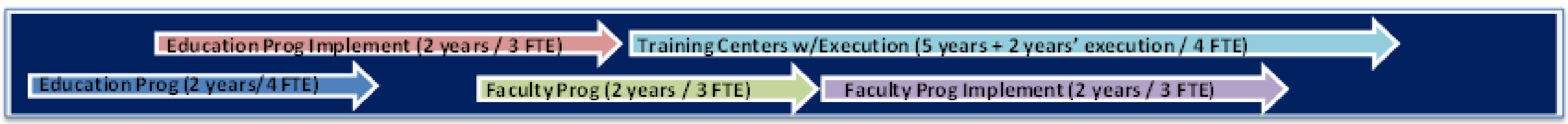
- ✓ Allow students to sift through the limited programs available and apply themselves to various industries in inconsistent numbers.
- ✓ Rely on state programs like NENY to take the lead in producing educational programs, recognizing that few states are as active as NY.

Impact — Status Quo

- ✓ There is unlikely to be significant improvement in the availability or appropriateness of program availability in the near term.
- ✓ Targeted education and training will be available only to those who reside in a state that takes an active interest in the battery industry.

Proposed Solution — Proposal

1. Develop standardized programs of education to be offered at universities, colleges, and trade schools. Offer federal incentives to provider and student. (2 years to execution / 4 FTE (2 years' execution / 3 FTE)
2. Develop faculty/instructor training courses to reskill/upskill faculty to teach proposed courses. Offer federal incentives to the schools that offer the programs and hire the graduates, as well as the faculty/instructor students. (2 years to execution (2 years' execution) / 3 FTE)
3. Establish four training centers across the country (5 years to execution (2 years execution) / 4 FTE).



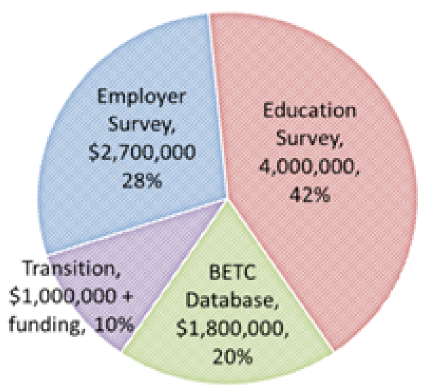
COURSE OF ACTION PROPOSAL #3

Facilitate access to educational programs across the battery workforce.

Problem Statement

There is very limited awareness of and access to battery education/training programs by potential students and employees.

Financial Considerations



No action option — Status Quo

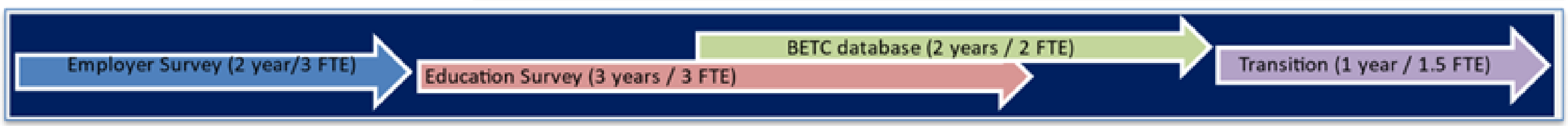
- ✓ Rely on prospective students or employees to contact schools and training centers until they find useful programs.
- ✓ Train/educate new employees after hiring, at corporate expense.
- ✓ Await results of NABWC's 2nd pillar.

Impact — Status Quo

- ✓ Those who seek to prepare for the battery industry may be lost to other industries due to a dearth of information.
- ✓ Current members of the workforce may leave due to a belief that development opportunities are limited, even as they increase.

Proposed Solution — Proposal

1. Survey employers throughout all sectors of the battery industry to determine ROS. (2 yrs/3 FTE)
2. Using ROS inventory, survey all U.S. education and training providers available to the public to catalogue all relevant programs. (3yrs/3 FTE)
3. Produce Battery Education and Training Catalog database. (2yrs/2 FTE)
4. Devise/implement transition (to include dbf maintenance) to ensure enduring usage (1 yr/1.5 FTE) (does not including funding of transition options).



COURSE OF ACTION PROPOSAL #4

Improve recruitment into education for the battery industry .

Problem Statement

Students are not enrolling in existing programs of education that might lead to careers in the battery industry.

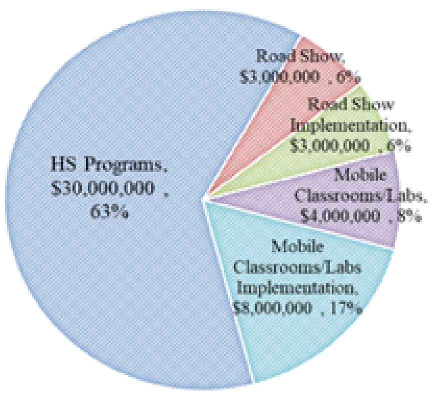
No action option — Status Quo

- ✓ Rely on the current, disjointed mechanisms of education/training recruitment to mature. One or more of them may grow to close some or all of the current gaps.
- ✓ Allow the CAR BIETNA survey to lead other groups to implement similar recommendations to below.

Impact — Status Quo

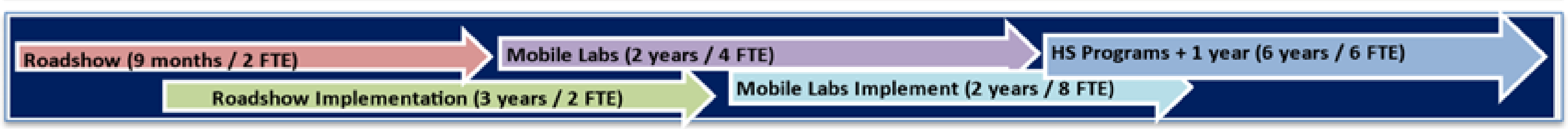
- ✓ Each capability sector will continue experiencing manpower shortages that will prevent support of the other capabilities, slowing down the whole value chain.

Financial Considerations



Proposed Solution — Proposal

1. Establish (and fund first year of) high school programs in 25 states and territories using NENY's "New Energy Lab" blueprint. Offer federal incentives to provider and student. (6 years / 6 FTE) – Scalable, i.e., 5 states first
2. Develop and execute roadshows at schools and colleges where local talent is sought (largely western U.S. for mining, and battery belt for manufacturing). (9 months to execution (3 years' execution) / 2 FTE)
3. Establish 4 mobile classrooms/labs (each in a U.S. region) that can be used for training and recruiting (2 years to execution /4 FTE (2 years' execution / 8 FTE)



COURSE OF ACTION PROPOSAL #5

Create national strategy for development of current workforce.

Problem Statement

Urgent need for employee reskilling and educational support to current workforce exists, with no consistent or coordinated programs available.

No action option

Status Quo

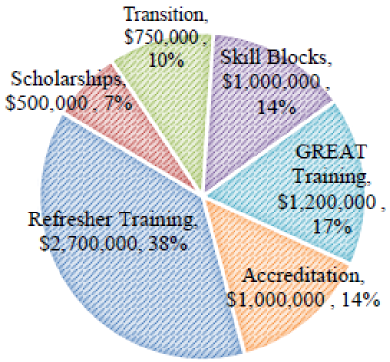
- ✓ Continue localized programs of instruction, often devised by employers, or contractors paid by the mines.
- ✓ Rely on workers to find their own upskilling resources.

Impact

Status Quo

- ✓ Workers will only benefit from inconsistent levels and types of development, as determined by individual employers.
- ✓ There is less incentive for the current workforce to remain due to lack of development opportunities.

Financial Considerations



Proposed Solution per Capability Sector

Proposal

1. Create and promulgate “Skill Blocks” that identify sets of occupational skills common to the jobs within the blocks (1 yr/1.5 FTE)
2. Create technical refresher training for each skill block. (2 yrs/3 FTE)
3. Create a program of online annual General Readiness Education and Training (“G.R.E.A.T.” training) that covers safety, culture, interpersonal communication, and other skills universally applicable within the workforce. (1.5 yrs/2 FTE)
4. Develop and market federally-funded scholarships (1 yr/1 FTE) **(Does not include funding of scholarships.)**
5. Establish an accreditation board and process for all battery curricula. (2 yr/1 FTE).
6. Devise and implement transition plan to ensure enduring usage (1 yr/1.5 FTE)

NOTES:
1 – Items are not sequential and may be pursued simultaneously with a workforce of 3-4 FTE over 4-5 yrs.
2 – Proposed solutions need to be applied to each capability sector individually, although cost and effort synergies may be realized.

COURSE OF ACTION PROPOSAL #6

Improve recruitment into the battery industry.

Problem Statement

There are persistent workforce shortages across the battery value chain, particularly for skilled local labor, technical and research and development roles.

No action option

Status Quo

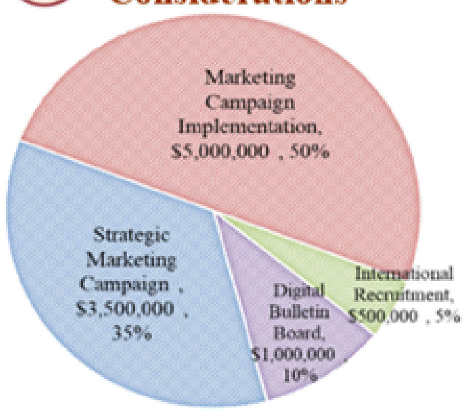
- ✓ Rely on existing recruiting sources to fill the gaps—unions, colleges, job boards, etc.
- ✓ Rely on state programs like NENY to take the lead in attracting potential employees, recognizing that few states are as active as NY.

Impact

Status Quo

- ✓ There is unlikely to be improvement in the availability of employees, particularly in areas of greatest need.
- ✓ Employees will only be available for recruitment from those states that takes an active interest in the battery industry and establish state-level programs.

Financial Considerations



Proposed Solution

Proposal

1. Create a marketing strategy to recruit to the battery industry, targeting the required domestic and allied demographic. Use data-driven means (i.e., targeted texting, social media searches. Effect fresh branding of the battery industry, educational and professional pathways, climate, and call to national service. Engage at job fairs. (2 yrs development (5 yrs' execution) / 3 FTE).
2. Create streamlined process for international recruitment, to include visa, relocation, settlement, language training, and on boarding (1 year / 1 FTE).
3. Establish/promulgate web-based digital bulletin board for posting of positions throughout the battery industry. Include transition planning (1 yr / 2 FTE).

COURSE OF ACTION PROPOSAL #7

Create ROS inventory for all sectors of the battery industry.

Problem Statement

There is no list of required occupational skills (ROS), resulting in limited ability to plan the workforce.

No action option

Status Quo

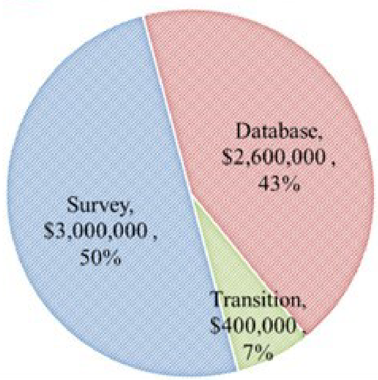
- ✓ Use existing, generalized resources to determine workforce needs.
- ✓ Rely on DoE BWI work (estimated 2 yrs for study, transition plans not established, 2 occupations studied to date)

Impact

Status Quo

- ✓ Programs of education will be planned for general needs, not specific.
- ✓ Recruitment will continue to be conducted individually by companies, without any nation-wide effort.

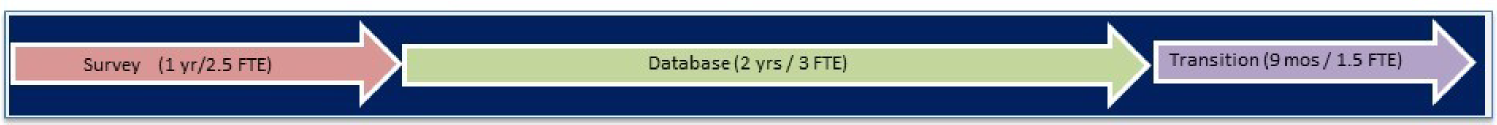
Financial Considerations



Proposed Solution

Proposal

1. Survey major employers and employee providers in each capability sector as to required occupational skills and compile into skill groups (3 yrs (1 per sector)/2.5 FTE) using DOE/BWI model.
2. Produce results database—ROS, skills groups, occupations, entry points, sources of education (2.5 yrs/3 FTE), including results of BWI study.
3. Devise and implement transition plan (to include database maintenance) to ensure enduring usage (9 mos/1.5 FTE) (does not including funding of transition options).



APPENDIX J. PROPOSED COURSES OF ACTION SELECTION MATRIX

Provided for convenience and in the interest of clarity, this appendix may be used to indicate which COAs will be implemented. Within ninety days of the Phase I(b) COA selections being communicated to the NPS/EAG research team, the team will provide to the sponsor an action plan that indicates the timing of each COA's implementation and the funding necessitated by that timing. Where complementary COAs or COA tasks are selected for implementation, resource savings are likely to be realized. In the selection matrix, the execution of any task is presumed to be unsynchronized with any other task. In actual execution, however, this is unlikely. Please note that evaluation criteria and success indicators are for the development phase, not implementation, unless so indicated.

Date:________________________

From: OUSD (Acquisition & Sustainment)
To: NPS Energy Academic Group
Subj: Selection of Courses of Action

1. The Naval Postgraduate School Energy Academic Group (NPS EAG) is directed to begin work on the Courses of Action indicated below, subject to any included notes.
2. It is anticipated that within 90 days of this date, the NPS EAG will submit an informational action plan which includes a sequencing of effort and funding that will indicate what is to be done, on what schedule, and when funding will be required.

Strategic Timeline Due:	01 April 2024	(by NPS EAG)
COA Selection Due:	28 June 2024	(by Sponsor)
Action Plan:	01 November 2024	(by NPS EAG)

RESEARCH REPORT ACCEPTANCE AND FORMAL CLOSURE OF PHASE I:____________________________________

Signature

COA PROPOSAL	TASK	SAMPLE EVALUATION CRITERIA	SAMPLE SUCCESS INDICATORS	TERM (YEARS)	FTE	COST (1,000s)	IMPLEMENT	NOTES
#1: Improve coordination and communication throughout the battery industry	CREATE A BATTERY OFFICE	Charter and stakeholder involvement; funding	Charter developed and approved by stakeholders; ongoing funding committed.	2	1	$ 1,000	YES NO	
	ESTABLISH REGIONAL HUBS NATIONWIDE	Level of stakeholder responsibility; organizational documents; # of active hubs; funding	Executive committee formed; active approved charter; 2 hubs per year; funding committed	2	2	$ 2,000	YES NO	
	ESTABLISH ENDURING CONSORTIUM	Status of Assoc for Collaborative Leadership (ACL) KPIs	Satisfactory completion of ACL checklist	1	1	$ 500	YES NO	
			TOTALS	5	4	$ 3,500		

Running Total Cost: $3,500,000

COA PROPOSAL	TASK	SAMPLE EVALUATION CRITERIA	SAMPLE SUCCESS INDICATORS	TERM (YEARS)	FTE	COST (1,000s)	IMPLEMENT	NOTES
#2: Develop education and training programs for the battery industry.	DEVELOP STANDARDIZED PROGRAMS OF EDUCATION	Relevance; Efficiency;	Meets stated goals as set by industry and academe; can be accomplished w/available funding;	2	4	$ 4,000	YES NO	
	IMPLEMENT EDUCATION PROGRAMS	Effectiveness; Impact; Sustainability	Student outcomes indicate achievement of learning; positive student/employer expectations (incoming) vs. satisfactory outcomes (outgoing); resources committed and strong employer support	2	3	$ 3,000	YES NO	
	DEVELOP FACULTY TRAINING COURSES	Relevance; Efficiency;	Meets stated goals as set by industry and academe; can be accomplished w/available funding;	2	3	$ 3,000	YES NO	
	IMPLEMENT FACULTY TRAINING COURSES	Effectiveness; Impact; Sustainability	Student-faculty outcomes indicate achievement of learning; positive student/ employer expectations (incoming) vs. satisfactory outcomes (outgoing); resources committed and strong employer support	2	3	$ 3,000	YES NO	
	DEVELOP REGIONAL TRAINING CENTERS	Relevance; Efficiency;	Meets stated goals as set by industry and academe; goals can be accomplished w/ funding allocated	5	4	$10,000	YES NO	

	IMPLEMENT REGIONAL TRAINING CENTERS	Effectiveness; Impact; Sustainability	Student outcomes indicate achievement of learning; positive student/employer expectations (incoming) vs. satisfactory outcomes (outgoing); resources committed and strong employer support	2	4	$4,000	YES NO	
			TOTALS	15	21	$27,000		Running Total Cost: $30,500,000

COA PROPOSAL	TASK	SAMPLE EVALUATION CRITERIA	SAMPLE SUCCESS INDICATORS	TERM (YEARS)	FTE	COST (1,000s)	IMPLEMENT	NOTES
#3: Facilitate access to educational programs across the battery workforce.	SURVEY EMPLOYERS AS TO NEED	# of employers surveyed on time; response rate	% survey rate targets in each sector; 15% response rate	2	3	$ 2,700	YES NO	
	SURVEY EDUCATION/ TRAINING PROVIDERS RE: AVAILABILITY OF PROGRAMS	# of providers surveyed on time; response rate	% survey rate targets at each educational level; 20% response rate	3	3	$ 4,000	YES NO	
	PRODUCE BETC DATABASE	Technical clearance; timeliness; effectiveness	Trouble calls less than 5% of users; completed on time; user surveys indicate utility	2	2	$ 1,800	YES NO	
	TRANSITION PLAN	Plan acceptance	Ownership established; responsibility/ process for maintenance established; long-term funding in place	1	1.5	$ 1,000	YES NO	
			TOTALS	8	9.5	$ 9,500		

Running Total Cost: $40,000,000

COA PROPOSAL	TASK	SAMPLE EVALUATION CRITERIA	SAMPLE SUCCESS INDICATORS	TERM (YEARS)	FTE	COST (1,000s)	IMPLEMENT	NOTES
#4: Improve recruitment into education for the battery industry	ESTABLISH/ IMPLEMENT HIGH SCHOOL PROGRAMS	Relevance; Efficiency; Effectiveness; Impact; Sustainability; Conversion rate	Meets stated goals as set by industry and academe; can be accomplished w/ available funding; Student outcomes indicate achievement of learning; positive student/employer expectations (incoming) vs. satisfactory outcomes (outgoing); resources committed and strong employer support; 1% student conversion rate	6	6	$ 30,000	YES NO	
	DEVELOP MOBILE CLASSROOMS	Relevance; Efficiency; Effectiveness; Impact; Sustainability	Meets stated goals as set by industry and academe; can be accomplished w/ available funding; Student outcomes indicate achievement of learning; positive student/employer expectations (incoming) vs. satisfactory outcomes (outgoing); resources committed and strong employer support	2	4	$ 4,000	YES NO	
	IMPLEMENT MOBILE CLASSROOMS	Conversion rate; ROI per student	2% conversion rate per region; positive ROI per student	2	8	$ 8,000	YES NO	

	DEVELOP ROAD SHOW	Relevance; Efficiency; Effectiveness; Impact; Sustainability	Meets stated goals as set by industry and academe; can be accomplished w/ available funding; Student outcomes indicate achievement of learning; positive student/employer expectations (incoming) vs. satisfactory outcomes (outgoing); resources committed and strong employer support	.75	2	$ 3,000	YES NO	
	EXECUTE ROAD SHOWS	Conversion rate; ROI per student	2% conversion rate per region; positive ROI per student	3	2	$ 3,000	YES NO	
			TOTALS	13.75	22	$ 48,000	Running Total Cost: $88,000,000	

COA PROPOSAL	TASK	SAMPLE EVALUATION CRITERIA	SAMPLE SUCCESS INDICATORS	TERM (YEARS)	FTE	COST (1,000s)	IMPLEMENT	NOTES
#5: Create national strategy for development of current workforce.	CREATE SKILL BLOCKS	Creation of skill blocks validated by industry	Satisfactory industry QR; on-time delivery	1	1.5	$ 1,000	YES NO	
	CREATE TECHNICAL REFRESHER TRAINING FOR EACH SKILL BLOCK	Creation of technical refresher training validated by industry and academia	Satisfactory industrial and academic QR; on-time delivery	2	3	$ 2,700	YES NO	
	DEVELOP G.R.E.A.T. TRAINING	Creation of G.R.E.A.T. Training validated by industry	Satisfactory industrial and academic QR; on-time delivery	1.5	2	$ 1,200	YES NO	
	DEVELOP FEDERALLY-FUNDED SCHOLARSHIPS	Creation of plan capable of being funded.	Satisfactory government QR; on-time delivery.	1	1	$ 500	YES NO	
	CREATE BATTERY CURRICULA ACCREDIT-ATION BOARD	Accreditation criteria established. Accreditation criteria approved.	Charter created and accreditation board funded. Stakeholder review and approval completed.	2	1	$ 1,000	YES NO	
	TRANSITION PLAN	Plan acceptance	Contract/ agreement in place	1	1.5	$ 750	YES / NO	
			TOTALS	8.5	10	$ 7,150	Running Total Cost: $95,150,000	

COA PROPOSAL	TASK	SAMPLE EVALUATION CRITERIA	SAMPLE SUCCESS INDICATORS	TERM (YEARS)	FTE	COST (1,000s)	IMPLEMENT	NOTES
#6: Improve recruitment into the battery industry.	CREATE RECRUITMENT MARKETING CAMPAIGN	Creation of approved campaign; timeliness	Campaign endorsed by industry; launched on time	2	3	$ 3,500	YES NO	
	IMPLEMENT MARKETING CAMPAIGN	KPIs: Time to hire, quality of hire	KPIs for candidates at sampled institutions increase by <10%	5	3	$ 5,000	YES NO	
	STREAMLINE INTERNATIONAL RECRUITMENT	KPIs: Time to hire, quality of hire	KPIs for candidates at sampled institutions increase by <10%	1	1	$ 500	YES NO	
	ESTABLISH WEB-BASED DIGITAL JOB BOARD; IMPLEMENT TRANSITION	# of users; plan acceptance	5k users by end of year 1 w/ growth in usage; contract/ agreement in place for maintenance	1	2	$ 1,000	YES NO	
			TOTALS	9	9	$ 10,000	Running Total Cost: $105,150,000	

COA PROPOSAL	TASK	SAMPLE EVALUATION CRITERIA	SAMPLE SUCCESS INDICATORS	TERM (YEARS)	FTE	COST (1,000s)	IMPLEMENT	NOTES
#7: Create ROS inventory for all sectors of the battery industry.	SURVEY EMPLOYERS	# of employers surveyed on time vs. total # of employers; response	50% mining employers >25 employees surveyed; 15% response rate	3	2.5	$ 3,000	YES NO	
	PRODUCE DATABASE	% of ROS implemented; quality review	100% ROS implemented on time; satisfactory quality review	2.5	3	$ 2,600	YES NO	
	TRANSITION PLAN	Readiness for funding	Ready for funding on time	0.75	1.5	$ 400	YES NO	
			TOTALS	6.25	7	$ 6,000	Running Total Cost: $111,650,000	