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NPS Battery Workforce Development
Summary of Ongoing Efforts and Activities
Phase 1(a)

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Abstract

The lack of expertise throughout the U.S. battery value chain will require nearly 3.5 million workers over the next decade; however, existing skills gaps will likely result in over 2 million of those jobs going unfilled. This systemic deficiency in skills and knowledge ranges from mining and refining to the final application in the field, and to the recycling of waste products of both production and end use. Each of these gaps, for any one of the resultant products as well as the aggregated deficiencies, has the potential to become a national security vulnerability. Therefore, the creation of a domestic battery supply chain requires a national commitment to achieve the requisite scientific breakthroughs and to develop an adequate manufacturing base capable of supporting American battery sufficiency. Toward understanding the gaps in the battery workforce, the researchers have sought to discover the work currently underway in this space, by the Federal Government and selected state governments, academia, and industry. It contains a snapshot of the battery workforce and industry as it stands, with recommendations as to how the next phase of research should be approached.

Acknowledgements

It is with extreme gratitude that we acknowledge the time and effort devoted to this project by a cross-section of representation from Government, academia, and industry. They served within the Stakeholder Group and provided contacts, context, and advice that was of inestimable value in moving the research forward.

We particularly thank Bernie Kotlier and Vijay Dhar of New Energy Nexus and Faraz Khan and Brian Kildee of International Federation of Professional & Technical Engineers for their time and effort.

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Executive Summary

The lack of expertise within the United States' battery value chain has created a national security vulnerability. In the next decade, it is estimated this country 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 and refining to the final application in the field, and even to the recycling of waste products. Each of these gaps, for any one of the resultant products as well as for the aggregated deficiencies, has the potential to become a national security vulnerability. Therefore, reinvigorating the domestic battery supply chain requires a national commitment to achieve the requisite scientific breakthroughs, to encourage both skilled and unskilled workers into the battery workforce, so that the nation might develop and solidify a manufacturing base.

The Naval Postgraduate School (NPS) Battery Workforce Development (BWD) program covers both new and continuing thrusts within its Energy Academic Group's (EAG's) ongoing efforts in DoD energy security research, outreach, curriculum development, and training programs. This paper expands these efforts beyond NPS to support energy-related research, and the delivery of professional, technical, research-based and accredited instruction. It seeks to identify areas where targeted teaching and degree programs, as well as just-in-time education and other forms of workforce development might further energy capabilities and capacities, as well as U.S. national interests.

The research began with this central question: What actions can be taken by the Federal Government, academia, and the industrial sector to enhance the development of the battery and strategic minerals workforce in the U.S. as contributors to national security?

The NPS BWD team's mission, which follows from the answer to this question, consists of two distinct phases. The gaps in the national effort to attract and train/educate members of the battery workforce will be identified. Once the gaps are understood, the research team will devise and begin to implement a mitigating strategy. The resulting workforce will be better equipped to discover, mine, refine, deploy, and recycle strategic minerals from domestic sources, and to conduct advanced research and development.

To identify the gaps in the battery workforce, the researchers have initially sought to discover the work currently underway, by Federal and selected state governments, academia, and industry.

For purposes of clarity and compartmentalization, the battery sector is divided into upstream, midstream and downstream sub-sectors. This paper discusses how each element of the triad of Government, academia, and industry is contributing to BWD within or across each of the three "streams." It then offers recommendations for the conduct of the gap analysis which forms the remainder of Phase I of this project.

Work being done in this area currently has benefited from a whole of government approach, which is likely to be the most productive approach to take where close coordination with academia and industry remains a priority. However, the existing emphasis on lithium-based batteries presents a challenge, notably through supply chain constraints and the safety issues inherent in this technology.

While there is much activity occurring in all sectors, examination of the downstream sector reveals many unanswered questions. While the U.S. is making significant contributions in the upstream and midstream sectors, the U.S. is not a major actor in the downstream sector. Robust funding streams in the Government's response to this reality has demonstrated overlapping equities in this space, with the potential for waste. Arguably, the downstream sector might be considered the weakest of the three, despite the attention it receives through integrated programs of study and assistance from public/private ventures and government programs. The activities of the academy and industry are sparser and more challenging to identify in this sector, and it is likely that the following phases of this project, while continuing to consider all sectors, will make the greatest contributions in the downstream sector.

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(06 July 2023)

CHAPTER ONE

1. Introduction

Due in large part to environmental concerns, energy storage technologies have moved to the forefront of many power generation, distribution, and storage conversations. This newfound prominence is seated in the global energy sector's shift from fossil fuel-based systems of energy production and consumption to renewable energy sources and their requisite power storage solutions. Lithium Ion batteries, in particular, are pertinent due to increased demand in all facets of modern life and national security, and their potential to mitigate many of the shortcomings of intermittent renewable energy sources. The availability of batteries is a vital military operational consideration allowing commanders mission flexibility and efficiency in an environment in which the United States must compete against great power adversaries.

Batteries require a large volume of minerals—frequently rare earth, or strategic minerals—that must be extracted from sub-surface mines or repositories. There is a lack of expertise within the United States, which has been years in the making and extends throughout the battery value chain. Indeed, studies demonstrate a requirement for nearly 3-1/2 million U.S. manufacturing workers over the next decade, but skills gaps will result in over 2 million of those jobs going unfilled. This systemic deficiency in skills and knowledge ranges from mining to refining to the final application in the field, and even through to the recycling of waste products of both production and end use. Each of these gaps, for any one of the resultant products as well as for the aggregated deficiencies, has the potential to become a national security vulnerability.

Recent reports have highlighted the need for the U.S. to develop and sustain a robust workforce for the domestic battery supply chain. This includes the President's 100-Day Supply Chain Review and the Department of Energy's 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 calls for the United States and its partners to establish a secure battery materials and technology supply chain by 2030. The creation of a domestic battery supply chain requires both a national commitment to achieve the requisite scientific breakthroughs, and to the re-creation of a national manufacturing base. U.S. Secretary of Energy 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, "Investments in Battery Supply Chain").

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1.1 Purpose of the Research

The research began with this central question: What actions can be taken by the Federal Government, academia, and the industrial sector to enhance the development of the battery and strategic minerals workforce in the U.S. as contributors to national security?

The NPS BWD team's mission, which follows from the answer to this question, consists of two distinct phases. First, the BWD team will identify the gaps in the national effort to attract and train or educate individuals to join the battery workforce. Once the gaps are understood, the research team will implement a mitigation strategy. The resulting workforce will then be better equipped to discover, mine, refine, deploy, and recycle strategic minerals from domestic sources, and to enact advanced R&D.

1.2 Phase I(a) Research Concept and Objective

As the existing battery supply chain is international, complex, and securitized, with multiple stakeholders from across the global economy, overlapping interests and mitigation strategies are to be expected. Concurrent and complementary, but potentially duplicative efforts by other organizations, may be underway during the period of performance of this project. Therefore, the NPS team has **conducted a preliminary assessment to discover similar or redundant projects in the battery workforce development space**. This Phase I(a) effort is designed to identify existing efforts through a high-level overview of the sector, with a report entitled, "Summary of Ongoing Efforts and Activities." This report will also inform subsequent phases of the project, notably Phase I(b), which will build on the work of Phase I(a) to produce a strategic roadmap for a workforce development program. It will identify stakeholder groups, key targets, and 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). A Battery Workforce Advisory Group will also be created in Phase I(b).

CHAPTER TWO

2. Literature Review of Key Documents

A review of the existing literature in the field of batteries and critical or strategic minerals was a key element of Phase I(a). As the goal of this part of Phase I was to determine what is currently underway in the field, the guiding documents created by the many organizations that are engaging in this work was a sensible starting point. Noted here are key documents produced by stakeholders within the industry.

Arora, et al. (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.

Lithium-based energy storage is a key technology of the 21st century. It will power future transportation systems, power grids (which are increasingly reliant on variable, renewable energy), and all manner of consumer, medical, and industrial electronics. Certain economic competitors of the United States recognized the importance of lithium battery technology nearly 20 years ago and began investing heavily. Although U.S. scientists originally invented lithium battery technology, according to the report, the U.S. is now at least a decade behind in this critically important industrial sector. Key deficiencies exist in manufacturing acumen and access to both raw and refined energy materials.

U.S. companies today play only a minor role in domestic and international markets for lithium battery production, however, the market for lithium battery cells in the U.S. is growing rapidly and is expected to reach $55 billion per year by 2030. Yet it is estimated that under current conditions U.S. companies and workers will capture less than 30% of the value of domestically consumed lithium-based cells.

The lack of a substantial lithium battery supply chain in the United States, coupled with limited access to energy materials poses serious threats to our national and economic security. These threats will not only inhibit domestic manufacture of lithium batteries but will stymie the development and growth of the many downstream industries that design, manufacture, and operate products powered by lithium batteries. Those downstream industries collectively contribute more than twenty times the gross domestic product and jobs contributions of the battery industry alone.

Building a robust and sustainable lithium battery manufacturing base in the United States will require addressing the challenges that have depressed investment in the domestic lithium battery supply chain. It must also respond to the aggressive actions of competing nations that have recognized the importance of lithium battery technology.

Immediate next steps for key stakeholders:

U.S. Congress

- Pass reforms that accelerate critical mineral mining and processing projects.
- Appropriate funding for pre-commercial battery production facilities.
- Work with industry to create a consistent, unified national approach to lithium battery recycling.

U.S. Federal Agencies

- Collaborate with Li-Bridge to implement the recommendations made in this report.
- Consult with U.S. industry to draft effective implementation guidelines for the Inflation Reduction Act (IRA) to catalyze new investment in lithium battery development and manufacturing capacity, including electrodes and electrolyte salts, and electrolyte solvents.
- Direct R&D toward priority areas in partnership with the existing Federal agencies (e.g., DARPA, ARPA-E), national laboratories, civilian universities and manufacturing institutes, while expanding support for demonstration and deployment.
- Support the establishment of a National Battery Workforce Council dedicated to rapidly advance training and education of battery industry workers.

State/local governments

- Streamline and accelerate critical mineral mining and processing projects; develop industrial zones for energy materials and battery cell production.
- Partner with industry to build support for battery-related projects among local communities.

Industry

- Further define industry needs (including workforce training needs), step up efforts to enact battery standards, and help shape solutions which allow U.S. industry to participate in the manufacture of lithium battery technology.

Center for Energy Workforce Development. (2021). ***Gaps in the Energy Workforce 2021 Pipeline Survey Results.*** https://cewd.org/wp-content/uploads/2022/02/Gaps-In-Energy-Careers-Report-2022_Final-pages.pdf.

The Center for Energy Workforce Development (CEWD) focused its 2021 analysis on four key job categories; lineworkers, technicians, plant/field operators, and engineers. In addition, following the expected growth of the renewable sector, a Renewable Technician role was added in the category of key jobs. It is important to mention some differences from this survey relative to the previous survey, which was conducted in 2019. First, there was a drop in participation due to member and work processes. Second, the global pandemic affected national employment levels and the ability to forecast, especially when looking at attrition. It should be noted that other industry sectors have experienced similar situational anomalies in the inability to forecast anticipated hiring demand.

The five key job categories included in the data analysis now comprise 32% of the total utility workforce and are critical for the generation, transmission and distribution of electricity and natural gas across the country. The remaining 68% are comprised of corporate service departments including human resources, customer service, finance, and information technology, as well as other occupations essential for the sector. The survey findings are based on the responses from electric and natural gas energy companies across the United States that are members of CEWD. The data provided by participating companies included information on age, years of service, hires, and attrition, along with information on the diversity and veteran composition of the workforce.

The five key findings from the report's internal survey are:

1) The size of the energy workforce remains stable since the previous survey
2) The energy workforce continues to get younger
3) Retirement attrition has reached its lowest level since 2014
4) Non-retirement attrition increased specifically among younger workers
5) There was a slight increase in women and minority hiring, and a decrease in veteran hiring, which follows the national trend (Gaps in Energy Careers, p.3).

Department of Commerce. (2018). ***A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals.*** Retrieved from https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf.

The U.S. is dependent on foreign sources of many minerals and global supply chains that build value-added products, resulting in the potential for strategic vulnerabilities to our Nation's economic prosperity and national security. In 2018, Executive Order 13817 was issued to address these vulnerabilities. The President issued two taskings:

- The Department of the Interior, in coordination with other Federal agencies, will develop a list of minerals deemed critical, and;
- The Department of Commerce, in coordination with other Federal agencies, should develop a strategy to reduce the Nation's vulnerability to disruptions in the supply of critical minerals.

The Department of the Interior published a list of 35 critical minerals in May 2018. This report, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*, is the strategy directed by the Executive Order. It is a comprehensive interagency strategy to address vulnerabilities within the critical minerals supply chain, with both civilian and defense applications. Specifically, this Strategy identifies 24 goals and 61 recommendations that will:

1) Help identify new sources of critical minerals
2) Enhance activity at all levels of the supply chain, including exploration, mining, concentration, separation, alloying, recycling, and reprocessing
3) Stimulate private sector investment and growth of domestic downstream value-added processing and manufacturing; and
4) Ensure that miners, producers, and land managers have access to current mapping data.

Federal Consortium for Advanced Batteries. (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.

The Federal Consortium for Advanced Batteries (FCAB) is led by the Departments of Energy, Defense, Commerce, and State, as well as other organizations across the U.S. Government. FCAB brings together Federal agencies for a coordinated approach to ensuring a domestic supply of lithium batteries and accelerating the development of a robust and secure domestic industrial base. Strong collaboration with U.S. academic institutions, national laboratories, industrial stakeholders, and allies is an integral feature of this blueprint.

Establishing a domestic supply chain for lithium-based batteries requires a national commitment to achieve breakthrough scientific results and develop a manufacturing base that meets the demands of the growing electric vehicle (EV) and electrical grid storage markets. This document outlines a national blueprint for lithium-based batteries and investments in the domestic value chain.

FCAB brings together Federal agencies interested in ensuring a domestic supply of lithium batteries to accelerate the development of a resilient domestic industrial base. It promotes a

holistic approach that covers the lithium-based battery ecosystem, focusing on the development of a supply chain, from raw-materials production to end-of-life recycling. For each stage of the supply chain, this blueprint identifies key actions that Federal agencies can take to strengthen and bolster domestic performance. Beyond the supply chain, FCAB promotes other factors to develop a secure domestic battery ecosystem. This includes identifying Federal policies and authorities, enhancing protection of intellectual property (IP) and knowledge transfer, accelerating the development of lithium-based battery materials and bolstering technology transfer across commercial and defense markets.

Global Battery Alliance. (2019). ***A Vision for a Sustainable Battery Value Chain in 2030: Unlocking the Full Potential to Power Sustainable Development and Climate Change Mitigation.*** https://www3.weforum.org/docs/WEF_A_Vision_for_a_Sustainable_Battery_Value_Chain_in_2030_Report.pdf.

The Global Battery Alliance's 2030 vision outlines a world in which batteries power sustainable development. Batteries are a key technology to achieve the Paris Agreement, create significant economic value, increase energy access, and drive the global value chain. This report describes a vision for the future battery value chain, the levers for realizing batteries' positive impact, and recommendations to achieve that vision. It does not aim to be conclusive but is a foundational piece for additional analysis and consultation to identify further risks and develop implementation strategies.

Office of Secretary of Defense for Acquisition and Sustainment (Industrial Base Policy). (2021). ***Industrial Capabilities Report to Congress 2020 Annual Report***. https://www.businessdefense.gov/docs/resources/USA002573-20_ICR_2020_Web.pdf.

As the National Security Strategy noted, a "healthy defense industrial base is a critical element of U.S. power." The American military industrial base requires an accelerated national focus over the coming decade. These problems cannot be solved by assuming advanced technologies like autonomous systems, artificial intelligence (AI), and 5G will ensure American prominence. These advanced technologies rely on a manufacturing complex whose capability and capacity must secure and protect the DoD's most vital supply chains. These include microelectronics, space, cyber, nuclear, and hypersonics, as well as the more conventional technologies that make up our legacy defense equipment. What's required is a defense industrial strategy based on a four-part program to:

1) Reshore the defense industrial base and supply chains to the United States and our allies, starting with microelectronics, and restore our shipbuilding base;

2) Build a modern manufacturing and engineering workforce and R&D base;

3) Continue to modernize the defense acquisition process to fit 21st century realities;

4) Find new ways to partner private sector innovation with public sector resources and demand. The defense industrial base is the key to preserving and extending U.S. competitive military dominance in the coming century. Realizing a defense industrial strategy will require a substantial commitment of capital investment and resources, as well as continuing and extending the reforms to the Defense Department's industrial base that have been underway in the past several years.

More broadly, a renewed commitment to reinforcing America's place as the world's leading maritime nation will support workers with skills useful to a variety of other domains such as electric transportation, and next-generation energy storage and batteries that loom large in America's future (p. 14).

White House, The. (2021). ***Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-based Growth.*** https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.

The high-capacity battery supply chain consists of five steps including: 1) raw material production; 2) material refinement and processing; 3) battery material manufacturing and cell fabrication; 4) battery pack and end use product manufacturing; and 5) battery end-of-life and recycling. Coordinated government and private sector action is required across all five stages, as gaps can undermine efforts to secure the supply chain. For example, if the U.S. increases battery recycling rates and not processing capacity, recycled minerals will be exported for processing only to be re-imported at a later step in the supply chain.

This report highlights critical materials for high-capacity lithium-ion batteries – particularly Class I nickel, lithium, and cobalt – as primary upstream supply chain vulnerabilities. For raw material production, the first supply chain step, where demand cannot be met through alternative means and secondary sources (e.g., increasing recycling, potentially sourcing from mine waste, identify mineral substitutes, etc.), the public and private sector should consider increased domestic production to support economically viable domestic extraction. New domestic extraction should focus on critical materials where the U.S. has known reserves to establish an economic base supply. For example, lithium could be a potential priority for increased domestic extraction given the United States holds 3.6 percent of the known global reserves, which could satisfy 2020 global lithium demand for more than 8 years.

The Federal Government, in collaboration with the private sector, must also continue a strategy of ally and partner engagement to diversify international sources. For the second supply chain step of refining and processing, the United States has an even greater deficit than in raw production capacity as critical minerals mined in the United States are often exported for processing. Increasing U.S. processing capacity alone would bolster the supply chain, and coupled with recycling, is a promising pathway to securing the supply chain for minerals where the United States lacks significant reserves.

CHAPTER THREE

3. Method

3.1 Study Design

The three-month effort which led to this paper was designated Phase I(a) of the project, with the purpose of determining the broader training and education landscape in this field. Toward understanding the comprehensive scope of activity already underway in government, academia, and industry, focus areas were needed to ensure that research efforts could reasonably produce a result in the three-month time period available.

The battery and strategic mineral sector was divided into subordinate parts—specifically upstream, midstream, and downstream. As shown in *Figure 1* below, recycling, or "end of life circularity," is a component of the downstream sector; it acts as a critical lynchpin to the process.

Figure 1: Battery Life Cycle (Source: Carreon, 2023)

This sectoral analysis was largely focused on efforts within the U.S. Government, notably the Departments of Defense, State, Energy, Interior, Commerce, Labor, Transportation, and other relevant organizations.

As there are many state-level programs engaged in battery workforce development, the study included one highly active state-level program. New Energy New York is included due to its close connections to manufacturing and workforce development, its maturity as an ongoing concern under the guidance of Nobel Laureate Stanley Whittingham (co-creator of Lithium technology), its supply chain focus, and its leadership's willingness to collaborate.

To initiate Phase I(a), NPS EAG convened two, formal stakeholder meetings designed to introduce the actors and develop a structured course of action. They were well attended by representatives from both academia and industry (see *Table 1*).

Synergies were found between many of the organizations and projects represented, and follow-up sessions were held between the NPS researchers and individual participants, as well as between the participants themselves.

Stakeholder Group membership is indicated in *Table 1*.

3.2 Research Methods

This study relied on primary and secondary research conducted by the NPS EAG team.

The primary research was in the form of stakeholder meetings with Government, academia, and industry representatives. Research was also conducted online, on websites, via internet searches, and through e-mail.

Secondary research was conducted using pre-existing research in battery workforce development. Indeed, this was the key to the success of Phase I(a)—to discover the work already being done.

3.3 Participants

The intent was to involve the triad of Government, academia, and industry in all aspects of study design and execution. While the list of those who are actively engaged is growing, to date the participants involved are noted in *Table 1* below.

Government	Academia	Industry
Dept of the Navy	New York University (Incl Tandon School of Engineering)	New Energy New York (NENY)
		Think Policy Consulting
National Advanced Battery Workforce Council (NABWC) – Joint effort with industry	Stanford University (Incl Doerr School of Sustainability)	NY State Energy Research & Development Authority (NYSERDA)
	Binghamton University	Bren-Tronics
Army Research Directorate	Colorado School of Mines	Int'l Federation of Professional & Technical Engineers (IFPTE)
	Cornell University	
	Columbia University	
	Colombia Business School	
	Harvard Business School	
	SUNY Stony Brook University	
	Naval Postgraduate School	

Table 1. Stakeholder Group Participation

3.4 Procedure

An analysis of the battery workforce activity underway in each sector (Government, academia, and industry) was conducted to determine status, scope and possible overlap. This sector analysis provided the basis for this report and is described in "Findings."

Government programs were examined to determine the degree to which they supported the battery workforce, notably training and education, the nature of the support, and the progress arising from policy. A sampling of academia was made to determine whether efforts were already in existence at U.S. universities or trade schools to recruit and educate the required workforce in adequate numbers. Representatives from the battery industrial sector were consulted to ascertain the extent of workforce development programs in place, their reach and efficacy, and their rate of success to date. The combination of these summary assessments is provided as the basis of this Phase I(a) final report.

3.5 Phase I(a) Plan of Action and Milestones (POA&M)

The Phase I(a) POA&M is listed below. It began with the project initiation "kickoff" in April 2023, and runs through its culminating report in the first week of July 2023.

1. 03 Apr 23 - Project Initiation
2. 25 Apr 23 - Stakeholder meeting #1 (Virtual)
3. 30 May 23 - Project IPR
4. 06 Jun 23 - Stakeholder meeting #2 (Virtual)
5. 23 Jun 23 - Draft report **Summary of Ongoing Efforts and Activities** completed
6. 07 Jul 23 - Final report **Summary of Ongoing Efforts and Activities** submitted
7. 28 Jul 23 - Sponsor comments and revisions

Table 2 illustrates the timeline for the full duration of the project.

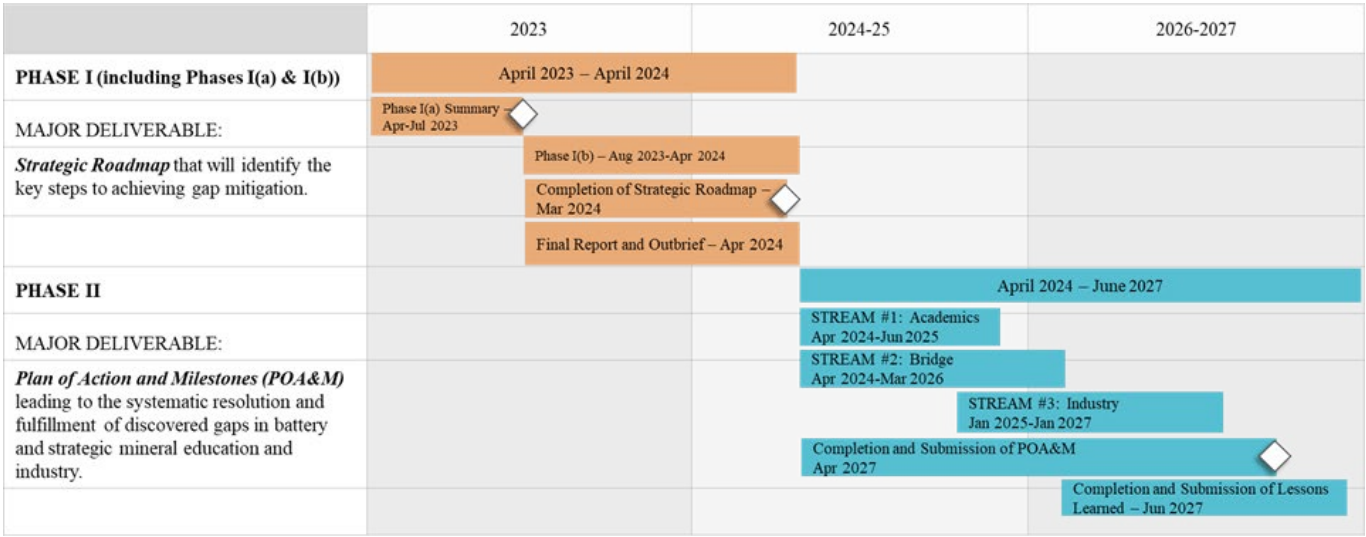


Table 2. Plan of Action and Milestones

3.6 Next steps

The results of this **Summary of Ongoing Efforts and Activities** will be leveraged to the benefit of Phase I(b) and the final roadmap. The roadmap is due in mid-2024 and will complete the Phase I task of the project. This phase will also shape the creation of the Battery Workforce Advisory Group, which will be a guiding component of the program writ large.

CHAPTER FOUR

4. Findings

To understand the depth and breadth of the battery supply chain challenge facing the nation, we can point to the 1979 Strategic and Critical Materials Stockpiling Act, which was a revision of the seminal 1939 legislation by the same name (Kessel, 1990). Acknowledging the United States' reliance on foreign resources and lack of national production, the aim of this Act was to tackle the risks of supply chain disruption that could occur in times of national emergency. Recognizing that critical minerals are central to many types of modern military equipment and at high risk of supply chain disruption, the Act authorizes stockpiling of these minerals. The stockpile is not to be used for economic or budgetary purposes but only in the interest of national defense. In addition to the process of stockpiling, the development of domestic sources of materials is encouraged under the act, to further decrease risks.

The government announced plans, in 2021, to recapitalize and restore the National Defense Stockpile of critical minerals and materials, following findings from the reviews directed under Executive Order 14017. In March 2022, the Departments of Energy, State and Defense executed a memorandum of agreement to launch an effort to include critical minerals necessary for the transition to clean energy alongside those needed for defense purposes. The memorandum created a new, interagency process for stockpiling minerals that enables vital clean energy technologies. Furthermore, sourcing for the stockpile encourages demand for responsibly sourced and sustainably processed minerals (IEA, 2022).

For purposes of clarity and compartmentalization, the EAG BWD team divided the study into more manageable subsectors--upstream, midstream and downstream. While *Figure 2* below outlines this three-stream supply chain for Lithium-based batteries, activities in each stream are applicable across the battery supply chain.

The U.S. has attempted comprehensive strategic mineral efforts before, notably in the interwar years and during the Cold War. But the acquisition of minerals was more reactive than proactive. Now, there is much work occurring to change that paradigm. **This report is a snapshot of work in progress toward enhancing the battery supply chain in the U.S. and the workforce that is required to support it.**

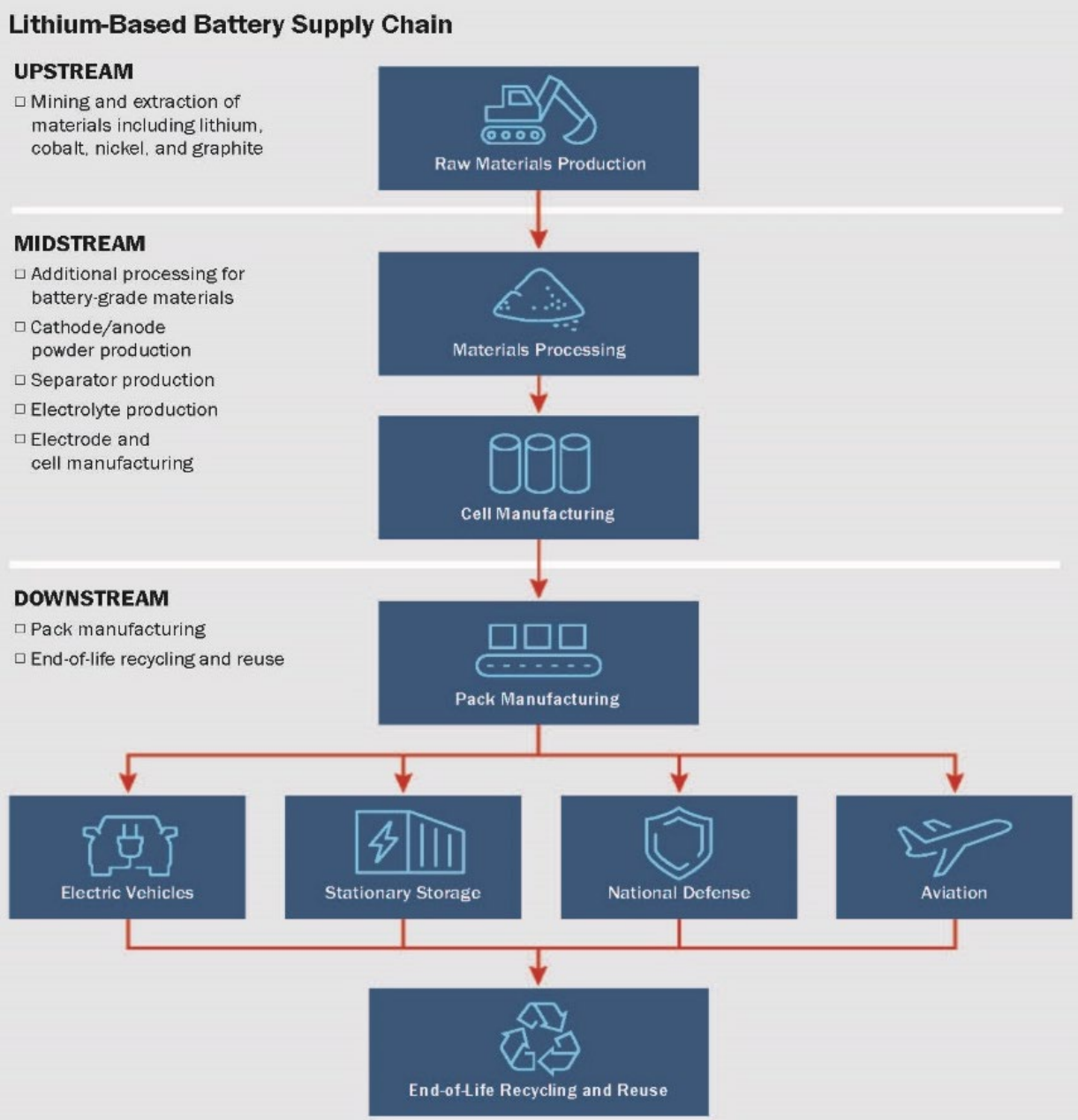


Figure 2: Lithium Based Battery Supply Chain (Source: FCAB, 2021)

4.1 Upstream

The upstream sector comprises mining and extraction of materials, including lithium, cobalt, manganese, nickel, and graphite. While much of the emphasis in the battery sector is on the lithium battery market, there are other key minerals and batteries under consideration.

The inability to extract these minerals to meet demand could lead to rising prices for consumers and slow adoption of technologies that depend on their output, such as electric vehicles (EVs). Further impacts could include lost economic opportunities, limited new job growth, and a missed opportunity to strengthen the U.S. battery supply chain and reduce dependence on foreign sources.

The U.S. requires access to a reliable supply of raw, refined, and processed material inputs to reduce dependence on rare materials, and to develop a stronger and more secure battery supply chain. Extraction techniques must adhere to environmental standards, stringent labor conditions, and community engagement, as well as the economic costs of waste treatment and processing (FCAB, p. 18).

As shown in *Figure 3* below, many of the raw materials needed for battery production are mined and refined outside the U.S., giving domestic users no option but to import products.

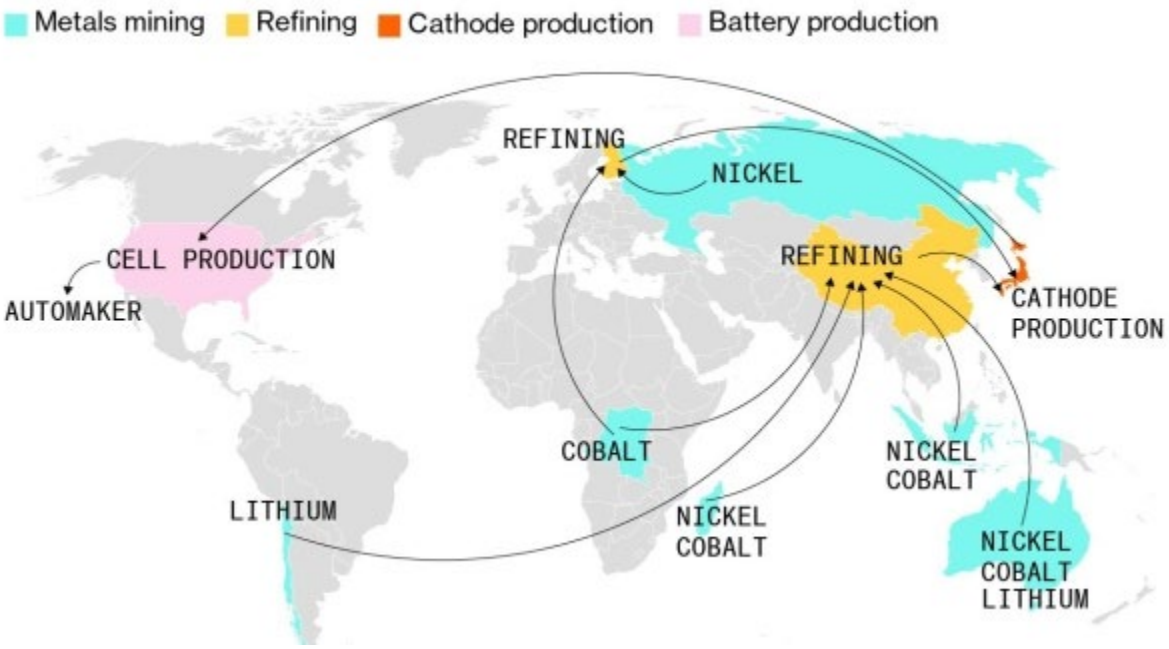


Figure 3: Battery Supply Chain Components (Source: Randall, 2022)

Though similar to **"critical minerals,"** the definition of **"strategic and critical materials"** for the purposes of the Strategic and Critical Materials Stockpiling Act of 1979 (50 U.S.C. 98 et seq.) encompasses any materials needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency; and not found or produced in the United States in sufficient quantities to meet such need (The White House, 2021, p. 154).

The Energy Act of 2020 defined a critical mineral as a "non-fuel mineral or mineral material essential to the economic or national security of the U.S. and which has a supply chain vulnerable to disruption" (Energy Act of 2020, section 7002, "Critical Minerals"). In accordance with this definition, there are approximately thirty-five minerals categorized as critical. While it is anticipated that U.S. industry has adequate supplies of these critical minerals to meet short-term demand, the problem remains that the upstream portion, while not the least functionally equipped sector of the supply chain, is yet unprepared in terms of processes and workforce. *Figure 4* delineates U.S. critical materials.

Although the definitions of "critical minerals" and "strategic and critical materials" overlap, there are two fundamental differences. First, the organizing principle for critical minerals is upstream activity--mining, mineral processing, and related metal products or compounds. In contrast, the definition of "strategic and critical materials" is broader, including downstream products and materials produced outside of mining activities. Second, the definition of strategic and critical materials, as described above, presupposes a national emergency.

What is a critical mineral?

- Material essential to the economic and national security of the United States
- A supply chain vulnerable to disruption
- Serves an essential function in the manufacturing of a product that we cannot live without

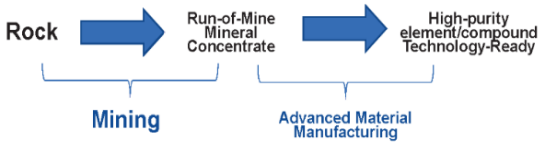
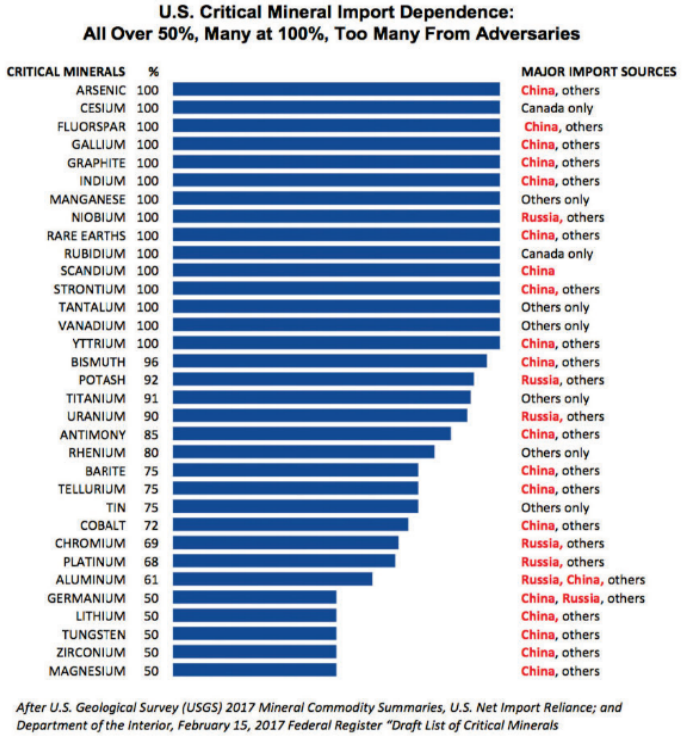


Figure 4: Critical Minerals
(Source: U.S. Critical Minerals, 2023)



In addition to the 35 minerals identified as "critical," the Department of Defense monitors more than 250 unique materials. Recognizing that, "imports are greater than 50 percent of annual consumption for 31 of the 35 minerals designated as critical by the Department of the Interior" (Dept of Commerce, 2018, p. 3), Executive Order 13818 directed the Secretary of Commerce to assess strategies and options regarding critical minerals. The results were six "Calls to Action" which largely addressed the upstream phase of critical minerals, such as improve and publicize the topographical, geological, geophysical, and bathymetrical mapping of the United States; support mineral information collection and analysis of commodity-specific mitigation strategies; focus and prioritize interagency efforts; and conduct critical mineral resource assessments to support domestic mineral exploration and development of conventional sources (Dept of Commerce, 2018, pp. 4-5).

Other sections of the Order, such as Call to Action No. 6, crossed the streams, and spoke directly to the subject matter of this report; "Grow the American Critical Minerals Workforce," addresses actions related to critical minerals needed to develop and maintain a strong domestic workforce and domestic industrial base (Dept of Commerce, 2018, p. 5).

The organizations included below were selected for the demonstrative nature of the work in which they are involved, the pervasive impact of their output, or the sole source nature of their contributions to the battery supply chain and workforce space.

4.1.1 Government

U.S. National Science Foundation

The U.S. National Science Foundation (NSF) is an independent Federal agency that supports science and engineering with solutions-oriented research. NSF provides grants, which account for about 25% of federal support to America's colleges and universities for basic research. The Foundation's Strategic Plan for Fiscal Years 2022 - 2026, which lays out a vision for accelerating research and innovation, was released on March 28, 2022.

There are eight research directorates, each encompassing several disciplines:

- Biological Sciences
- Computer and Information Science and Engineering
- Engineering
- Geosciences
- Mathematical and Physical Sciences
- Social, Behavioral and Economic Sciences
- Education and Human Resources
- An eighth directorate, the Directorate for Technology, Innovation and Partnerships (TIP), was created in 2022 to accelerate the transition of results to the market and society.

NSF funding is distributed in a variety of scientific focus areas. The most relevant funding area to this project is Chemistry and Materials. Within this funding area, NSF has recently awarded six grants that provide undergraduate students with hands-on research opportunities in STEM priority areas. The Division of Materials Research (DMR) supports fundamental experimental and theoretical materials research and education via programs focused on condensed matter physics, solid-state and materials chemistry, and the science of materials that are ceramic, metallic, polymeric, nanostructured, biological, electronic, photonic, and multifunctional purposes.

Department of Energy

The United States Department of Energy (DOE) oversees national energy policy and manages the nation's research and development of nuclear power and nuclear weapons. The Department's mission is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions. The DOE's Federal Consortium for Advanced Batteries (FCAB), which produced the National Blueprint for Lithium Batteries, demonstrates the Department's lead in a broad national battery strategy. DOE supports students, technical workers, and early career employees on Department research and development awards. The DOE is uniquely positioned to support the nation's battery workforce development, with extensive STEM-based education and training programs.

The DOE STEM program coordinates across the Department to share, improve, and increase accessibility to training, education, and engagement for students, educators, professionals, and skilled workers. DOE STEM promotes science and energy literacy and encourages collaborative partnerships with the National Laboratories, institutions of higher education, industry, and non-profit organizations. These efforts provide a continuum of training and engagement opportunities—from the K-12 level to the skilled technical worker and the Ph.D.-trained scientist or engineer—aligned with DOE and broader national STEM workforce needs.

DOE's Office of Science supports basic research across multiple disciplines, as well as the construction and operation of major scientific facilities. The Office of Science also supports Workforce Development for Teachers and Scientists (WDTS), Community College Internships (CCI), and Graduate Student Research.

DOE Energy Innovation Hubs provide bridges to commercialization or dual-use technologies. The DOE Innovation Hub most relevant to this study is the Joint Center for Energy Storage Research (JCESR), led by Argonne National Laboratory. The Center was established in 2012 to promote battery science and technology for both transportation and the grid, such as "beyond lithium-ion" technologies with a primary focus on lithium-sulfur, multivalent and solid-state batteries. JCESR-developed intellectual property may be licensed to existing/start-up companies capable of turning early technology into commercial products.

Current technologies available for licensing through JCESR include Flow Battery Technologies and Multivalent-ion Battery Technologies—more specifically, Lithium-Sulfur (Li-S) Battery Technologies, Solid-State and Lithium-Metal Battery Technologies. Energy storage devices based on multivalent metals have the potential to meet the needs of large-scale energy storage, due to the relative abundance and low cost of elements such as magnesium, calcium, aluminum, and zinc. Next generation lithium-based batteries are typically focused on cells containing lithium-metal anodes due to their potential to enable high energy capacities and densities.

JCESR has strong ties to academia and industry through its affiliates and partners programs. It also supports the Advanced Vehicle Technology Competitions, a venue for North America's Premier Collegiate Automotive Engineering Competitions.

The Advanced Materials and Manufacturing Technologies Office (AMMTO), Critical Minerals and Materials portfolio addresses opportunities and challenges across the life cycle of high priority critical minerals and materials for energy technologies. Its strategy is to diversify supplies and develop alternatives to critical minerals and materials; improve materials and manufacturing efficiency; invest in circular-economy approaches; and enable activities such as criticality assessments. In addition to supporting a Critical Minerals and Materials projects database, AMMTO offers resources such as:

- Lithium Research, Development, and Demonstration Virtual Center (RD&D), also known as the Lithium Center, is a U.S. Government-led center for promoting cooperation on lithium supply chain related topics.
- The Critical Minerals Rare Earths Supply Chain Roundtable and Workshop evaluates the state of the United States critical materials rare earths supply chain and identifies the challenges and opportunities facing the industry.
- Battery Critical Materials Supply Chain Challenges and Opportunities encapsulates results of the 2020 Request for Information (RFI) and Workshop. Key takeaways include technology validation; resource diversification; and increased supply chain connectivity.

The Office of Energy Efficiency and Renewable Energy (EERE) supports research and development of energy efficiency and renewable energy technologies and has training and education resources under its own STEM program. EERE provides opportunities for students, recent graduates, and others looking for internships, fellowships, and similar programs with the Federal Government.

EERE support includes the Education Opportunities and Career Resources, to include college and continued career planning, resources for the workforce and job vacancies. EERE funds many competitions, prizes, and similar contests to support the next generation of scientists and entrepreneurs. Of relevance to this study is the EcoCAR 3 Mobility Challenge, which is aligned with the JCESR. EcoCAR helps develop a skilled, domestic workforce by providing hands-on experience designing and building next-generation mobility solutions.

The Office of Energy Efficiency and Renewable Energy (EERE) Strategic Analysis (SA) team performs cross-cutting analysis associated with the research, development, demonstration, and deployment of EERE technologies. SA's mission is to provide evidence-based, analysis for energy decision makers in EERE and beyond. The SA team does this by sharing and advancing EERE priorities at international engagements, facilitating technical exchanges with international partners, and supporting EERE technology offices with international audiences on specific clean energy technologies. Through SA, EERE also offers a (potentially) $60M grant opportunity to create a Battery Research and Development Consortium.

DOE's Energy Storage Grand Challenge (ESGC) is a comprehensive program to accelerate the development, commercialization, and utilization of next-generation energy storage technologies to sustain American global leadership in energy storage. They are guided by an aggressive goal; to develop and domestically manufacture energy storage technologies that can meet U.S. market demands by 2030.

The Energy Earthshots Initiative aims to accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade. *Figure 5* illustrates the goals of the Initiative.

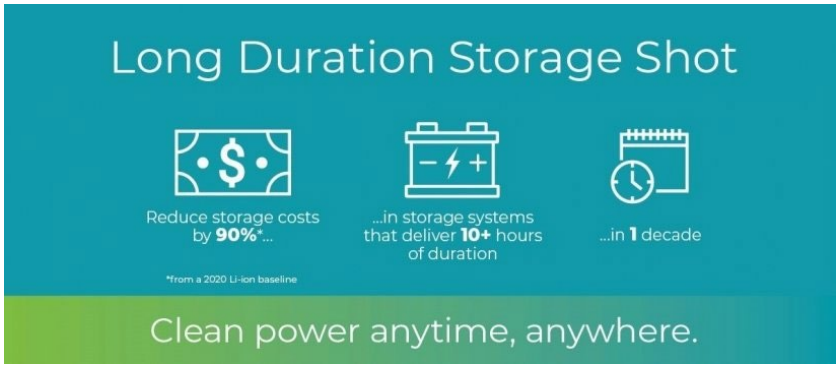


Figure 5: Energy Earthshots Initiative Goals (Source: EERE Energy Earthshots, 2023)

The Office of Manufacturing and Energy Supply Chains is responsible for strengthening and securing manufacturing and energy supply chains needed to modernize the nation's energy infrastructure. The office promotes the energy sector industrial base through targeted investments that establish domestic energy supply chains and manufacturing, and by engaging with the private-sector, other Federal agencies, and key stakeholders to collect, analyze, respond to, and share data about energy supply chains. The office emphasizes opportunities for small and medium enterprises.

Argonne National Laboratory

Argonne National Laboratory is a multidisciplinary science and engineering research center born out of the University of Chicago's work on the Manhattan Project in the 1940s. The laboratory works in concert with universities, industry, and other national laboratories on questions and experiments too large for any one institution to manage unilaterally. Argonne created Li-Bridge, a public-private alliance aimed at bridging the lithium battery supply chain gap. It works to bring together stakeholders to develop and execute a national strategy. The Federal Government is represented by the Federal Consortium for Advanced Batteries (FCAB).

Argonne, working with other DOE labs, has partnered with three U.S.-based convenor organizations that represent private industry. These organizations are: NAATBatt International, New York Battery and Energy Storage Technology Consortium (NY-BEST), and New Energy Nexus.

Department of the Interior (DOI)

The U.S. Department of the Interior protects and manages the Nation's natural resources and provides scientific and other information about those resources. On 16 February 2018, EO 13817 was issued, which tasked the Secretary with identifying critical minerals. Among the objectives it sets are requirements for:

- A strategy to reduce the Nation's reliance on critical minerals
- An assessment of progress toward developing critical minerals recycling and reprocessing technologies, and technological alternatives to critical minerals
- Options for accessing and developing critical minerals through investment and trade with our allies and partners (E.O. 13817, Section 4, "Implementation")

The USGS (United States Geological Survey) is a bureau within the DOI that promotes scientific analysis of water, energy, minerals, and other natural resources. The "U.S. Geological Survey Energy and Minerals Science Strategy—A Resource Lifecycle Approach" document, authored in 2013, provides a future framework that capitalizes on core growth capabilities and leverages their application in energy and mineral resources research. It is reflected in five interrelated goals.

Goal 1. Understand fundamental Earth processes that form energy and mineral resources.

Goal 2. Understand environmental behavior of energy and mineral resources and their waste products.

Goal 3. Provide inventories and assessments of energy and mineral resources.

Goal 4. Understand the effects of energy and mineral development on natural resources and society.

Goal 5. Understand the reliability and availability of energy and mineral supplies.

Within each goal, multiple actions are identified, yet the level of specificity and complexity of these actions varies. Implementation of these actions is largely dependent on available resources and the sequencing of prerequisite steps. This strategy places emphasis on interdisciplinary collaboration and leveraging of expertise across the USGS and with external partners.

The USGS Energy and Minerals Mission Area saw more than 110 graduate students matriculating at USGS working with scientists on projects complimentary to their academic work. The workforce planning of the USGS relies on these students to join the workforce, as it assesses gaps and determines strategies to ensure the skills to fulfill its mission and objectives. Workforce planning tools and resources are supported by the USGS, where there is also standard workforce data for use at various organizational levels.

The USGS Strategic Initiatives (SI) team under the Office of Human Resources provides Bureau leadership in linking USGS vision, mission, and strategic direction with human capital management strategy. The SI team facilitates the development of USGS' Human Capital Strategic Plan, offers expertise with USGS-wide workforce/succession planning efforts, and provides education and training to USGS supervisors, managers, and program support staff involved in workforce reshaping or restructuring initiatives or other organizational change efforts. The Workforce Planning Desk Guide offers a template for a five-step, guided enquiry approach to workforce planning.

The USGS supports students and recent graduates through an Internship Program which is designed for students enrolled from high school to graduate level, with opportunities to work in agencies and explore Federal careers. Eligibility includes students at accredited high school, college (including 4-year colleges/universities, community colleges, and junior colleges); professional, technical, vocational, and trade school; advanced degree programs; or other qualifying educational institution while pursuing a qualifying degree or certification. The Internship Program has two types of appointments: (1) a student on a temporary basis, not to exceed 1 year, to complete temporary or short-term projects; or (2) a student for an initial period expected to last more than 1 year, which may lead to permanent employment. Interns may work part- or full-time.

The Recent Graduates Program promotes careers in the Federal civil service to individuals graduated from qualifying educational institutions or programs. Recent graduates who complete the program may be eligible for conversion to a permanent (or, in some limited circumstances a term appointment lasting 1-4 years) job in the civil service. The Recent Graduates Program is available to individuals who have completed a qualifying associate's, bachelor's, master's, professional, doctorate, vocational or technical degree or certificate educational program within the preceding 2 years (with exceptions for certain veterans unable to apply within two years of receiving their degree due to military service obligation, who have as much as six years after degree completion to apply).

The Energy Resources Program at USGS conducts research and assessments to advance the understanding of the Nation's energy resources. The program's participants study geologically based energy resources, prepare resource assessments, and evaluate the environmental and socioeconomic effects of energy resource occurrence, production, and use.

In 2001, the USGS started the Mendenhall Research Fellowship Program. The Program provides Fellows with research experiences that enhance their scientific stature and credentials. The program includes educational resources based on research in the natural sciences with lesson plans, activities, maps, podcasts, lectures, videos, animations, as well as the STEP-UP Student & Teacher.

The USGS maintains Nationwide Standard Position Descriptions, a tool to determine the types of positions supported by USGS. The position descriptions aid in understanding the expected abilities and tasks in this workforce sector.

The USGS Mineral Resources Program (MRP) delivers science and information to increase understanding of ore formation, undiscovered mineral resource potential, production, consumption, and how minerals interact with the environment. MRP supports data collection and research on a wide variety of non-fuel mineral resources that are important to the Nation's economic and national security.

The Bureau of Ocean Energy Management's (BOEM's) focus is on the development of U.S. Outer Continental Shelf energy and mineral resources. The U.S. is wholly import-dependent for about half of the 35 minerals defined in 2018 as critical by the U.S. Geological Survey (USGS). Executive Order 14017, America's Supply Chains, published on February 24, 2021, directs agencies across the Federal Government to take actions to foster resilient supply changes by reducing dependence on foreign sources of critical materials.

BOEM is the steward of minerals on the U.S. Outer Continental Shelf (OCS), including critical minerals. BOEM is in the process of developing a National Offshore Critical Mineral Inventory (NOCMI) initiative, which strives to locate, identify, and understand potential critical minerals on the OCS.

BOEM also participates in the internship programs noted in other departments of the DOI. There are three of these "Pathways Programs," which offer paid internships for students and careers for recent graduates to provide training and career development for individuals starting their Federal careers. BOEM participates in three Pathways Programs: Internship Program, Recent Graduates Program, and the Presidential Management Fellows Program.

4.1.2 Academia

The Institute for Collaborative Biotechnologies (ICB) is an Army-sponsored University Affiliated Research Center (UARC). The ICB is an interdisciplinary research alliance led by the University of California, Santa Barbara, in collaboration with the Massachusetts Institute of Technology, the California Institute of Technology and partners from the Army and industry.

ICB research is driven by faculty working with graduate students and postdoctoral researchers as interdisciplinary teams of biologists, chemists, physicists, psychologists, physicians, and engineers. These teams develop biologically derived, revolutionary technological innovations in various areas including bio-enabled materials, which study the biochemical syntheses of new materials.

4.1.3 Industry

The Center for Energy Workforce Development (CEWD) is a non-profit consortium of more than 120 energy companies, associations, unions, educational institutions, and government entities working in partnership to ensure a skilled workforce pipeline for the energy industry. It offers an annual Workforce Development Summit, a Veteran Troops to Energy Jobs program, curriculum resources and energy lesson plans, industry research report sponsorship, and a community exchange.

- CEWD created Get Into Energy to build awareness among students, teachers, military veterans, career changers, and others about opportunities available in the energy industry. The site has a clearinghouse job board as well as information such as how to find: an apprenticeship; what technical positions require pre-employment testing; schools that offer energy curriculum; information on scholarships; industry compensation; and insight on the industry's commitment to the environment and social responsibility.
- A further initiative of Get Into Energy is the Troops to Energy Jobs program. It has resources for the veteran seeking entry into the energy industry, including Career Coaches, MOS/NEC translation facility, job listings, and direct communication with employers via resume upload.
- Veterans in Energy (VIE) is a national organization supporting Employee Resource Groups that provides transition, retention, and professional development support to veterans working in energy. It advocates through education and networking to improve the working environment, career development and quality of life for military veterans in the energy industry.

New Energy Nexus is an ecosystem of funds and accelerators that support diverse clean energy entrepreneurs, from emerging technology through deployment and adoption. It runs programs that are locally tailored to support the specific needs of entrepreneurs in that region: providing accelerator services, capital, mentoring, skills, and networks to help energy entrepreneurs. New Energy Nexus is a convenor organization with Li-Bridge.

The National Alliance for Advanced Transportation Batteries ("NAATBatt") is a not-for-profit trade association of companies, associations and research institutions, supporting commercialization of advanced electrochemical energy storage technology for emerging, high-tech applications. It promotes the commercial interests of its members by supporting developments in the science of and markets for advanced electrochemical energy storage technology in North America consistent with the goals of enhancing energy efficiency, reducing petroleum dependence, and enabling carbon-free electricity generation.

Of interest to the NPS/EAG BWD project is its specific objective to promote job creation and intellectual property development in the advanced battery industry in North America. NAATBatt also seeks:

- To and promote collaboration among industry groups focused on advanced battery technology outside of North America, including Europe, Japan, and Korea.
- To build relationships among companies engaged in advanced electrochemical energy storage to enhance commercial opportunities for our members.
- To accelerate commercialization of emerging electrochemical energy storage technology by facilitating collaboration among private industry, research institutions and government laboratories in North America.
- To integrate electricity storage into the North American power system.
- To educate industry, consumers and financial markets about advanced electrochemical energy storage technology and its benefits.
- To advocate for increased market demand for vehicles and systems incorporating advanced electrochemical energy storage technology.
- To promote the recycling of and development of aftermarkets for advanced batteries and electrochemical energy storage systems.

4.2 Midstream

The midstream sector provides additional processing for battery-grade materials, to include cathode/anode powder production, separator and electrolyte production, as well as electrode and cell manufacturing. In

the case of lithium and other minerals, the U.S. relies on international markets for processing. The U.S. could benefit greatly from an increased focus on the development and growth of cost-competitive domestic materials processing for lithium-battery materials (FCAB, p. 19).

This issue has been the subject of Congressional action and is reflected in the IRA, which requires that a certain percentage of EV battery minerals be extracted and processed in the U.S. or a country with which the U.S. has a free-trade agreement.

Like the upstream portion of the battery supply chain, the midstream portion is concentrated in a small number of Asian countries, notably China, South Korea, and Japan, with China dominating (BloombergNEF, 2022, "China's Battery Supply..."), as seen in *Figure 6* below.

Country	Raw Materials	Battery manufacturing	ESG	Industry, innovation and infrastructure	Downstream demand	Overall ranking
China	1	1	17	9	1	1
Canada	3	8	6	4	10	2
US	6	4	16	5	2	3
Finland	9	15	2	1	11	4
Norway	18	10	1	3	7	5
Germany	21	6	4	7	2	6
South Korea	17	2	10	6	5	6
Sweden	21	9	3	2	8	8
Japan	13	3	8	12	8	9
Australia	2	15	9	13	11	10
France	24	10	5	10	5	11
UK	26	15	7	8	4	12
Czechia	23	10	11	11	18	13
Poland	24	5	15	16	15	14
Hungary	26	6	13	14	20	15
Chile	7	18	14	23	19	16
Turkey	15	18	21	15	13	17
India	13	10	26	21	13	18
Vietnam	20	10	20	18	17	19
South Africa	8	18	19	17	26	20
Brazil	4	18	23	22	20	21
Indonesia	5	18	22	27	25	22
Argentina	11	18	12	19	26	23
Slovakia	26	18	18	25	24	24
Thailand	26	18	24	20	16	25
Philippines	10	18	29	28	22	26
Mexico	16	18	27	26	23	27
Morocco	19	18	25	24	28	28
DRC	11	18	30	29	30	29
Bolivia	26	18	28	30	28	30

Figure 6: BNEF 2022 Global Lithium-Ion Battery Supply Chain Ranking (Source: BloombergNEF, 2022)

The United States is not a midstream leader; however, its midstream capacity is growing, in part due to the Advanced Manufacturing Production Credit which offers up to $45 per KWh of battery capacity and has the potential to strengthen the U.S. midstream sector (Carreon, "Midstream").

Further driving midstream capacity is the IRA, which contains incentives which encourage domestic production and sourcing. To incentivize demand, the law provides tax credits for the lithium-ion battery value chain for EVs and energy storage. It also mandates that from 2024, US vehicles cannot have any battery components sourced from a "foreign entity of concern," and from 2025, EV batteries cannot have any critical minerals sourced from a "foreign entity of concern" (DoT, 2023).

4.2.1 Government

The Department of Labor (DOL) supports employment and training programs to improve the employment prospects of American workers. While not dedicated solely to battery workforce development, the Department's Employment and Training Administration (ETA) has numerous programs designed to help workers identify career paths, as well as education and training programs.

- WorkforceGPS is sponsored by the ETA for professionals, educators, and business leaders. It hosts communities of interest, webinars and other training resources, workforce development practices, and relevant evidence-based research.
- Apprenticeship.gov connects career seekers, employers, and education partners with apprenticeship resources.
- The Workforce Innovation and Opportunity Act (WIOA) was signed into law on 22 Jul 2014, designed to strengthen and improve the public workforce system. WIOA helps job seekers access employment, education, training, and support services, and to match employers with skilled workers.
  WIOA requires states to align their core workforce development programs and coordinate the needs of both job seekers and employers through combined four-year state plans. Additionally, WIOA promotes negotiated performance goals that are publicly available, fosters regional collaboration within states through local workforce areas, and improves the American Job Center system.
  Additionally, the ETA administers skills training grants in H-1B Skills Training, Community Colleges Training Grants Program, Trade Adjustment Assistance Community College and Career Training and Workforce Opportunity for Rural Communities (WORC).
- The Job Corps Scholars program helps eligible workers, aged 16-24, complete high school and earn college credit, career training, and provides employment assistance for career technical training at accredited public colleges. Job Corps offers technical skills training in the following relevant industry sectors: advanced manufacturing; renewable resources and energy; and transportation. Twenty-six public colleges and universities receive Job Corps Scholars grants. The U.S. Bureau of Labor Statistics provides analysis on economic and employment sectors for job seekers and providers.
- The Veterans' Employment and Training Service (VETS), supports transition and retraining opportunities for Veterans and family members.
- The Department of Labor's Workforce Information Advisory Council (WIAC) provides recommendations to the Secretary of Labor, working jointly through the Assistant Secretary for Employment and Training and the Commissioner of Labor Statistics to evaluate and improve the national workforce and labor market information system and statewide systems that comprise the nationwide system, and; how the Department and the states can cooperate in the management of those systems.

4.2.2 Academia

The NSF's Industry-University Cooperative Research Centers Program (IUCRC) partners with universities to drive innovations in several focus areas, including biotechnology, information, communication and computing, health and safety, advanced manufacturing, advanced materials, energy, and the environment. The IUCRC Center for Solid-State Electric Power storage (CEPS) helps industries, government, and national laboratories develop energy storage technology for portable and medical applications, the automotive industry, centralized and decentralized electric grids, military applications, and energy security. These include Syracuse University. Northeastern University and the South Dakota School of Mines and Technology.

4.2.3 Industry

Dalhousie University, funded by Tesla Motors, does research on the physics and chemistry of materials for energy storage, primarily in lithium-ion batteries. Their goal is to improve the energy density, increase safety, decrease cost, and improve the cycle and calendar lifetime of the batteries. There are projects on new positive electrode materials, new negative electrode materials, and lithium-ion battery safety.

As of June 2023, Panasonic plans to expand production of EV batteries at a factory in Nevada jointly operated with Tesla by 10% within three years. This Gigafactory Nevada facility will be Panasonic Energy's 15th production line. Panasonic Energy has further announced a plan to increase the Nevada factory's production capacity by 10% by March 2026 (Reuters, 2023).

Panasonic disclosed in May 2023 that it planned to build at least two new factories to produce Tesla 4680 battery cells in North America by 2030. With that move, Panasonic seeks to boost its auto battery capacity to 200 gigawatt hours per year by March 2031, about four times its level at the end of March 2023 (Reuters, 2023).

4.3 Downstream

Downstream activity incorporates pack manufacturing and end-of-life recycling and reuse. In the last decade, advancements in battery energy storage technologies have led to energy density increases and battery pack cost decreases of approximately 85%, reaching $143/kWh in 2020 (FCAB, 2023, p. 6).

Recycling cells reduces constraints imposed by materials scarcity and enhances environmental sustainability, resulting in a more secure, resilient, and circular domestic supply chain. Several factors create challenges for recycling, such as end-of-life and transporting costs. The costs are high due to the hazardous waste classification which accounts for over half of the end-of-life recycling costs.

Beyond the recycling supply, spent EV battery cells can be transitioned to second-use applications, including grid storage. Second use of battery cells will require better methods for sorting, testing, and balancing of cell packs. Finally, enhanced recycling penetration into the commercial market for batteries will help create a domestic circular battery economy (FCAB, 2023, p. 20).

The U.S. goal is the creation of a competitive and efficient domestic battery supply chain to generate higher performance and lower costs. The R&D pipeline ranges from new electrode and electrolyte materials for next-generation batteries, to advances in solid-state batteries, novel material, and cell manufacturing methods. The R&D will be supported by strong IP protection and rapid movement of innovations from lab to market through public-private partnerships using the semiconductor industry as an example (FCAB, p. 21).

These goals, taken together, serve as a holistic blueprint to maintain and expand U.S. leadership in R&D and manufacturing across the battery supply chain. Woven into the goals is the creation of a trained battery supply chain workforce that promotes career transition and equal access through programs in trade schools, community colleges, and public universities (FCAB, p. 22).

Chinese, South Korean, and Japanese companies dominate global battery manufacturing; together, these countries accounted for nearly 70 percent of the battery market in 2021. The top three companies are China's CATL (33 percent), South Korea's LG Energy Solution (22 percent), and Japan's Panasonic (15 percent). China's dominance is attributed to its prioritization and investment in battery manufacturing, while South Korea's and Japan's rankings have been influenced by building on their extensive experience and expertise in manufacturing consumer electronics (Donnelly, "Where EV batteries are today").

Today, the United States is responsible for only 7% of the world's battery production capacity. As with the midstream portion of the supply chain, the Advanced Manufacturing Production Credit is expected to

strengthen the U.S. downstream sector. The IRA and the Infrastructure Investments and Jobs Act are incentivizing growth, by providing $83 billion in loans, grants, and tax credits that could support the production of low- or zero-emission vehicles, batteries, or chargers (Gabriel, para. 1). Further, according to the International Energy Agency, between August 2022 and March 2023, post-IRA investments amounted to approximately $52 billion in North America—50 percent of which was for battery manufacturing and 20 percent for components and EV manufacturing (IEA, 2023).

A significant market shift in evidence is the increased partnership between automakers and battery manufacturers. For example, Ford is diversifying its raw material suppliers and General Motors and LG have partnered to co-locate battery pack and cell production; at the time of this writing, they have one active plant in Ohio and plan to open two others in Tennessee and Michigan. Some are planning to create manufacturing facilities that house both battery and EV plants, while other downstream manufacturers are creating contracts that enable them to source directly from upstream providers (Gabriel, para. 9).

4.3.2 Government

There are several work/study or leadership development programs created and managed by the Federal Government. While these programs are not direct contributors to the battery workforce, they speak to the need to incentivize education and government service, which could ultimately benefit the target population of this study.

- Presidential Management Fellows (PMF) Program is the Government's premier leadership development program for advanced degree holders across all academic disciplines. The program's goals are to recruit and develop a cadre of future Government leaders. The PMF Program seeks to create lasting professional contacts between Fellows and Alumni.
- The Internship Program allows students to be exposed to the work of the Government through internships while matriculating. Internship Program positions are open to current students enrolled at least half-time in high school/GED, vocational, technical, undergraduate, graduate or professional programs.
- The Recent Graduates Program provides developmental experiences in the Federal Government. It is intended to promote possible careers in the civil service to individuals who, within the previous two years, graduated from qualifying educational institutions with an associates, bachelors, masters, professional, doctorate, vocational or technical degree or certificate from qualifying educational institutions. To be eligible, applicants must apply within the previous two years of degree or certificate completion, who will have up to six years after degree or certificate completion to apply. Veterans are exempted from doing so due to their military service obligation.

4.3.1 Academia and Industry

Contributions are being made by academia and industry in the downstream sector, as part of activity already listed in other sectors due to their cross-sector impact (i.e., FCAB, USNSF, NPS, etc.). For commentary on this contributor to the downstream segment, see "Conclusions."

4.4 Across the Streams, or "Integrated"

Some organizations, programs, or legislation impact the battery workforce and supply chain so pervasively, that they might be considered integrated providers throughout each of the upstream, midstream, and downstream phases.

4.4.1 Government

Department of Defense

To improve supply chain resilience and protect against material shortages, the President signed Executive Order (E.O.) 14017, America's Supply Chains. In response to the EO, the Office of the Secretary of Defense issued a report entitled Securing Defense-Critical Supply Chains to provide DoD's assessment of defense critical supply chains. Its recommendations focus on how the U.S. can increase domestic production capacity and renew the sources of our economic security. The report advocates development of an industrial workforce that will ensure the right skillsets are available as needed to meet U.S. security requirements. It also notes an intent to contribute to the national defense stockpile and utilize it to provide flexibility in the case of disruptions or emergencies. Of particular interest are the sections on Energy Storage and Batteries, and Supply Chain Workforce.

It is noted that no central organization or entity was responsible for addressing battery challenges within DoD. To date initiatives to build resilient battery supply chains have been service-specific, sporadic, and difficult to coordinate. This decentralized and siloed approach complicates engagement with industry and hinders DoD's ability to reliably source necessary batteries. To combat this situation, the DoD established a flow of policy and directives, as shown in *Figure 7* below.

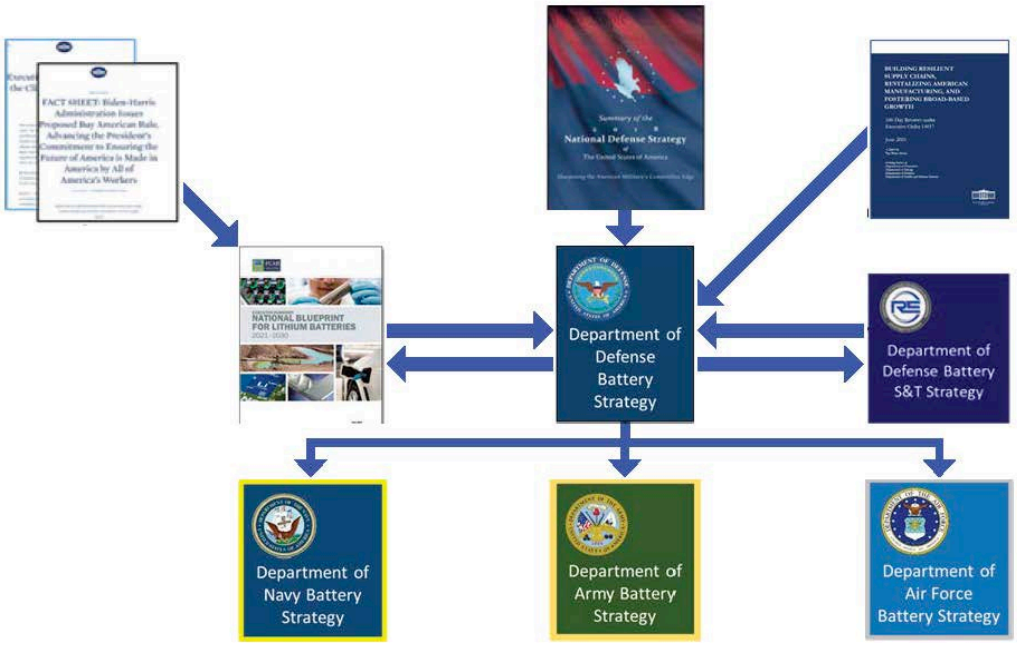


Figure 7: Flow of Policy and Directives (Source: Office of the Deputy Secretary of Defense, 2022)

The report further discusses the skilled labor shortage, which undermines its productivity and innovation. As a result of these lower numbers, changing worker expectations, and a lack of interest in manufacturing, the labor pool of traditional manufacturing employees is decreasing. This labor shortage is combined with a manufacturing skills deficiency where the labor market is unable to find workers who have the manual, operational, and technical skills, knowledge, or expertise to fill open positions. This skills deficiency impairs U.S. manufacturing and is exacerbated by a lack of effective job training and the ongoing retirement of experienced baby boomers (Office of the Deputy Secretary of Defense, 2022, "Securing Defense-Critical Supply Chains").

The efforts of the Office of the Deputy Assistant Secretary of Defense for Energy (ODASD(Energy)) are aligned with the goals of the National Defense Strategy, and create policy, share information, and solve

challenges related to operational energy use across the Department. One of the programs under ODASD and of relevance to this project is Battery Network (BATTNET), a manufacturing technology program designed to reduce product costs while improving battery availability, performance, and standardization. BATTNET links battery supply chain members, engineering support for researchers, and users to address sustainment risks and bridge technical solutions. BATTNET's goal is to improve DoD battery logistics through lighter weight, higher performance, longer shelf life, and lower maintenance batteries.

Department of Energy

The Federal Consortium for Advanced Batteries (FCAB) brings together Federal agencies concerned with ensuring a domestic supply of lithium batteries and are committed to accelerating the development of a robust and secure industrial base. The consortium is led by the Departments of Energy, Defense, Commerce, and State and includes many organizations across the government.

One of FCAB's most significant contributions to the battery landscape is its National Blueprint for Lithium Batteries 2021-2030, which presents a holistic approach that covers the lithium-ion battery ecosystem and focuses on the domestic supply chain. The blueprint lays out five critical goals and actions to guide Federal agency collaboration to secure the nation's long-term economic competitiveness.

4.4.2 Academia

New Energy New York (NENY) is a comprehensive ecosystem of project initiatives led by Binghamton University that supports the establishment of an American hub for battery innovation, manufacturing, and workforce development in upstate New York — all made possible by a coalition of academia, non-profit, government and industry partners.

- *Battery-NY*: Creating a first-of-its-kind Battery Technology and Manufacturing Center hosted by Binghamton University in an Opportunity Zone on the Huron Campus in Endicott, NY will help to develop advanced battery technology manufacturing and a manufacturing infrastructure to support the battery industry and its supply chain.
- *Workforce Development*: Developing a host of coordinated and innovative programs throughout the supported regions is vital for training the workforce required to support the storage manufacturing ecosystem — with specific programs to promote equity and participation of individuals from underrepresented and marginalized backgrounds.
- *Supply Chain*: To support the growth in energy storage projects and increase demand for a strong supply chain, this project will help implement a strategy for a storage supply chain throughout upstate New York — including the creation of a supplier catalog and supplier certification program.

Faculty and students at the Naval Postgraduate School are engaging in ongoing research into batteries and their use in the fleet. Two recent examples include:

- The design, development, and fielding of new and emerging technologies onto Navy vessels is driving an increase in power requirements. The Deputy Chief of Naval Operations Warfare Systems (N9) office requires research to assess the current employment of lithium-ion batteries within the Navy fleet and to aid future battery requirements to power a wide variety of vehicles, weapons, and other subsystems. Lithium-ion technology is the power source of choice for systems that have large instantaneous and continuous power needs, and the Navy expects that Li-ion battery technology will continue to be needed to support many future systems. One incidence of research conducted at NPS, "Electrical Energy Storage to Support Electrification of the Fleet," was intended to inform the Department of the Navy (DON) of the current state of lithium-ion battery use and substantiate requests for resources to equip the fleet through 2045.

- Another NPS student team's capstone project was funded in part by a Naval Research Program (NRP) grant secured in Oct. 2021 to explore net-zero pathways for the operational Navy. The students conducted a cost-benefit analysis on converting a gas-powered warship to be powered using a lithium-ion battery system, eventually developing a working financial model that can be used to calculate the carbon emissions of the service fleet using gas turbine as well as the battery alternative over the span of 15 years.

4.4.3 Government/Industry

The National Advanced Battery Workforce Council (NABWC) has created a public-private partnership comprised of industry, community organizations, government, workforce/labor intermediaries, and educational and training organizations, "to catalyze, coordinate, and execute national advanced battery workforce objectives" (NABWC, para. 1). NABWC is a public service, non-profit, brand neutral, volunteer based organization dedicated to the success of the U.S. battery industry.

NABWC's formation occurred as a key recommendation of the Li-Bridge Workforce and Communities Committee. Li-Bridge is tasked with developing a national strategy that creates 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. Private industry participation is facilitated by an alliance of NAATBatt, NY-BEST, and New Energy Nexus.

NABWC's work is well underway. Its objectives for 2023 are to:

- 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
- 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

The NPS/EAG BWD research team has established a close working relationship with NABWC. This relationship is already flourishing through the following:

- NABWC and NPS/EAG BWD serve with reciprocity on one another's executive steering committees.
- NPS/EAG is reviewing the workforce survey that NABWC has developed, prior to its circulation. Upon completion, NPS/EAG will assist in its circulation through reach out to the BWD Stakeholder Group.
- NPS/EAG has consulted with NABWC on the internet platform in development, multiple times.

CHAPTER FIVE

5. Conclusions

Although the purpose of the present research was to discern what work is being done in the battery workforce area, there are some indications of what may be revealed during the gap analysis and mitigation planning that will occur in the next phase of the project. While extensive engagement to address the challenges of the lack of a domestic battery supply chain is clearly in evidence, some gaps are beginning to show.

There is large-scale Government funding into this sector, though it has not been coordinated across the Departments, several of which have integrated programs that attempt to be all things to all sectors, where some level of specialization may be more effective.

Supply chain education and training is an afterthought in most of the programs reviewed to date. It is noted as a goal, but no actual emphasis is evident from the output shown in terms of investment, subcommittees formed, etc. While it is too soon to tell whether the funding and effort that has been allocated will be effective in the areas where attention has been afforded, a possible result of current practices could be isolated pockets of excellence, with an inability to contribute across the sectors.

The upstream sector has received much attention from the Government, with numerous programs addressing enhanced strategic and critical mineral mining and processing. Many of these programs engage academia and industry; although they are categorized as "government programs," they could easily slide into any of the categories identified in this paper. For instance, the FCAB's "Blueprint" addresses everything from access to raw materials to recycling, as well as workforce education and robust programs that demonstrate significant attention to each of their five goals.

Academia and industry are researching more and better techniques and materials to address the needs of this sector. What this research has not yet revealed is the efficacy of the programs in place. As the objective of the BWD project is to develop the battery workforce, the next phase of research in the upstream sector will focus on how well the programs in place are improving opportunities and thereby increasing the population's quantity and quality.

In the midstream sector, the situation is much the same. There is activity, but it remains to be seen whether all that movement is being harnessed into substantive outcomes.

In the downstream sector, however, there yet remain many questions. While the U.S. is already showing itself to be a significant player in the upstream and midstream sectors, in the downstream sector the U.S. is not a major actor. The activities of academic and industrial players are more sparse and challenging to identify. There are five main actors in the downstream battery production supply chain, and none of them are in the U.S.: LG Chem (South Korea), Samsung SDI (South Korea), Panasonic Sanyo (Japan), BYD (China), and CATL (China) (MacroPolo, 2023). The U.S. lithium-ion battery production industry depends largely on Tesla's/Panasonic's prospects. But if China continues to support its EV industry and provide more subsidies to its manufacturers than the U.S. does, then global battery cell production will shift even more strongly toward China, further reinforcing East Asia's dominant position in the industry.

Consequently, while the next and following phases of this research will continue to examine the entire supply chain for gaps, it is likely that the greatest need, and therefore this project's greatest contribution, will be in the downstream sector.

CHAPTER SIX

6. Recommendations

As the remit of Phase I(a) was to discover other work being done in battery workforce development, it is premature to derive any studied observations as to how to fill any gaps, but there are some early observations that the research has revealed and that lead to preliminary recommendations.

6.1 State Programs. State programs are very active in this space. Although only one state program, New Energy New York, was included in this first look at the industry, both the number of state programs and the community engagement they generate will be a significant factor in the planning of the next phase. ***Consideration of state-level programs should be expanded as the research focuses on action planning***. State and local governments are natural allies in the BWD process.

6.2 Educational Programs. Educational programs have long lead times. Experience shows that there is a long period anticipated to develop curricula and programs, associated with not only development but also approval and accreditation, whether university-based, battery-centric coursework, ranging from capstones to minor or major concentrations, or trade schools. ***Where educational programs are indicated, their creation should begin at the earliest possible opportunity.***

6.3 NPS Battery Workforce Advisory Group (NBWAG). On the strength of Phase I(a), the research team will move into Phase I(b). The Stakeholder meetings conducted during Phase I(a) of this project moved the work forward immeasurably. ***This methodology, having proven its value to the project, should be maintained***. The NPS BWD Advisory Group will be established in Phase I(b) of this research, but the Stakeholder meetings that invite in a wider range of participants will continue.

6.4 Public Private Partnerships

6.4.1 National Advanced Battery Workforce Council (NABWC).

The activity underway by NABWC is highly relevant to the work in which the NPS EAG team is engaging, and the teams will certainly find synergy in staying closely aligned. NABWC's objectives align closely with the NPS Battery Workforce Development project's Phase I objective, and the NPS Research Team has formed a relationship with NABWC. Synergies have already been revealed in the wide array of contacts that NPS has developed, on which NABWC will be able to capitalize in releasing its workforce assessment. NPS will serve on the executive committee of NABWC, and NABWC will have a permanent chair in the NPS BWD Advisory Group which will form in the next phase of research. ***This relationship is one of the most important to this research to date, and it should be maintained throughout the life of the research and execution phases of this project.***

6.4.2 International Federation of Professional and Technical Engineers (IFPTE).

The NPS research team has formed a relationship with representatives of IFPTE, a labor union advocating on behalf of more than 90,000 workers in professional, technical, administrative, and associated occupations in Canada and the United States. This organization is unique in representing highly educated and skilled workers, as well as representing the midstream and upstream employment sectors, but have offered connections in the downstream sector. ***This organization should play a substantive role in this body of work, serving as coordinators and facilitators for subject matter experts throughout the life of the project.*** Additionally, its ongoing effort of creating a $10M training facility in the Chattanooga, Tennessee area, will

develop a pathway for community members, could create synergies between IFPTE and the NPS BWD.

Some of the activity in which IFPTE and NPS will engage include: discovery of and discussions with subject matter experts in the field and from the labor/industry perspective as we move through Phase I and into Phase II; local worksite meetings as necessary to the understanding of the issues; and collaboration on other issues of mutual concern.

6.4.3 Center for Energy Workforce Development (CEWD).

CEWD's annual Workforce Development Summit brings hundreds of industry professionals together for critical conversations and action-focused dialogues about developing a skilled energy workforce. Networking opportunities with sessions on workforce development in energy fields, roundtable discussions on strategic workforce planning, and state energy workforce consortia meetings. ***The NPS/EAG BWD research team will attend the CEWD Workforce Development Summit on 14-16 November 2023 in National Harbor, MD.***

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APPENDICES

Appendix A. Phase I(a) Budget

Appendix B. USGS Mineral Resources Program (MRP) Partner Organizations

Appendix C. Joint Center for Energy Storage and Research (JCESR) Affiliates and Collaborators

Appendix A
Phase I(a) Budget

Budget Item	Labor*	Other	Total
FTE 1	$75,000		$75,000
FTE 2	$75,000		$75,000
FTE 3	$40,000		$50,000
Faculty Consultation	$10,000		
NPS Overhead (on $300K)		$72,000	$72,000
Management Reserve		$28,000	$28,000
Total	**$200,000**	**$100,000**	**$300,000**
Expended Phase I(a)	$78,554	$72,000	$150,554
Total Funds Remaining (Carryover to Phase I(b))	$121,446	$28,000	**$149,446**

Based on an average loaded rate of $300K.

Appendix B

USGS Mineral Resources Program (MRP) Partner Organizations

MRP collaborates with States, Industry, and Academia, as well as international organizations, on most research. Below is a listing of the USGS Mineral Resources Program Partners.

Association of American State Geologists (AASG)

Board of Governors of the Federal Reserve System

Bureau of Economic Analysis (BEA) DOC

Bureau of Land Management (BLM)

California Geological Survey (CGS)

Cameco Resources Smith Ranch-Highland

Central Intelligence Agency (CIA)

CODES - Centre for Ore Deposit and Earth Sciences

Controlled Thermal Resources

Council for Geoscience

Dajin Resources Corporation

Desert Research Institute

Florida Department of Environmental Protection (DEP) Florida Geological Survey

Friedrich-Alexander-Universität Erlangen-Nürnberg

Geological Survey of Japan, AIST

Highland Copper Company, Inc.

Illinois State University

Imerys

Indiana University Bloomington

Instituto Geológico Minero y Metalúrgico (INGEMMET) Peruvian Institute of Geology, Mining, and Metallurgy

Ioneer Ltd

Jet Propulsion Laboratory

Jindalee Resources Limited

Lithium Americas Corporation

Materion Corporation

Michigan Geological Repository for Research and Education

National Aeronautics & Space Administration (NASA)

National Geospatial Intelligence Agency (NGA)

National Jewish Health

Natural Resources Research Institute, University of Minnesota

NioCorp Developments Ltd.

Northwest Territories Geological Survey

Office of Science and Technology Policy (OSTP)

Office of the United States Trade Representative (USTR)

Ontario Geological Survey

Pure Energy Minerals

Ralph J. Roberts Center for Research in Economic Geology (CREG)

Rare Element Resources

Sealaska Native Corporation

Sociedad Geológica del Perú (Geological Society of Peru)

SoS RARE Project

SRK Consulting

Trilogy Metals Inc.

Twin Metals Minnesota

U.S. Department of Agriculture (USDA)

U.S. Department of Commerce (DOC)

U.S. Department of Defense (DOD)

U.S. Department of Energy (DOE)

U.S. Department of Homeland Security (DHS)

U.S. Department of State (DOS)

U.S. Environmental Protection Agency (EPA)

U.S. Forest Service (USFS)

UCore Rare Metals

Universidad Nacional del Altiplano (National University of the Altiplano in Puno, Peru)

Universiteit Gent (Ghent University)

University of Alaska Fairbanks (UAF)

University of Cincinnati

University of Science and Technology Beijing

University of the Witwatersrand, Johannesburg

Appendix C

Joint Center for Energy Storage and Research (JCESR) Affiliates and Collaborators

Within JCESR are institutions working across all stages of the innovation chain, from national laboratories and universities to industry. JCESR has a combination of national laboratories, universities, industry, and key experts in one centrally managed organization.

The scientific gaps in knowledge and the challenges JCESR has identified require expertise in many different fields. This expertise resides in many different institutions and requires a collaborative approach to ensure that progress is made toward the overall goals. This requires an organization of more than 150 researchers—across 20 institutions, spanning fundamental materials science to engineering expertise.

JCESR's affiliates and other collaborators in the community are critical to achieving its vision and mission and are listed below by state and country.

California
- 4D Energetics Inc.
- Ampaire
- California Clean Energy Fund
- Citrine Informatics
- Electric Power Research Institute
- Envia Systems
- General Atomics
- Imergy Power Systems
- Lawrence Livermore National Laboratory
- Liox
- MCV Energy, Inc.
- NASA Jet Propulsion Laboratory
- PlugVolt
- PolyPlus Battery Company

Colorado
- Electrochemical Energy Laboratory (ECEL) – University of Colorado at Boulder
- National Renewable Energy Laboratory
- SolidPower Battery
- Xerion Advanced Battery Corp.

Connecticut
- Praxair, Inc.
- Proton OnSite

Delaware
- DuPont Central Research and Development
- University of Delaware

Florida
- NextEra Energy Resources

Georgia
- Georgia Institute of Technology
- Southern Company Services

Idaho
- Idaho National Laboratory

Illinois
- AllCell Technologies
- Center for Electrical Energy Storage
- Chicago Innovation Exchange
- Chicago Transit Authority
- City of Evanston
- ComEd
- Energy Foundry
- Exelon Corporation
- Gas Technology Institute
- Glidepath Power
- Illinois Institute of Technology
- Materion
- National Alliance for Advanced Technology Batteries (NAATBatt)
- Navigant
- Navitas Systems
- New Mobility Lab
- Northern Illinois University
- Renewance Inc.
- SiNode Systems
- SoCore Energy
- Southern Illinois University Carbondale
- Town of Normal

Indiana
- Battery Innovation Center
- Cummins Inc.
- Richard G. Lugar Center for Renewable Energy

Maryland
- Lockheed Martin Advanced Energy Storage, LLC
- Nanostructures for Electrical Energy Storage

Massachusetts
- 24M Technologies, Inc.
- Material Alchemy
- Pellion Technologies
- PowerHydrant
- TIAX LLC
- XL Hybrids

Michigan
- Dow Corning
- Energy Storage Safety Products International (ESSPI)
- General Motors
- Lakeshore Advantage
- National Center for Manufacturing Sciences
- NextEnergy
- Sakti3
- Spider9

Mississippi
- Mississippi State University

Missouri
- Ameren
- Energizer
- University of Missouri

Montana
- ViZn Energy

New York
- alpha-En Corporation
- Besstech
- Bettergy Corp.
- Center for Electrocatalysis, Transport Phenomena, and Materials for Innovative Energy Storage
- Corning Incorporated
- Eastman Business Park
- Energy Materials Center at Cornell
- Eos Energy Storage
- GE Global Research
- Northeastern Center for Chemical Energy Storage
- Voltaiq

North Carolina
- Albemarle

Ohio
- Case Western Reserve University
- Design Flux Technologies, LLC
- Duracell
- NASA Glenn Research Center
- University of Akron

Pennsylvania
- Carnegie Mellon University
- Concurrent Technologies Corporation
- Element 3 Battery Ventures, LLC
- Pennsylvania State University

South Carolina
- Paraclete Energy

Tennessee
- Tennessee Valley Authority

Texas
- Sabre Industries
- Understanding Charge Separation and Transfer at Interfaces in Energy Materials and Devices
- University of Texas at Arlington

Utah
- Ceramatec

Washington
- BrightVolt
- TRIDEC | Tri-Cities Washington Development Council

Wisconsin
- B&W MEGTEC
- Kohler Power Systems
- Rayovac
- Responsible Battery Coalition
- University of Wisconsin-Madison

Canada
- Hydro-Québec

Germany
- Bosch

Korea
- LG Chem