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ADVANCED MATERIALS &
MANUFACTURING
TECHNOLOGIES OFFICE

Education and Workforce Development for Critical Minerals and Materials Supply Chains

Workshop Report

Disclaimer

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List of Acronyms

AMMTO	Advanced Materials and Manufacturing Technologies Office
CMI Hub	Critical Materials Innovation Hub
CMM	Critical minerals and materials
DEIA	Diversity, equity, inclusion, and accessibility
DOE	U.S. Department of Energy
EWD	Education and workforce development
FECM	Office of Fossil Energy and Carbon Management
K–12	Kindergarten to 12th grade
MESC	Office of Manufacturing and Energy Supply Chains
RDD&D	Research, development, demonstration, and commercial deployment
STEM	Science, technology, engineering, and mathematics

Executive Summary

The Advanced Materials and Manufacturing Technologies Office (AMMTO) aims to improve the efficiency, productivity, environmental impact, and competitiveness of the manufacturing sector. Education and workforce development (EWD) efforts are essential for AMMTO to achieve these goals, and for this reason the current and future EWD landscape in the critical minerals and materials (CMM) sector requires renewed attention.

To better understand the existing CMM EWD efforts and prepare for future needs, AMMTO hosted a workshop on April 19, 2023. Stakeholders from industry, academia, state and local government, non-governmental organizations, and across DOE assembled to discuss the gaps in and barriers to existing EWD initiatives, opportunities for new or improved EWD efforts, and recommendations for solutions that can be best supported and promoted by AMMTO on behalf of the entire CMM sector.

During the workshop breakout sessions, participants were prompted to discuss three central questions, which were further refined for each stakeholder audience:

- What are the most significant barriers to expanding the CMM workforce?
- What are the most significant opportunities to help build the needed CMM workforce?
- How will you measure the success of EWD efforts? What metrics are most relevant?

Through facilitated discussion, each group of participants shared challenges in their CMM EWD efforts as well as their recommendations for how they, in partnership with DOE, could mitigate those issues.

Conversations throughout the workshop revealed to the community[1] that there is a need for stronger, more robust, and more consistent EWD efforts. Stakeholders involved in the workshop identified several barriers to improving the current CMM workforce development process and to developing future initiatives. Among those barriers are a lack of clear, consistent communication between public and private entities; inconsistent credentialing and education for similar jobs across companies and municipalities, which makes switching jobs or relocating difficult for employees; and an overall lack of funding—from industry, academia, and government—to bolster existing EWD efforts.

Each sector group—industry, academia, government, and non-governmental organizations—discussed additional recommendations for improving the CMM EWD space. One of the most-discussed solutions was the need for significant collaboration

[1] The CMM ecosystem includes industry, academia, state and local government, nonprofit organizations, and the federal government.

with each other and with DOE. This solution calls for better communication between industry and other public and private groups providing EWD initiatives to ensure that the provided training and education meets the real-world needs of industry. Another concern that arose was the need for increases in funding for EWD initiatives—with many participants suggesting that DOE could be a key funder of cross-sector efforts to enable the level of engagement needed and demonstrate the seriousness of the need for collaborative EWD initiatives within the CMM space.

In addition to these recommendations, the stakeholders in the workshop discussed how DOE can better assist the CMM sector in advancing EWD efforts. Across the three main groups, there were three primary takeaways for DOE (Table 1):

Table 1. Key Takeaways from the U.S. Department of Energy Critical Minerals and Materials Education and Workforce Development Workshop (April 2023)[2, 3]

Strategic Collaborations	Support Entire Supply Chain	Feedback Loops Update Investiments
Partnerships among professsinoal organizations and industry, academia, and local government are critical to growing the workforce; DOE should play a role in supporting and resourcing these collaborative efforts.	DOE should support workforce development needs across critical minerals and materials supply chain, including downstream, midstream, and upstream industries.	DOE should invest in workforce capabilities in evidence-based solutions that address current and emerging needs in critical minerals and materials industries.

AMMTO will use the insights from this workshop to inform how future investment in EWD initiatives for the CMM sector will fit into its research, development, and deployment efforts.

[2] CMM supply chains include upstream (e.g., mining and extraction), midstream (e.g., refining), and downstream (e.g., production of final products) processes.
[3] Mehta, Jeremy. 2024. Personal Communication. Technology Manager, Advanced Materials and Manufacturing Technologies Office, U.S. Department of Energy.

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Background

1 Background

Critical minerals and materials (CMM) are designated by their importance to clean energy technologies and the risk that disruption of their supply can cause to the nation's economic, energy, and overall national security.[4,5] Because of their criticality, the U.S. Department of Energy (DOE) and other federal agencies are expanding the development and deployment of domestic critical material and manufacturing technologies.

The 2019 Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals[6] includes a call to action: "Grow the American Critical Minerals Workforce: The entire U.S. critical minerals supply chain faces workforce challenges, including aging and retiring personnel and faculty; public perceptions about the nature of mining and mineral processing; and foreign competition for U.S. talent. Unless these challenges are addressed, there may not be enough qualified U.S. workers to meet domestic production needs across the entire critical minerals supply chain."

DOE's CMM strategy (Fig. 2) is built on four key pillars underpinned by education and workforce development:

- **Diversify and Expand Supply**: Diversify and expand critical mineral and material supply from varying sources while minimizing waste and increasing techno-economic coproduction of materials to ensure material availability.
- **Develop Alternatives**: Innovate alternative materials and/or manufacturing components to reduce demand and partially offset the need for virgin materials.

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[4] Critical minerals and materials are defined by the United States Geological Survey and also by DOE. The 2022 United States Geological Survey critical materials list includes 50 mineral commodities critical to the U.S. economy and national security. To help mitigate potential supply risks and anticipate the criticality of a certain material, the Energy Act of 2020 provided a statutory definition of critical materials:

- Any nonfuel mineral, element, substance, or material that the secretary of energy determines:
  - Has high risk for supply chain disruption; and
  - Serves an essential function in one or more energy technologies, including technologies that produce, transmit, store, and conserve energy; or
- A critical mineral, defined as:
  - Any mineral, element, substance, or material designated as critical by the Secretary of the Interior, acting through the Director of the U.S. Geological Survey

[5] Advanced Materials and Manufacturing Technologies Office."2023 DOE Critical Materials Assessment." U.S. Department of Energy. April 1, 2023. https://www.energy.gov/eere/ammto/articles/2023-doe-critical-materials-assessment.

[6] U.S. Department of Commerce. "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals." June 4, 2019. https://www.commerce.gov/data-and-reports/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals.

- **Improve Materials and Manufacturing Efficiency**: Use and process materials efficiently across the entire supply chain and lifecycle to reduce waste.
- **Build the Circular Economy**: Remanufacture, refurbish, repair, reuse, recycle, and repurpose to extend the lifetime of materials and partially offset the need for virgin materials.

To accelerate progress, DOE also conducts enabling activities: vital, crosscutting efforts that support all four pillars, such as interweaving education and workforce development (EWD) throughout the innovation pipeline.

Figure 1. DOE critical minerals and materials strategy

While DOE has invested in critical minerals and materials research, development, demonstration, and deployment (commercialization) (RDD&D) activities for over a decade, there has, recently, been a much stronger emphasis on EWD efforts. Historically, EWD activities across the CMM sector—including both public and private sectors—have been narrowly focused and have often centered on the collegiate and post-graduate populations. Moreover, these programs have not reached their potential as enduring resources that promote feedback loops and cultivate community and collaboration over time.

DOE CMM stakeholders have echoed their interest in education and workforce development. For example, in direct response to industry and academic partners' needs, the Critical Materials Innovation (CMI) Hub recently began a short course on

rare earth magnets, expanded its leadership training program, and developed classroom modules mapped to common core standards.

To better understand the existing CMM EWD efforts and better prepare for future CMM EWD needs, DOE's Advanced Materials and Manufacturing Technologies Office (AMMTO) hosted a workshop on April 19, 2023. The purpose of the workshop was twofold: first, to understand the gaps and opportunities to build a diverse and skilled workforce that matches the growing needs of the CMM manufacturing sector; and second, to inform sustained investments and long-term programmatic activities with commercial and labor relevance in the critical materials sector. This workshop will inform a report to congress as required by *H. Rept. 117-394 - ENERGY AND WATER DEVELOPMENT AND RELATED AGENCIES APPROPRIATIONS BILL, 2023*. The Fiscal Year 2023 House Report, p. 96, states:

> *The Committee notes the significant workforce needs in critical minerals and materials that are of national security interest, including industries in the domestic battery materials supply chain. The Department is directed to prioritize activities for workforce training and development initiatives to meet these needs. The Department is directed to provide to the Committee not later than 180 days after enactment of this Act a report assessing workforce needs in critical minerals and materials industries, primary impediments to meeting these needs, and existing federal efforts supporting workforce initiatives to ensure that the United States remains competitive to meet global demand.*[7]

The United States currently lacks the workforce capacity needed to carry out the expansion of CMM manufacturing in which the public and private sectors are investing. Developing the CMM workforce is essential to ensuring U.S. manufacturing competitiveness and requires collaboration across the CMM ecosystem to:

- Address concerns over diminishing U.S. technology to extract, process, and supply critical minerals and materials in various phases of the supply chain due to a lack of retainment of core knowledge and the lack of ability to prepare and educate the workforce at all levels (e.g., on-the-job trained and 2-year, 4-year, master's, and Ph.D. degree holders).
- Ensure communities, particularly disadvantaged communities,[8] benefit from progress made in the CMM space.
- Expand the skilled talent base and encourage a younger generation to pursue careers in the CMM industries.

[7] Congress.gov. "H. Rept. 117-389 - LEGISLATIVE BRANCH APPROPRIATIONS BILL, 2023." March 29, 2024. https://www.congress.gov/congressional-report/117th-congress/house-report/389/1.
[8] Disadvantaged Communities can be identified with the Climate and Economic Justice Screening Tool as described by the White House in the Justice40 Initiative.

- Recruit, upskill, and retain workers in the CMM manufacturing space.
- Clearly define the present and anticipate the future skills gaps between CMM industry needs and the workforce development system so they can be properly addressed.
- Ensure diversity, equity, inclusion, and accessibility is incorporated into workforce development activities to represent the communities in which the work is performed.
- Leverage existing resources and impactful EWD programs—from the United States Geological Survey and the CMI Hub—to drive greater impact.

The **workshop's purpose** was to assemble representatives from industry, academia, federal, state, and local government, and other organizations that have a vested interest in the domestic CMM industry and technologies to discuss the challenges, opportunities, and needs for education and workforce development.

Each breakout session focused on a specific education and workforce development influence group: industry, academia, as well as state/local government and other organizations.

SECTION

2

Approach

2 Approach

The workshop and the breakout sessions were conducted virtually. The workshop began with federal agencies framing their missions and priorities in the context of CMM EWD. Afterward, the workshop featured an industry panel that covered the roles and skills needed to grow the CMM industry in the United States. The scene-setting was followed by breakout sessions designed to characterize workforce and education needs from industry, academia, and state and local organizations. The workshop concluded with a discussion on how the federal government can act to address the needs discussed during the previous sessions and overcome the barriers that stakeholders highlighted throughout the day. A detailed agenda is in Appendix A.

The attendees represented a limited number of small and large companies, academic institutions, consulting firms involved in critical minerals and materials, and government agencies and laboratories. Federal agencies represented at the workshop include the U.S. Department of Homeland Security, United States Geological Survey, U.S. Department of Commerce, National Science Foundation, and U.S. Department of Labor. Trade organizations, as well as a variety of nonprofit and nongovernmental organizations and associations were represented. There was no representation from K–12 educators (Fig. 3). Most states and regions in the United States were represented by the attendees (Fig. 4).

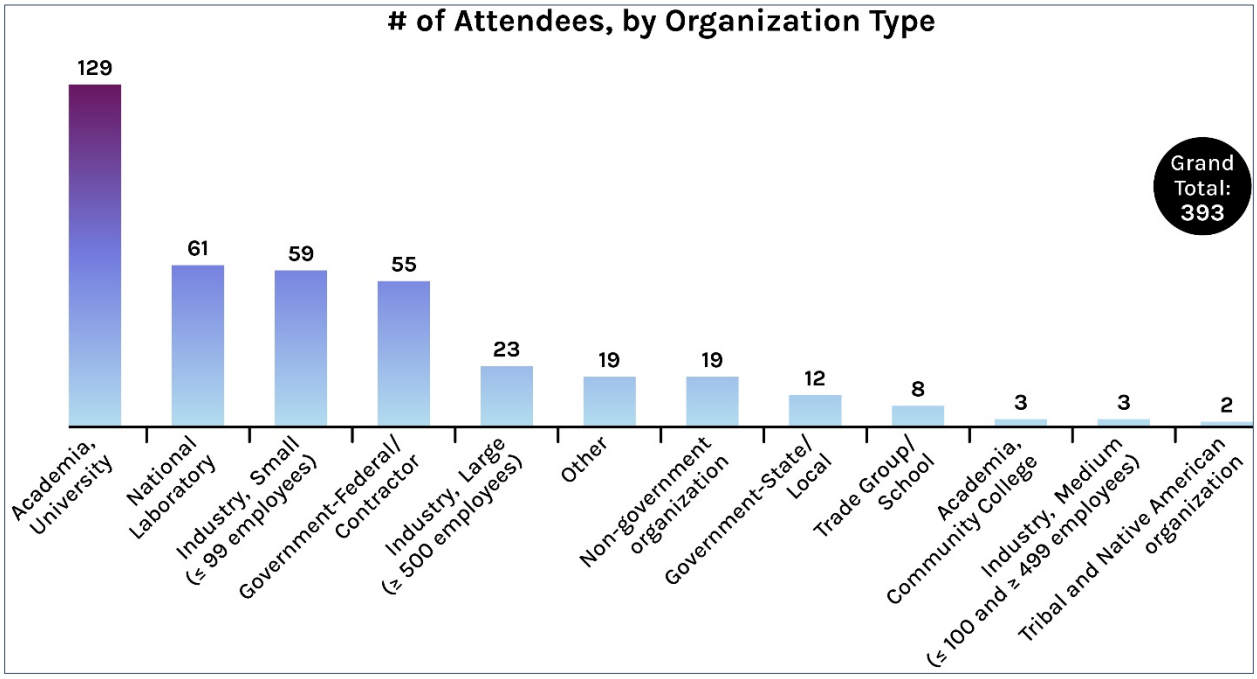


Figure 2. Workshop attendance by organization type

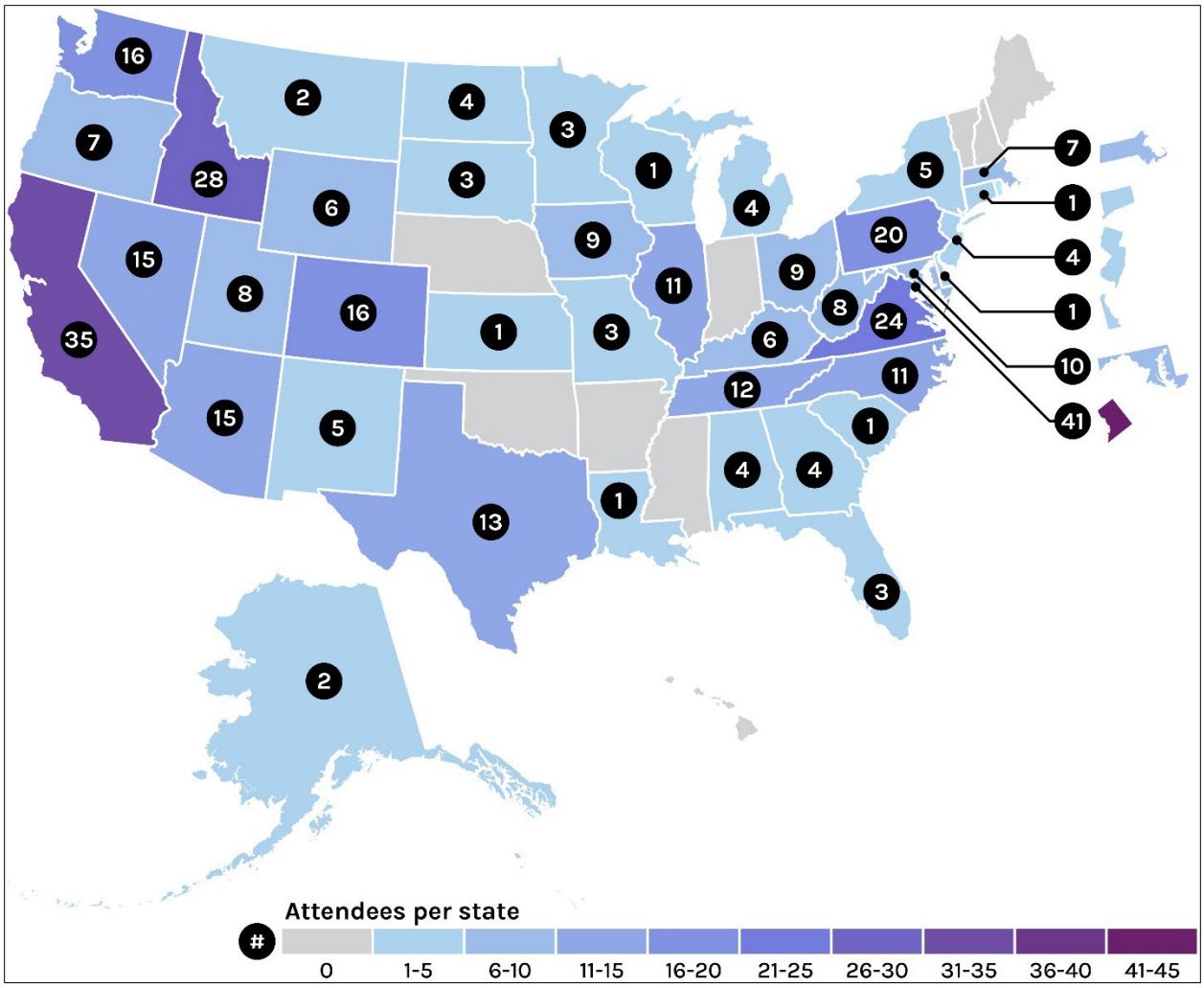


Figure 3. Workshop attendance by state of residence

Federal staff representing multiple offices in DOE and one in U.S. Department of Labor set the stage by sharing information on existing EWD activities and their understanding of EWD needs to promote deeper discussions. Next, industry speakers were invited to share brief presentations on the current state of EWD needs and challenges before participating in a panel discussion. Speakers gave examples of existing resources and initiatives that can serve as models to be scaled, replicated, or leveraged in future work. They also shared where additional work and investment is needed to meet growing needs.

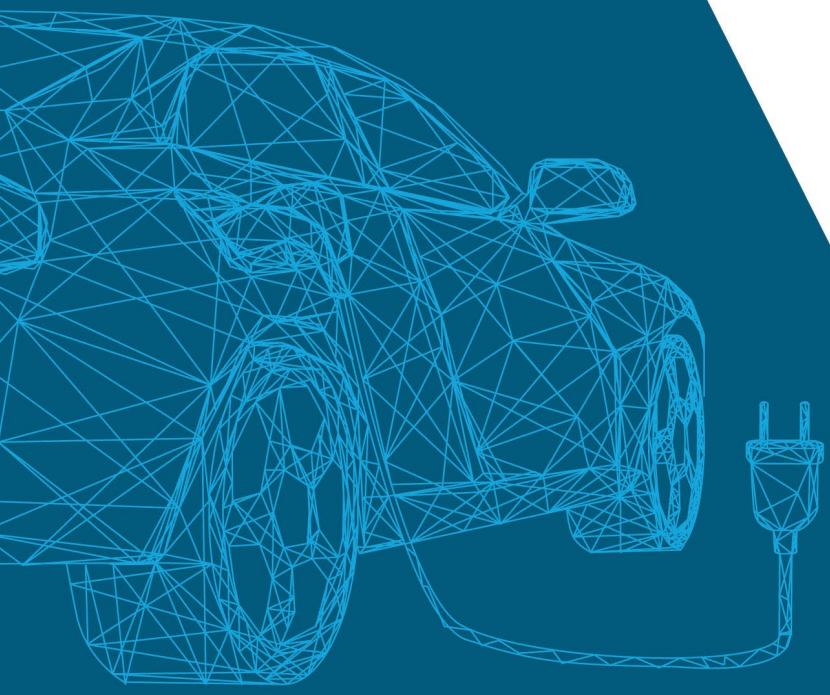
Following the presentations and panel discussions, workshop attendees spent approximately 50% of the workshop (around 2 hours) in discussion, both in the form of breakout sessions of 10–15 participants and in larger group discussions. The smaller breakout groups were intended to allow all participants an opportunity to share ideas and insights on three discussion questions. Participants were assigned to breakout groups based on the segment of the CMM sector they represented: industry, academia, or state/local organizations.

The breakout discussions focused on three key questions:

- What are the most significant barriers to expanding the CMM workforce?
- What are the most significant opportunities to help build the needed CMM workforce?
- How will you measure the success of EWD efforts? What metrics are most relevant?

During the breakout sessions, the facilitation team used an online platform called X-Leap to allow participants to provide written comments. All comments entered were anonymous to ensure participants felt they could speak freely. In addition to the participants' written comments, the facilitation team also took notes of the oral discussion.

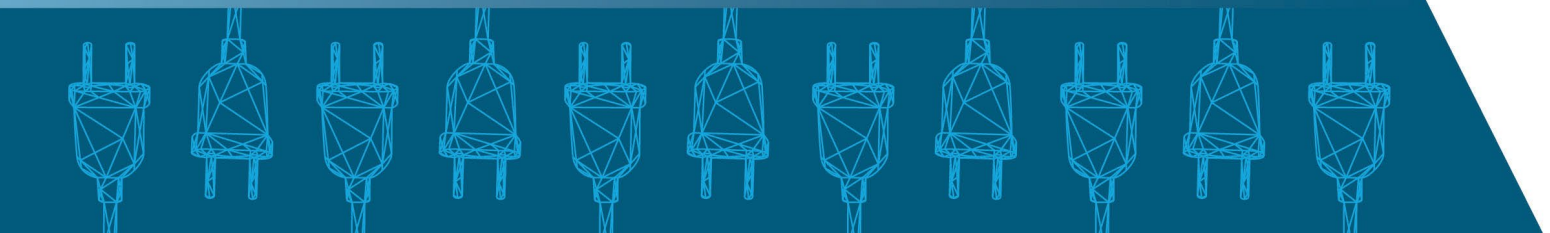
At the end of the breakout sessions, the group reconvened, and each breakout group facilitator provided a high-level overview of the discussion.



SECTION

3

3 Workshop Keynotes and Opening Panel



3 Workshop Keynotes and Opening Panel

3.1 Keynote Speakers

Each of the keynote speakers, representing perspectives from across DOE and the federal government, shared introductory remarks to kick off the workshop. Their remarks are summarized below.

AMMTO Perspective: Diana Bauer, Deputy Director

AMMTO operates at an interface of the transformation of manufacturing and the transformation of energy and CMM is critical to these.[9,10] Federal strategies for critical materials workforce development include Building Resilient Supply Chains; Revitalizing American Manufacturing; Fostering Broad-Based Growth (2021)[11]; Securing America's Clean Energy Supply Chain (2022)[12]; and the National Strategy for Advanced Manufacturing (2022)[13]. Building a skilled and diverse CMM workforce aligns with AMMTO's charge to drive materials and manufacturing technology innovations and build a next-generation workforce to transform future energy-related manufacturing. The need for significant innovation in these sectors—and the related need for a ready and capable workforce to navigate the challenges of today and the technology of tomorrow—has led AMMTO to broaden their thinking on EWD. It is not just about educating people; the sector also needs to enable workers to adapt to change as opportunities develop and shift.

Additionally, AMMTO is looking to scale up existing hands-on EWD opportunities. DOE and AMMTO want to collaborate with industry and academia, with a vision of broadening the CMM workforce and creating a steady stream of well-trained workers for the sector. This expansion of the CMM workforce pipeline requires focus on not only those people already aware of and interested in the energy and manufacturing work needed in the CMM sector, but also a focus on a more inclusive pool of potential workers from underrepresented communities and those who may come to CMM work through non-traditional pathways. Also important is the regionality of many jobs within

[9] U.S. Department of Energy, "Critical Materials Strategy," December 2010, https://www.energy.gov/sites/prod/files/edg/news/documents/criticalmaterialsstrategy.pdf.
[10] U.S. Department of Commerce, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," 2019, https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf.
[11] The White House, "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-based Growth," June 2021, https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.
[12] U.S. Department of Energy, "America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition," February 24, 2022, https://www.energy.gov/policy/articles/americas-strategy-secure-supply-chain-robust-clean-energy-transition.
[13] This report has not yet been published, but DOE and others have had the opportunity to review the initial findings.

the CMM ecosystem, particularly those jobs where materials are mined, extracted, and processed.

To meet the workforce needs of the manufacturing sector, AMMTO organizes its EWD efforts to align with four strategic pillars: scale up, collaborate, diversify, and expand (Figure 5).

Figure 4. Four pillars of AMMTO's EWD strategy

In **scale up**, successful hands-on/experiential training programs in technology areas relevant to AMMTO are deployed and expanded. AMMTO will then **collaborate** with industry, labor, and academia to accelerate and broaden the pipeline of well-trained, diverse workers and grow desirable career paths in the advanced manufacturing sector. To **diversify** programs, AMMTO will use deliberate design to be inclusive of underrepresented identities and address energy and environmental justice challenges faced by specific communities. Finally place-based advanced manufacturing EWD initiatives at the local and regional levels will **expand** the workforce across the sector.

Office of Fossil Energy and Carbon Management's Perspective: Caleb Woodall, Program Manager, University Training and Research

The DOE Office of Fossil Energy and Carbon Management's (FECM) strategic vision includes three primary directions: advancing justice, labor, and engagement; advancing carbon management approaches toward deep decarbonization; and advancing technologies that lead to sustainable energy resources. The vision aims for decarbonization goals of a 50% reduction in U.S. greenhouse gas pollution by 2030, a carbon-neutral power sector by 2035, and a carbon-neutral economy by 2050. FECM has consistently invested in EWD programs, with an increasing emphasis on funding Historically Black colleges and universities and minority-serving institutions to improve diversity. Recently, FECM has extended EWD funding to social sciences and humanities to support analysis of social aspects of these programs, including community impacts.

Office of Manufacturing and Energy Supply Chains Perspective: Mallory Clites, Manufacturing and Supply Chains Technology Manager, Batteries and Critical Materials

> "Many high-demand jobs don't require a higher education, just training."

The role of the Office of Manufacturing and Energy Supply Chains (MESC) within DOE is to bridge the gap between research and development (R&D) and manufacturing and deployment. In this role, MESC highly values recycling of critical minerals and materials, as it allows for a more secure supply chain while also decreasing the carbon footprint of battery manufacturing in the United States. Though not exhaustive, DOE supports battery manufacturing and recycling across many technologies and throughout the supply chain. Regarding workforce development, MESC's Industrial Assessment Centers (IACs) educate the next generation of workers in this sector through hands-on training to conduct technical assessments to help small- and medium-sized U.S. manufacturers identify opportunities to save energy, improve productivity, and reduce waste. The program's focus on reuse and recycling can help not only secure the supply chain, but help the future workforce understand and anticipate the unique supply chain needs of the CMM sector and prepare for the innovation and challenges that will arise in coming years.

Federal Data Analysis Findings: Pam Frugoli and Lucas Arbulu, U.S. Department of Labor

The U.S. Department of Labor was tasked with researching how many and what kind of CMM jobs are currently available within the United States, with initial findings delivered in December 2022. Research questions looked at the education levels necessary to have a career in the CMM sector, which institutions are graduating students in CMM-related fields, and what educational programs are related to critical mineral and materials activities. Initial findings noted 27 key occupations that involve critical minerals and materials; 19 of those have a significant 10-year growth pattern with a mix of educational requirements. Meanwhile, eight occupations showed signs of decline in popularity and need, including inspectors, samplers, and clerks.

> "Around 88% of the current workforce is white and 84% are men, demonstrating the severe lack of diversity in the CMM sector."

Only four jobs required a postsecondary education. The highest degree completions in the field included: mining and mineral engineering, surveying, and technology, geological and geospatial engineering. Many high-demand jobs do not require a higher education, just training, and training on new technologies can be significantly less time-consuming than initial job training.

Finally, around 88% of the current workforce is white and 84% are men, demonstrating the severe lack of diversity in the CMM sector.

Workforce Development Resources from CMI Hub: Cynthia Howell, Research Faculty, Energy Education Specialist

Founded by DOE and located within the Colorado School of Mines, the Innovation Lab has been wildly successful inspiring younger generations to pursue careers involving critical minerals. The foundation works with K–12 students, along with recent college grads and those currently pursuing a higher education. With 300-plus researchers across the nation working with the program, the Innovation Lab is particularly good at leveraging community assets and working with preexisting institutions. The museum, which sees around 30,000 visitors each year, offers take-home kits so teachers can foster interest in the classroom through experiments. These critical materials educator toolkits demonstrate how raw critical materials are vital to energy and advanced technologies and are used in annual teacher workshops. The toolkits are easily accessible, with demonstrations and classroom activities for hands-on engagement with critical materials in any professional or academic setting.

In addition to developing and deploying EWD resources, CMI Hub tracks the career advancements of recent graduates within the CMM workforce. Through greater understanding of the career paths within the CMM sector, CMI Hub can support dwindling fields in critical minerals and materials while also spearheading future developmental opportunities. So far, students who have been involved in the CMI Hub's tracking project have largely joined the CMM workforce through three main pathways: work in academia, work at national laboratories, and work directly with industry. Smaller cohorts have chosen to continue their CMM work in government or nonprofit jobs.

3.2 Industry Panel

The panelists each made introductory remarks, summarized below, regarding significant challenges and opportunities for workforce development in the critical minerals and materials industry. Panelists then responded to a moderated discussion question.

Ford Motor Company: Rachel McCleery, Director, Manufacturing Policy

Ford's internal workforce report for 2023 is focused on downstream efforts for the workforce and ensuring employees are receiving the necessary support across all nodes of the supply chain in both job training and long-term career progression. Looking ahead to the future workforce, the Ford Automotive Student Service Education Training Program will be an innovation hub for the progression of representation and workforce diversity.

American Battery Technology Company: Doug Hamilton, Head of Public Policy and Government Affairs

It is important to foster relationships with representatives from across the industry—both in the public and private sectors. There are three main priority protocols at American Battery Technology Company: lithium-ion battery recycling, primary minerals resource development, and having a diverse and skilled workforce. The last protocol is contingent upon increased accessibility to science, technology, engineering, and mathematics (STEM) education, training and re-training, and trade schools. STEM education can be expanded in the curriculum and can be supported with more funding. The same is true for post-secondary education. More certifications are required to ensure specific skills are taught to the workforce. Government support and funding will be critical in the progression of workforce development, along with an emphasis on diversity. Rural communities could benefit from critical minerals production, as it may grow the economy.

Rio Tinto: Cory Smith, Principal Advisor, Processing

Rio Tinto is the second largest global mining company in the world and employs a skilled workforce that is highly educated. The challenge is to recruit and maintain the employees for the future. There is a parallel decline in the number of employees across the world, specifically in the United States and Australia, since younger populations are not attracted to mining. To attract employees, the company is offering paternity and maternity leave, semi-annual work surveys to learn more about needs, work-life balance initiatives, facility changes to improve quality of employee experience, outreach to younger populations, and university partnerships to support more incoming employees. Government support and grants for students to join the workforce and support education for mining are also critical.

Piedmont Lithium: Malissa Gordon, Vice President, Government Affairs

> "With the higher education community, there is a need to improve perception of the mining industry and debunk myths by educating people on what a day in the life of a mining employee looks like."

Piedmont Lithium is a global producer of lithium and provides domestic energy. The Carolina Lithium Project includes a mining operator and facilities. The Tennessee lithium project focuses on lithium hydroxide production. With all these projects comes the elevated demand for employees. In terms of workforce challenges, the company is putting an emphasis on trade association needs and coalitions and trying to better understand the needs of the population to support the workforce. The company is also working at a local level with colleges to offer more advancement opportunities and grow skillsets. With the higher education community, there is a need to improve perception of the mining industry and debunk myths by

educating people on what a day in the life of a mining employee looks like. For K–12 education, the focus is on instilling motivation for the STEM fields and supporting education for younger populations. We need those schools, and we need programs with additional STEM based curriculum in these schools to nurture growth for these populations.

3.3 Moderated Panelist Question

Q: Mention one thing in the company that is a sign of optimism for the field and workforce. What is working?

McCleery: Being able to get enough workers to operate our facility is a major success, as there are over 6,000 job positions. Nearby applied technology colleges are developing curricula focusing on skills needed for new jobs at Ford, and there have been positive developments to increase investments and recruitment to support a new battery manufacturing site. We want to build the workforce with members of the local community first, allowing Ford to invest in helping grow the community and new projects.

Hamilton: Public-private partnerships are extremely important in this industry, and the American Battery Technology Company has been collaborating with the University of Nevada-Reno. One of the benefits of such a partnership is the ability to recruit interns from the university who are interested and educated in the industry.

Smith: We have attracted many more people to the industry in the past two years. While workers aging out of the field has been a challenge, we have found an abundance of smart people excited to start anew. We've also been able to add more diversity to the company, and diversity is key to improving a company's functionality. We're looking forward to working with the local community to further expand and diversify our workforce.

Gordon: We've partnered with Be Pro Be Proud to help introduce new audiences to the work we do at Piedmont Lithium. Through their road show, Be Pro Be Proud can demonstrate different technology careers through the use of portable simulators, and we are working on adding a mining-focused demonstration as well. The partnership has helped spark interest in the jobs offered at Piedmont Lithium and created a new optimism in the community for the CMM sector.

3.4 Summary of Panel Discussion Themes

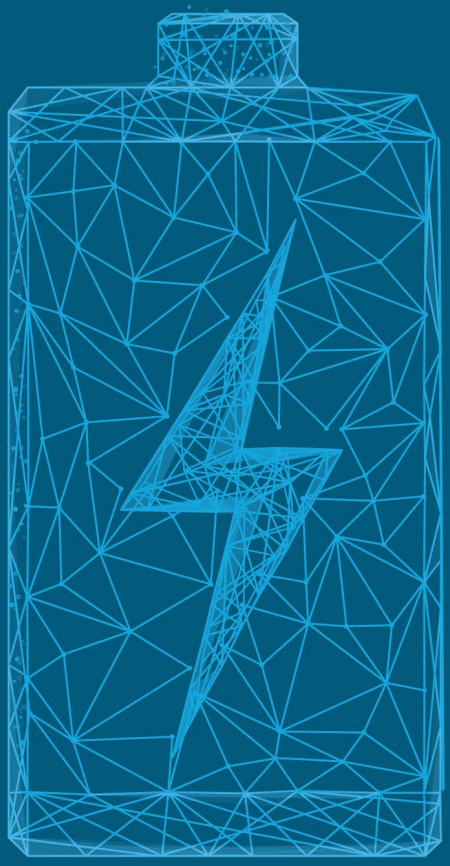
Challenges

- There is not yet significant education and training infrastructure across the sector to support the necessary workforce growth.

- The existing workforce is aging, and young people have not shown as much interest in the work within the CMM sector—in part because of a negative perception of the mining industry.
- The industry is lacking in diversity, which is hurting companies' bottom lines and the ability to attract new potential workers to the field.

Initiatives

- Public-private partnerships—particularly those between industry and academia—can help expand the potential talent pool and attract younger, more diverse workers to the CMM sector through existing talent pipelines.
- Focusing on attracting talent within the region—rather than attracting talent *to* the region—can help businesses demonstrate investment in their communities while expanding the workforce and increasing diversity.



SECTION

4

4 Discussion Group Takeaways

4 Discussion Group Takeaways

Takeaways from each of the breakout groups are broken into three main categories:

Overarching Theme condenses the overall discussion of that breakout group into a few sentences to help explain the overall mood of the conversation and the general feelings of the particular category of participants.

Questions Posed outlines the questions used to prompt discussion between participants about problems and solutions.

Characterizing the Problems condenses the most-discussed overarching issues within that discussion group that stand in the way of expanding the CMM workforce.

Proposed Solutions condenses the most-discussed solution options and breaks them into categories based on AMMTO's four EWD Strategy priorities, including:

- Encourage and Facilitate Collaboration
- Develop and Scale Innovative EWD Initiatives
- Advance Diversity, Equity, Inclusion, and Accessibility (DEIA)
- Promote Worker-Centric Efforts.

4.1 Industry Takeaways

Overarching Theme: Industry's success in CMM depends on an expanded talent base of potential workers from K–12 to those in trade schools, 2- and 4-year degree programs, and graduate-level education. But existing workers also need clear pathways to success, such as through portable credentials, on-the-job training, and significant opportunities for advancement. These populations of current and future workers cannot be expanded without significant outreach efforts to more diverse groups, including not only underrepresented and minority communities, but also rural and urban communities that are not always considered "local" to the CMM workforce.

Questions Posed

- What are the industry's most significant gaps with the CMM workforce? (e.g., specific skill gaps, regional/geographic needs, supply chain segments, etc.)
- What are the most significant opportunities for DOE to engage with industry to build the needed CMM workforce?
- How will industry measure the success of CMM education and workforce development efforts? What metrics are most relevant?

Characterizing the Problems

- The gap in industry's current and emerging workforce needs must be clearly defined so that it can be properly addressed. There is no current cross-industry agreement on the defined skills needed to fill specific roles or the roles most needed to fill across the industry.
- Diversity is lacking in the industry, which has the potential to limit success.
- Unclear career paths and a lack of direct advancement opportunities cause young workers to feel "stuck" and leave the CMM workforce quickly.
- Upskilling and reskilling efforts are often underfunded by industry or overlooked by employees, creating larger gaps in certain areas, particularly those reliant on ever-evolving technology.

Proposed Solutions

- Encourage and Facilitate Collaboration
    - Sponsor collaborations between universities, national laboratories, and industry to ensure work being done addresses current industry needs.
    - Information in the U.S. CMM space is often siloed, particularly between government and industry and between companies within industry. Efforts that can open the flow of communication across the sector are urgently needed to allow the United States to compete in CMM on a global scale.
- Develop and Scale Innovative EWD Initiatives
    - CMM needs a "moonshot" project to promote collaboration among industry, academia, and government, while also advancing technology and workforce development to achieve the goal.
    - Through DOE collaboration with industry, small and large companies developing new CMM technologies can more efficiently and rapidly reach new technology readiness levels.
- Advance Diversity, Equity, Inclusion, and Accessibility (DEIA)
    - Outreach efforts are needed that target younger audiences, particularly those in the K–12 population, if the industry is to have the talent needed in the workforce in the coming decade-plus.
    - DOE support of paid industry internships, particularly with startup/emerging companies, can help a more diverse population enter the CMM workforce and provide companies that may not otherwise be able to expand their DEIA outreach to do so.
- Promote Worker-Centric Efforts

- Harmonize skill competencies and create credentials/certification that operators can take with them from one job to another as proof of knowledge and skills.
- Pursue potential talent in their own community (e.g., bring jobs to rural spaces instead of expecting them to come to you seeking jobs).

4.2 Academia Takeaways

Overarching Theme: An immediate need exists at all educational levels for resources to train and educate the future, emerging, and current workforce. Present efforts are insufficient to meet the demands of an expanding CMM workforce that can be competitive on a global scale. Significant investment in education and a broad outreach program to target underrepresented populations are essential to meet the United States' CMM workforce needs.

Questions Posed

- What are academia's most significant barriers limiting the ability to educate and train the CMM workforce?
- What are best practices that academia should seek to replicate and scale to build the needed CMM workforce?
- How will academia measure the success of CMM education and workforce development efforts? What metrics are most relevant?

Characterizing the Problems

- Support and funding (especially government-sourced) of faculty is insufficient, and as senior faculty retire there are insufficient junior faculty replacing them to continue undergraduate and graduate programs for CMM technologies.
- Significant gaps in curriculum for extraction and mining leave students in these programs unprepared for the realities of the workforce, and industry cannot always afford the process of reskilling these potential employees.
- Academia lacks diversity, and students who can't see themselves in the field are unlikely to continue down the path toward the CMM workforce.
- Industry sectors do not share the same technical language, making it difficult for academia to understand and teach to the overarching needs of industry.
- The first time many students encounter information on CMM is in undergraduate or graduate school, when it can be too late to attract them to study the STEM subjects needed to enter the CMM workforce. More attention needs to be paid to bringing CMM learning to K–12 students to encourage a greater interest in the relevant STEM fields when they still have time to develop an interest before reaching higher education or the workforce.

Proposed Solutions

- Encourage and Facilitate Collaboration
  - Include parents and other adult influences in K–12 students' lives in outreach efforts. These adults often have more of an impact on a student's choice of field of study or work than outreach takes into account, and collaborating with them can increase the number of students who seek out further engagement with CMM educational opportunities.
  - Consider an interdisciplinary approach to materials science and engineering, particularly with a focus on environmental concerns.
- Develop and Scale Innovative EWD Initiatives
  - Develop specialized short courses for industry personnel—particularly around processing and refining needs, such as electrochemistry and electrochemical engineering—to help existing workers and those looking to pivot to CMM.
- Advance Diversity, Equity, Inclusion, and Accessibility (DEIA)
  - There needs to be more of a focus on K–12 STEM education, particularly those areas relevant to CMM work, to attract more diverse students to consider education pathways into the CMM workforce.
  - More funding and more undergraduate educators are needed to help attract college students to CMM-related fields and encourage them to pursue graduate programs, which is necessary for several critical roles in the CMM workforce.
  - Experiential learning programs at both the K–12 and undergraduate levels could help attract students through hands-on learning, which often has a greater impact than standard lecture-based lessons.

Promote Worker-Centric Efforts

- Academia, industry, and community leaders should work together to determine the needs of the local workforce and what will help support potential CMM workers in the community.
- Expand Educational Programs that Support Critical Minerals and Materials Technical Areas:
  - Academic degree granting undergraduate and graduate programs.
  - Apprenticeship and similar technical and technology programs.

4.3 State, Local, and Other Organization Takeaways

Overarching Theme: Community governments and organizations are ready and willing to provide support and resources to advance CMM EWD efforts, but the barriers that exist make it difficult for them to provide such support in a consistent manner across local and state lines. Collaboration across the CMM EWD ecosystem can help create the conditions needed for these public and private organizations to provide effective support, particularly in the areas of educational outreach and economic development.

Questions Posed

- What are state, local, and other organizations' most significant barriers limiting their ability to support the CMM workforce?
- What best practices can be replicated and scaled to build the needed CMM workforce?
- How will state, local and other organizations measure the success of the CMM education and workforce development efforts? What metrics are most relevant?

Characterizing the Problems

- Environmental and social justice issues are present at every stage of CMM production, use, and end-of-life stages. Unless addressed in the education and hiring processes, these issues can be dealbreakers for younger people considering work in CMM fields.
- Community colleges and vocational schools do not have the same connections to industry that more traditional academic institutions have, creating potential gaps between the education they provide and the actual needs of industry.
- Inconsistencies in language, credentialing, regulations, and EWD efforts across states and localities make it particularly challenging to consistently and collaboratively advance national priorities.
- State and local governments are willing to support increased economic development opportunities and EWD initiatives related to CMM, but poor public perception of CMM-related fields often causes these efforts to be pulled back or to fall flat.

Proposed Solutions

- Encourage and Facilitate Collaboration
    - Communicate that environmental and social justice considerations are part of the process; younger generations are being driven away from industry because of environmental concerns.

  - More national-level collaboration with non-CMM partners is needed to spread awareness of the value of CMM and the need for an expanded CMM workforce. Initiatives such as the Smithsonian's "Scientist Is In" program and the National Museum of Natural History exhibit "Cellphones: Unseen Connections" are examples of partnerships that can attract interest from those with only a tangential interest in CMM and increase their understanding of and interest in the possibilities in the CMM sector.

- Develop and Scale Innovative EWD Initiatives
  - Job sites that provide clear career paths and help prospective workers understand the types of jobs available, education levels needed, and average salaries must be scaled at the regional and national levels to help current and future CMM employees see their path into the CMM workforce and the benefits they can gain from the work.
- Advance Diversity, Equity, Inclusion, and Accessibility (DEIA)
  - K–12 education needs to do a better job of introducing students to CMM-related STEM subjects at age-appropriate levels. This should include, among other efforts, integrating CMM education into earth science classes; providing more hands-on learning opportunities; and encouraging students who show an interest or aptitude for STEM to consider continuing that education, whether through vocational training or a 2- or 4-year degree program.
  - Investment is needed for educators at all levels to help teach staff new skills and increase their knowledge of cutting-edge CMM technologies to help them not only grow their own careers, but also more effectively communicate the value and opportunities in CMM to students.
  - Efforts to expand and ease pathways for non-citizens to apply for jobs in CMM-related fields, particularly those from under-represented populations.
- Promote Worker-Centric Efforts
  - Develop outreach best practices across the entire EWD ecosystem (academia, industry, economic development organizations, state, local, and federal government, etc.) to provide consistent messaging about the benefits of CMM work to both current and potential workers.
  - Provide more opportunities for internships at all levels of education and across the CMM sector to help potential workers learn more about the opportunities that exist in their own regions and communities.

4.4 Group Takeaways: Cross-Cutting Topics

Overarching Theme: There is an urgent need to get the pipeline started and begin developing the required skilled workforce. There are three key factors to take into account in building and expanding the pipeline: A common language used across the CMM ecosystem is necessary to explain the jobs and opportunities available; place-based, worker-centric approaches should be implemented to demonstrate the CMM sector's willingness to support local communities and diversify the workforce; and other nations are in the midst of growing their CMM workforces, presenting opportunities to learn from different approaches and bring new best practices to the U.S. CMM EWD community.

Questions Posed

- How do we connect industry, academia, state/local programs, and labor to accelerate increases in the pipeline of well-trained, diverse workers and desirable career paths in CMM?
- What programs have worked well and can be scaled up (e.g., hands on/experiential training programs)? What has not worked well or is unlikely to scale?
- How can we deliberately design programs to be inclusive of underrepresented identities and address environmental, energy, and economic justice challenges faced by specific communities?

Characterizing the Problems

- Industry and academia are not adequately communicating; industry needs to share the real-life workforce gaps and challenges with academia and training organizations to educate workers appropriately, particularly as it relates to urgent workforce needs.
- There is not enough place-based collaboration between industry and EWD organizations; the industry is very small in local regions, and collaboration can help generate new pathways into the workforce.
- Potential workers do not understand the value that *they* bring to the CMM ecosystem. Focusing on the value of the people and not only on the value of CMMs during recruitment could help attract more potential workers to the sector.
- Competition between entities within the CMM ecosystem prevents industry, government, and academia from collaborating sufficiently.
- Messaging around CMM and mining is not consistent. Specifically, much of what the public sees is negative—rejections of new mines and closures of older mines—making work in CMM seem unattractive, especially to younger people.

Proposed Solutions

- Encourage and Facilitate Collaboration
  - Organizing meetings and workshops that can connect stakeholders from across the CMM ecosystem would allow people throughout the sector to engage with one another and form relationships, creating more opportunities for collaboration.
  - Develop a platform for knowledge-sharing and skill-building that incorporates industry and regulatory perspectives. By making communities "smarter," they will be better partners and can further collaborate with the CMM sector.
  - Community colleges and trade schools should partner with local industry to provide EWD providers with a greater understanding of industry's needs and provide industry with direct connections to a wider pool of potential workers.
- Develop and Scale Innovative EWD Initiatives
  - Educators in traditional CMM and STEM fields should collaborate with educators in adjacent fields of study—such as environmental and social justice and liberal arts—to advance understanding of all the issues and opportunities that impact CMM and encourage students and educators in other fields to consider their potential path in the CMM sector.
  - The NSF has programs that fund groups of graduate students with registered apprenticeships and fellowships to work in interdisciplinary areas framed for the mining/CMM industry. DOE could build on this by partnering with industry to provide internships for students *and* faculty, allowing educators firsthand experience with the workforce and helping industry advance their research efforts.
  - Entire communities should be engaged in the development of new EWD initiatives to bolster their success and encourage wider participation. By including the local community (i.e., potential future workers), economic development leads, local industry and businesses, and regional EWD organizations, there is potential for a much stronger connection between the community and industry and an opportunity to demonstrate the value the CMM sector can provide to communities and workers.
- Advance Diversity, Equity, Inclusion, and Accessibility (DEIA)
  - By connecting R2 universities with R1 schools, undergraduate students can be introduced to the opportunities available in STEM and CMM research. This would be particularly beneficial for universities with high populations of first-generation college students.

  - Early outreach—particularly in the K–12 years—could help younger generations see themselves in the CMM workforce earlier and encourage them to consider CMM-related fields of study as their education advances. This would not only help widen the pool of potential CMM workers but would also help diversify the workforce by capturing students from underrepresented communities early and showing them that paths into the CMM workforce exist for them.
  - Colleges and universities can offer general education classes focused on CMMs and their societal impact, introducing students without technical backgrounds to the subject and encouraging interest in CMMs, even if the students choose not to go into more technical CMM-related fields.

- Promote Worker-Centric Efforts
  - Webinars and other free educational opportunities can help raise awareness of the opportunities within the CMM ecosystem on a national level. Participation from national labs, start-up companies, and local industries can provide attendees an understanding of the opportunities across the sector and introduce them to people and organizations that can help them find their own CMM career path.
  - Encourage the development of equitable and inclusive environments by communicating the value that individuals bring to CMM organizations. Recruitment and retention of diverse individuals requires a commitment to DEIA at the organizational level, and workers should be included in the development of any DEIA initiatives.
  - The development of internal company programs that rotate workers across a company's operations and through multiple offices and regions can help workers better understand the company and their role, show them additional opportunities for growth within their company, and break them out of their usual silos, introducing them to new ideas and perspectives that can help them grow and advance their careers.

Appendix A. Workshop Agenda

Table A 1. Workshop Agenda

Time	Activity
12–12:05 p.m.	Sign on and Welcome
12:05–12:30 p.m.	Overview of U.S. Department of Energy Strategy for Critical Minerals and Materials Advanced Materials and Manufacturing Technologies Office Perspective – Diana Bauer Office of Fossil Energy and Carbon Management Perspective – Caleb Woodall Office of Manufacturing and Energy Supply Chains Perspective – Mallory Clites
12:30–1 p.m.	Analysis of the Critical Minerals and Materials Workforce Needs Federal Data Analysis Findings – Pam Frugoli and Lucas Arbulu, U.S. Department of Labor Workforce Development Resources from Critical Materials Institute – Cynthia Howell, Critical Materials Institute
1–1:50p	Industry Panel: Needs for the Critical Minerals and Materials Workforce Rachel McCleery, Ford Motor Company Doug Hamilton, American Battery Technology Company Cory Smith, Rio Tinto Malissa Gordon, Piedmont Lithium
1:50–2 p.m.	Break
2–3 p.m.	Breakout Sessions: Defining Needs of Industry, Academia, and State/Local Programs Participants will self-select into one of three breakout groups to identify needs, opportunities, barriers, and metrics for success
3–3:50 p.m.	Group Discussion: Identifying Education and Workforce Development Activities to Fulfill Needs

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