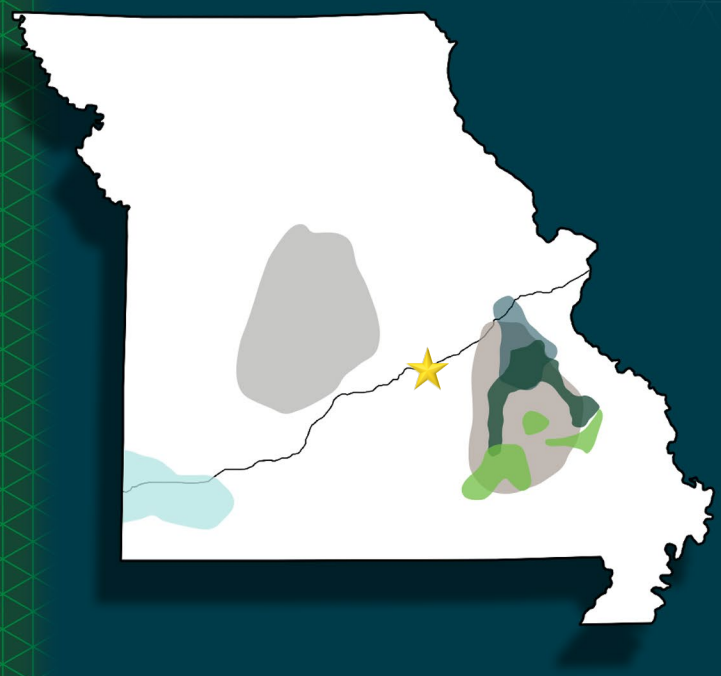

Summary Report:

3rd Annual National Workshop:

Resilient Supply of Critical Minerals

August 9-10, 2023

Rolla, Missouri

Hosted by Missouri University of Science and Technology

criticalminerals.mst.edu

Cover: Known critical mineral distribution in the state of Missouri. Data courtesy of the Missouri Department of Natural Resources, PUB2912. https://dnr.mo.gov/document-search/other-critical-minerals-missouri-pub2912/pub2912

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Acknowledgements and Disclaimer

The 2023 workshop on 'Resilient Supply of Critical Minerals' was made possible by the National Science Foundation (NSF) through award #2314530: Conference CAS - Climate: Resilient Supply of Critical Minerals, Rolla, MO, August 9-10, 2023 awarded to the following Missouri S&T faculty: Marek Locmelis (PI), Michael Moats (Co-PI), Kwame Awuah-Offei (Co-PI), Lana Alagha (Co-PI), Alanna Krolikowski (Co-PI), Mark Fitch (SP), and Mahelet Fikru (SP).

The findings presented in this report are based on discussions during the workshop, i.e., presentations and breakout sessions. The views and opinions presented here do not necessarily reflect those of the workshop organizers who prepared the report.

Preferred Citations

Workshop Proceedings

Locmelis, M., Clark, S., Moats, M., Awuah-Offei, K., Alagha, L., Fitch, M., Krolikowski, A., & Fikru, M. (2023): Summary Report: 3rd Annual Workshop on Resilient Supply of Critical Minerals, 9-10 August 2023, Missouri University of Science and Technology, Rolla, Missouri, USA, 36 pages.

Individual Abstracts (example)

Mauk, J. (2023): Uncertainties in translating U.S. critical mineral resources to domestic supply. In: Locmelis, M., Clark, S., Moats, M., Awuah-Offei, K., Alagha, L., Fitch, M., Krolikowski, A., & Fikru, M. (2023): Summary Report: 3rd Annual Workshop on Resilient Supply of Critical Minerals, 9-10 August 2023, Missouri University of Science and Technology, Rolla, Missouri, USA, 36 pages.

Executive Summary

On August 9-10, 2023, the Thomas J. O'Keefe Institute for Sustainable Supply of Strategic Minerals at Missouri University of Science and Technology (Missouri S&T) hosted the third annual workshop on 'Resilient Supply of Critical Minerals'. The workshop was funded by the National Science Foundation (NSF) and was attended by 218 participants. 128 participants attended in-person in the Havener Center on the Missouri S&T campus in Rolla, Missouri, USA. Another 90 participants attended online via Zoom. Fourteen participants (including nine students) received travel support through the NSF grant to attend the conference in Rolla. Additionally, the online participation fee was waived for another six students and early career researchers to attend the workshop virtually.

Out of the 218 participants, 190 stated their sectors of employment during registration showing that 87 participants were from academia (32 students), 62 from the private sector and 41 from government agencies. Four topical sessions were covered:

A. The Critical Mineral Potential of the USA: Evaluation of existing, and exploration for new resources.
B. Mineral Processing and Recycling: Maximizing critical mineral recovery from existing production streams.
C. Critical Mineral Policies: Toward effective and responsible governance.
D. Resource Sustainability: Ethical and environmentally sustainable supply of critical minerals.

Each topical session was composed of two keynote lectures and complemented by oral and poster presentations by the workshop participants. Additionally, a panel discussion with panelists from academia, the private sector and government agencies was held that discussed *'How to grow the American critical minerals workforce'.* The 2023 workshop was followed by a post-workshop field trip to the lead-zinc mining operations of the Doe Run Company in southeast Missouri that was attended by 18 workshop participants from academia (n=10; including 4 students), the private sector (n=4), and government institutions (n=4).

Discussions during the workshop led to the following suggestions to increase the domestic supply of critical minerals:

(i) Research to better understand the geologic critical mineral potential of the USA, including primary reserves/resources, historic mine wastes, and mineral exploration potential.
(ii) Development of novel extraction techniques targeted at the recovery of critical minerals as co-products from existing production streams, mine waste materials, and recyclables.
(iii) Faster and more transparent permitting processes for mining and mineral processing operations.
(iv) A more environmentally sustainable and ethical approach to mining and mineral processing.
(v) Development of a highly skilled critical minerals workforce.

This workshop report provides a detailed summary of the workshop discussions and describes a way forward for this workshop series for 2024 and beyond.

1. Introduction

On June 4, 2019, the U.S. Department of Commerce released the strategic report "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals". The report outlines six Calls to Action that, if executed, will reduce the vulnerability of the United States to critical mineral supply disruptions. These six Calls to Action are:

1. Advance Transformational Research, Development, and Deployment Across Critical Mineral Supply Chains.
2. Strengthen America's Critical Mineral Supply Chains and Defense Industrial Base.
3. Enhance International Trade and Cooperation Related to Critical Minerals.
4. Improve Understanding of Domestic Critical Mineral Resources.
5. Improve Access to Domestic Critical Mineral Resources on Federal Lands and Reduce Federal Permitting Timeframes.
6. Grow the American Critical Minerals Workforce.

In 2020, the Thomas J. O'Keefe Institute for Sustainable Supply of Strategic Minerals at Missouri University of Science and Technology (Missouri S&T) received funding from the National Science Foundation (NSF) to host a workshop on the Missouri S&T campus (Rolla, Missouri) to identify research needs associated with these Calls to Action. Initially scheduled for May 2020, the in-person workshop was cancelled because of the global COVID-19 pandemic. Consequently, the format of the workshop was changed to a two-part virtual workshop series. The first virtual workshop was conducted on August 2-3, 2021, via Zoom. The second virtual workshop was conducted on August 4-5,2022, also via Zoom. The 2021 and 2022 workshop reports are accessible through the workshop website: https://criticalminerals.mst.edu/previous-workshops/.

In 2023, the Thomas J. O'Keefe Institute for Sustainable Supply of Strategic Minerals received continued funding from NSF to host a third workshop on August 9-10, 2023. The workshop was held in-person in the Havener Center on the Missouri S&T campus in Rolla, Missouri. Online participation via Zoom was offered to participants who could not travel to Rolla. The workshop was followed by an optional field trip to the lead-zinc mining operations of the Doe Run Company on August 11, 2023.

2. Workshop Content

The 2023 workshop was divided into four topical sessions that discussed pressing critical mineral research needs as identified by participants during the preceding workshops:

Session A: The Critical Mineral Potential of the USA: Evaluation of existing, and exploration for, new resources.

Keynote Lectures:

- **Jeffrey Mauk** (United States Geological Survey): Uncertainties in translating U.S. critical mineral resources to domestic supply.
- **Adam C. Simon** (University of Michigan): The Transition to Renewable Energy: Truths and Consequences.

Session B: Mineral Processing and Recycling: Maximizing critical mineral recovery from existing production streams.

Keynote Lectures:

- **Saskia Duyvesteyn (Rio Tinto)**: Unlocking new resources through full-value copper mining.
- **Isabel Barton (University of Arizona)**: Developing the critical minerals workforce: roadblocks and opportunities.

Session C: Critical Mineral Policies: Toward effective and responsible governance.

Keynote Lectures:

- **Thomas Sonderman (SkyWater Technology)**: Supply Chain Challenges in the Semiconductor Manufacturing Industry: Why Critical Materials are Vital to the Nation's Future.
- **Michelle Michot Foss (Rice University's Baker Institute)**: New Sheriffs in Town? Part Deux, In Which the Minerals Wild West Gets Wilder.
- **Alex Silberman (United States Department of Labor):** Identifying Labor Risks in Critical Mineral Supply Chains

Session D: Resource Sustainability: Ethical and environmentally sustainable supply of critical minerals.

Keynote Lectures:

- **Roderick G. Eggert (Colorado School of Mines)**: Key considerations in thinking about public policy toward critical minerals
- **José M. Cerrato (University of New Mexico)**: Metal mixtures in uranium mine wastes from tribal land

Keynote lectures were followed by oral presentations of attendees and complemented by a student poster session (*cf.* Appendix 1: Workshop Schedule). Each topical session was followed by a breakout session. The goals of the breakout sessions were to (i) identify research pathways towards removing materials from the critical minerals list, and to (ii) provide a networking opportunity for participants to start cross-disciplinary collaborations. The findings of the breakout sessions are summarized and discussed in sections 4 and 5.

One important focus of the workshop was on strategies that can help create a strong critical minerals workforce. For this purpose, each topical session included at least one presentation related to workforce development strategies. Moreover, a panel discussion was held with panelists from academia, government agencies, and the private sector. The panelists were:

- Jeffrey Mauk – Research Geologist, United States Geological Survey.
- Michelle Michot Foss – Fellow in Energy, Minerals, and Materials, Rice University's Baker Institute.
- Thomas Sonderman – CEO, SkyWater Technology.
- Amber Steele – Program Director, Missouri Geological Survey.

- Dawn Wellman – Manager of Research and Development, Rio Tinto.

Key observations from the workforce development panel are summarized and discussed in section 5.5 (Workforce Development Focus Area).

3. Workshop Demographics

The 2023 workshop was attended by 218 participants (Fig. 1-A). 128 participants attended in-person in the Havener Center on the Missouri S&T campus in Rolla, Missouri, USA. Another 90 participants attended online via Zoom. Fourteen participants (including nine students) received travel support through the NSF grant to attend the conference in Rolla. Additionally, the online participation fee was waived for another six students and early career researchers to attend the workshop virtually.

190 Participants stated their affiliation during the registration process. Among these, 87 participants were from academia (32 students), 62 from the private sector, and 41 from federal- and state-level government agencies (Fig. 1-B). The majority of the 190 registrants who stated their affiliation were from the USA (177, 93.2%). The remaining participants were from Canada (n=5, 2.6%) and one each (=0.5%) from the following countries: Australia, Brazil, Columbia, France, Mongolia, Switzerland, Pakistan, and the United Kingdom (Fig. 2). Within the United States, participants were from 30 states (Fig. 3).

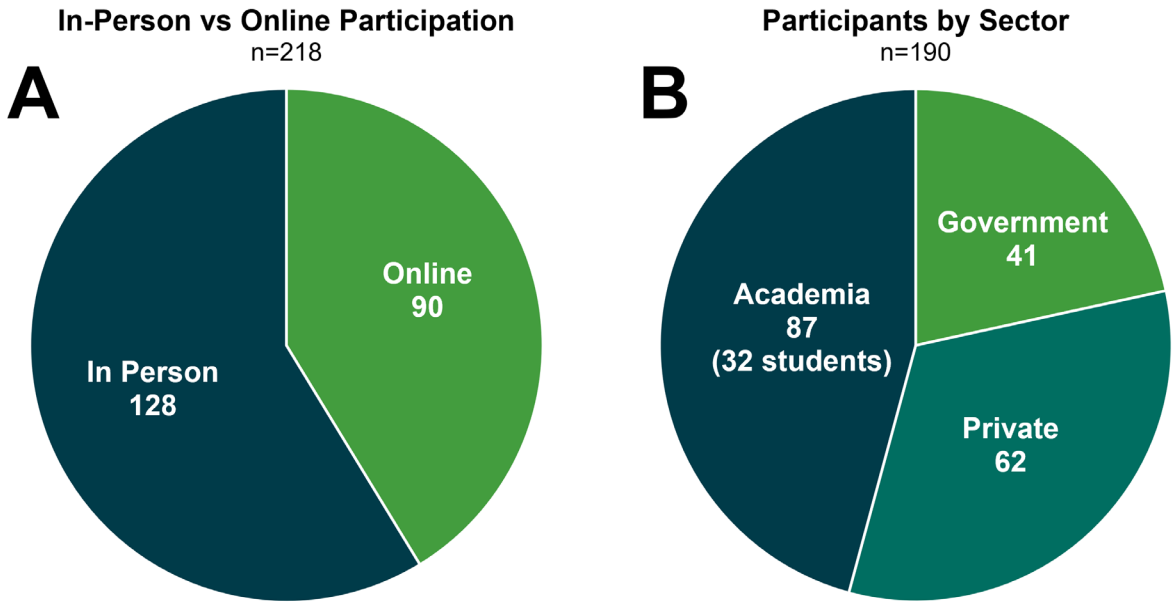

Figure 1: Breakdown of workshop participants based on (A) In-person vs. online participation, and (B) Sector of employment. It is noted that only 190 out of the 218 workshop participants stated their sector of employment during the registration process.

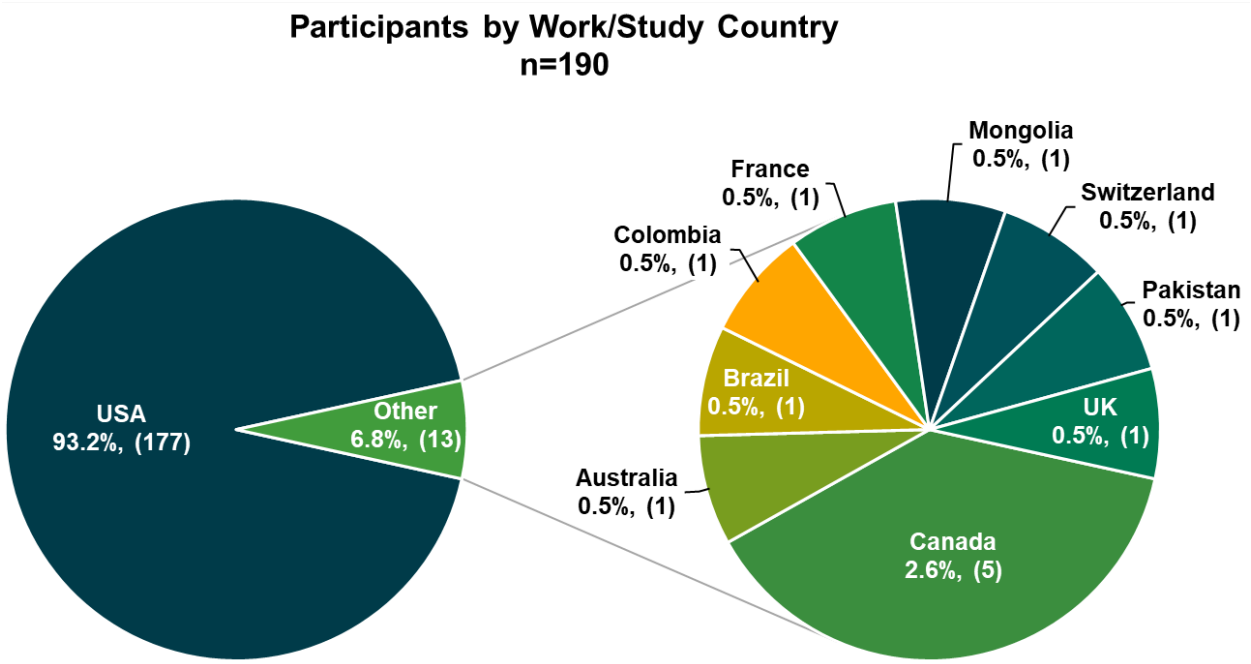

Figure 2: Workshop participants by country of residence. Note: Only 190 participants (out of 218) stated their work/study country during the registration process.

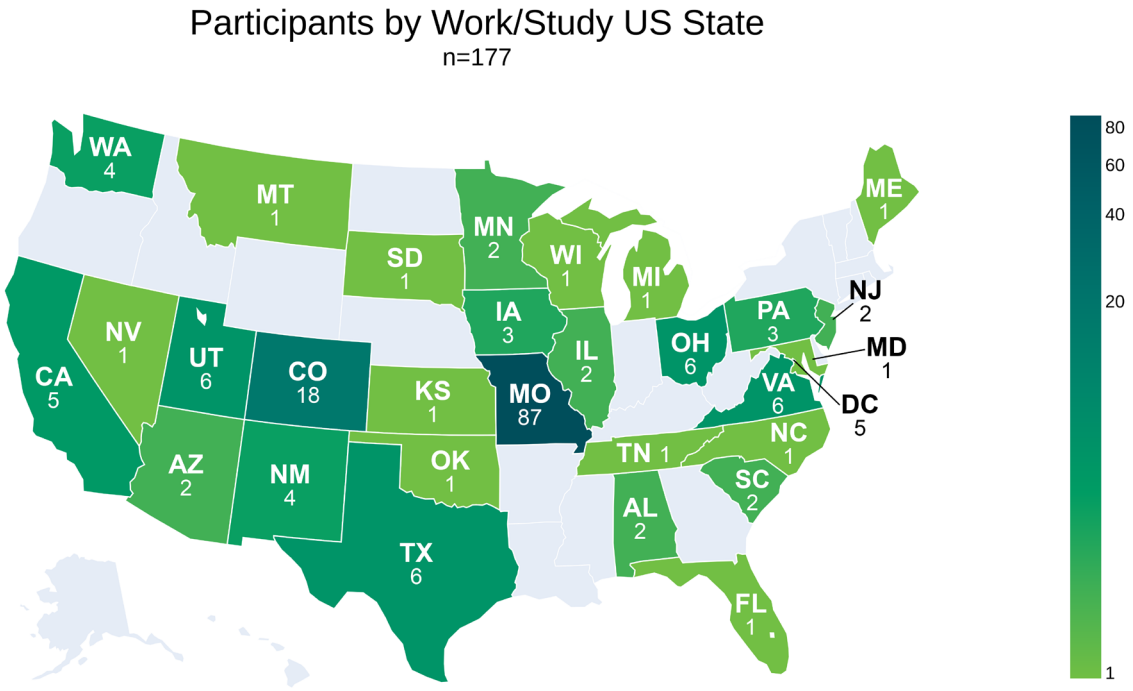

Figure 3: Distribution of workshop participants within the USA. Shown are the states of the 177 participants who stated the USA as the primary place of work/study during registration.

4. Breakout Sessions and Panel Discussion Results Summary

Each breakout session independently discussed how critical mineral supply chain resilience can be improved in the United States within the framework of each topical theme. Separate breakout sessions were held for in-person participants and online attendees via Zoom. At the beginning of each breakout session, the main findings from the previous workshops were summarized for all attendees (see below) and the following questions were asked to start off the discussions:

Q1: Are there additional issues that need to be considered?
Q2: What research would transform this topical area and overcome the identified challenges?
Q3: What opportunities do you see in this room for future research collaborations?

Each group consisted of 10-15 workshop participants and was provided with a scribe/moderator. A summary of the participants' comments during the breakout sessions is presented in sections 4 and 5; all comments are included in Appendix 2 (anonymized). It is noted that the comments presented in this report do not necessarily reflect the opinion of the workshop organizers but are taken verbatim from individual attendees.

4.1 Session A - The Critical Mineral Potential of the USA: Evaluation of existing, and exploration for new resources

To help start the group discussions, the most pressing research needs and/or issues as identified during the previous workshops were presented to the participants. These research needs/issues were:

- Comprehensive evaluation of existing domestic critical minerals resources.
- Opening of new exploration space for domestic critical mineral deposits.
- Mineralogical characterization of secondary sources to improve recovery from existing production streams, including tailings, slags and recyclables.
- Identify and unlock the critical mineral potential of unconventional sources (brines, seawater).
- Facilitate effective collaboration between government, mining companies, researchers, end users, and local communities.
- Machine learning and AI to support the development of better geologic models, critical mineral exploration and exploitation.

Figure 4 shows the top-40 themes mentioned during breakout session A and the frequency with which these themes were mentioned among the different groups. Figure 5 presents the data from Figure 4 visually in a word cloud. A compilation of all answers is presented in Appendix 2.

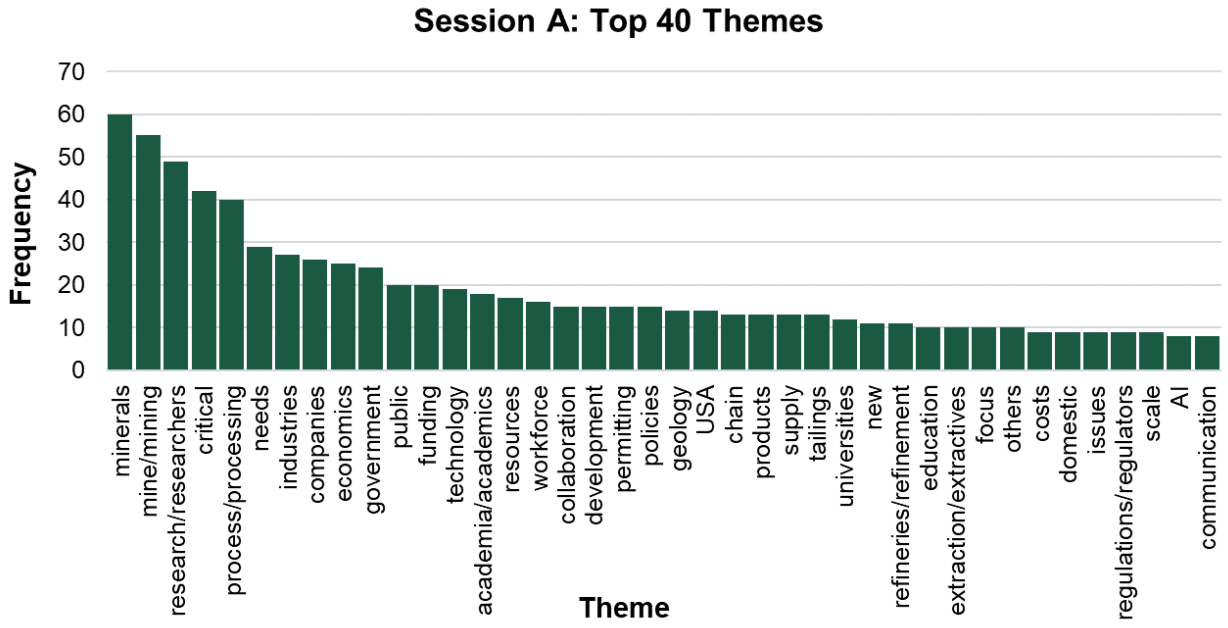

Figure 4. Top-40 themes mentioned during the breakout session discussion for session A: The Critical Mineral Potential of the USA: Evaluation of existing, and exploration for new resources.

Figure 5: Visualization of Figure 4 as a word cloud.

4.2 Session B - Mineral Processing and Recycling: Maximizing critical mineral recovery from existing production streams

To help start the group discussions, the most pressing research needs and/or issues as identified during the previous workshops were presented to the participants. These research needs/issues were:

- Limited economic viability of critical mineral recovery during mining and recycling.
- Lack of efficient, low energy and environmentally sustainable mineral processing and recycling technologies.
- Insufficient characterization of tailing and slag piles.
- Difficulties in forecasting short-, mid-, and long-term demand for critical minerals.
- Current regulatory environment for mining and processing permits, including long processing times.
- Lack of smelters in the US which limits domestic critical mineral supply chain resilience.

Figure 6 shows the top-40 themes mentioned during breakout session B and the frequency with which these themes were mentioned among all groups. Figure 7 presents the data from Figure 6 visually in a word cloud. A compilation of all answers is presented in Appendix 2.

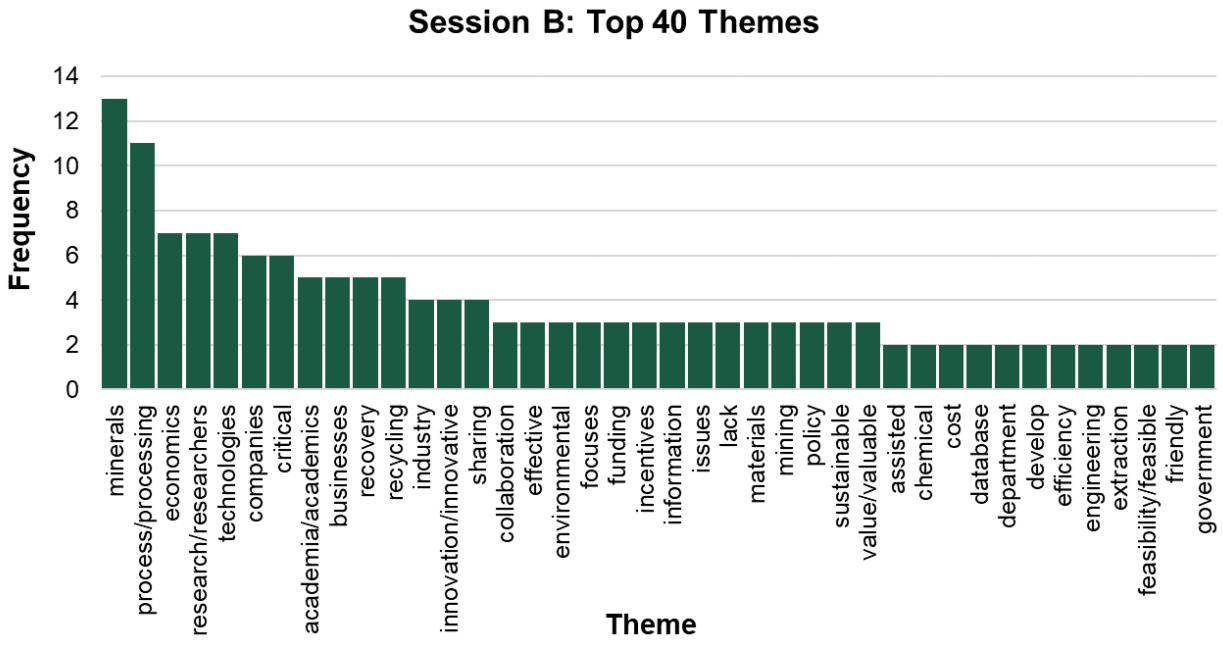

Figure 6. Top-40 themes mentioned during the breakout session discussion for session B: Mineral Processing and Recycling: Maximizing critical mineral recovery from existing production streams.

Figure 7: Visualization of Figure 6 as a word cloud.

4.3 Session C - Critical Mineral Policies: Toward effective and responsible governance.

To help start the group discussions, the most pressing research needs and/or issues as identified during the previous workshops were presented to the participants. These research needs/issues were:

- Minimize uncertainties associated with permitting processes in the United States.
- Mitigate shifts in policies following each election.
- Federal/state-level mechanisms to support to scale-up research efforts in recycling, efficiency, etc.
- Overcome reluctance to invest into mineral exploration and mining activities in the USA.
- Improve quantification / forecasting of future industrial needs.
- Incentivize recycling and/or tighten regulations to increase recycling efforts.

Figure 8 shows the top-40 themes mentioned during breakout session C and the frequency with which these themes were mentioned among all groups. Figure 9 presents the data from Figure 8 visually in a word cloud. A compilation of all answers is presented in Appendix 2.

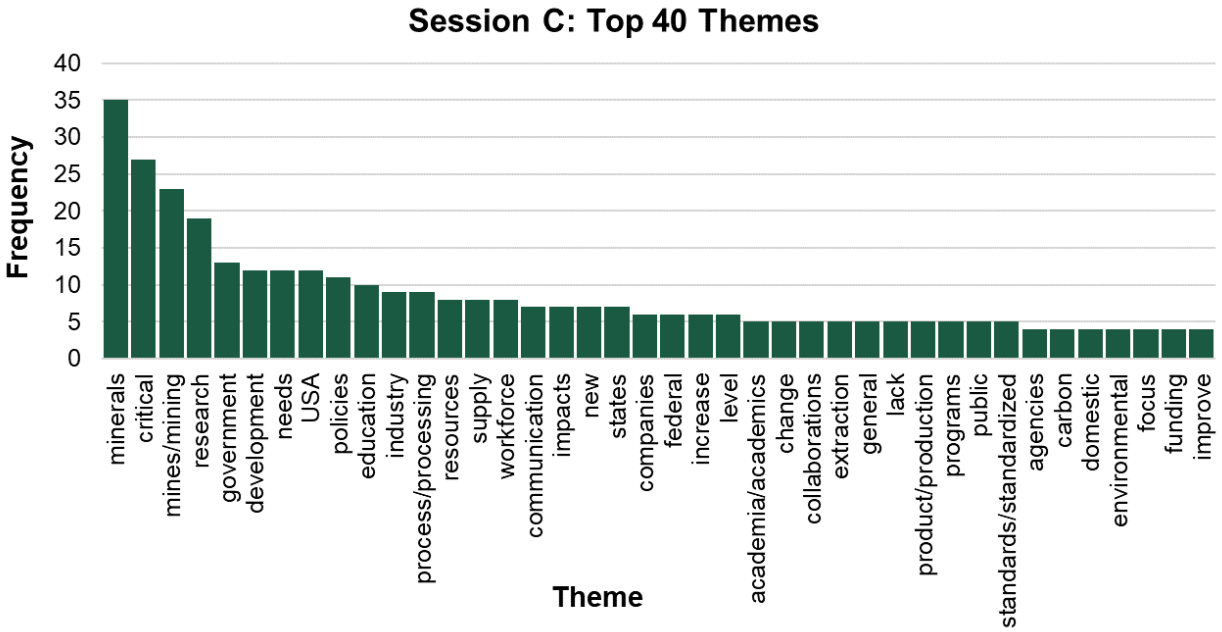

Figure 8. Top-40 themes mentioned during the breakout session discussion for session C: Critical Mineral Policies: Toward effective and responsible governance.

Figure 9: Visualization of Figure 8 as a word cloud.

4.4 Session D - Resource Sustainability: Ethical and environmentally sustainable supply of critical minerals

To help start the group discussions, the most pressing research needs and/or issues as identified during the previous workshops were presented to the participants. These research needs/issues were:

- Understanding barriers to e-waste collection and recycling to address currently insufficient recycling efforts.
- Incentivize recycling and/or tighten regulations to increase recycling efforts.
- Resolve knowledge gaps in environmentally and ethically sustainable mining practices.
- Improve policies / processes for handling radioactive products associated with rare-earth element mining.
- Quantification of energy needs associated with critical mineral recycling and reclamation and comparison to the amount of energy that can be generated with renewable sources.
- Geochemical fingerprinting of conflict minerals.

Figure 10 shows the top-40 themes mentioned during breakout session D and the frequency with which these themes were mentioned among all groups. Figure 11 presents the data from Figure 10 visually in a word cloud. A compilation of all answers is presented in Appendix 2.

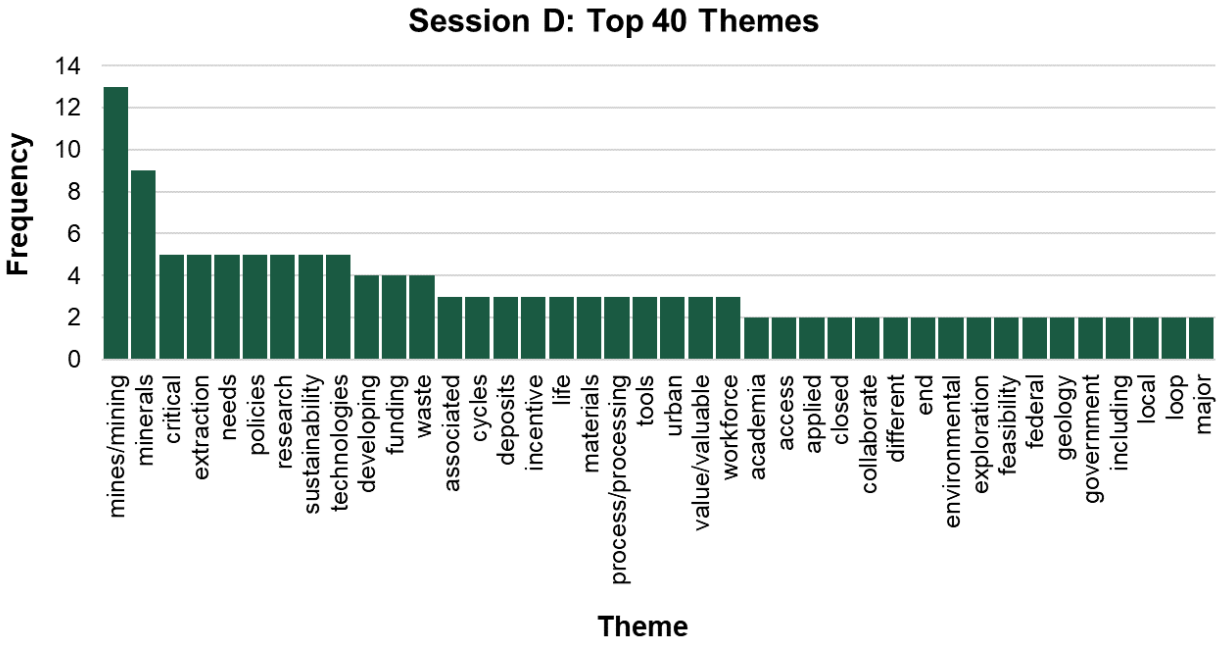

Figure 10: Top-40 themes mentioned during the breakout session discussion for session D: Resource Sustainability: Ethical and environmentally sustainable supply of critical minerals

Figure 11: Visualization of Figure 10 as a word cloud.

5. Discussion of major themes

As illustrated in Figures 4 to 11, several themes were repeatedly discussed by the workshop participants (during the breakout sessions, but also during the Q/A portions of the oral presentations and the workforce development panel discussion). This section summarizes the most common themes discussed by the workshop participants for each topical area (*cf.* section 5.1 to 5.4) as well as the workforce development focus area (section 5.5). All comments are included in Appendix 2 (anonymized). It is noted that the comments and or views presented in this report do not necessarily reflect the opinions of the workshop organizers.

5.1 Session A: The Critical Mineral Potential of the USA: Evaluation of existing, and exploration for, new resources.

The workshop participants generally concurred that an important step towards increasing domestic supply of critical minerals is to improve the understanding of the existing critical mineral resource and reserve potential of the USA. The most frequently mentioned issues that need to be addressed were:

- Exploration for new ore deposits.
- Comprehensive characterization of existing deposits and reserves/resources, particularly focused on critical minerals that might be extracted as co-products.
- Characterization of (historic) mine waste materials for their critical mineral contents.
- Inclusion of experts representing various disciplines (e.g., geologists, environmental engineers, economists, policy experts) from academia, government agencies and the private sector already at an early stage of mining operation development to enhance chances for long-term success.
- Machine learning and AI to improve geologic models and guide critical mineral exploration.

5.2 Session B: Mineral Processing and Recycling: Maximizing critical mineral recovery from existing production streams.

There was wide consensus among the workshop participants that the United States has the potential to be a leader in the development of novel extraction techniques targeted at critical mineral recovery from mine waste materials as well as recyclables. To enhance critical mineral processing and recycling capacities in the USA, workshop participants suggested increased research efforts in the following areas:

- Innovative mineral processing technologies.
- Recovery of critical minerals and co-products from existing production streams.
- Improved recovery of critical minerals from secondary geologic sources (mine tailings, slags, etc.) and recyclables.
- Development automated recycling technologies for e-waste.
- Development of low energy and environmentally friendly critical mineral extraction techniques.
- Extraction technologies that that maximize the recovery of every possible commodity.
- Federal/state-level supported pilot-scale research to address the issue that small-scale academic studies may not scale up to industry scale and needs.

5.3 Session C: Critical Mineral Policies: Toward effective and responsible governance.

Long permit processing times for mining and mineral processing operations with often unpredictable outcomes were the main roadblocks identified by the workshop participants with regard to increasing domestic critical minerals supply. It was also argued that future policies should be aimed at creating incentives for the private sector to recover critical minerals that are currently neglected because of low profit margins. It was suggested to create a federal centralized office (for example with an advisory board composed of representatives from the Departments of Defense, Energy, State, and Interior) that will help inform policymaking, regulative oversight, and community outreach. Other frequently mentioned themes were:

- Needed mitigation of shifts in policies following each election. A new government should remove the previous obstacles and not increase the problems of the mining sector with new rules.
- Inclusion of communities already during the earliest stages of permitting processes to help overcome the negative perception commonly associated with new mining and mineral processing operations.
- Need for large investments in domestic smelters and processing plants.
- Development of holistic economic models to better predict future commodity needs and price development.
- Review and revision of current regulations and policies to reflect new realities and technologies.
- Improve public awareness on the importance of mining to mitigate public resistance to new mining and mineral processing operations.
- One size fits all policies will not work, but modifications may be required on a case-by-case basis.

5.4 Session D: Resource Sustainability: Ethical and environmentally sustainable supply of critical minerals.

Workshop participants stated that although the term 'Resource Sustainability' is widely used, it still lacks a clear definition. Properly defining the term will make it easier to communicate its importance going forward, particularly when the importance of critical minerals is discussed with local communities. Workshop participants also argued that a "one size fits all" policy approach will not necessarily provide an ethical or sustainable solution for every mining situation in the USA. Additionally, the workshop participants recommended that the following topics should be addressed in the near future:

- A better focus on labor development and traceability of mineral resources, including artisanal mining.
- A more holistic approach to critical mineral innovation that considers cradle-to-grave supply chains for each commodity.
- Improving communication between Earth scientists, engineers, policymakers and the general public with regards to the dynamics of critical mineral supply chains.
- Holistic life cycle assessments of critical minerals and renewable technologies.
- Urban mining feasibility.
- Investigate possibilities for closed-loop recycling processes that enable the recovery and reuse of elements from end-of-life products.
- Develop methods to minimize waste generation by optimizing processes to extract the maximum value from raw materials.

5.5 Workforce Development Focus Area:

The workshop participants generally agreed that the development of a highly skilled critical minerals workforce remains a significant challenge. Several problems were identified that limit workforce growth, i.e., (i) the negative image of the mining and mineral processing sector, (ii) a lack of awareness regarding the career opportunities that the critical mineral sector provides, and (iii) the absence of science and mining engineering topics in many K12 curricula. Several activities were suggested to overcome these challenges:

- Outreach activities at an early age to highlight critical mineral-associated career paths.
- Community outreach at an early developmental stage to overcome the negative perception commonly associated with mining and mineral processing operations.
- Closer collaborations between academia and the private sector to ensure that curricula are closely aligned with 'real-life' needs, including opportunities for students to work parallel with industry for achieving their coursework as well as undergraduate and graduate research projects.
- Attracting relevant talents through targeted geoscience and engineering education.
- Mining Engineering at 4-year colleges should always include sustainability and economics courses.
- Work force development through trade schools and 2-year colleges.

6. Outlook

The workshop received overwhelmingly positive feedback from the workshop participants. During a post-survey workshop, 97% of participants that took the survey indicated that they are very likely and/or somewhat likely to attend a 2024 workshop (the categories were: very likely (77.4%), somewhat likely (19.4%), not sure (3.2%), somewhat unlikely = 0%, very unlikely = 0%).

The participants particularly appreciated the unique networking opportunity the workshop provided, owing to the wide range of science and engineering disciplines that were represented as well as the different sectors (i.e., academia, government, private sector, politicians). The participants also appreciated the hybrid in-person/online mode of the workshop that gave the workshop a wider reach.

Discussions during the breakout sessions resulted in the preliminary formation of topical task forces for a possible future workshop in 2024. The goal of the taskforces is to develop strategies to translate the findings of this workshop series into real-life applications, for example by presenting roadmaps to increase domestic critical mineral supply and for workforce development to lawmakers, funding agencies, educational boards, and the private sector in the USA.

Appendix 1 -Workshop Schedule

WEDNESDAY, AUGUST 9, 2023	
THE CRITICAL MINERAL POTENTIAL OF THE USA (*ST. PAT'S BALLROOM A)* Evaluation of existing and exploration for new resources *Chaired by: Marek Locmelis, Missouri S&T*	
8:30-8:40	Welcome and Opening Remarks – *Marek Locmelis, Workshop Chair*
8:40-9:00	Welcome to Missouri S&T – *Mo Dehghani, Chancellor at Missouri S&T*
9:00-9:30	Keynote Speaker – *Jeffrey Mauk, USGS*
9:30-10:00	Keynote Speaker – *Adam Simon, University of Michigan*
10:00-10:30	Oral Presentations
10:00-10:10	*Mike Cochran – Missouri Cobalt*
10:10-10:20	*Rona J. Donahoe – University of Alabama*
10:20-10:30	*James D. Kubicki – The University of Texas at El Paso*
10:30-10:45	Break
10:45-12:15	Breakout Sessions – *St. Pat's Ballroom B and Carver Turner Room*
12:15-13:00	Lunch and Posters – *St. Pat's Ballroom B*
MINERAL PROCESSING AND RECYCLING (*ST. PAT'S BALLROOM A)* Maximizing critical mineral recovery from existing production streams *Chaired by: Lana Alagha, Missouri S&T*	
13:00-13:30	Keynote Speaker – *Saskia Duyvesteyn, Rio Tinto*
13:30-14:00	Keynote Speaker – *Isabel Barton, University of Arizona*
14:00-14:30	Oral Presentations
14:00-14:10	*Isabelle Harris – Colorado School of Mines*
14:10-14:20	*José L. Corchado-Albelo – Missouri S&T*
14:20-14:30	*Molly Morgan – Colorado School of Mines*
14:30-14:45	Break
14:45-16:15	Breakout Sessions – *St. Pat's Ballroom B and Carver Turner Room*
16:15-17:30	Panel Discussion *Moderated by: Kwame Awuah-Offei*
	Thomas Sonderman – SkyWater Technology
	Dawn Wellman – Rio Tinto
	Mo Dehghani – Missouri S&T
	Amber Steele – Missouri Geological Survey
	Jeffrey Mauk – United States Geological Survey

	Michelle Michot Foss – Rice University's Baker Institute
17:30-19:00	Break
19:00-21:00	Workshop Dinner – Missouri S&T Experimental Mine *Dinner Presentation by Stacy Hastie, Chief Executive Officer at Missouri Cobalt*

THURSDAY, AUGUST 10, 2023

CRITICAL MINERAL POLICIES (*ST. PAT'S BALLROOM A)*
Toward effective and responsible governance
Chaired by: Alanna Krolikowski, Missouri S&T

8:30-8:40	Welcome and Opening Remarks – *Marek Locmelis, Workshop Chair*
8:40-9:00	Welcome to Day 2 – *Kamal Khayat, Vice Chancellor for Research and Innovation at Missouri S&T*
9:00-9:30	Keynote Speaker – *Thomas Sonderman, SkyWater Technology*
9:30-10:00	Keynote Speaker – *Michelle Michot Foss, Rice University's Baker Institute*
10:00-10:30	Keynote Speaker – *Alex Silberman, United States Department of Labor*
10:30-10:45	Break
10:45-12:15	Breakout Sessions – *St. Pat's Ballroom B and Carver Turner Room*
12:15-13:00	Lunch and Posters – *St. Pat's Ballroom B*

RESOURCE SUSTAINABILITY (*ST. PAT'S BALLROOM A)*
Ethical and environmentally sustainable supply of critical minerals
Chaired by: Mark Fitch, Missouri S&T

13:00-13:30	Keynote Speaker – *Roderick G. Eggert, Colorado School of Mines*
13:30-14:00	Keynote Speaker – *José M. Cerrato, University of New Mexico*
14:00-14:30	Oral Presentations
14:00-14:10	*Saurav Kumar Dubey – South Dakota School of Mines and Technology*
14:10-14:20	*Emma J. Hunt – Furman University*
14:20-14:30	*Randy Vander Wal – Penn State University*
14:30-14:45	Break
14:45-16:15	Breakout Sessions – *St. Pat's Ballroom B and Carver Turner Room*
16:15-16:30	Workshop Wrap-up (Sessions 1-4)
16:30-17:30	Field Trip Introduction

FRIDAY, AUGUST 11, 2023

FIELD TRIP TO PB-ZN MINING OPERATIONS
Brushy Creek Mine, The Doe Run Company, Southeast Missouri

7:00-15:00	Field Trip

Appendix 2 – Anonymized Compilation of Questions and Answers during the Workshop Breakout Sessions

Session A: The Critical Mineral Potential of the USA

Question 1: Are there additional issues that need to be considered?

- The group pointed out that China takes fewer regulations of critical mineral processing and even less on the breakthrough of the processing strategies.
- We discussed the possibility of reconnecting people to target tailings as a secondary resource and make an economic approach. Focus on cleaning out the tailing piles. Set up a MINE-set and education of collaboration. Collaboration between similarly-minded companies.
- Cost accounting and finance drive all the mining decisions, which must be considered when discussing CM [critical minerals].
- Large investments are needed in smelters and processing plants.
- Need for PR managing and aggregate crushers, especially in cities.
- Middle side of refining supply chain - need to export U.S. concentrates to China to process.
- CMs [critical minerals] are byproducts. Need to focus on products.
- Only 2 domestic copper refiners.
- Conflict between increased mining/processing and sustainability.
- Intersection of AI and sustainability.
- Political and public communications, public education and awareness. - mining demonized, alignment of sustainable goals.
- DOE spending vs. land protections.
- Policy not informed by science. Focus on refining, not production.
- Finite resources vs. demand - need disruptive innovation.
- What is the U.S. long-term, CM [critical mineral] strategy? Needs a 10–20-time horizon.
- Complex mineral separation processes for original ore minerals and mine waste.
- Storage for processed/refined minerals (pre-cathode material).
- Recycle and reuse of materials - take a review of current technologies employed at Doe Run.
- Acceptance processes including social licenses.
- Attracting relevant talents through targeted geoscience education.
- Promoting the relevance of industry through practical time-tested approaches. Movies, outreach programs, social media, pushing for a "day-without-technology" so the public will cease protests and appreciate the relevance of mining.
- Fast tracking permitting and refining processing development.
- Societies view of mining.
- Promote positive view of mining and why it is important.
- Economics - money - economic modeling.
- Difficulty of predicting future - value of products in the future - volatile products.
- Better or other technology that could replace, innovation.

- Permitting process, length of getting permission - legal environment.
- Research on smelting, refinery (bringing back) facilities - Updated regulations, conventional smelting - hugely damaging, environmental liability, circulating waste material into something useful - microbial extraction, electrochemical, bioleaching, and technological innovation to make economic.
- Actual economics of getting it out. Could not make money or will need subsidies. Consider economics from the beginning.
- Permit adjustments in ideal time to optimize fully operational mines (i.e., access to additional BLM lands).
- Time fines are very long. Longer than unexpected timelines for needs, initiatives.
- External factors - need fair and transparent and quick permitting process nationally variations state to state can affect locations, permits, etc. Fats track indicates issues with timelines, fairness.
- Concerns that permitting is partisan. Need policy to have academia, industry involvement to be more science, fact informed.
- Could there be a board (like FDA) that uses a structured process to permitting and licensing.
- Land ownership issues. Property owners do not want to release their lands for mining.
- Relatively higher mineral processing costs, and if they could be an improvement in that workflow to reduce costs.
- There seems to be a lack of awareness on the importance of mining. If publicity works can be done to increase the awareness/importance.
- Mining impacts with respect to coal footprints need to be investigated, since there is likely the social license to operate by the communities in which companies intend mining. Historic mining sites! - Superfund sites.
- Have but cannot get to - cannot process.
- How do we communicate issues to folks not in industry.
- Build products in U.S.
- Expenses on development.
- Training, education, and workforce development.
- Facilitating permitting process what is happening in government to allow this to happen. International examples on permitting reform.
- Private and public funding model.
- How to deal with changing technology element demands for long-term investment.
- Gaining public and political support for domestic mining and processing.
- Revising EPA regulations and policies to reflect new realities and technologies.
- Public marketing messages.
- Permitting/investing for small scale companies. Government funding? Convincing investors? Communicating potential value down the road?
- Communicating potential value of research while looking past EV market, solar, wind, etc. Certain research fields show promise but no short-term ROI will draw focus to other fields.
- Effective communication between academics and the public. Making scientific findings relatable/understandable for the public.

- The conflict of government red tape as the consideration of what is actually required to complete the work.
- The relationship between companies and the public. Issues with technology for mineral extraction and funding for research.
- Comprehensive evaluation of existing domestic critical mineral resources.
- The depletion of natural resources, supply chain risk, environmental risk, political risk, economical risk and geopolitical issues are the most important concerns for critical minerals industries. The issue of recovering the critical elements from secondary sources such as domestic mine tailings must be further paid attention to.
- To perform more geological research to identify potential domestic resources and increase the knowledge of the processes of critical minerals formation.
- A comprehensive evaluation of the recovery of critical minerals as by-products from unconventional domestic resources.
- To develop the quantitative assessment and model of the potential of critical mineral domestic resources.
- General public awareness and interest in keeping critical mineral supply chain.
- Insights on the USA plan working with other foreign countries to increase the production and processing of critical minerals.
- Insights on the status of Deep-Sea Mining for critical minerals, especially on international waters.
- Ethical Practices and alternatives for critical minerals.
- Impacts from demand, ethical problems, trouble meeting demands.
- NIMBY
- Mineral separation with alternate sources, coal ashes, etc.
- Logistics of using alternate sources.
- Deposit availability in the US.

Question 2: What research would transform this topical area and overcome the identified challenges?

- They mentioned the following about the control of the supply chains: The US has good processing technologies, and the government help should be more focused on mining than processing.
- Mining departments should always include sustainability and economics courses.
- Finding strategies for teaching kids the importance of geosciences and creating a pipeline for this new CM [critical minerals] workforce.
- Developing recycling technologies would need significant upfront investment and subsidies.
- Disruptive innovation. Transform tech to use different of less critical minerals. New battery chemistry.
- Systems research, lifecycle of SM value chain.
- Nuclear, hydrogen, other. (Link with public education)
- Carbon capture/sequestration - part of the equation.

- Clearly defining "domestic" supply chain - all steps, allies, whose are saw materials coming from. Making framework for that.
- Transmission, e.g., in a decentralized way.
- Research on where we are installing green tech.
- What does "streamlining" really look like? Good Practices, local/state/federal levels.
- "Possibilities" research, horizon-scanning. Building and designing at scale.
- Ecosystem approach to CM [critical minerals] innovation - as we design/research/build new things, how is it all working together? Holistic approach.
- Analysis into continuous investment trends for mining projects in the U.S. and the challenges faced when a mine is deemed unprofitable.
- Review on current regulatory restrictions (possibly taken from the above analysis) into key issues like; water permitting, Nepa process, and social licenses.
- Identifying the magic box in downstream refining risks compared to the environmental liability.
- USGS should do what it was originally structured to do - fund projects to assess geological prospects.
- Analysis into current structures that limit U.S. companies including patenting and the lack of unified associations.
- Ore processing and waste products can use calcium carbonates to make lime especially in Missouri - recycle and reuse.
- Bureau of Mining resurgence - government support focused on mining and is non-partisan.
- Extraction technologies - environmentally sustainable and economically feasible. - fully recover every possible commodity and make new uses on by-products.
- Mining technologies - less damaging and efficiency.
- Government funds needed, subsidies, incentives - Federal labs contribute to research on extractions and make innovations applicable (without patens, licenses, etc.) to industries.
- More geometallurgy studies. - Often cannot recover minerals/metals.
- more pilot scale studies - small/academic studies may not scale up to industry scale and needs.
- Need scaling studies to be able to respond needs.
- Full characterization of materials beyond just the economic minerals of interest. What other minerals, phases are present?
- Need for micro-scale research. Plus, how does it relate back to the real-world scale.
- Implementation of more automated technology in processing.
- Hydrometallurgy facility acceptance, understanding benefits and risks vs. smelting; incorporation into communities.
- Failure analysis of previous projects that did not go forward.
- Comprehensive extraction - what else is in material being refined offshore.
- Is it possible to create networks of multiple companies/organizations with unique specializations so that as new economic commodities are identified at a mine project, the processing can be developed? i.e., Newmont in Navada gold joint ventures or Rio Tinto and others for processing Te.
- Research into chain of custody from producers downstream to products.
- Outright programs for improving awareness and the need in this area of research.

- Economic geology, exploration programs exist but policy to allowing things to happen is missing or lacking.
- Improving recoveries of waste impoundments of existing and closed mines. Researchers should take that role from operating companies who only own these large tonnages of waste.
- Social license to operate by mining companies taking responsibilities in forms of surcharged for any environmental impact negatively.
- Economic refining process.
- Need to make primary (Zn) economic to make other by-products.
- Mine waste projects.
- Need to define within tailings.
- How do you do environmental permitting faster while still meeting goals.
- Pushback in previously mined areas.
- Economic side - not good data available especially on critical minerals.
- Unconventional reserve development.
- Marketing research - change perception.
- Educational transition - K-12 education, mining schools act., possible career paths.
- Where is the disconnect with the public? Where we are at and how did we get here?
- Ultimately needs for legislative action.
- Research to gauge public attitudes towards mineral exploration and the reasons for it. How can we shape public attitudes in a positive way.
- Research as to the potential economic value of onshoring supply chain processes for critical minerals and energy storage.
- Ignite funding for pilot scale research.
- Design new markets to direct research not geared toward EV/wind/solar.
- Expand the funding pool for smaller industry/companies to test ideas (e.g., pilot studies), that would be otherwise difficult owing to a lack of capital/funding.
- Government - academia - industry consortium for research and development, seed funding, and workforce development.
- CO_2 reduction in smelting.
- Exposure of deep-sea life to cobalt/Ni/Cadmium nodule mining plumes alternative resources.
- Alternative mineral extraction techniques - materials science research for optimizing limited resources.
- Mineralogical characterization of secondary sources to improve recovery from existing production streams, including tailings, slags and recyclables.
- Increase the geological knowledge of existing ore deposits and mine tailings in terms of critical minerals characterizations, chemical grades of elements, deportments, inclusions and liberation degree.
- Doing comprehensive research on mine tailings, including abandoned mines, tailing damps that may contain critical minerals previously discarded as waste.
- Recovery of critical minerals from tailings is a complicated process because of heterogenous and poorly characterized sources and a lack of suitable beneficiation techniques.

- Machine learning and AI to support the development of better geologic models, critical mineral exploration and exploitation.
- AI can help with critical minerals exploration, mining drilling and exploitation, transportation, processing, by analyzing huge amounts of data to produce high-quality derivative products from raw input data that would be difficult to spot by human analysts.
- Mining companies, researchers are able to predict the grade and tonnage of a mineral deposit more accurately, based on its geological characteristics, allowing them to optimize the process and extract more critical minerals and reduce tailings.
- AI has the ability to increase safety by monitoring the working conditions and warning operators and supervisors of any potential risks at a mine or mineral processing site.
- Recent progresses in computer algorithms have permitted researchers to discover the potential of AI algorithms in critical mineral resource prediction.
- AI in critical mineral beneficiation has significant advantages in terms of improving the estimation, optimization, maintenance, and control of the processes.
- The main challenge when using AI in the case of critical mineral exploration and processing is the availability of suitable data.
- More scientific research to focus on developing methods for better characterizing and reporting of critical minerals and building a critical mineral database.
- Research to report, how much of AI is currently employed in the studies of critical mineral resources and its impact.
- Cost of processing in the US – not economically viable to obtain these minerals.
- Resources from other sectors- oil, coal, etc. to reduce the cost, lower price of products
- Investment in research to reduce costs and increase supply – funding, NSF, industry funding.

Question 3: What opportunities do you see in this room for future research collaborations?

- The EPA and the state regulators should work together to expedite the mine permits and ESG targets.
- Attempting what the workshop was doing to connect the different fields into an interdisciplinary environment on a larger scale. Include Arts and Economics departments in the conversation of CM [critical minerals]. Incorporate labs where the students get to build a mine and follow the supply chain in the different mining and geology departments, including a complete economic balance.
- Interdisciplinary research! Aimed in part at bridging the technical/non-technical divide on CMS.
- Policy-oriented research. Research that brings experts to education and policy offices leverages state resources!
- Government as more then funder: research that helps shape policy.
- Local communities and companies - change perception of mining industry. How things have changed, accentuating positives.
- Research on positive benefits of mining - unionization, jobs, workers' rights. Plus, savings in domestic supply chain, less costs in shipping, capture more value.
- Communication to adults.
- Venture capital for mining/tech innovation.

- We see a lot of private companies that can come together and bridge the silos in the critical mineral industry such that collaborations can be made in:
- Reinstating and quota funding of the U.S. Bureau of mines (not just in coal).
- Research and development towards funding metallics.
- The geological survey is ready to collaborate with any company and institutions to conduct more studies.
- Policy framework structuring between the Geologic survey, private or public companies.
- Missouri Cobalt with Missouri S&T in ongoing critical minerals institute (tech hub).
- Missouri Cobalt and Doe Run will be interested to support the research and development of the U.S. Bureau of Mines and this could be done possibly through tech hub.
- Caldera (Pea Ridge Iron Mine) looking at refining capabilities and open to companies in the Rare Earth space with a Korean technology.
- How do you make collaboration possible? Finding that is mutually beneficial.
- Public forum of interesting projects for companies to consider funding.
- Public research facility for companies to do research and development.
- Bodies need to be included in research collaboration:
- Industry, academics (various disciplines - do not work together), including economics.
- Local governments.
- Human resource, work force developments.
- Colleges, universities.
- Bring forces together to develop more technologies (mathematician, statistician, etc.)
- U.S. and Canada/North American supply chains.
- Create models to optimizing the resource - supply chain for critical minerals - is there a fiscal, science-based approach.
- May be a North American approach, not U.S. solely.
- Industry and government to optimize processing, refinement.
- University - industry research into processing.
- How to bring industry/company proprietarily processes to the larger industry - where it can become 'generic' because many companies are doing something similar in their processing.
- Univ research collaborations in industry: how do we use the 'whole' rock, not just extracts the commodity of interest? Can 'waste' be processed by another company, for example are there other steps that may help primary production but also create secondary production routes.
- Government programs/panels to evaluate projects/longevity for loans for building longer term projects.
- Government-company-academia input for developing robust policy.
- Ways by government to incentivize mining companies in reducing cost of operations.
- Collaborations between policymakers, state, federal, technical staff, and academics.
- Liaison of FBI operatives and academics in this body of research where academics can freely present novel ideas on demand-supply as a national security concern.
- Max of specialties.
- Work on supply chain links.
- More data! Land ownership.

- Who is doing what?
- Research needed, need more capable of doing it, more push for universities.
- More connection between geology and economics worldwide.
- Getting all stakeholders to be on the same page.
- Partnerships with local, state, academics, private organizations.
- Bringing in humanity specialists to figure out how to change the narrative.
- Connecting academia to the "real-world".
- Greater inter departmental engagement in higher education institutions.
- Targeted grants at real world application.
- Collaborations between academia and industry.
- Industry and academia and government.
- Engineers and policy/permitting (public movement).
- Facilitate effective collaboration between government, mining companies, researchers, end users and local communities.
- Government, mining companies, universities and researchers play a major role as regulators, developers and facilitators for improving the performance of mining to produce critical minerals.
- The correct policies and effective collaboration between government, mining sectors, universities, and international and local communities, decrease the obstacles for innovation in mineral characterization and processing by incentivizing investments in developing new technologies.
- Encourage universities and research centers through infrastructure support, network development, and procurement policies for doing comprehensive research in areas of critical minerals.
- Providing frameworks and mechanisms that motivate and incentivize mining sectors and universities to examine the new approaches in terms of integration and economic feasibility of primary and secondary sources and to consider share infrastructure among each other to minimize costs.
- Establish a critical minerals department at universities with specialized faculty members to train researchers, students and mining engineers in engineering programs from mine to product such as efficient extraction, environment and safety, economic benefits.
- An increased focus on critical minerals training courses in higher education levels.
- Collaboration with USGS, that has recently developed a Yearbook on critical mineral resources that provides vital information on different commodities (available in different volumes).
- Collaboration with National Mineral Information Center focusing on mineral resources avoiding policy and diplomacy issues.
- Coal ashes – coal products, mineral separation research and developments, working with industry and academia.
- Opportunities need to involve collabs between industry, academia, government, everyone. Main funding agencies do not fund this research, need more ways to gather together to make developments.
- Conversations focused on historical deposits, mine tailings – easier to mine than starting new mining operation – need to turn to tailings and et cetera.

- Government regulations are the biggest enemy, companies struggle to reclaim tailings and waste due to government regulations.
- Lots of opportunities for academics and industry to work in political science/government.
- Chances to understand how to communicate between the sectors, US public does not understand the complexity and criticality of these topics, academics need to teach industry and government, and vice versa. Stimulate the conversation with everyday citizens to make policy changes.
- Learn what committees in congress deal with these issues, be a part of those conversations.
- Government red tape around reclamation, environmental regulation takes a long time (5+ years).

Additional Comments

- How do we solve the data gap on reserves?
- Science is less of a problem then regulations. 16 years are too long!
- Gap between policymakers and expertise.
- Flexible, adaptable funding mechanisms to pivot to emerging needs. Lack of systematic and compatible approach. Short-, medium-, and long-term funding.
- Public private partnership is a big need!
- Lack of dedicated mining agency can create gaps.
- Attract students to geosciences - incentives needed and involve industries - practical field learning, expose students to industries to make students more interested.
- Update curriculum, administrations be involved.
- Universities could have a lot more authorities over their curriculum rather than national curriculum system which is restricted.
- More funding from government, industries, organizations.
- International collaborations: what about entire North America, NATO, etc.
- Universities bring different nationals, support visiting scholars, exchange of completely different perceptions - might be challenges of national security.
- Save the planet - become a geologist.
- Extractive metallurgy - recycling.
- Do we have enough metallurgical companies? - conservation, association problems, no collaborations and universities could bridge.
- Our table make up: Industry, academia - faculty, student, applies R and D.
- Evaluation: open new exploration.
- Improve upon existing bachelor's degrees in geology to incorporate economic geology courses on critical minerals.
- Put smelters on mars.

Session B: Mineral Processing and Recycling

Question 1: Are there additional issues that need to be considered?

- How many times do we need to process the tailings? Can we get it all the first time? Is there a way to recover more value? Can we designate a total economic value to raw materials?

- Creation of a raw/critical mineral database technology refining database.
- Lack of technology specifically extraction techniques.
- Public acceptance of prospective of mining.
- Having companies share at least what critical minerals they have and whether researchers should look at them or go somewhere else.
- Traceability of critical mineral supply chain.
- How to encourage companies share their information? Disclosure and traceability.
- Permitting
- Connecting feasible projects with academics (Online PhD posting/G.G economy and employers connection.
- More crossover between Chemical Engineering + Metallurgy - Interdisciplinary interaction, leadership and industry issues.
- Mining companies usually focuses on specific mineral/elements of interests, this affects the critical mineral potential.
- Department to department communication within companies to utilize old data in modern mineral exploration.
- Disconect between Science and Policy.
- Limited economic viability of critical mineral recovery in mining and recycling continues to be the pressing issue.
- Lack of efficient, cost- effective technologies for sustainable mineral processing and recycling.
- Lack of economic incentives for corporations (Missouri does offer some tax incentives).
- Roadblocks in inviting businesses into the state of Missouri.
- Political hot topics and a bipartisan view on wind farm technologies make enacting effective policy difficult (or even just presenting a friendly business environment).
- Framing to policymakers is key, stressing urgency.
- Smaller companies are likely to pursue tailings management with greater incentives comparatively to the missions of larger companies.

Question 2: What research would transform this topical area and overcome the identified challenges?

- Centralized research lab and long-term plan that depend on the government funding.
- Opportunities for more collaboration and sharing of information between industry, academia and government.
- Research innovation for efficient and cost- effective technologies for sustainable mineral processing and recycling.
- Put simply "partner better with industry." Coordinate academia's technical advancement with strong economic feasibility.
- Understand audience and stakeholders for academic or research related business plans.
- Having students understand business/ economics no matter the degree is an important focus for producing innovative leaders and business managers.
- Interdisciplinary work, moving out of your comfort zone or realm of expertise.

Question 3: What opportunities do you see in this room for future research collaborations?

- Research funding and collaboration between industry and academia to develop better scientific methods and accelerate innovation and ongoing technologies studies for sustainable mineral processing and recycling.
- Collaboration and information-sharing efforts between various institutions, including seeking for funding opportunities for researchers focusing the current issues limiting domestic processing and recycling of critical minerals.
- Advanced Separation Technologies: Develop innovative separation techniques to efficiently extract and recover valuable minerals from complex ores and waste materials.
- Circular Economy Strategies: Research ways to optimize resource utilization through closed-loop processes, minimizing waste generation and maximizing material recovery.
- Green Chemical Engineering: Explore environmentally friendly reagents and processes that reduce the environmental impact of mineral extraction and recovery.
- Process Intensification: Investigate ways to enhance process efficiency and reduce energy consumption through intensified processes, such as microwave-assisted or ultrasound-assisted processing.

Additional Comments:

- n/a

Session C: Critical Mineral Policies

Question 1: Are there additional issues that need to be considered?

- Consideration to Artisanal mining.
- Formalization should be well defined.
- Revisit tailings with available new technologies to extract at a profitable scale.
- Review of timing for permitting process, capacity building, and a need to form a central agency to accelerate investment.
- Consider developing defunct brown-ground.
- Work force development through trade schools and curriculum development like standardized testing requirements.
- What are the impacts of shifting away from current extraction practice on the other areas of the workflow.
- Communicate and educate policymakers on the steps involved in exploration and production of critical minerals.
- More work focus on labor development and traceability of mineral resources.
- Focus should be placed on incentivizing American companies on critical minerals, making sure that American companies are able to produce and see their product in the critical mineral supply chain.
- US relations with China and India on critical mineral resources, friend shoring, limits to onshoring

- Will Chinese domination in critical mineral lead to worldwide domination in EV's to the death of US / European automotives resurgence in ICV'S (Alliance with Saudi Oil?)
- Minimize uncertainties associated with permitting processes in the United States
- The critical elements are essential for wide range of important applications to the US economy and national security ranging from green energy equipment to advanced defense structures. There is a worldwide competition because of the secure supply chains to ensure the economic and national security interests. There is a necessity for government and politicians to state an integrated critical minerals strategy for the US. This strategy must meet two aims. First increasing domestic and global production and processing of critical minerals so that reduce vulnerability to external risks and second generate new methods to limit environmental risk and decrease the global temperature increases.
- The government should improve substitute international contracts to provide domestic demands.
- Environmental and social concerns are indispensable parts of the critical minerals issues. Politicians need to work with federal agencies to create standards for mining and extracting projects that qualify for support.
- Mitigate shifts in policies following each election.
- Mining companies are struggling profit margin pressures because of increased shipment prices, reducing or removing carbon emissions, and current expenses growth. They have to increase their efficiency and decrease operational expenses to alleviate these challenges and increase productivity. Any quick policy change, especially after the election, has a strong impact on the mining industry. The new government should remove the previous obstacles and not increase the problems of the mining sector with new rules.
- Lack of general understanding on the critical mineral resources in the high level of policymaking and legislature body.
- Limited data to address factors affecting the critical mineral supply and changes in mineral reserves that can be used during policy analysis and in decision making.
- Lack of a better communication between, earth scientists, engineers the policymakers, and the general public on the dynamics of critical mineral supply.
- Changes in policy should be driven from the ground, such as educating general population in the respective constituency on significance of traceability and emphasize on awareness to higher education and end–consumer.
- Address current major issues with the mining of the critical minerals especially in the South Asia region (Cambodia) including corruption, along lack of best labor practices, health, safety and environmental compliance.
- Effective land procurement methods that consider native's lands and populations
- NEPA document in public review.
- States have standards, teachers need to work around standards to interest students in new subject.
- Introduce curriculum that integrates industry experience with submitted reports to grow interest, knowledge and skills.

Question 2: What research would transform this topical area and overcome the identified challenges?

- Understanding of critical mineral supply network.

- Alternative methos EVs —Public Transit increase.
- Restrict dissemination of information that can negatively impact process.
- Evaluate cultures impacts of Mining / labor development—The workflow in the community and identify ways to benefit the communities' apprenticeships?
- Monetary incentive for impacts of sustainably sound resources—How could this impact decision makers?
- Carbon transformation—Reduce carbon emissions semi-conductors development to have a SEPP—supply of semi-conductors material, do not depend on the other countries.
- More research to provide a better data on factors affecting the critical mineral supply and reporting changes in annual mineral reserves.
- A high-level federal research plans to attract a new generation workforce and academia focus into the critical mineral resources.
- Improve educational standards including enforcing science classes in high school teaching to provide the right information related to critical mineral polices and introduce an education curriculum focusing on industrial experience in mining and mineral recovery.
- More public awareness and education and improve level of communication between states and federal government on critical minerals to stop anti-mining cultures in some states.
- A study to highlight a need to re-establish a government entity within a Department of Energy to overseas the critical resources.
- 100-day reports mandated.
- Recommendation reports—potential to address many questions surrounding critical mineral advancements and research.
- Is there policy that can guide recruitment? Incentivized programs as seen in healthcare and education positions.
- In General, Policy and Regulatory Frameworks: Research ways to streamline regulatory processes and develop policies that promote responsible mineral extraction, processing, and recycling.
- FECM
- Refunding Bureau of Mines, or something similar. As companion to USGS.
- Essentially no fed research between mineral research identification, people think these minerals will sprout out of the ground and be processed, but no research is being done on what is there and how much.
- High level research program that does research that impacts battery plants, R&D in next generation mining, think Bureau of Mines.
- Harder for academics to keep their work going, have an additional agency to help fund those research initiatives and it will trickle back down to education in younger people.
- Setting up national scale test bed for testing various extraction methods.
- Better level of comm between states and fed/New York as EX, USGS not allowed to field map due to possibility of mining, extreme NIMBY.
- Immense lack of strategic understanding of mines and mine cycles and origins and etc.
- Brand something as office of earth resources, all-encompassing facility.

- Anti-mining culture, we need more education in government and normal citizens to educate them on mining and whatnot. This needs to change. The majority of pollution does not come from mines. More educational research needs to exist. (like Dr. Barton's research).

Question 3: What opportunities do you see in this room for future research collaborations?

- Collaboration and extensive communication between government, industry and academia.
- Let industry to communicate with academia on the challenges and skills needed for successful workflow.
- More opportunities for students to work parallel with industry which achieving their coursework (remote course on-site).
- Develop carbon transform societies on industry production plants.
- Promote government industry- policies to increase the market inside the USA.
- Platform to involve earth scientists and engineers to communicate clearly with policymakers and the general public regarding the nature of critical minerals from mining to supply chain.
- USA to take advantage and experiences of the collaborations happening in the other part of the world for example UK.
- Research collaboration between industry and academia to develop a workflow for the domestic issues within USA.
- USA and other western countries to be a key role player in the critical mineral projects to enforce the best practices and mechanisms for better mineral traceability.
- Cradle to grave emissions efforts.
- Life cycle assessments of renewable technologies and inorganic resources (minerals)
- Parties that are local to businesses - collaboration to improve full cycle resourceful processing.
- Rio announced 150 mil research collab with imperial college in UK, how do we get that in US.
- Old atomic energy commission, became the champion of nuclear research.
- Build it and they will come, specialty programs like NSF but specialized. 23 agencies feel they are in charge but no one is in charge, it is a farce.
- Centralized office that contains a board from DOT, DOL, DOI, USGS, etc. to bring together.
- Need to develop worldwide approach.
- NGO connection, NGO and mineral community needs to not be at odds.
- American legal system is too complex. Everyone always says no and no one ever says yes. Government needs to work together.

Additional Comments:

- Federal/state-level mechanisms to support scale-up research efforts in recycling, efficiency, etc.
- Congress should increase funding and providing authorities for mining companies to invest in critical mineral research projects inside and outside of the US with U.S. support.
- Congress should expand funding and grant programs for R&D mining programs to recycle critical minerals from spent batteries, coal fly ash, smelter dust and etc.
- Government should make a certain fund for training and education initiatives in critical minerals topics.
- Congress should simplify permitting by using a place-based approach.

- Overcome reluctance to invest into mineral exploration and mining activities in the US
- Political instability.
- Not paying attention to byproduct metals in mining companies when the primary metal has a high grade.
- Government and many different parties can certainly influence mining companies.
- Small size of the markets.
- There is scarce of social and environmental safeguards.
- Lack of knowledge about the current and future needs for critical elements.
- On one hand, the government tends to be a leader for production of critical minerals and meet domestic needs, on the other hand, setting requirements that are too tight. There must be a balance.

Session D: Resource Sustainability

Question 1: Are there additional issues that need to be considered?

- Address challenges associated with technologies currently used in recovery of different critical minerals.
- Highlights the major key environmental concerns and risks associated with critical minerals mining, processing and recycling.
- Canadian mechanism that allows junior or small miners to approach an investor will newly issue shared to immediately attain write off - through shares.
- Sustainability may be understanding life cycles – effectively extracting a non-renewable resource the first time.
- Rio Tinto Mines: Policies tools and incentives to get everything out of an ore deposit when you access it the first time.
- Developing technologies that would allow the harnessing of theses less concentrated materials.
- What is sustainability? Just life cycle of a mine? What else does it encompass.
- Rio conversations: policies tools and incentives to get everything out of an ore deposit when you access the rock for the first time. If 98% of income comes from copper and gold, there is no incentive to get extra elements the first time through so we are stuck in the cycle of main mines and tailings.
- One size fits all policies will not work to provide an ethical or sustainable solution for every mining situation in US or world. → We need to determine what the common end goal is and work towards it.
- We need to determine what the common end goal is and work towards it. It seems many different sectors cannot agree on what sustainability is, or what success would look like.

Question 2: What research would transform this topical area and overcome the identified challenges?

- Develop mechanisms to allow tax policy tools into the exploration and production of major mineral deposits and their associated by-products including the critical minerals.

- Research to innovate better environmental measures and practices for sustainable mining of critical minerals.
- Closed-Loop Systems: Investigate closed-loop recycling processes that enable the recovery and reuse of minerals and materials from end-of-life products, reducing the need for virgin resources.
- Zero Haz-Waste Approaches: Develop methods to minimize waste generation by optimizing processes to extract the maximum value from raw materials and byproducts.
- Urban Mining Technologies: Explore technologies for recovering valuable minerals from electronic waste, discarded appliances, and other urban sources to reduce the reliance on traditional mining.
- Feasibility reports on supply chains and the exploration of other energy alternatives – Biofuels, Nuclear, Waste etc.
- Need to develop extraction technologies that allow us to do a one-time around type of extraction, extract everything.
- Research into markets.
- How critical minerals influx could affect markets locally and globally.
- Urban mining feasibility.

Question 3: What opportunities do you see in this room for future research collaborations?

- To tap into the current available federal funding opportunities to increase a workforce in the mineral sector to avoid inadequacy of future supply.
- Federal funding agency to collaborate with academia and industry to ensure more research funding go to programs focusing on applied research opportunities including geology, geological and mining engineering and the like.
- A lot of money is going to the battery plants and not mining.
- A high value program would draw great attention.
- Bill before congress right now the mining schools act.
- Replace the applied research that used to occur with the Bureau of Mines.
- Institutions are ready to apply matching funds to these projects.
- Government needs to make effort.
- No one size fits all policies can exist: Communities and local government need to collaborate to find best solutions with best info provided by academia.

Additional Comments:

- n/a