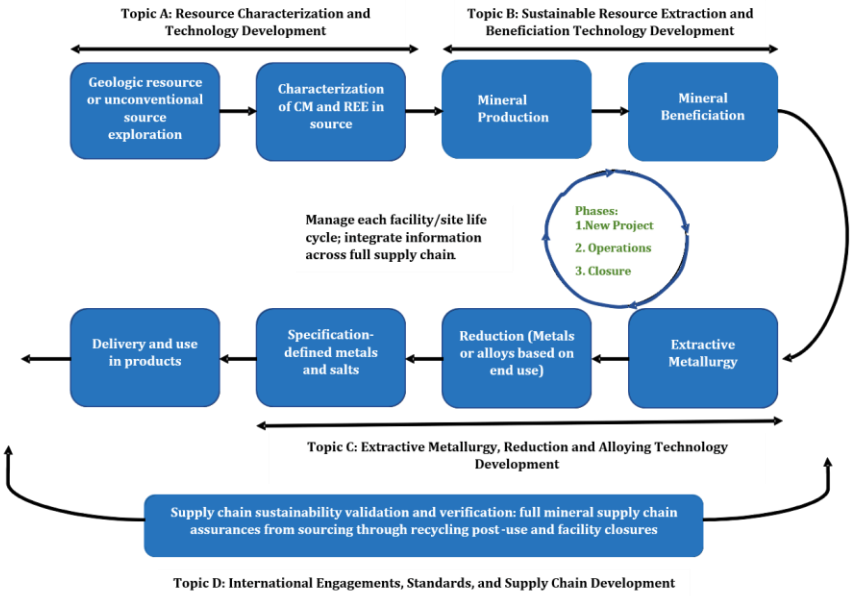
# Summary Report and Appendix to Critical Minerals Sustainability Program Plan: Summary, Synthesis, and Analysis of USEA's Workshops on Critical Minerals Sustainability




April 9, 2021

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U.S. DEPARTMENT OF ENERGY
Office of Fossil Energy

USEA
United States Energy Association

Division of Minerals Sustainability

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## Acknowledgement and Disclaimer

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The Federal Advisory Committee Act (FACA), enacted in 1972 to ensure that advice by the various advisory committees formed over the years is objective and accessible to the public, was considered as part of this effort. This effort is NOT part of a Federal Advisory Committee, and therefore no advice nor consensus was sought nor provided to DOE.

# Executive Summary

The U.S. Department of Energy (DOE) sought new methods to engage regional stakeholders in the area of Critical Minerals Sustainability that included facilitated listening sessions at four regional workshops and one workshop for the National Laboratories. The facilitated listening sessions provided an opportunity for USEA to gather insights from a variety of stakeholders and to look across listening sessions to identify critical factors of interest to DOE. This report summarizes the results and stakeholder feedback from the four DOE Regional Workshops on Critical Minerals Sustainability that were hosted by USEA in the West, Appalachia & East, Gulf Coast, and Midwest & Plains Regions. Some data extracted from the National Laboratories workshop is also included. The Regional workshops focused on the areas of Assessment of Available Resources, Industrial Activity Across the Entire Critical Minerals (CM) Supply Chain, Regional Policy Context, and Regional Needs and Opportunities for Research & Development (R&D) followed by facilitated breakout listening sessions.

A summary of the data that include participant demographics, major themes, observations, and analysis is as follows:

- Total Registered (all 5 workshops): 272
- Total Participants (all 5 workshops, DOE, USEA, & facilitators): 300+
- Organizations represented: 160

The major themes identified through analysis of participant discussions fall into 62 discrete themes that have been further refined into three tiers; Tier 1 represents the top 10 themes by frequency and relative importance, Tier 2 represents those topics that were used with double digit frequency (e.g., >9), and Tier 3 represents those topics that were used with single digit frequency (e.g., <10).

The Tier 1 themes provide major insights into areas of focus for program planning and resource development that include ***mining***, which was by far the most discussed topic, and virtually all in the context of re-use of existing mines and mine waste with little to no discussion of new mines; ***data*** was the second most discussed theme and seen as mission critical, especially the need for shared and open-source data, digitization of paper data; ***sustainability*** was discussed in several ways that included a need to understand the circular economy, sustainable business models, recycling, and utilization of waste streams; ***waste & technology*** themes were often connected with sustainability, including recycling, waste processing, resources, separation, and extraction; ***education*** is a broad topic discussed by participants primarily in the policy context including K-12 STEM to workforce needs, need for increased undergraduate and graduate programs, and engagement with the general public; ***federal government*** was listed by participants as to what, how, and why the federal government should engage and interact with the CM/RE industry; and ***economic*** themes including bonding, property rights for waste streams, and concern over China's role and control in the market.

The participants expressed a desire for the federal government to bring clarity to the what, where, when, and why of R&D programs, cross-regional collaborations, and educational opportunities in the Critical Mineral/Rare Earth Elements arena. Data from the workshops provides greater understanding and some guidance/suggestions:

> *"We don't have a framework for this discussion. And what I mean by that is, we have to think about what our objectives are and what are the timeframes in which we're trying to achieve them…but the timeframes for realizing that in terms of anything tangible about making the United States minerals independent is decades…if we want to make the United States minerals independent in the next year, then we have to look at what we've just done in the last nine months in terms of trying to find a vaccine for, for the COVID virus…we need a framework that says, what are we going to have trying to accomplish, by when?"*

In response to overwhelming support by stakeholders, as well as questions asked to better understand and inform their support moving forward, these high-level observations could provide implementation insights for DOEs Division of Minerals Sustainability Strategic Planning efforts. The observations include:

1. Address the identified themes in a tiered approach, **prioritize the Tier 1 themes.**
2. Continue and **expand regional mineral district concept** with respect to materials and waste streams which vary across regions.
3. **Facilitate knowledge** sharing, encourage development of networks, and working groups among regions.
4. Correlate the regional findings so that **cross-cutting ideas** generated through National Laboratories and other collaborations can be **applied to the regional context**.
5. Understand and **highlight regional differences** by introducing flexibility in the FOA approach taking into consideration that not all regions will share the same continuum of resource charazterization, development of processing, and access to waste materials.
6. Assess policy needs and barriers relative to supply chain, economics, and **level the international playing field.**
7. Encourage **participation in international standards development.**
8. Further **consider cross-agency and extramural National Laboratory activities** and ways to support, coordinate, and expand CM/RE networks, projects, and programs.
9. **Facilitate an ogoing collaborations** with National Laboratories and stakeholders to develop a CM/RE implementaion road map.
10. Create ways to **bring together National Laboratories and stakeholders** to engage the strong desire for future collaborations.

## Introduction

The U.S. Department of Energy (DOE) remained open and engaged throughout the COVID-19 pandemic. However, stakeholder engagement, by necessity, shifted primarily to virtual environments during 2020 and early 2021. In order to continue with strategic and advanced planning, the DOE Division of Minerals Sustainability sought new methods to engage regional stakeholders in the area of Critical Minerals Sustainability.

Through this work, virtual stakeholder engagement methods, such as polling and listening sessions, were used to provide insights and reactions on the regional perspectives on Critical Minerals Sustainability. The facilitated listening sessions provided an opportunity for USEA to gather insights from a variety of stakeholders and to look across listening sessions to identify critical factors of interest to DOE. Based on information gained through the listening sessions, the project team is providing this summary report to contribute to DOE program planning needs.

This report summarizes the results and stakeholder feedback from the four DOE Regional Workshops on Critical Minerals Sustainability that were hosted by USEA in the West, Appalachia & East, Gulf Coast, and Midwest & Plains Regions. The workshops were approximately 3.5-hours in length and consisted of presentations in the areas of Assessment of Available Resources, Industrial Activity Across the Entire Critical Minerals Supply Chain, Regional Policy Context, and Regional Needs and Opportunities for Research & Development (R&D) followed by facilitated breakout listening sessions. The agendas for the four workshops are included in Appendix A. A fifth workshop provided for the National Laboratories was conducted as well and the agenda is also provided in Appendix A. The report from that workshop is being prepared contemporaneously with this report and as such, demographic data are included in this report, but summary and analysis from the National Laboratories workshop is not included.

## Objective

The objective of this report is to provide a summary, synthesis, and analysis from the four workshops on Critical Minerals Sustainability conducted with four regions and to the extent possible based on timing and schedule, inclusion of the National Laboratories Workshop on Critical Minerals Sustainability.

## Method

Carpenter Global used their expertise in strategic planning for energy and natural resources, virtual convening, and conducting listening sessions to assist USEA and DOE in developing their plan and scope for the four workshops. The results from this report can be used to inform program planning, potential Request for Information (RFI), and possible 5-year planning.

Each workshop provided keynote or plenary sessions followed by facilitated breakout sessions which were recorded and transcribed for detailed analysis. Participants were assured no attribution would be made regarding comments. After the breakout sessions were completed, the USEA Host conducted final remarks and invited facilitators to comment. Contact information was given to participants to encourage further communication with USEA and/or DOE. A follow-up email was sent to all Workshop participants after the completion of the final listening session providing the RFI, inviting further comments, and a final opportunity to provide feedback.

## Demographic and Poll Results

Total Participants of all four Regional Workshops and the National Laboratories Workshop

- 272 participants registered
- 300+ attended including US DOE, USEA, notetakers, and facilitators
- 160 organizations represented

Figure 1 represents the number of participants per workshop. Note that the number of participants is listed as *n* = 300+. This is done to represent those participants who joined by phone only and were indistinguishable from the email count of participants. Figure 1 shows that data input from the workshops was roughly equal with respect to contribution.

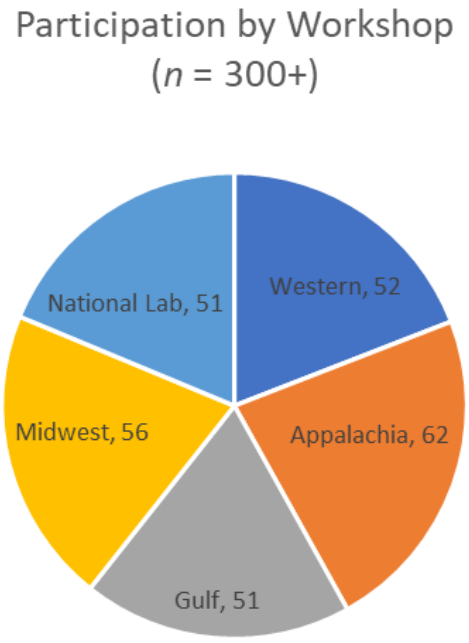


*Figure 1. Breakdown of Number of Participants per Workshop.*

Poll Results of all four Regional Workshops and the National Laboratories Workshop

**Where do you feel your organization fits in the supply chain and regional industrial activity?**

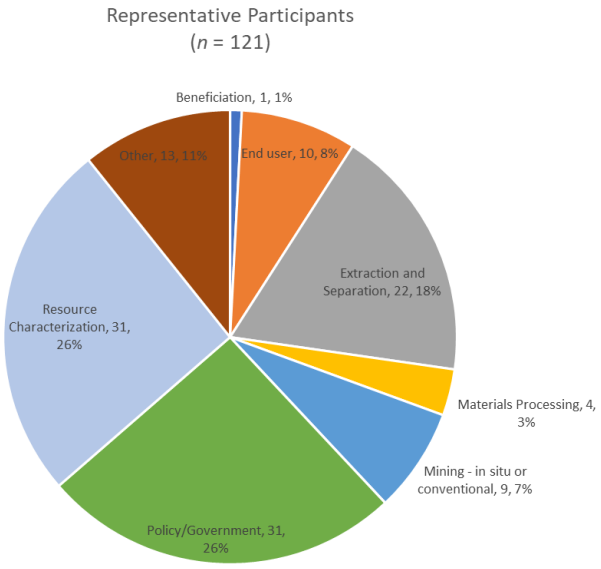


*Figure 2. Demographic Breakdown of Poll Participants from the Four Regional Workshops. n = the cumulative number of participants who responded to the poll question.*

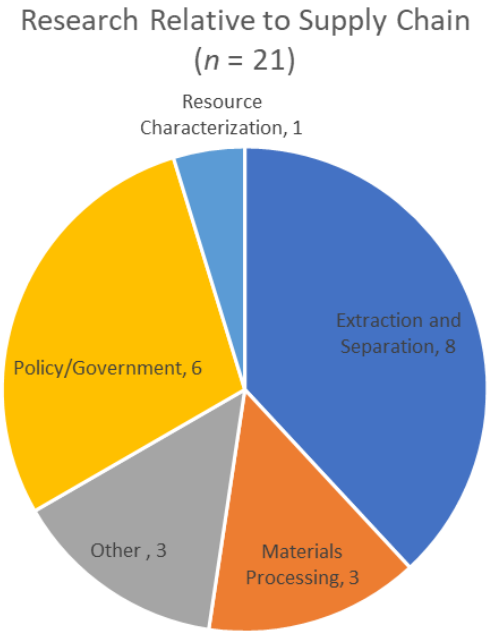


*Figure 3. National Laboratory Research Relative to Supply Chain.*
*n* = number of participants who responded to the poll question.

**Where in the supply chain is policy most needed?**

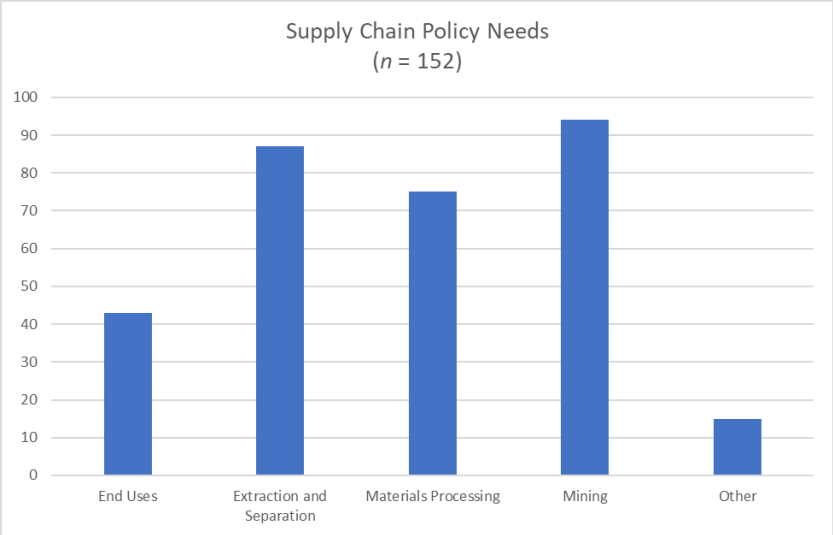


*Figure 4. Supply Chain by Perceived Policy Need Based on All Five Workshops.*
*n* = the cumulative number of participants who responded to the poll question.

**On a scale of 1-3, how aware are you of the status of assets in your region?**

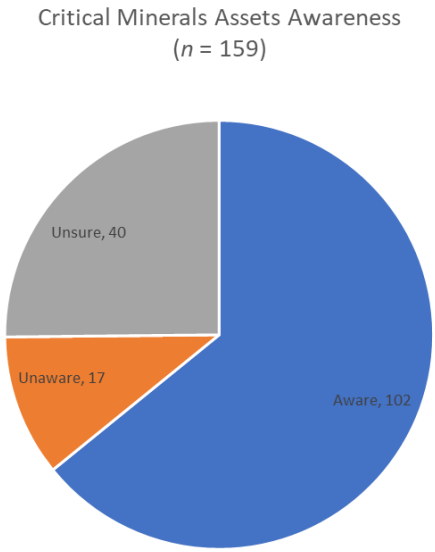


*Figure 5. Awareness of Regional RE and CM Assets From all Five Workshops.*
*n* = the cumulative number of participants who responded to the poll question.

A list of the participating organizations to all four regional and National Laboratories workshops is provided in Appendix B.

# Themes and High Level, Non-regional/Programmatic Observations

Each of the four workshops consisted of introductory remarks by the U.S. DOE-FE leadership and were followed by a keynote presentation. The focus of the keynotes was the importance of critical minerals to American innovation. The list below are the keynote presenters from the four regional workshops.

**U.S. DOE-FE Leadership**

- Dr. Jennifer Wilcox, Acting Assistant Secretary for Fossil Energy, U.S. Department of Energy
- Mr. Lou Hrkman, Deputy Assistant Secretary for Fossil Energy, U.S. Department of Energy
- Mr. Angelos Kokkinos, Associate Deputy Assistant Secretary for Clean Coal and Carbon Management, U.S. Department of Energy

**Keynotes: Importance of Critical Minerals to American Innovation**

- Dr. Julie Klinger, Professor, University of Delaware
- Dr. Thomas Graedel, Clifton R. Musser Professor Emeritus of Industrial Ecology, Professor Emeritus of Chemical Engineering, Yale University
- Dr. Jack Lifton, Co-founding Principal, Technology Metals Research LLC
- Ms. Jane Nakano, Senior Fellow, Energy Security and Climate Change Program, Center for Strategic & International Studies

Following the keynotes were specific regional presentations by thought leaders that presented the regional perspectives to the breakout session questions that would follow. The thought leaders who shared their views and the four focus areas were centered around the following themes.

**Assessment of Available Resources**

- Dr. Warren Day, Earth MRI Science Coordinator, U.S. Geological Survey
- Mr. Brian Somers, President, Utah Mining Association
- Dr. Tim White, Research Professor, Penn State University
- Dr. Amy Gartman, Research Oceanographer, U.S. Geological Survey
- Dr. W. Crawford Elliott, Associate Professor, Department of Geosciences, Georgia State University
- Mr. John Yellich, President, American Association of State Geologists, Director, Michigan Geological Survey

**Industrial Activity Across the Entire CM Supply Chain**

- Ms. Sarah Maryssael, Group Manager, Battery Supply Chain, Metals, & Mining, Tesla
- Mr. Alex Grant, Principal, Jade Cove Partners

- Dr. Pete Rozelle, Manager, Churnside Technology Management
- Ms. Atusa Amiri, Senior Manager, Process Water Operations and Optimization, Mosaic Fertilizer
- Mr. Jon Blumenthal, President & CEO, Blue Line Corporation
- Mr. Clint Cox, President, The Anchor House, Inc.

**Regional Policy Context**

- Mr. Mark Compton, Executive Director, American Exploration & Mining Association
- Dr. Seth Blumsack, Professor, Penn State
- Ms. Sharon Mustri, Mining and Metals Analyst, Bloomberg New Energy Finance
- Dr. James Mennie, Business Director, Florida Industrial Phosphate Research Institute, Florida Polytechnic University
- Ms. Elizabeth Tate, JD, Director – Public Policy and Sustainability, Clarios

**Regional Needs and Opportunities for R&D**

- Dr. Rod Eggert, Deputy Director, Critical Materials Institute
- Dr. Dick Bajura, West Virginia University
- Dr. Ramanan Krishnamoorti, Chief Energy Officer, University of Houston
- Dr. Kwame Awuah-Offei, Professor, Mining & Nuclear Engineering, Missouri S&T University

**National Laboratories Workshop included presentations about Laboratory Research Capabilities. Laboratories that presented include:**

- Ames Laboratory
- Argonne National Laboratory
- Brookhaven National Laboratory
- Idaho National Laboratory
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- National Energy Technology Laboratory
- National Renewable Energy Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Savannah River National Laboratory
- SLAC National Accelerator Laboratory

A Report summarizing the National Laboratories Workshop has been created contemporaneously with this Summary Report and will be provided as an addendum to this report when finalized.

## Thematic Data Analysis

Based on the breakout session discussions with participants, the following is an analysis of the frequency with which words/themes were discussed. Figure 6 below, represents all the major themes that were discussed and the relative frequency in which participants mentioned them. In order to better understand and evaluate these themes, we have broken them down into three (3) tiers.

- Tier 1 represents the top 10 themes by frequency, identified in green
- Tier 2 represents those topics that were used with double digit frequency (e.g. >9), identified in blue
- Tier 3 represents those topics that were used with single digit frequency (e.g. <10), identified in purple

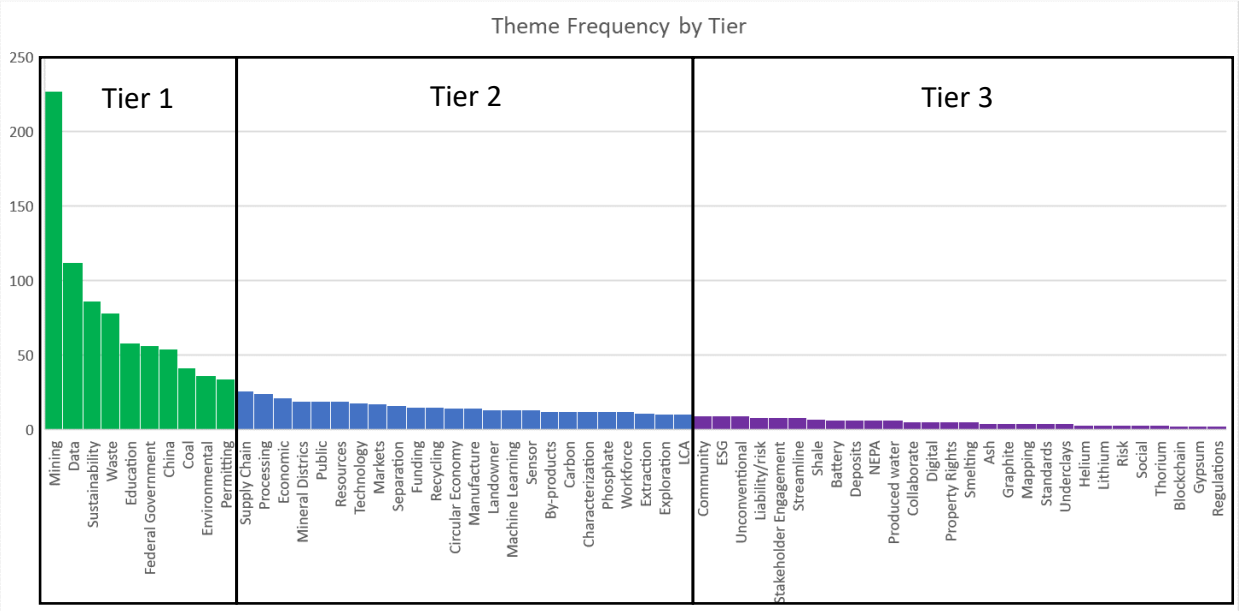


*Figure 6. Cumulative Frequency of Themes by Participants*

Figure 7 represents Tier 1, 2, & 3 themes graphically in a word cloud.


*Figure 7. Tier 1, 2, & 3 Frequency of Themes in Word Cloud.*

Figure 8 below represents the top 10 themes or the Tier 1 themes in a wheel or pie graph, showing their relative weight based on their usage by participants.

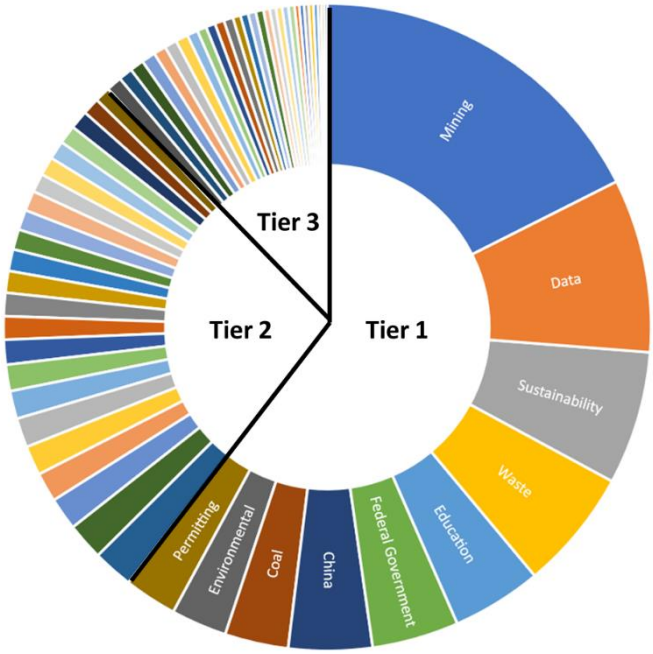


*Figure 8. Tier 1 or Top 10 Themes Wheel or Pie Graph.*

The four areas of focus and questions/discussion during the breakout sessions were 1) an assessment of available critical mineral and rare earth resources, 2) the policy context for the critical minerals and rare earths, 3) an understanding of the industrial activity across the entire supply chain, and 4) an identification of the needs and opportunities for R&D in critical minerals and rare earths. A brief summary of the discussions and reactions from the participants by each of these four sectors is provided below.

***1: Assessment of Available Resources***

When asked to discuss the current level of activity and interest in characterizing RE and CM deposits, participants identified both deposits by type and by region, sharing their understanding of where work has been done to date. Those types and areas, listed alphabetically, include:

- Alkaline carbonatite-type in Nevada
- Alumina
- Barite
- Central Kentucky minerals district
- Coal, AMD, and coal fly ash
- Coal deposits in the Powder River Basin
- Cobalt
- Gallium
- Germanium
- Illinois & Kentucky fluorspar district
- Indium
- Kansas critical minerals
- Lithium
- Manganese
- Mineral sand mining in SE Georgia & N Florida
- Molybdenum
- Monazite deposits in the Utah area
- Near-shore & offshore deposits
- Nebraska niobium deposit at Elk Creek
- Neodymium
- Nickel
- Phosphates
- Potato River intrusion in NW Wisconsin
- Produced water
- Rare earths in coal ash, tailings, fly ash
- Southeast Alaska deposits
- Synthetic graphite production
- Thorium
- Titanium
- Tungsten
- Underclays
- Uranium
- Vanadium
- Warrior Basin coals
- Western Kentucky fluorspar district
- Wolf River batholith, Wausau Sinai Complex, Central Wisconsin
- Yttrium
- Zirconium

Participants were asked to comment on what advances could be made if increased analytics and modeling, processes, applications of new technology, and/or new applications to existing

problems were available. Based on their responses, the following responses were provided by the attendees, and listed in order of priority, based on the frequency they were discussed. **Of significance to this list is the fact that the first 3 items (data, China, and environment) of the 6 items listed are Tier 1 themes**, signifying a relative importance and consistency among the participants from all four regions. Note **recycling, reprocessing, byproducts** likely relates to 2 additional Tier 1 themes, **sustainability and waste**.

- **Data** – the need for more and digitization of analog, use of Machine Learning and AI, access to existing data/cores
- **China** – market share, levelized economics, competition with China
- **Environment** - protection and impact
- **Recycling, reprocessing, byproducts [sustainability, waste & technology]**- from waste streams
- **Extraction and separation** – from new/raw materials and byproducts
- **Mapping** – of existing deposits and access to geologic data

Figure 9 represents the major themes across all four regions relative to the focus area of an assessment of available critical minerals and rare earths.

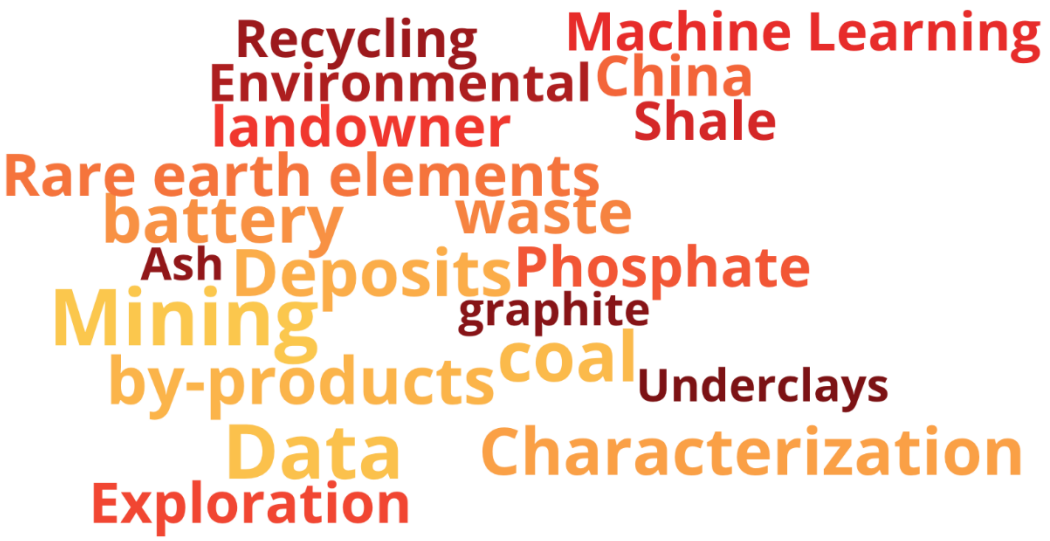


*Figure 9. Cumulative Assessment of Available Resources in a Word Cloud*

***2: Policy Context***

When asked to discuss the regional policy context, policy developments, and opportunities for changes in a region, participants identified the following as important, listed in priority based on the frequency of the mention. **Of significance to this list is the fact that 6 of the 7 items**

**(mining, data, sustainability, education, permitting, and funding) listed are Tier 1 themes**, signifying a relative importance and consistency among the participants from all four regions.

- **Mining** - addressing negative perceptions of mining, recycling of mine waste and AMD
- **Data** - availability, mapping, technology transfer, making public all the data in the RE/CM industry
- **Sustainability** - international standards, social behavior
- **Education** - undergraduate and graduate education, economic geology, mining engineering, research funding for graduate students, education of decision-makers such as Provosts, Deans, and University Presidents, workforce development, address liabilities, develop Cooperatives and Partnerships
- **Permitting** - streamlining
- **Funding** - economics, government incentives, loan programs
- **Market development**, level playing field environmentally between U.S. operations and competing countries

Figure 10 represents the major themes across all four regions relative to the regional policy context, policy developments, and opportunities for changes in the regional context.


*Figure 10. Cumulative Regional Policy Context Word Cloud.*

***3: Industrial Activity Across the Entire CM Supply Chain***

Participants were asked what role sustainable practices play in their organizations' sourcing within the supply chain and what sustainable practices they are implementing. Participants identified the following as important, listed in priority based on the frequency of the mention. **Of significance to this list is the fact that 3 of the 5 items (data, sustainability, and federal government) listed are Tier 1 themes,** signifying a relative importance and consistency among the participants from all four regions.

- **Data –** access to state-wide databases, application of machine learning
- **Sustainability** – understanding and applying a standard definition of sustainability, creating and using sustainable industry best practices, use of life cycle analysis (LCA) and understanding of supply chains, understanding the social license to operate (SLO), environmental and landowner perspectives, the need for additional human and financial resources to ensure that there is no loss of institutional knowledge, public willingness to pay, and finding ways to utilizing the full resources
- **Federal government** – assistance and changes to the grant application and review processes, more flexibility in the Technology Readiness Levels (TRL) and Manufacturing Readiness Levels (MRL)
- **Process, extraction, metallization** - processing locations, instrumentation and sensor development, availability of raw materials, processes to convert oxides and chlorides into metals or alloys, carbon products and carbon as a separation mechanism, REE from acid mine drainage, and waste minimization
- **Funding** - circularity, market certainty, suggested use of the Buy American Act of 1933

Figure 11 represents the major themes across all four regions relative to the regional industrial activity across the entire CM supply chain.


*Figure 11. Cumulative Industrial Activity Across the Entire CM Supply Chain Word Cloud.*

***4: Needs and Opportunities for R&D***

Participants were asked what they considered to be the most critical shortfalls or technical gaps that could be addressed by federally funded R&D. Participants identified the following as important, listed in priority based on the frequency of the mention. **Of significance to this list is the fact that 4 of the 5 items (data, sustainability, education, and federal government) listed are on the overall frequency top 10 list,** signifying a relative importance and consistency among the participants from all four regions.

- **Data** - potential for existing data to be digitally available, understanding and mapping existing resources, application of blockchain, creation of and of larger data sets, collaboration between mining engineers and machine learning and Artificial Intelligence (AI) experts
- **Sustainability -** LCA, the need and use of international standards, how to create region-specific benefits and keep jobs, application of sustainability on the back end
- **Education** – Science, Technology, Engineering, and Math (STEM) and workforce education, stakeholder engagement and education across the supply and value chain, educating the consuming public on the source and manufacturing of the technology devices they all crave, stakeholder and community engagement
- **Federal Government** - federal government involvement/assistance, higher level TRL federal support, market support, support in competition with China, policy developments, finding ways to make the "whole mineral valuable", property rights of waste streams, establishing regional mineral districts – each region is different, finding ways to engage/collaborate with USGS and state geological surveys, access to federal stockpiles or materials
- **Processing -** resource identification, quantification, and concentration; processing and the characterization of by-products and waste streams; advanced separation technologies; nanotechnology potential, applying new technologies on existing operations; waste minimization; developing economic methods to extract low levels of molybdenum and copper from uranium-vanadium feeds; regional radiometric surveys for onshore and offshore deposits

Figure 12 represents the major themes across all four regions relative to the regional needs and opportunities for R&D.


*Figure 12. Cumulative Regional Needs and Opportunities for R&D Word Cloud.*

## Discussion of Major Themes

The observations and conclusions drawn from the data are sorted and presented based on the frequency by which participants discussed them, thereby providing weight or importance on the criteria, theme, or phenomenon. As outlined in this section, we discuss all (100%) of the top 10 themes, or Tier 1 themes; 9 of the 24 Tier 2 themes (38%); and 3 of 28 Tier 3 themes (11%). All 62 themes are provided in Appendix C: Participant Themes, Criteria, or Phenomenon.

<u>Mining (includes additional themes from Tiers 1, 2, & 3):</u>

Mining was by far, statistically and by frequency, the most discussed topic. Virtually every participant mentioned mining in some form. The vast majority of the discussion of mining was in the unconventional context with some discussion about mining and higher education. Specific discussion revolved around mining - addressing negative perceptions of mining, recycling of mine waste, access to mine tailings, and use of AMD to extract CM/RE.

Only 4 of the 227 mentions of mining even considered mining in the context of opening a new mine, which is less than 2% of the use of mining by the participants.

> *"I can tell you that there is a large storage reservoir of mineral deposits in the Upper Peninsula. We have some data that we have been able to retrieve from old mining records and/or records of the geological survey."*

In discussing themes and high level, non-regional observations from the Assessment of Available Resources sessions, participants readily shared a list of the current level of activity and interest in characterizing RE and CM deposits. Participants identified both deposits by type and in some cases by region, creating a list from Alkaline carbonatite-type in Nevada to Zirconium.

> *"And we somehow have got to get the public to understand that their lifestyle depends on mining and that we've got to do that in this country…But you just can't get this concept through to the public, that we've got to have mining and that mining can be done environmentally. So, policy would definitely go a long way to help get the public to understand this."*

> *"We are mapping in the Gallinas Mountains looking at rare earths. We also are starting to map in the Cornudas Mountains looking at rare earths. I also put together a number of databases on rare earth deposits and other critical minerals in New Mexico…I have been approached by some of the Alamogordo group to try to figure out where rare earths and other critical minerals might be in some of these brine deposits."*

<u>Data (includes themes from Tiers 1, 2, & 3):</u>

Data issues were the second most discussed theme/topic. Data is seen as mission critical and the perception is that there is a lot of existing data as well as the need for new data. Participants suggested that the U.S. has significant amounts of data that reside with industry and with state geological surveys and this data needed to be accessed, mined, and digitized. There is a perception that much of the existing data are in paper form. Making this data available and allocating resources to create the mapping, provide technology transfer was listed as a priority. It is expected that the use of Machine Learning (ML), Big Data (BD), and AI will be needed to accomplish this effort.

> *"We can't manage what we cannot measure"*

> *"I'm not a geologist, but was in a meeting with a bunch of them yesterday and…I heard…that at the current rate of mapping in the Black Hills, we're looking at 20 years to complete that. So, we need the Earth MRI on steroids…[and we must tell] Congress."*

Sustainability (includes themes from Tiers 1, 2, & 3):

Even though sustainability was the third most discussed topic, there was an identified lack of understanding of a common definition, and therefore the use and applicability of sustainability varied widely by participant. As used in the RFI and assumed to be understood, the definition of sustainability facilitators used was per ISO Guidelines on Addressing Sustainability in Standards, Guide 82:2019 as the "state of the global system, including environmental, social and economic aspects, in which the needs of the present are met without compromising the ability of future generations to meet their own needs." This definition was not necessarily well understood, known, or used by participants. Participants did express concern for a level playing field across the supply chain and life cycle of CM/RE with China being their most impending foreign actor.

> *[via email] "If the US does not have a means for a sustainable business as a user of CM there will never be a sustainable CM supply chain. Whether it is electronics, batteries or magnets, the US cannot compete with China. Not without innovation in the products and the manufacturing of the products that use CM. It is disappointing to see that the DoE CM 'effort' is missing this. Without advancing CM end-use technologies and competitive manufacturing process/technologies there will never be 'Critical Mineral Sustainability'."*

Participants suggested that their views and application of sustainability manifested in several ways that included a need to understand the circular economy, sustainable business models, recycling, and utilization of waste streams.

Waste & Technology to include recycling, waste processing, resources, separation, and extraction (includes themes from Tier 1, 2, & 3):

Undoubtably, as participants focused virtually all their discussion efforts of mining on the unconventional/recycling aspects, it is not surprising that waste, waste re-use, and waste re-cycling is a top 10 theme. Areas of particular interest focused on separation, characterization, recycling, and improved recovery of waste and byproducts.

> *"We need to find a way to implement the policy of 'no molecule left behind' and extract every mineral along the extraction, processing, and separation process, regardless of the economic factors"*

Additional areas of particular interest focused on chemical processes for separation and concentration, technological enhancements through remote sensing, application of nanotechnology in metallurgy, and the use of AI modeling combined with geologic input.

Education (includes themes from Tiers 1 & 3):

Education is a broad topic discussed by participants primarily in the policy context that included a variety of issues that spanned from K-12 STEM to workforce education needs. Participants also expressed a need for human and financial resources to be available to ensure that a loss of institutional knowledge can be minimized.

> *"I think there's a huge public education component that needs to be undertaken."*

> *"...[its] an area where we really have a gap in human resources and it's very difficult to find people that are working in this field and the science that needs to go into this in the future."*

> *"…[it] is no surprise…[that]…we are desperate for folks who understand mineral economic geology and mineral economics…and we just don't have the people that understand these systems, and how to move forward, [to] further discovery and recovery."*

Another aspect of education expressed by participants was that of stakeholder engagement and how DOE, and the federal government in general, interacts with the public, the stakeholders in the CM/RE industry, and how data is collected and outcomes measured. There was a desire expressed for diverse models for engagement that connect with groups outside the traditional stakeholders.

> *"More integration of social science with science. They are doing this very successfully in the research institutes in Europe because many of the barriers to overcome are beyond just the science itself."*

> *"I must admit that was one of the most fun meetings I've been in all fall. It was so great to hear from a broad cross-section of stakeholders in the critical minerals arena. Hats off to the folks who planned the meeting. The Zoom platform was managed very well, the prepared questions very much on target, and they elicited great discussions from the group."*

> *"One of the best meetings I have attended all year."*

> *"I love these dialogues. This is fantastic."*

> *"Well, I've never been on a phone call with this many geologists. [Facilitator]: Does that mean you won't ever do it again or what does that mean? [Respondent]: No, well, my*

*comment is they clearly know what needs to be done. Give them the money that they need to do it."*

Federal government (includes themes from Tier 1):

Participants had some specific ideas and recommendations as to what, how, and why the federal government should engage and interact with the CM/RE industry. Regulatory challenges and permitting issues were among the most widely suggested. Relative to the government, and DOE specifically, the participants suggested flexibility in the use of the TRLs with respect to Funding Opportunity Announcements (FOA) and grants. Participants believe that the government has a role in reducing risk associated with CM/RE throughout the supply chain, and therefore a larger role in the grant process with less cost share required, as well as to have the government address liabilities and risks. Industry and academia expressed concern over China's role, how to engage with them, and the role that markets and government do and should play in the RE/CM industry.

*"…if you don't have a market, we can do all the geologic work, all the metallurgy research, but we're never going to have companies who are going to enter this sector, and importantly, they're never going to get the financing and the funding for it. And so, a tie-in to that would also be to be thinking about what is a national stockpile program to look for some of these... Basically that creates the market pull that allows companies to have a business case to get into this."*

*"…you can mine, you can extract, you can produce metal alloys, but your only customer will be China unless you approach it in a different way. It's very much a commodity market now, piece part market, etc. So, it's really the innovation that's needed both technically and in the business model."*

Economics (includes themes from Tier 1 & 2):

Participants' focus on economics was broad and diverse. Economics was a common theme among participants, as issues like bonding and understanding property rights for waste streams will be critical to advance the industry at the speed and size believed necessary. They also expressed concern over China's role and control in the market. Participants also expressed a need for human and financial resources, that would only be made available with appropriate funding and the U.S. need to understand circularity in the RE/CM economy.

*"…we don't do a good job of making the case about why this is important."*

*"China is losing billions to make trillions"*

## Summary of National Laboratory Workshop

The National Laboratories Workshop Final Report was prepared contemporaneously with the Summary of the Four Regional Workshops. As such, some data and anecdotes were available and where prudent, are included in this report to provide context for DOE's Mineral Sustainability Division RFI and program planning.

One of the more **significant learnings from the National Laboratory workshop** was the **level of engagement, passion, and excitement** on behalf of the National Laboratory researchers who participated. **They all expressed a desire to continue these facilitated breakout sessions to engage the Laboratories from an extramural standpoint, as well as with a wider, industry-based audience.** The participants suggested extending the analogy of speed dating which was used in the facilitation to a large approach. Some researchers expressed a desire to provide a list of research capabilities that each Laboratory is working on electronically, as a means to "post" and "search" for an industry "partner". Many of the Laboratory participants expressed difficulty in finding, keeping, and expanding their "relationships" with industry and partners needed for collaborative research. As a result of this revelation and the Laboratories' request for further engagement, it was noted by DOE at the conclusion of the workshop that, *"We did something much bigger today than we thought we could do."*

The participants of the National Laboratories expressed many of the same themes or issues as did the regional participants. As those who work within the federal government system of FOAs and grants almost exclusively, there was across the board support for flexibility in and expansion of the TRL and MRL systems. The reason expressed was to engage industry partners earlier in the process and to retain them longer throughout the TRL/MRL process.

There was a desire by the Laboratories to access data and to incorporate as much machine learning and AI as possible.

The Laboratories expressed both the possession of skill sets and a desire to expand skill sets and assets into the more traditional social science and economics areas that would focus on eco-systems, circular economies, and LCA capabilities. Similar to the regional workshop participants, there was a lack of understanding of the definition of sustainability and therefore how best to implement best practices in their work. Some researchers expressed need and willingness to consider the social aspects of sustainability in a cross-Laboratory or extramural manner.

## Priority Observations

Four Focus Areas:

The Top Ten Priority Observations identified fall into four main categories, or topic areas, that were listed in the RFP. These include:

- **Topic A - Resource and Operational Considerations**: An understanding of the basic geologic characterization of CM and REE deposits is crucial to evaluating known deposits and delineating prospective areas of sustainable resource extraction. Studies on mineralogy, framework geology, and ore deposit genesis can help to better define the characteristics of mineral deposits and can lead to new discoveries of minerals. This new environmentally sustainable program of R&D activities will assess regional differences for onshore (and offshore) CM and REE resource availability.
- **Topic Area B - CORE/CM Regional Focus:** Information from stakeholders needed to formulate a new program of research and development (R&D) activities for conventional mining ore deposits and processing CM and REE from those ores, with co-production of other minerals present and new and innovated extraction/mining practices, such as in-situ extraction, targeted extraction (high-grade/low-volume), and co-production with other resource extraction (i.e., oil and natural gas, produced waters, geothermal, and carbon storage) and industrial operations (bauxite residuals from aluminum mining). Co-production could also include tailings, mine refuse, coal ash, acid mine drainage and other legacy related sources.
- **Topic Area C – International Activities:** Information from stakeholders needed to formulate a new program of research and development (R&D) activities for mineral ore processing needed to obtain CM and REE mixed and purified oxides, salts, phosphates, etc. These could be sources from ores, as well as unconventional sources as previously defined sources where possible through extractive metallurgy. The intent of these Technical Areas is to support development of research initiatives that would lead to environmentally sustainable, efficient, and cost-effective technologies. The development and validation of advanced and novel technologies for mineral processing and extractive metallurgy and reduction to metals would maximize production from mineral ores and unconventional feedstocks. In addition, a more thorough understanding and design of flow sheets that could minimize processing steps could further reduce costs and environmental impacts, while advancing- US industrial interest in the energy sector.
- **Topic D – Stakeholders and National Laboratories:** Information from stakeholders needed to make sure that the U.S. engages in effective collaborative R&D in this area and has an active voice in creating international standards on environmental and labor safety laws that create sustainable CM and REE supply chains. Experts from the United States through engagement with the International Standards Organization (ISO) technical committees on CM are working on standards and supply chain sustainability.

Regional Perceptions:

One observation that can be made across the four regional workshops is that each region is unique and has varying levels of understanding and advancement with respect to RE/CM. It was expressed by participants that DOE could benefit from a regional or non-cookie cutter approach to RFPs and FOAs. Some participants advanced this theme by suggesting that DOE might benefit from establishing regional mineral districts that focus on the elements, materials, waste available in the given regions. The participants of the American Gulf Coast region expressed concern that their region may be "behind" other regions in development of CM capacity. The American Midwest and Plains region participants suggested that their region was well known, and much analog data exists to advance the mapping and understanding of rare and critical minerals.

Implementation Considerations:

Based on the data collected from the workshops, the participants have provided data that can be interpreted and summarized from an implementation perspective. In short, the data may be used to assist in developing a possible Road Map or implementation plan. The RFI issued by DOE on December 17, 2020 contained a diagram that outlined the four topic areas that are the focus of the request for information. These four topic areas are (A) Resource Characterization and Technology Development, (B) Sustainable Resource Extraction and Beneficiation Technology Development, (C) Extractive Metallurgy, Reduction and Alloying Technology Development, and (D)International Engagements, Standards, and Supply Chain Development and is depicted as Figure 13 below.

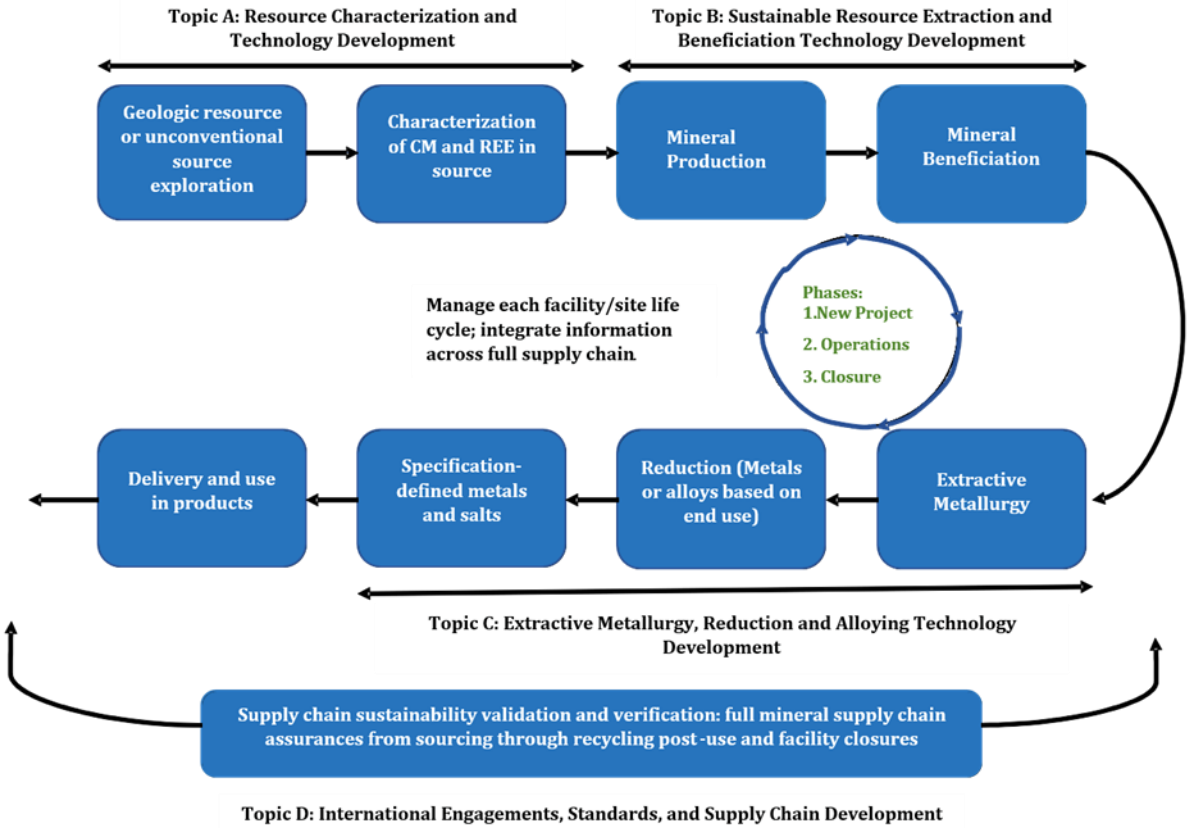


*Figure 13. Relationship RFI Topics to Achieving Sustainable CM and REE Supply Chains.*

| | Resource Characterization and Techology Development | Sustainable Resource Extraction and Beneficiation Technology Development | Extractive Metallurgy, Reduction and Alloying Technology Development | International Engagements, Standards, and Supply Chain Development |
|---|---|---|---|---|
| Mining | x | x | x | x |
| Data | x | x | x | x |
| Sustainability | x | x | x | x |
| Waste | x | x | x | x |
| Education | x | x | x | x |
| Federal Government | x | x | x | x |
| China | | | | x |
| Coal | x | x | x | ? |
| Environmental | x | x | x | x |
| Permitting | | | | x |

*Figure 14. Four Focus Areas in RFI and Top 10 Theme Relationships.*

Figure 14 above presents the four DOE RFI focus areas, cross referenced with the top 10 themes. The figure presents a good correlation between the top 10 themes and the 4 RFI focus areas indicating that DOEs programmatic approach to the MSD program plan matches stakeholder understanding and input. Note the "?" in engagement for China denotes the need

for increased discussion on this topic given the change in Administration between when the workshops started, were completed, and the time at which this report was written.

The participants expressed a desire for the federal government to bring clarity to the what, where, when, and why of R&D programs, cross-regional collaborations, and educational opportunities in the Critical Mineral/Rare Earth Elements arena. Data from the workshops provides greater understanding and some guidance/suggestions:

> *"We don't have a framework for this discussion. And what I mean by that is, we have to think about what our objectives are and what are the timeframes in which we're trying to achieve them…but the timeframes for realizing that in terms of anything tangible about making the United States minerals independent is decades…if we want to make the United States minerals independent in the next year, then we have to look at what we've just done in the last nine months in terms of trying to find a vaccine for, for the COVID virus…we need a framework that says, what are we going to have trying to accomplish, by when?"*

In response to overwhelming support by stakeholders, as well as questions asked to better understand and inform their support moving forward, these high-level observations could provide implementation insights for DOEs Division of Minerals Sustainability Strategic Planning efforts. The observations include:

1. Address the identified themes in a tiered approach, **prioritize the Tier 1 themes.**
2. Continue and **expand regional mineral district concept** with respect to materials and waste streams which vary across regions.
3. **Facilitate knowledge** sharing, encourage development of networks, and working groups among regions.
4. Correlate the regional findings so that **cross-cutting ideas** generated through National Laboratories and other collaborations can be **applied to the regional context**.
5. Understand and **highlight regional differences** by introducing flexibility in the FOA approach taking into consideration that not all regions will share the same continuum of resource charazterization, development of processing, and access to waste materials.
6. Assess policy needs and barriers relative to supply chain, economics, and **level the international playing field.**
7. Encourage **participation in international standards development.**
8. Further **consider cross-agency and extramural National Laboratory activities** and ways to support, coordinate, and expand CM/RE networks, projects, and programs.
9. **Facilitate an ogoing collaborations** with National Laboratories and stakeholders to develop a CM/RE implementaion road map.

10. Create ways to **bring together National Laboratories and stakeholders** to engage the strong desire for future collaborations.

From these priority observations, there are some suggested next steps to implement and advance the observations. These include:

1. DOE is well-positioned to **ask key questions and drive integration across the Administration**, Earth MRI & similar programs, fill former Bureau of Mines gap…**what is needed, when, where, and led by whom?**
2. Consider how DMS & DOE-FE can/should **communicate & coordinate across DOE & Administration.**
3. The **workshops were significantly successful**; however, they were "invitation-only" and may have bias. **Consider expanding the "facilitated workshop" approach with a wider & broader stakeholder group**, possibly to include the CORE/CM Initiative.
4. Consider replicating **RCSP-style "Working Groups"** across the new CORE-CM Initiative to **address topics such as stakeholder engagement, international standardization, data collection & dissemination, and assessment of the CM/RE asset continuum**; beginnings of **best practices development.**
5. Workshops **confirmed this high-value approach** and **identified significant desire for collaboration**, especially by the National Laboratories. Consider **how best to continue and expand this momentum** with NLs and Partnerships/Consortia.
6. **Facilitate an exercise** to assist the National Laboratories in **identifying and sharing** with potential industrial partners and stakeholder to better understand **cross-laboratory research efforts**.

# Appendix A: Workshop Agendas

U.S. DEPARTMENT OF ENERGY | Fossil Energy

USEA United States Energy Association

# Western Regional Workshop on Critical Minerals Sustainability

November 19, 2020
12:00 – 3:30 PM PT
Zoom Meeting

**12:00 – 12:20PM** **Critical Minerals Introductory Panel**

**Critical Minerals Introductory Remarks**
Lou Hrkman, Deputy Assistant Secretary for Clean Coal and Carbon Management, Office of Fossil Energy, U.S. Department of Energy

**Importance of Critical Minerals to American Innovation**
Dr. Thomas Graedel, Clifton R. Musser Professor Emeritus of Industrial Ecology, Professor Emeritus of Chemical Engineering, Yale University

**12:20 – 1:00PM** **Assessment of Available Resources**
Warren Day, Earth MRI Science Coordinator, U.S. Geological Survey

Brian Somers, President, Utah Mining Association

Interactive Breakout Session #1

**1:00 – 1:45PM** **Industrial Activity Across the Entire CM Supply Chain**
Sarah Maryssael, Group Manager, Battery Supply Chain, Metals, & Mining, Tesla

Alex Grant, Principal, Jade Cove Partners

Interactive Breakout Session #2

**1:45 – 2:30PM** **Regional Policy Context**
Mark Compton, Executive Director, American Exploration & Mining Association

Interactive Breakout Session #3

**2:30 – 3:20PM** **Western Regional Needs and Opportunities for R&D**
Rod Eggert, Deputy Director, Critical Materials Institute

Interactive Breakout Session #4

**3:20 – 3:30PM** **Future Direction and Conclusion**

U.S. DEPARTMENT OF ENERGY | Fossil Energy

USEA United States Energy Association

# Appalachia and Eastern U.S. Regional Workshop on Critical Minerals Sustainability

December 17, 2020
1:00 – 4:30 PM ET

| | |
|---|---|
| 1:00 – 1:20PM | **Critical Minerals Introductory Panel** |
| | **Critical Minerals Introductory Remarks**<br>Angelos Kokkinos, Associate Deputy Assistant Secretary for Clean Coal and Carbon Management, Office of Fossil Energy, U.S. Department of Energy |
| | **Importance of Critical Minerals to American Innovation**<br>Julie Klinger, Professor, University of Delaware |
| 1:20 – 1:40PM | **Assessment of Available Resources**<br>Warren Day, Earth MRI Science Coordinator, U.S. Geological Survey |
| | Tim White, Research Professor, Penn State |
| 1:40 – 2:00PM | **Regional Policy Context**<br>Seth Blumsack, Professor, Penn State |
| 2:00 – 2:50PM | **Interactive Breakout Session #1** |
| 2:50 – 3:10PM | **Industrial Activity Across the Entire CM Supply Chain**<br>Sharon Mustri, Mining and Metals Analyst, Bloomberg New Energy Finance |
| | Pete Rozelle, Manager, Churnside Technology Management |
| 3:10 – 3:30PM | **Appalachia and Eastern U.S. Regional Needs and Opportunities for R&D**<br>Dick Bajura, WVU |
| 3:30 – 4:20PM | **Interactive Breakout Session #2** |
| 4:20 – 4:30PM | **Future Direction and Conclusion** |

U.S. DEPARTMENT OF ENERGY | Fossil Energy

USEA United States Energy Association

# American Gulf Coast Regional Workshop on Critical Minerals Sustainability

January 19, 2021
1:00 – 4:30 PM ET

| | |
|---|---|
| **1:00 – 1:20PM** | **Critical Minerals Introductory Panel** |
| | **Critical Minerals Introductory Remarks**<br>Angelos Kokkinos, Associate Deputy Assistant Secretary for Clean Coal and Carbon Management, Office of Fossil Energy, U.S. Department of Energy |
| | **Importance of Critical Minerals to American Innovation**<br>Dr. Jack Lifton, Co-founding Principal, Technology Metals Research LLC |
| **1:20 – 1:35PM** | **Assessment of Available Resources**<br>Dr. Amy Gartman, Research Oceanographer, U.S. Geological Survey |
| | Dr. W. Crawford Elliott, Associate Professor – Department of Geosciences, Georgia State University |
| **1:35 – 1:45PM** | **Regional Policy Context**<br>Dr. James Mennie, Business Director – Florida Industrial Phosphate Research Institute, Florida Polytechnic University |
| **1:45 – 2:50PM** | **Interactive Breakout Session #1**<br>Facilitators:<br>Dr. Steven Carpenter, Founder, Carpenter Global LLC |
| | Dr. Sallie Greenberg, Consultant, Carpenter Global LLC |
| **2:50 – 3:05PM** | **Industrial Activity Across the Entire CM Supply Chain**<br>Atusa Amiri, Senior Manager – Process Water Operations and Optimization, Mosaic Fertilizer |
| | Jon Blumenthal, President & CEO, Blue Line Corporation |

| | |
|---|---|
| 3:05 – 3:15PM | **Gulf Coast Regional and Offshore Needs and Opportunities for R&D**<br>Dr. Ramanan Krishnamoorti, Interim Vice President / Vice Chancellor for Research & Technology Transfer, University of Houston |
| 3:15 – 4:20PM | **Interactive Breakout Session #2**<br>Facilitators:<br>Dr. Steven Carpenter, Director – Enhanced Oil Recovery Institute, University of Wyoming<br><br>Dr. Sallie Greenberg, Associate Director – Energy & Minerals, Illinois State Geological Survey |
| 4:20 – 4:30PM | **Future Direction and Conclusion** |

U.S. DEPARTMENT OF ENERGY | Fossil Energy

USEA United States Energy Association

# American Midwest & Plains Regional Workshop on Critical Minerals Sustainability

February 11, 2021
1:00 – 4:30 PM CT

| | |
|---|---|
| 1:00 – 1:30PM | **Critical Minerals Introductory Panel** |
| | **Critical Minerals Introductory Remarks**<br>Dr. Jennifer Wilcox, Acting Assistant Secretary for Fossil Energy, U.S. Department of Energy |
| | **Importance of Critical Minerals to American Innovation**<br>Jane Nakano, Senior Fellow – Energy Security and Climate Change Program, Center for Strategic & International Studies |
| 1:30 – 1:40PM | **Assessment of Available Resources**<br>Dr. John Yellich, President, American Association of State Geologists & Director, Michigan Geological Survey |
| 1:40 – 1:50PM | **Regional Policy Context**<br>Elizabeth Tate, Director – Public Policy and Sustainability Clarios |
| 1:50 – 2:50PM | **Interactive Breakout Session #1**<br>Facilitators:<br>Dr. Steven Carpenter, Founder, Carpenter Global LLC<br><br>Dr. Sallie Greenberg, Consultant, Carpenter Global LLC |
| 2:50 – 3:00PM | **Industrial Activity Across the Entire CM Supply Chain**<br>Clint Cox, President, The Anchor House, Inc. |
| 3:00 – 3:10PM | **Midwest Regional Needs and Opportunities for R&D**<br>Dr. Kwame Awuah-Offei, Professor – Mining & Nuclear Engineering, Missouri S&T |
| 3:10 – 4:20PM | **Interactive Breakout Session #2**<br>Facilitators:<br>Dr. Steven Carpenter, Founder, Carpenter Global LLC<br><br>Dr. Sallie Greenberg, Consultant, Carpenter Global LLC |
| 4:20 – 4:30PM | **Future Direction and Conclusion** |

U.S. DEPARTMENT OF ENERGY | Fossil Energy

USEA United States Energy Association

# DOE National Laboratories Workshop on Critical Minerals Sustainability

March 11, 2021
1:00 – 4:30 PM ET

| | |
|---|---|
| 1:00 – 1:20PM | **Critical Minerals Introductory Remarks**<br>Dr. Jennifer Wilcox, Acting Assistant Secretary for Fossil Energy, U.S. Department of Energy<br><br>**Critical Minerals Sustainability Program Remarks** |
| 1:20 – 2:30PM | **Interactive Breakout Session 1**<br>Facilitators:<br>Dr. Steven Carpenter, Founder, Carpenter Global LLC<br><br>Dr. Sallie Greenberg, Consultant, Carpenter Global LLC |
| 2:30 – 3:30PM | **National Laboratory Presentation of Capabilities**<br>**(2 slides/3 minutes MAX per Laboratory)**<br>National Energy Technology Laboratory - Dr. Mary Anne Alvin<br>Ames Laboratory - Dr. Thomas Lograsso<br>Argonne National Laboratory - Dr. Nwike Iloeje<br>Brookhaven National Laboratory - Dr. Martin Schoonen<br>Idaho National Laboratory - Dr. Yoshiko Fujita<br>Lawrence Berkeley National Laboratory - Dr. Michael Whittaker<br>Lawrence Livermore National Laboratory - Dr. Eric Schwegler<br>Los Alamos National Laboratory - Dr. George Guthrie<br>Oak Ridge National Laboratory - Dr. Edgar Lara-Curzio<br>Savannah River National Laboratory - Dr. Richard Wyrwas<br>SLAC National Accelerator Laboratory - Dr. John Bargar<br>Pacific Northwest National Laboratory - Ms. Casie Davidson |
| 3:30 – 4:20PM | **Interactive Breakout Session 2**<br>Facilitators:<br>Dr. Steven Carpenter, Founder, Carpenter Global LLC<br><br>Dr. Sallie Greenberg, Consultant, Carpenter Global LLC |
| 4:20 – 4:30PM | **Future Direction and Conclusion** |

# Appendix B: Breakout Session Registrants

*Alphabetic by Organization*

| Organization | Workshop |
|---|---|
| ADI Analytics | Gulf |
| Alaska Division of Geological & Geophysical Surveys | Western |
| Alliance for Automotive Innovation | Midwest |
| Ambient Environmental & Regulatory | Gulf |
| Ames - Critical Materials Institute | National Lab |
| Ames Laboratory | National Lab |
| AML SuperConductivity | Gulf |
| Anactisis | Appalachia |
| Antelope Water | Western |
| Appalachian School of Law | Appalachia |
| Argonne National Laboratory | National Lab |
| ARI | Gulf |
| Arizona Geological Survey - Mineral Resources Group | Western |
| Arizona State University - School of Sustainable Engineering and the Built Environment | Western |
| Association of American State Geologists | Midwest |
| BASF | Gulf |
| Battelle | Gulf |
| Benchmark Mineral Intelligence | Appalachia |
| BloombergNEF | Appalachia |
| Blue Line Corporation | Gulf |
| Boeing | Midwest |
| Brookhaven National Laboratory | National Lab |
| Carina Energy Group | Gulf |
| Cemvita Factory Inc. | Gulf |
| Chemours | Gulf |
| Churnside Technology Management | Appalachia |
| Clarios | Midwest |
| Colorado Geological Society | Western |
| Colorado School of Mines | Western |
| Consol Energy | Appalachia |
| Critical Minerals Institute | Western |
| CSIS | Midwest |
| DOE - Arctic Energy Office | Gulf |
| Duke University | Appalachia |
| Eck Industries | Midwest |
| Electron Energy Corporation | Appalachia |
| Energy Fuels Resources | Western |
| Eutectix | Midwest |
| Florida Geological Survey | Gulf |
| Florida Phosphate Institute | Gulf |
| Florida Polytechnic University | Gulf |
| Geological Survey of Alabama | Appalachia |
| Geological Survey of Alabama | Gulf |
| George Washington University | Appalachia |
| Georgia State University | Gulf |
| HDI | Appalachia |
| I2M Consulting LLC | Gulf |
| Idaho Governor's Office of Energy and Mineral Resources | Western |
| Idaho National Laboratory | National Lab |
| Illinois State Geological Survey | Midwest |
| Imerys | Gulf |
| Indiana Geological and Water Survey | Midwest |
| Individual Participant | Appalachia |
| INL | National Lab |
| Institute for Advanced Composites Manufacturing Innovation | Appalachia |
| Ioneer | Midwest |
| Iowa Geological Survey | Midwest |
| Jade Cove Partners | Western |
| Just Transition Fund | Appalachia |
| Kansas Geological Survey | Midwest |
| Kentucky River Properties | Appalachia |
| Lawrence Berkeley National Laboratory | National Lab |
| Lawrence Livermore National Laboratory | National Lab |
| Lehigh University | Appalachia |
| Li-Cycle | Midwest |
| Lixivia | Western |
| Los Alamos National Laboratory | National Lab |
| Marshallton Research Labs Inc. | Appalachia |
| Materia | Appalachia |
| MC Technologies | Appalachia |
| Melzer Consulting | Midwest |
| Metteck | Appalachia |
| Michigan Oil, Gas, and Minerals Division | Midwest |
| Minnesota Department of Natural Resources | Midwest |
| Minnesota Geological Survey | Midwest |
| Minnesota Pollution Control Agency | Midwest |
| Missouri S&T | Midwest |
| Montana Tech | Western |
| Montana Tech - Center for Advanced Mineral, Metallurgical, and Materials Processing | Western |
| Mosaic Fertilizer, LLC | Gulf |
| MP Materials | Western |
| MSCI | Appalachia |
| National Energy Technology Laboratory | National Lab |
| National Renewable Energy Laboratory | National Lab |
| National Tribal Energy Association | Western |
| National Wildlife Federation | Appalachia |
| Navajo Transitional Energy Company | Western |
| New Mexico Institute of Mining and Technology - Mineral Engineering | Western |
| New Mexico Mining and Minerals Division | Western |
| NioCorp Development | Western |
| North Carolina Geological Survey | Appalachia |
| North Dakota Geological Survey | Midwest |
| North Star Strategies | Appalachia |
| Northeastern University | Appalachia |
| NREL Joint Institute for Strategic Energy Analysis | National Lab |
| NRG Energy | Gulf |
| NTEC | Western |
| Oak Ridge National Laboratory | Appalachia |
| Oak Ridge National Laboratory | National Lab |
| Ohio State University | Appalachia |
| Pacific Northwest National Laboratory | National Lab |
| Pennsylvania State University | Appalachia |
| PSI Corp | Appalachia |
| Purdue | Midwest |
| Railroad Commission of Texas | Gulf |
| Rare Element Resources | Western |
| Rayonier | Gulf |
| Resourcesxtract, Inc. | Gulf |
| Rock Whisperer LLC | Midwest |
| Rocky Mountain Coal Mining Institute | Western |
| Sagebrush Hill Group | Western |
| Sanpete County | Western |
| Savannah River National Laboratory | National Lab |
| Securing America's Future Energy | Midwest |
| SLAC | National Lab |
| SLAC National Accelerator Laboratory | National Lab |
| South Dakota Geological Survey | Midwest |
| South Dakota School fo Mines and Technology | Midwest |
| Southern Company | Appalachia |
| Southern Illinois University | Midwest |
| Southern Illinois University | Midwest |
| SSEB | Gulf |
| State of North Dakota | Midwest |
| Synfuels Americas | Appalachia |
| Technology Metals Research | Gulf |
| TenCate Geosynthetics | Gulf |
| Tesla | Western |
| Tesla | Western |
| Tetra Tech | Appalachia |
| Texas Mineral Resources Corp. | Appalachia |
| The Anchor House | Midwest |
| The North American Coal Corporation | Gulf |
| The University of Texas at Austin | Gulf |
| Trout Unlimited | Midwest |
| Twin Pines Minerals, LLC | Gulf |
| Univ. of Texas at Austin | Gulf |
| University of Utah - Mining Engineering | Western |
| University of Alabama | Appalachia |
| University of Alabama | Gulf |
| University of Arizona - Mining & Geological Engineering | Western |
| University of Arkansas | Gulf |
| University of Delaware | Appalachia |
| University of Houston | Gulf |
| University of Kentucky | Midwest |
| University of Nevada Reno - Department of Mining and Metallurgical Engineering | Western |
| University of South Dakota | Midwest |
| University of Texas | Gulf |
| University of Utah - College of Mines and Earth Sciences | Western |
| University of Wisconsin | Midwest |
| University of Wyoming - School of Energy Resources | Western |
| Urban Mining Co. | Gulf |
| US Geological Survey | Appalachia |
| US Geological Survey - Energy and Minerals | Western |
| USA Rare Earths | Gulf |
| USGS | Gulf |
| USGS -Geology, Geophysics, and Geochemistry Science Center | Western |
| Utah Division of Oil, Gas and Mining | Western |
| Utah Governor's Office of Energy Development | Western |
| Utah Mining Association | Western |
| Villanova | Midwest |
| Virginia Tech | Appalachia |
| Virginia Department of Mines, Minerals, & Energy | Appalachia |
| Wayne State University | Midwest |
| West Virginia Department of Environmental Protection | Appalachia |
| West Virginia Geological Survey | Appalachia |
| West Virginia University | Appalachia |
| Western Governors Association | Western |
| Western Michigan University | Midwest |
| Western Pocahontas Properties | Gulf |
| Winner Water Services | Appalachia |
| Wisconsin Geological Survey | Midwest |
| Wyoming State Geological Survey | Western |
| Yale University | Western |

# Appendix C: Participant Themes, Criteria, or Phenomenon

*Sorted by Tiers 1, 2, and 3: Frequency of Use*

| Theme, Criteria, or Phenomenon | Frequency used by Participants |
|---|---|
| **Tier 1 (Top 10)** | |
| min(ing) (e) | 227 |
| data | 112 |
| sustainability | 86 |
| waste | 78 |
| education | 58 |
| federal government | 56 |
| China | 54 |
| coal | 41 |
| environment(al) | 36 |
| permit(ting) | 34 |
| **Tier 2** | |
| supply chain | 26 |
| processing | 24 |
| economic | 21 |
| minerals/districts | 19 |
| public | 19 |
| resources | 19 |
| technology | 18 |
| markets | 17 |
| Separation | 16 |
| funding | 15 |
| recycl(e) (ing) | 15 |
| circular (economy) | 14 |
| manufacture | 14 |
| land owner | 13 |
| machine learning | 13 |
| sensor | 13 |
| by-, co-products | 12 |
| carbon | 12 |
| Characterization | 12 |
| phosphate | 12 |
| workforce | 12 |
| extraction | 11 |
| exploration | 10 |
| LCA | 10 |

| Theme, Criteria, or Phenomenon | Frequency used by Participants |
|---|---|
| **Tier 3** | |
| community | 9 |
| ESG | 9 |
| unconventional | 9 |
| liability/risk | 8 |
| stakeholder engagement | 8 |
| streamline | 8 |
| shale | 7 |
| Battery | 6 |
| Deposits | 6 |
| NEPA | 6 |
| produced water | 6 |
| collaborate | 5 |
| digital | 5 |
| property rights | 5 |
| smelting | 5 |
| ash | 4 |
| graphite | 4 |
| map (pping) | 4 |
| standards | 4 |
| underclays | 4 |
| helium | 3 |
| lithium | 3 |
| risk | 3 |
| social | 3 |
| thorium | 3 |
| blockchain | 2 |
| gypsum | 2 |
| regulation(s) | 2 |