CORE-CM in the Greater Green River and Wind River Basins: Transforming and Advancing a National Coal Asset

DE-FE0032047

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School of Energy Resources
University of Wyoming

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U.S. Department of Energy

National Energy Technology Laboratory

U.S. Department of Energy
National Energy Technology Laboratory
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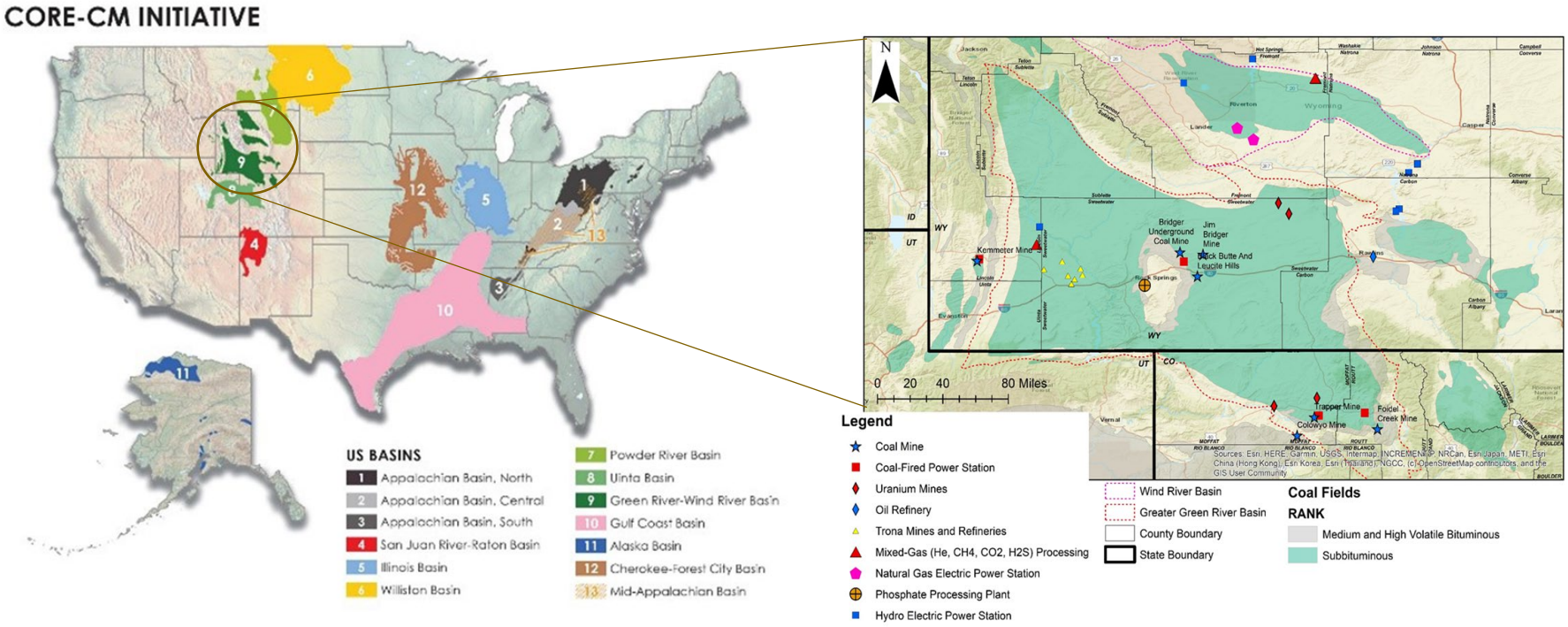
Acknowledgement and Disclaimer

Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-FE0032047

Project Overview

CORE-CM Region 9

Green River-Wind River Basins



https://netl.doe.gov/node/11045

Project and Objectives

Major Objectives

- Establish a strategic volume, including strategic plans to maximize the development of potential carbon ore, rare earth elements, and critical minerals (CORE-CM); within the creation of public-private partnerships.

- Complete detailed assessments, including State of The Art DATA (SOTA) acquisition of potential CORE-CM materials across both the Greater Green River and Wind River Basins.

- Develop planning to leverage highly trained workforces, existing and novel coal technologies, and energy infrastructure in development of CORE-CM supply chains.

- Bring together a committed network of stakeholders, gaining acceptance of new energy technology within coal regions and across communities.

Period of Performance: 2.75 years (September 2021 to May 2024)

Project Funding: Total Project $2,584,625
DOE Contribution $2,066,446
Participant Cost share $518,179

Project Team

University of Wyoming School of Energy Resources - Centers of Excellence

School of Energy Resources
Center for Economic Geology Research

School of Energy Resources
Center for Energy Regulation & Policy Analysis

School of Energy Resources
Center for Carbon Capture and Conversion

College of Business
Center for Business and Economic Analysis

Coalgeo, LLC

Wyoming Partners & Supporting Stakeholders:

U.S. Congressional Delegation of Barrasso, Lummis, and Cheney; Wyoming Governors Office; Wyoming Mining Association; Wyoming Representive Donald Burkhart; Wyoming Representative Mike Greear; Wyoming County Commissioners Association; Wyoming Business Council; Wyoming Small Business Development Center; Impact 307; Wyoming Counties of Sweetwater, Sublette, Fremont, Carbon, and Uinta; Kemmerer Operations, LLC; Black Butte Coal; Bridger Coal Company; Sweetwater Economic Development Coalition; Southwest Wyoming Manufacturing Partnership; Central Wyoming College; City of Rock Springs; City of Green River

Colorado Partners & Supporting Stakeholders:

Colorado State Land Board; Colorado Division of Reclamation, Mining and Safety; Colorado Office of Just Transition; Associated Governments of Northern Colorado; Routt County, CO Economic Development Office; Moffat County, CO; Trapper Coal Mine; Colowyo Coal Mine; Mango Materials; Ur-Energy Inc.

Regional

Tri-State; Peabody Energy; PacifiCorp; The University of Texas at Austin; Concurrent Technologies Corporation: Tetra Tech; Novex, LLC; Disa, LLC; NTEC

Technical Approach – Success Criteria and Strategic Planning

Project Success Criteria

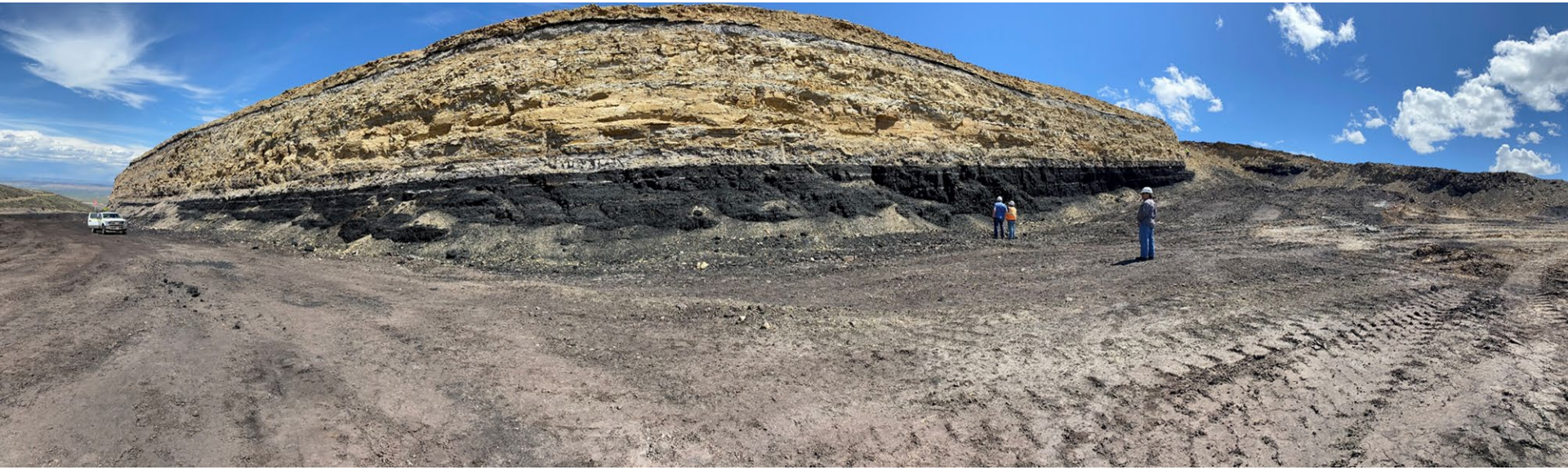
- Creation of a **project coalition team**
- Produce usable resource and waste stream **summaries** and a **strategic plan** to begin to implement and fulfill the CORE-CM program's upstream, midstream, and downstream goals.
- Identify opportunities for **technology development** and **placement within the GGRB-WRB region**, and include **experienced stakeholder,** both **public and private**, and **regional communities supporting extensive workforces** into this planning.
- Develop **strategies** for combining **feedstocks** and **waste-streams** within **optimized technology pathways**
- Identify the **reuse** of **existing infrastructure** and **social arrangements** to catalyze growth, and realize the full potential of the CORE-CM resources of the GGRB-WRB.

Project Strategic Planning

- Resource Assessment, Gap Analysis, & the CM National Prospectus
- Creation of a Strategic Volume focused on Technology Innovation Center(s) Development
  - Summary of Environmental Justice Considerations
  - Summary of Economic Revitalization and Job Creation Outcomes
  - Environmental, Safety, and Health Analysis for Products Proposed to be Manufactured from CORE-CM Resources

Technical Approach – Task Outline

- Task 2.0 - Basinal Assessment of CORE-CM Resources
- Task 3.0 - Basinal Strategies for Reuse of Waste Streams
- Task 4.0 - Basinal Strategies for Infrastructure, Industries and Businesses
- Task 5.0 - Technology Assessment, Development and Field Testing
- Task 6.0 - Technology Innovation Centers
- Task 7.0 - Stakeholder Outreach and Education



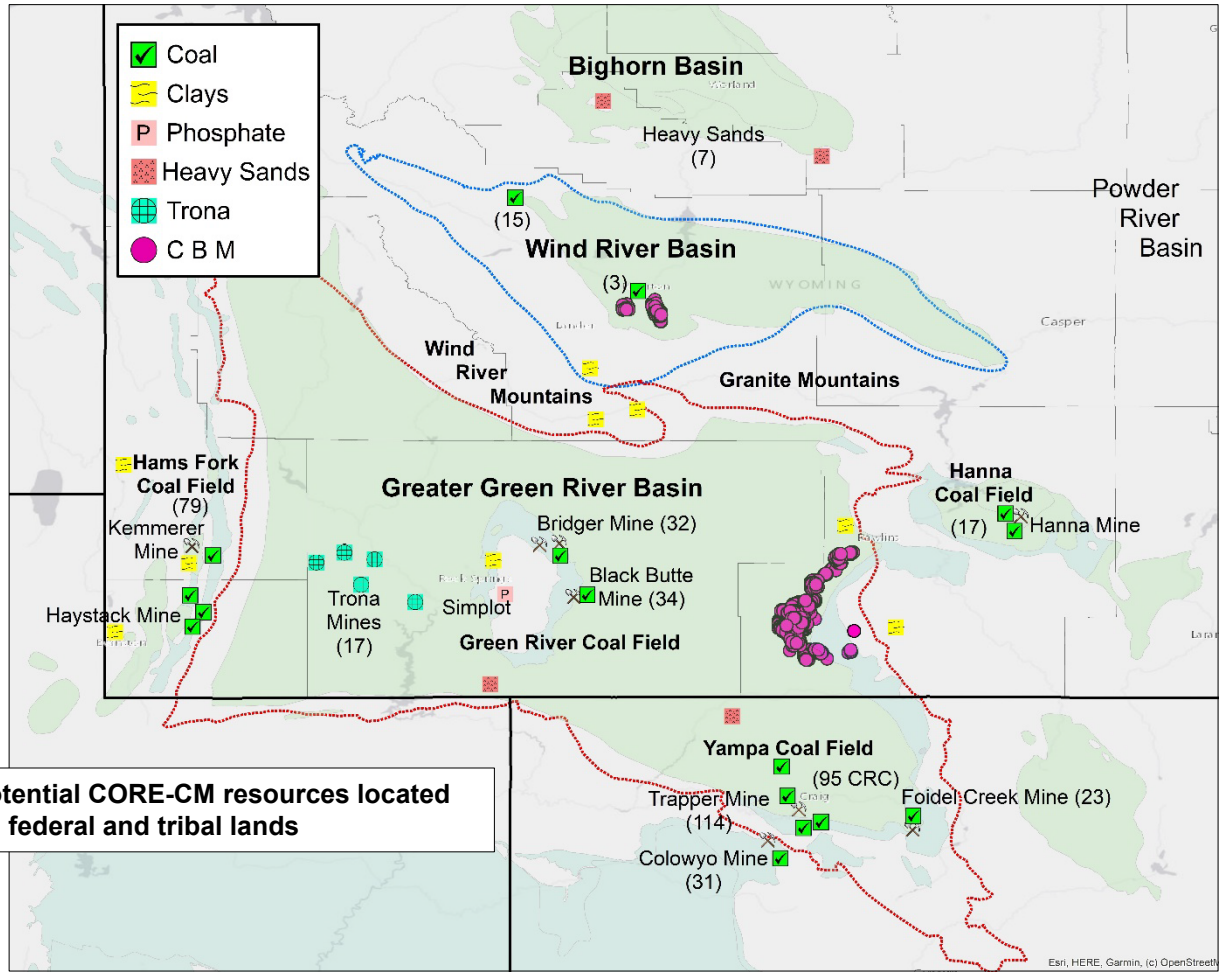
Progress and Current Status – Basinal Assessment of CORE-CM Resources

Coal feedstocks

- ✓ **Hams Fork Coal Field (Kemmerer Mine & Haystack Mine)**
- ✓ **Central Green River Basin (Black Butte & Bridger Mines)**
- ✓ **Yampa Coal Field (Colowyo, Trapper & Twenty Mile Mines)**
- ✓ **Denver Basin Lignites**
- ✓ **Hannah Coal Field (retired)**
- ✓ **Wind River Basin CBM and exploratory sites**

Non-Coal feedstocks

- ✓ Coal byproducts
- ✓ Heavy mineral "Black Sands" & other paleoplacers
- ✓ Ash beds
- ✓ Clays, bentonites, & carbonaceous Shales
- ✓ Phosphates & related wastes
- ✓ Trona wastes
- ✓ Zeolites
- ✓ Intrusive rocks (pegmatites, altered rocks, & fault zones
- ✓ Produced waters
- Tailings
- Uranium Deposits



Potential CORE-CM resources located on federal and tribal lands

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Coalgeo, LLC

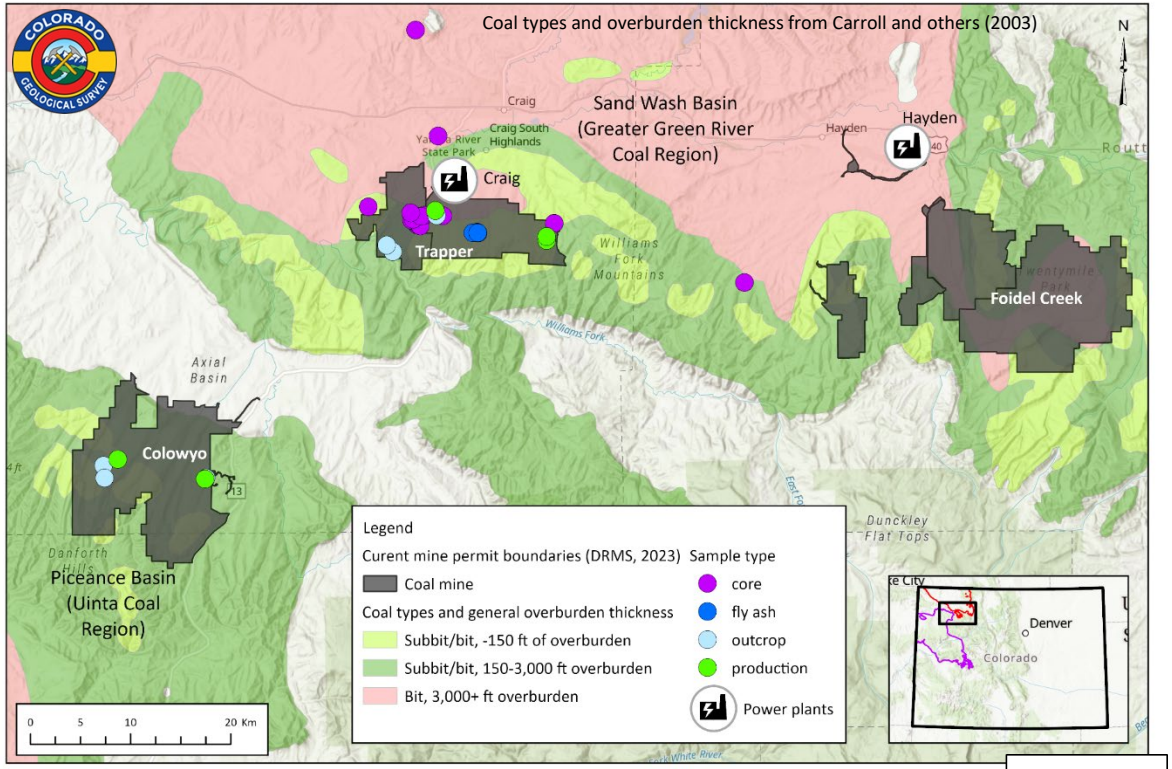
Basinal Assessment of CORE-CM Resources – Yampa Coal Field Example

Sample Collection / Analyses

- Access agreements w/ three active coal mines – Colowyo, Trapper, Foidel Creek.

- Obtained samples from pits, underground, exploration core, CRC core library, outcrops.

- Collected +245 samples & 200 analysis - coal, coal-related stratigraphy, ash beds, fly ash, production
  - ~110 CRC core (5 cores)
  - ~126 two active mines (Trapper, Colowyo) (core, pit, production, fly ash)
  - ~19 outcrops (other)



Coalgeo, LLC

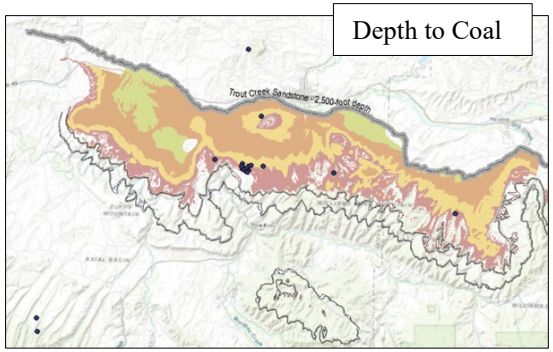
Sampling at the Colowyo Mine, Moffat County, Colorado. "X" coal seam in the upper coal group, Upper Cretaceous Williams Fork Formation, Mesaverde Group.

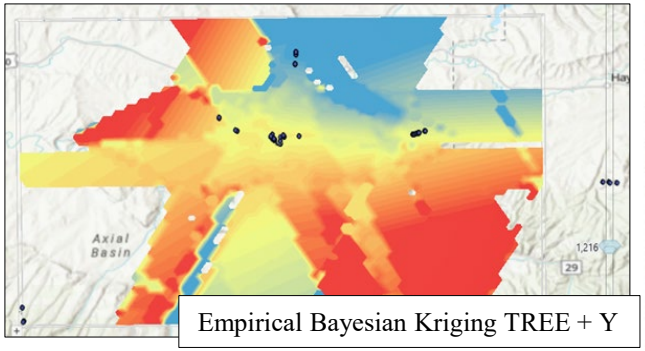
Logging and sampling exploration core. Collected from the "I" coal seam, Upper Cretaceous Williams Fork Formation, Trapper Mine, Moffat County, Colorado.

Basinal Assessment of CORE-CM Resources – Geologic Model Development

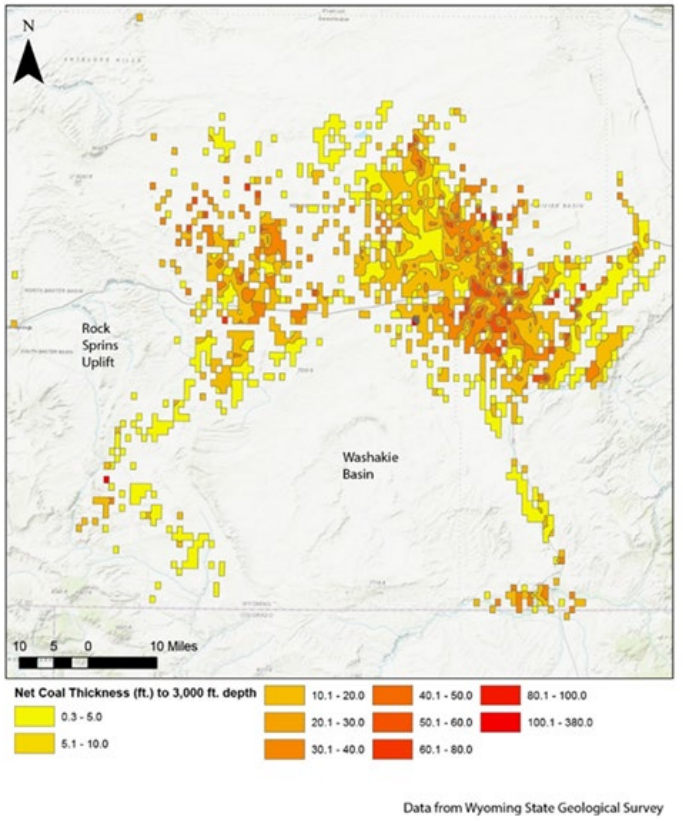
Develop CORE-CM specific geologic models to show the basin's large-scale stratigraphy

1. ArcGIS based models are complete for the Greater Green River Basin and Yampa Coal Fields
   - Testing of geochemical data in these models is ongoing

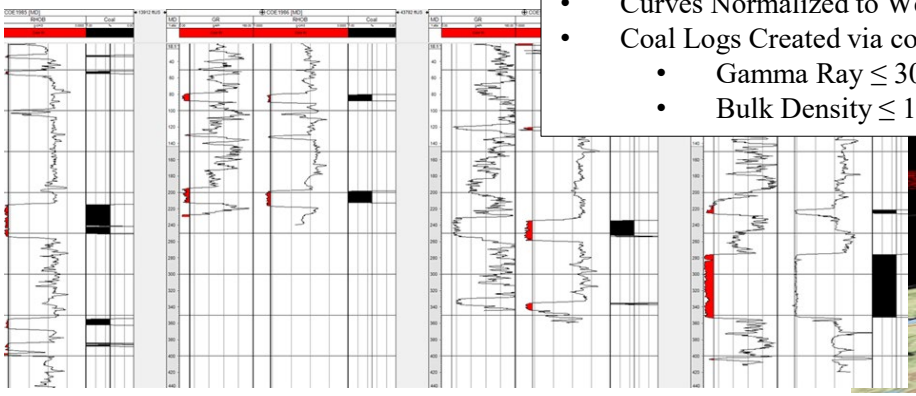


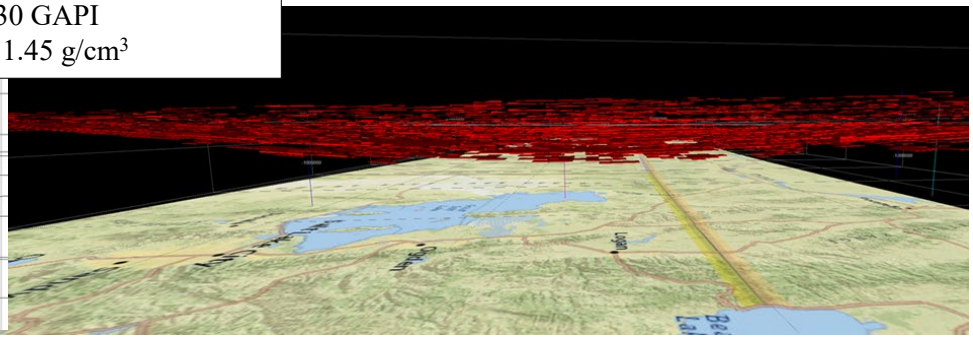


2. Statistically based modeling, dependent on geophysical log data was initiated and developed for the Hams Fork Coal Field



- Curves Normalized to Well COE1985
- Coal Logs Created via combination log filter
  - Gamma Ray ≤ 30 GAPI
  - Bulk Density ≤ 1.45 g/cm^3

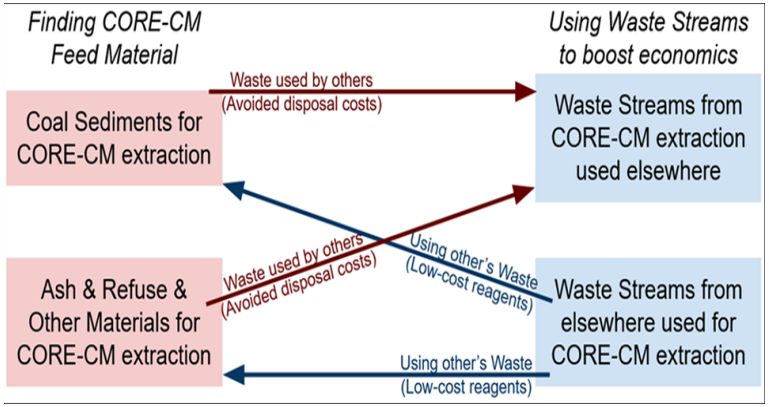




Basinal Strategies for Reuse of Waste Streams

Initial Basinal Waste Streams Catalogue

- ✓ **Basinal waste streams catalogue completed**
- ✓ **R&D Partnerships and integration catalogue completed**
- ✓ **Preliminary uses for CORE-CM catalogue completed**
- • **Gap Analysis currently being finalized**



Organization/Site	Activity	CORE-CM, Waste Streams, etc.
Kemmerer Mine Colowyo Mine Twentymile Coal Mine Foidel Creek Mine Bridger Coal Co. Black Butte Coal Co. Trapper Mine	Surface and underground coal mining	coal, non-spec coal-sediment, overburden
Naughton Power Station Craig Power Station Jim Bridger Power Station Hayden Power Station	Electricity production using coal from the mines above, and also natural gas at one Naughton unit.	fly ash, bottom ash, CO_2, flue-gas treatment byproducts
Alchem Trona Mine Allied Trona Mine Westvaco Mine Big Island Mine Ciner Mine	Trona underground mineral mining	trona, non-spec trona waste
Ciner Wyoming Genesis Alkali Solvay Chemicals Tata Chemicals	Trona processing using trona minerals from the mines above	soda ash, soda liquor, sodium sulfite, other soda-based custom products.
Shute Creek gas plant[49][50] Lost Cabin gas plant[51]	Gas production and separation with mixed acid gas injection and sulfur recovery	CH4, CO_2, H_2S & sulfur, He, water, low-pressure pore space, geothermal heat
Boysen Dam Fontenelle Dam	Hydroelectric dam, and reservoir	water, sediment
Lost Creek Uranium Jab and Antelope Uranium Maybell Mine Sugar Loaf Mine	In-Situ-Recovery of uranium, yellowcake production	uranium, vanadium, resin-wash water, spent oxidizer
Smoky Canyon Mine	Surface phosphate mine and milling	Phosphate Slurry, non-spec ore
Simplot Phosphates	Fertilizer and custom phosphate-production	Anhydrous ammonia, H2SO4, phosphoric acid, fertilizer, FSA

Stakeholder	Site Location	Activity	State	Waste-Stream material(s)	Site access agreement	Legacy samples	New samples	Legacy data	New data expected	Data location	Notes	References
Genesis Alkali	Genesis Alkali (owns Granger and Westvaco)	Trona processing	WY	Intermediate Brine Solution Impurities, Residuals from Disolution, ash from thermal process	N	Y	N	N	Y	CEGR's Sample Library	CEGR has sample left over from a previous study with Genesis, which can be reused. Trona is not expected to age.	Study of Trona process for the Center for Carbon Capture and Conversion's previous work
J.R. Simplot	Simplot Phosphates	phosphate production	WY	anhydrous ammonia, H2SO4, phosphoric acid, fertilizer, FSA	N	N	Y	N	Y	on-site	Contact established with host	**Currently under NDA**

Basinal Strategies for Infrastructure, Industries and Businesses

College of Business
Center for Business and Economic Analysis

Facilitating a CORE-CM Ecosystem

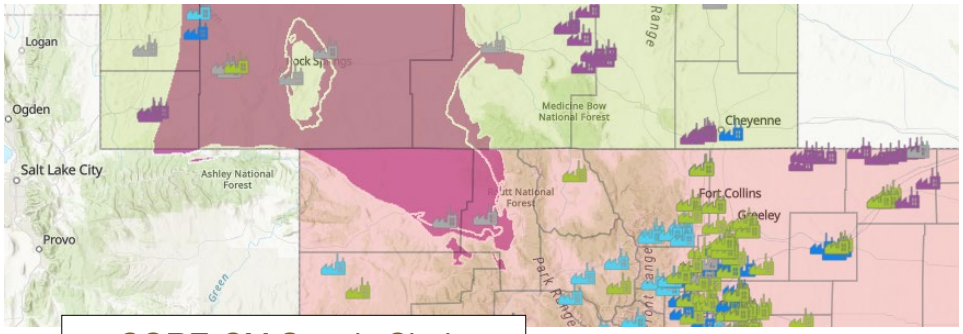
- ✓ **Evaluation of existing infrastructure, industries and businesses in the GGRB-WRB**
- **Gap analysis & identification of regional and basinal needs and challenges**
- **Results of Basinal Strategies for Infrastructure, Industries and Business Assessment**

Current Information

- Coal and energy sources
- Top industries and relevant business
- Transportation infrastructure

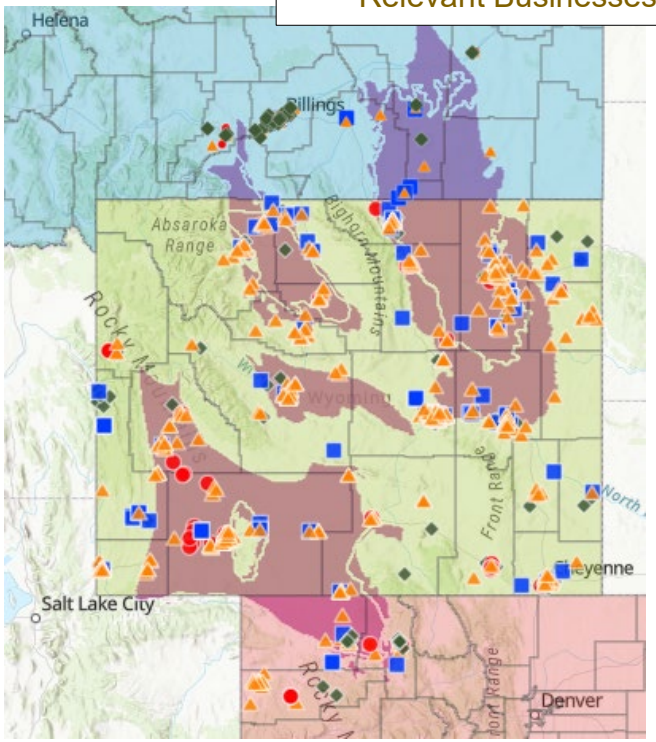
Next Steps

- Water resources and use
- Leases and permits structure
- Community engagement
- CORE-CM use case studies



CORE-CM Supply Chain Relevant Infrastructure

CORE-CM Supply Chain Relevant Businesses



Coal Mining; Metal Ore Mining; Nonmetallic Mineral Mining and Quarrying; Support Activities for Mining; Basic Chemical Manufacturing; Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing; Other Chemical Product and Preparation Manufacturing; Nonferrous Metal (except Aluminum) Production and Processing; Coating, Engraving, Heat Treating, and Allied Activities; Iron and Steel Mills and Ferroalloy Manufacturing; Architectural and Structural Metals Manufacturing; Other Fabricated Metal Product Manufacturing; Other Electrical Equipment and Component Manufacturing; and Alumina and Aluminum Production and Processing

Basinal Strategies for Infrastructure, Industries and Businesses

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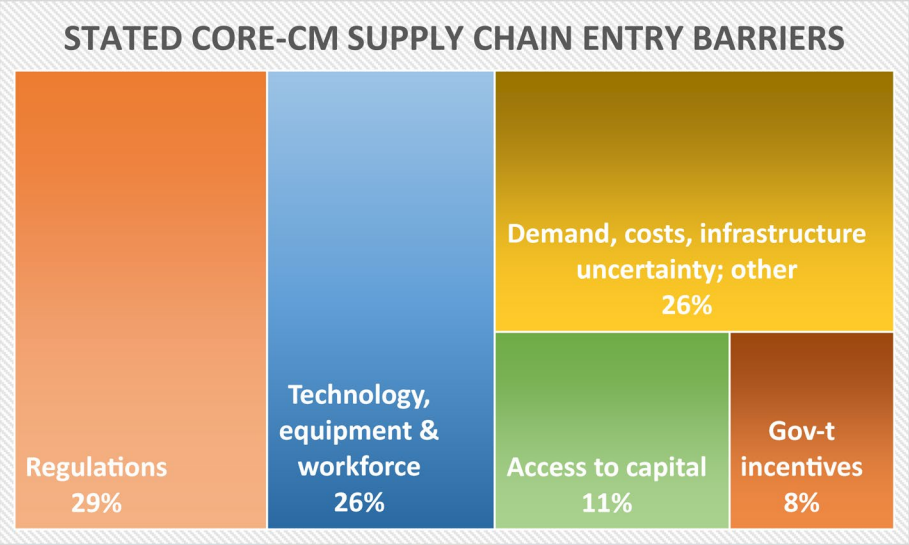
Exploratory Business Survey



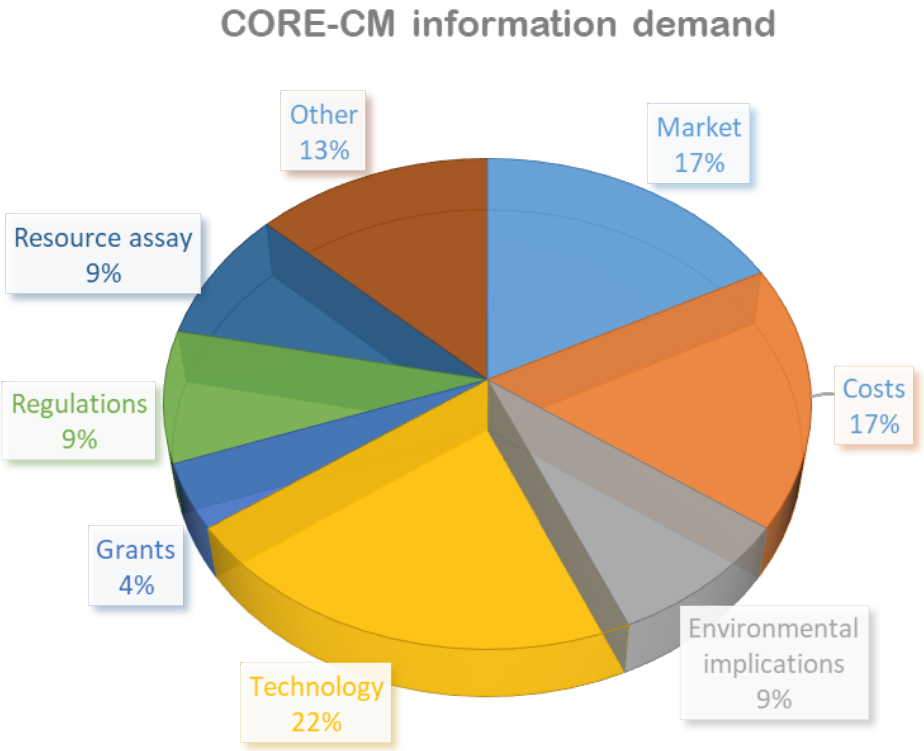
Benefits

- additional revenue
- trade independence

Risks & Uncertainty*

- regulations
- market demand
- technology and production process

**50% of respondents indicated that they do not have access to the information required to enter the CORE-CM supply chain*



Information demand

- lack of accurate information that is crucial for making business decision

Technology Assessment, Development and Field Testing

Technology Planning

- ✓ **Identification of SOTA and existing technologies**
- ✓ **Novel technology integration in GGRB-WRB resource chains**
- • **Basin-specific Technology Planning**

Current & Novel Technology Opportunities

- **Development of assessment methods of CORE-CM "ore stocks":**
  - In-mine applications
  - Remote sensing
- **Mine specific technologies:**
  - Selective mining
  - Ore Sortation
- **Materials Processing:**
  - Optimizing process efficiencies
  - Adaptive sortation/processing
- **Selective Extraction:**
  - Bio-extractive processes
  - High-grading stocks
  - Utilizing mixed CM stocks
- **Carbon Ore to Products**


CHAR INSULATION FOAM (CIF)


CHAR BRICK (CCB)


COAL DERIVED ASPHALT


CHAR MORTAR

CHAR-BASED CEMENT GROUT (CCG)


(DOE) CARBON-BASED STRUCTURAL UNIT(CSU)


STONE VENEER

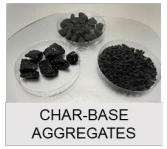

GRAPHENE OXIDE (GO)


SOIL AMENDMENT AND RECLAMATION WORK


CHAR PLASTER


(DOE) PRE-COATING PYROLYSIS CHAR BRICK


BLOCK PAVER


CHAR-BASE AGGREGATES


GO IN CONCRETE

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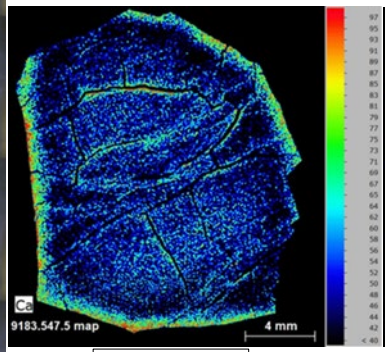
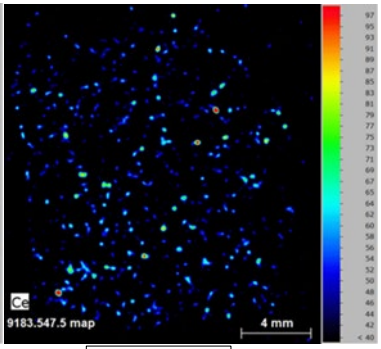




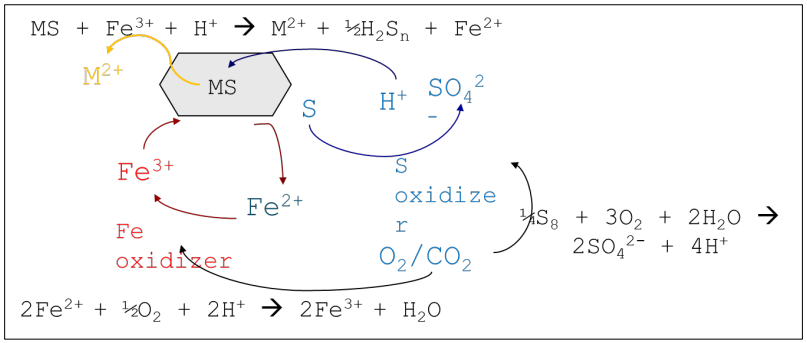
Calcium **Cerium**

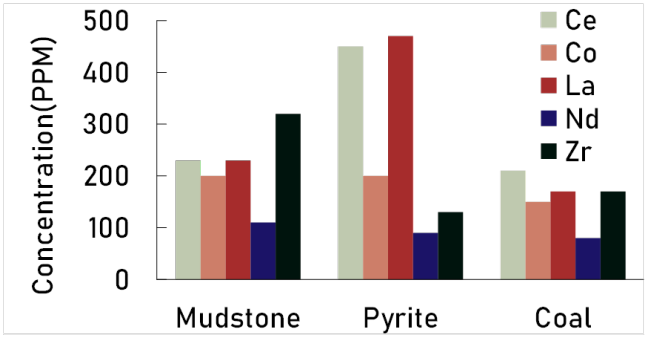
Micro XRF mapping shows co-hosting of REE (as Ce) with Ca and both tend to rim grains within coal

Los Alamos NATIONAL LABORATORY

Basin-specific Technology Planning – Bioleaching example

Bioleaching/Biooxidation Mechanism



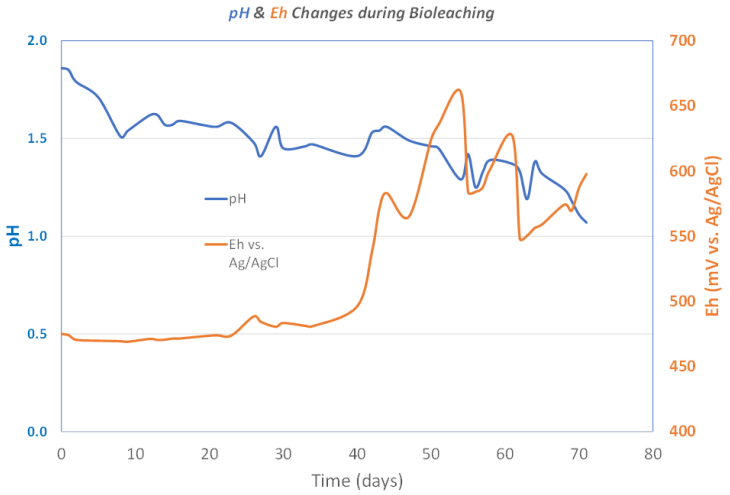


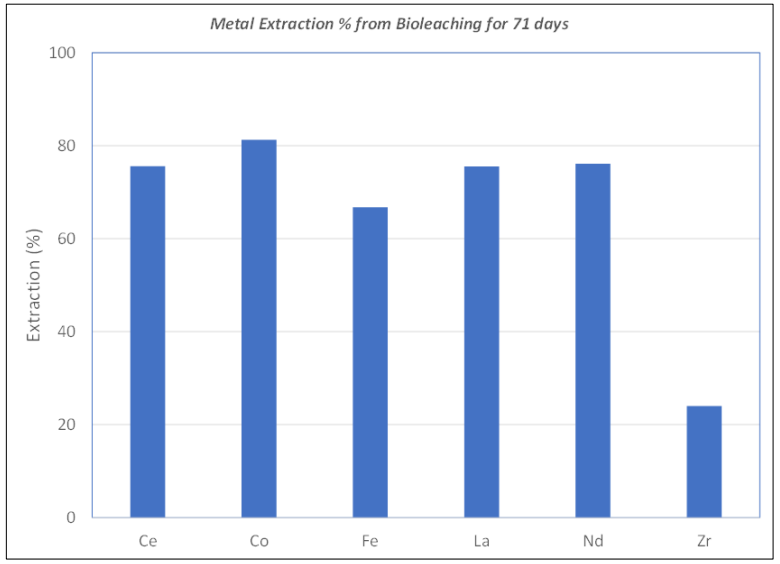
Only pyrite sample showed microbial responses

Bioleaching with mesophilic bacteria with Fe/S oxidizers
MKM nutrient solution
30°C with water-jacketed bioreactor
Bioleaching for 71 days

pH continuously drops as sulfide oxidized and produce sulfuric acid

Eh increases as Fe(II) oxidized to Fe(III) by bacteria



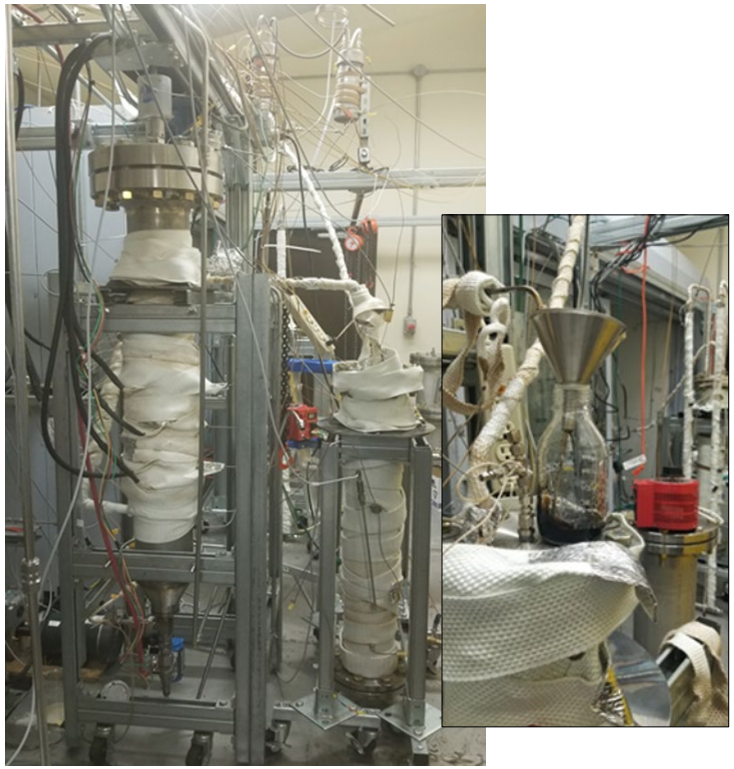


Selected Metal Extraction by Bioleaching
Ce, Co, La, Nd > 70% for 71 days

Technology Innovation Centers

University of Wyoming | School of Energy Resources Center for Carbon Capture and Conversion

- ✓ **Establish criteria defining successful TIC implementation**
- ✓ **Develop guiding principals and scope**
- • **TIC plan**



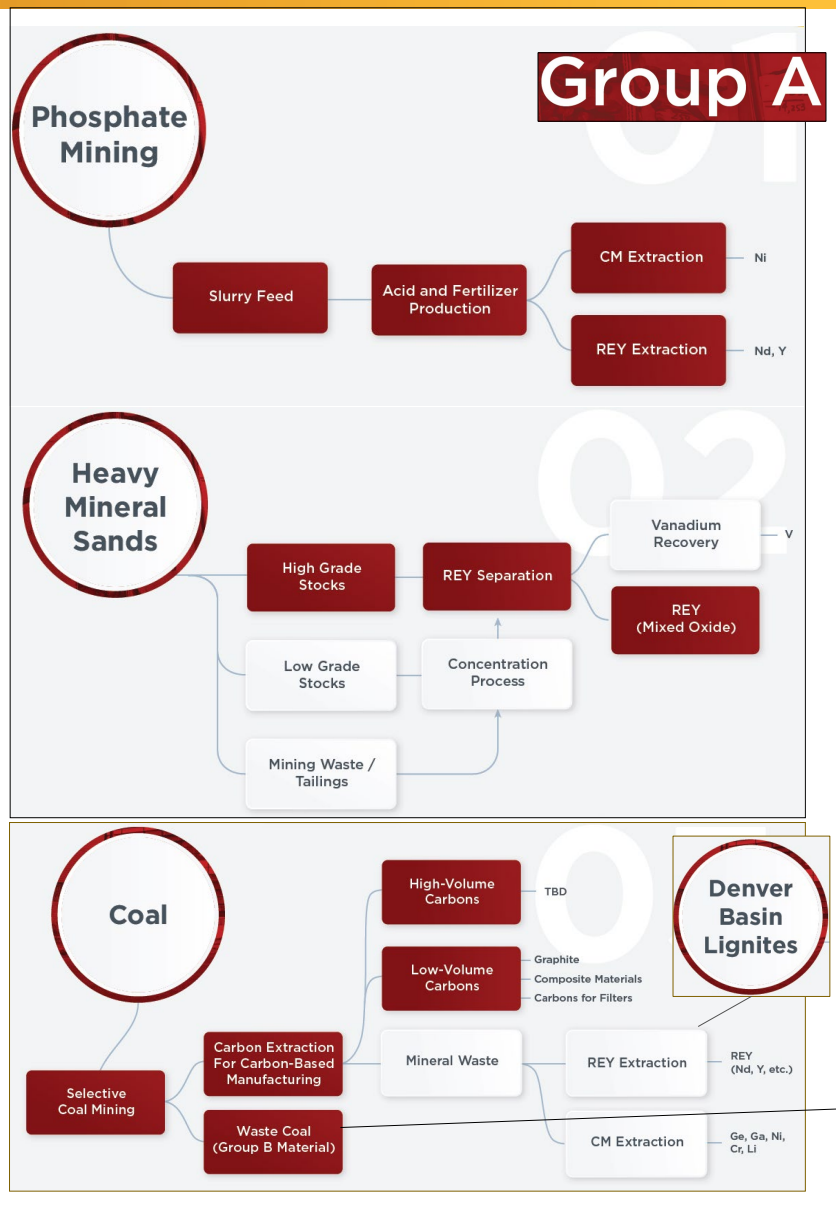
SELECTION CRITERIA

- Counters anticipated shortages & reduces foreign dependence for supply.
- Preferentially addressing scarcity challenges that cannot be fulfilled from other sources.
- Reduced carbon emissions & 'waste' compared to the current situation.
- Feedstock availability in sufficient quantity within the GGRB-WRB to address long term US. projected demand.
- Potential to co-process different source feedstocks.
- Economic viability, job creation prospects together with business & Investors interests.
- Leveraging existing resources, asset capabilities & competencies available within the GGRB-WRB region

Technology Focus Areas

- Selective Mining for Carbon-Ore, REE, and Critical Minerals targets
- Extractive metallurgy
- Carbon-Ore Manufacturing
- Recovery Processes/supply chain development for EV components
- REE-CM Goods Production

Technology Innovation Centers – Current understanding



Primary (A): Explore feedstocks for carbon-ore potential while developing a CM supply chain nucleus around long-term existing industries.
Secondary (B): Manage carbon-ore feedstock residuals to recover REE's and Critical Materials of specific interest.
Tertiary (C): Use remaining mineral matter & study gaps

Technology Innovation Centers – Next Steps for Regional Development

Metals Extractive Processes

- Mild-thermal Treatment and Solvent Extraction Processing of REE and CM rich Carbon Ore
- Bio-leaching of REE/CM from coal & coal waste

Developing Li-ion Carbon Energy Storage Value Chain

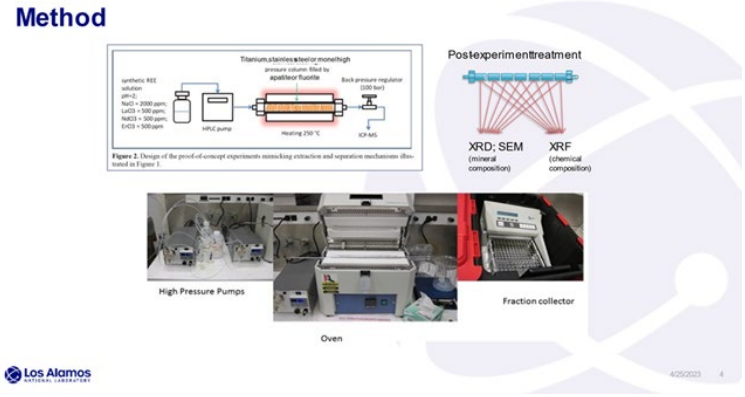
Coal Based Materials

- Graphite from coal – individual coal seams analysis
- High value products – carbon fibers, coatings, resins
- High volume carbon-based materials

Mineral wastes from non-coal Industries

- Phosphate and Trona waste streams
- Hydro-thermal Processing of mixed REE sources
- Uranium waste streams

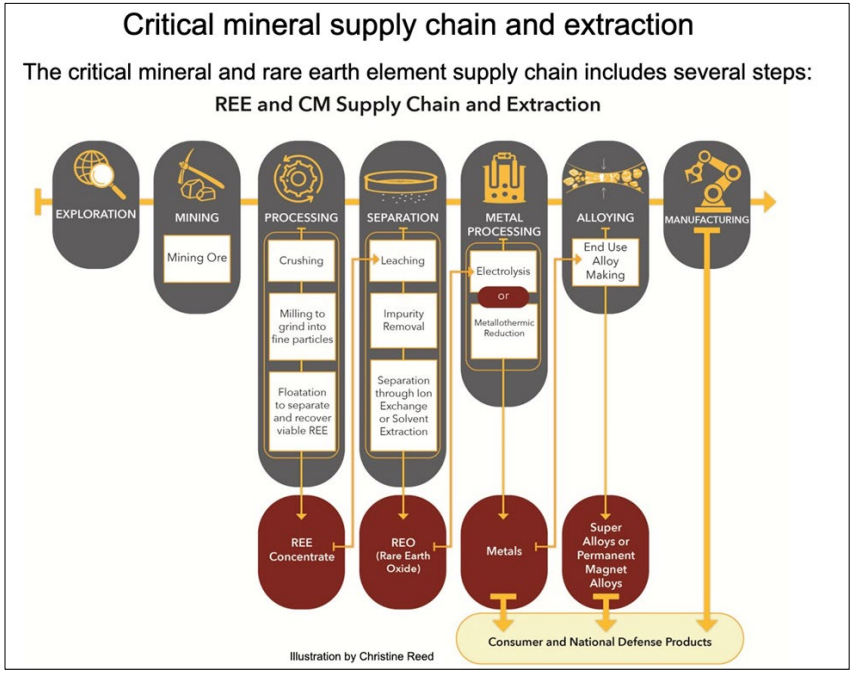
AGNC
ASSOCIATED GOVERNMENTS OF NORTHWEST COLORADO



Outreach and Stakeholder Engagement

Objectives of CORE-CM Outreach and Stakeholder Education

- ✓ **Complete a catalogue of content-creators and experts who possess education and outreach content**
- ✓ **Complete a catalogue of stakeholders who must be provided content to realize project objectives**
  - ✓ Providing information on the project to the target communities within the identified basins
  - ✓ Identify gaps in communication and training
- ✓ **Content distribution methods to match stakeholders to content –creators**
  - ✓ Make recommendations on stakeholder outreach and education practices
- ✓ **Identify and develop potential collaborations**
- • **Initial stakeholder outreach and education plan**



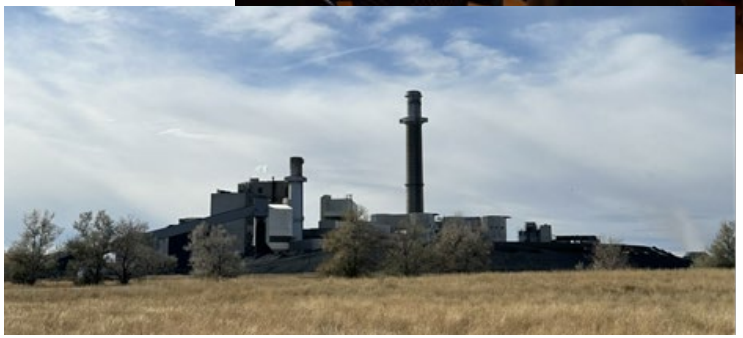
High-Level Informational Resources

- Content for Makerspace Badge and App including infographics
- Public Summary of Resources by Mine for Stakeholder Engagement and Education (under development)

Outreach and Stakeholder Engagement – Education and Collaboration

CORE-CM GGRB-WRB Annual Forum

The Second Annual Forum was successfully completed. The forum event was held November 2nd, 2023, in Craig, CO, and was hosted by project partner Colorado Northwestern Community College. The forum also included a visit to the Hayden Power Station. Over 60 people were in attendance and the recording the presentations has been distributed to the GGRB-WRB stakeholder list.



Collaboration with other CORE-CM & DOE Projects

- The GGRB-WRB CORE-CM & Powder River Basin CORE-CM projects have worked in tandem on overlapping tasks (ex. Task 4.0).
- Hosted Charles Sims to give a presentation on the economic analysis of REE and CM globally. Dr. Sims is the Co-P.I. of the Southern Appalachian CORE-CM.
- The University of Wyoming and the University of Utah jointly hosted a 2-hour virtual town hall focused on critical minerals research.

Outreach and Stakeholder Engagement – Tribal Communities Example

Tribal Outreach and Engagement:

Throughout 2023 and into 2024, the project team worked to better engage with tribal communities and listen to needs. Activities included:

- Met with tribal leadership on the Wind River Reservation as well as representatives from all of the K-12 schools on the reservation to discuss ways to further engage with the tribe.
- Hosted a presentation on Tribal Sovereignty to all University of Wyoming Leadership.
- Promoting the National Tribal Energy Roundtable Discussions sponsored by USEA for the CORE-CM stakeholder lists.
- Met with High Plains American Indian Research Institute (HPAIRI), Native American Indian Studies DEPT. (NAIS), and SER academics to discuss potentially cross-listing of courses and development of a tribal governance and energy course at UW.
- Hosted the Native American Summer Institute for an energy presentation and activities for native students visiting campus.
- Visited the Wind River Reservation for community meetings and a screening of the film “Tribal Waters.”

Created a permitting resource guide for REE, CM, and Uranium on tribal lands which is currently under review by tribal members.

Environmental Justice and CORE-CM

A place-based approach to understand the unique social, economic, and environmental aspects of a region and a community

Building Partnerships and Community Engagement

Collaborating with Community Colleges (Western Wyoming Community College and Colorado Northwestern Community College)

Annual GGRB CORE-CM Meetings (hosted in Rock Springs, WY (2022) and Craig, CO (2024)

Outreach and Education

Social and Environmental Justice Webinar

Presentations at Conferences (e.g. National Environmental Justice Conference and International Pittsburg Coal Conference

Tribal Engagement

Meetings with Tribal representatives to discuss CORE-CM and build relationships

Attending DOE Tribal Clean Energy Summits

Research

Contributing to CORE-CM Environmental Justice Working Group's best practices

Policy analysis of challenges to building environmentally just CM domestic supply chains of

Summary of EJ concerns related to CORE-CM

Colorado Northwestern Community College

WESTERN Wyoming Community College

Summary – Key Findings, Outcomes, & Future Plans

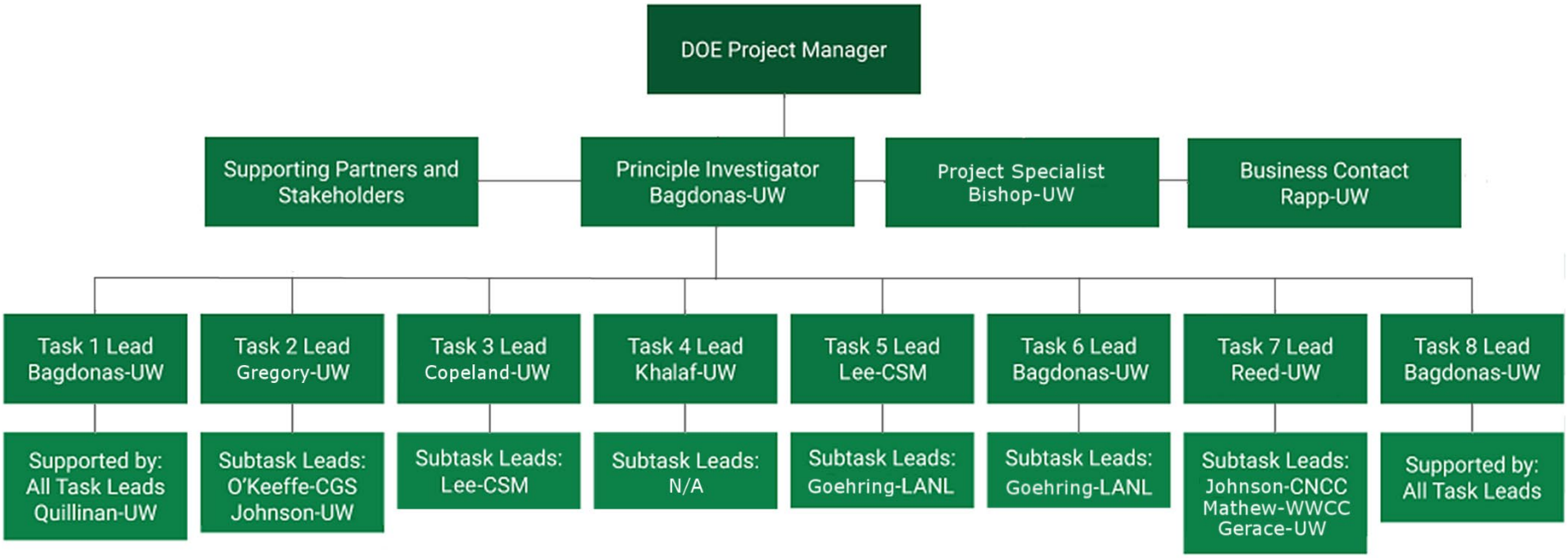
Key Findings and Outcomes:

- A diversity of existing natural resources and related industries provide a diverse pathway for potential CORE-CM supply chain development within the GGRB-WRB region
- Despite a robust fossil energy and natural resources extraction economy, the region will greatly benefit from development of larger regional collaborations to realize full potential of CORE-CM supply chains
- The region boasts a motivated and experienced stakeholder group, including a work force that is eager for new opportunity
- Work forces and communities are aware of and concerned by contrasting state-level policy differences

Future Plans:

- Finalize resource assessment data to better understand potential technology and economic outcomes of a diverse CORE-CM supply chain
- Develop larger-than-regional scale collaborations with neighboring basins/CORE-CM projects in developing a nexus of TIC R&D
- Work directly with, and educate communities in the region to not only develop a “sense of ownership”, but develop actual ownership within public-private partnerships
- Focus on Environmental and Social Justice topics, including tribal members, to fairly assemble regional outcomes around CORE-CM

Appendix – Organization Chart



Appendix – Gantt Chart