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**Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) Assessment of San Juan
River-Raton Coal Basin**

3rd Quarterly Research Performance Progress Report
Reporting Period: March 31, 2022-June 31, 2022
Project Performance Period: 10/01/2021 – 09/30/2023

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1. ACCOMPLISHMENTS

The objective of this project is to determine the rare earth elements (REE) and critical minerals (CM) resource potential in coal and related stratigraphic units in the San Juan and Raton basins, New Mexico. We will conduct the following tasks: (1) a basinal assessment for CM and REE potential, using state-of-the-art technologies to estimate basin-wide CM and REE resources in coal and related stratigraphic units; (2) identify, sample, and characterize coal waste stream products; (3) conduct bench tests to develop a basinal reuse of waste strategy; (4) illustrate the current status of the feedstock supply of REE and CM to understand the basinal REE industry's capital expenditures and obstacles to expanding REE-related business development; (5) develop a life-cycle analysis to establish pathways, process engineering, and design requirements to upgrade REE processing industry, (6) evaluate technology gaps, (7) establish a Center of Excellence and Training Center (COE) for coal ash beneficiation at San Juan County; and (8) create REE research-based activities that can be shared during the NMBGMR summer geology teacher workshop and assemble REE research-related articles for an REE-centered issue of *Lite*. This project will delineate favorable geologic terranes and priority areas containing potential REE and CM deposits for the DOE mandate, which is also a priority of the NMBGMR and state of NM.

A. Major goals and objectives

The following are the major goals of this project as described in the approved Statement of Project Objectives (SOPO):

1. Identify and quantify the distribution of critical minerals (CM), including rare earth elements (REE), in coal beds and related stratigraphic units in the San Juan and Raton basins in New Mexico (including coal, coal refuse, ash, coal seam, interstitial clays/shales, volcanic ash beds, acid mine drainage, associated sludge samples, mine dumps, other nonfuel carbon-based products, process waters, etc.).
2. Identify possible sources of CM and REE in the basins.
3. Identify the coal mine and nonfuel carbon-based waste products that could contain CM and REE.
4. Characterize the CM and REE in these materials.
5. Determine the economic viability of extracting CM and REE from these materials
6. Test and develop new technologies in identifying and quantifying CM and REE in high-fidelity geologic models.

Table 1 describes the tasks and subtasks that will be undertaken to accomplish these goals and Table 2 provides a listing of the revised project milestones, along with anticipated delivery dates.

TABLE 1. List of tasks and subtasks

Task 1.0 Project Management and Planning
Task 2.0 Basinal Assessment of CM and REE in the San Juan and Raton Basins Subtask 2.1 Identification of Sampling Sites Subtask 2.2 Collection and Review of Existing Data Subtask 2.3 Develop a Sampling Plan Subtask 2.4 Collect Samples Subtask 2.5 Sample Characterization Subtask 2.5.1 Bulk Rock Characterization Subtask 2.5.2 Micro-scale Characterization Subtask 2.5.3 3D Multiscale Petrography Subtask 2.5.4 In situ LIBS/RAMAN Analyses Subtask 2.6 Application of Machine Learning techniques for basin-wide resource assessment
Task 3.0 Basinal Strategies for Reuse of Waste Streams Subtask 3.1 Waste Streams Sampling and Characterization Subtask 3.2 Coal Ash Subtask 3.3 Technology Development of Basinal Reuse Strategy
Task 4.0 Basinal Strategies for Infrastructure, Industries and Businesses Subtask 4.1 Infrastructure Investigation Subtask 4.2 Competitiveness and Challenge Subtask 4.3 Life-Cycle Analysis
Task 5.0 Technology Assessment, Development and Field Testing Subtask 5.1 Identify and Assess Existing and Novel Technologies Specific to the Resource Subtask 5.2 Develop Plan for Field Testing
Task 6.0 Technology Innovation Centers Subtask 6.1 SonoAsh Center of Excellence
Task 7.0 Stakeholder Outreach and Education Subtask 7.1 New Mexico State and Regional Education Subtask 7.2 Lessons Learned and Narratives Constructed Subtask 7.3 Publications Subtask 7.4 Training and Conferencing with SJC and Sonoash COE

TABLE 2. Revised List of Milestones (**bold=completed**)

Task/ Subtask	Milestone Title	Planned Completion	Verification method	Status
	Quarterly reports	Quarterly	Report every quarter	3rd quarter 7/19/2022 completed
1.0	A: Project Kick-off meeting	10/15/21	Attend, report	Completed (see https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf)
2.1	B: Identification of Sampling Sites	Quarterly	Reports every quarter	Ongoing, planned in 2 phases
2.2	C: Collection and Review of Existing Data	2 nd quarter	Map, description	Report in progress, ongoing activity, REE in produced waters

				(https://geoinfo.nmt.edu/staff/mclmore/ree_produced_waters_for_GIS.xlsx) and USGS coal chemistry (https://geoinfo.nmt.edu/staff/mclmore/REEcoal.mpk) are on the project web site
2.3	D: Sampling Plan Database	10/31/2021, progress report 2 nd quarter. 3/31/2022	Sampling plan Database, web forms, reports.	Sampling plan is completed (https://geoinfo.nmt.edu/staff/mclmore/documents/samplingplan_v3.pdf). Database and data entry web pages are being developed; initial availability 3/31/2022.
2.4	E: Collect Samples	Quarterly	Report, database	Started sampling in April 2022 (see Table 3)
2.5	F: Characterization	Quarterly	Progress report quarterly, database	Ongoing once samples are collected, samples submitted to laboratories for chemical analyses in July 2022
2.6	G: Application of Machine Learning techniques for Basin-wide Assessment	12/31/2022	Progress report quarterly, database	Future activity
3.0	H: Sampling and Characterization of Waste Streams	Quarterly	Progress report quarterly, database	Ongoing, future activity
4.0	I: Results of Basinal Infrastructure, Industries and Business Assessment	03/31/2023	Progress report quarterly, database, publications	Future activity; Life cycle analysis started (see below)

B. Accomplishments during 3rd quarter

Task 1.0 Project Management and Planning

Project management activities during this quarter included the implementation of regular procedures including regular management and biweekly working group meetings. The team also has regular weekly meetings of the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) database group to develop the project database. McLemore and other team members attended DOE CORE-CM Characterization Working Group April 11, 19, May 9, June 13, 2022, and CORE-CM Env Justice and Soc Responsibility Working Group, April 18, 2022.

Task 2.0 Basinal Assessment of CM and REE in the San Juan and Raton Basins

Status:

Subtask 2.1 Identification of Sampling Sites

Sample sites include the coal fields and mines in the San Juan and Raton basins, shown in Figure 1. Samples from each coal field (Table 3) will be collected. Sampling began in April 2022.

Subtask 2.2 Collection and Review of Existing Data

Legacy chemistry data have been collected and a report evaluating that data is in progress.

Subtask 2.3 Develop a Sampling Plan

The field sampling plan is completed and revised

(https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v5.pdf). Figure 1 shows the coal fields and mines in the area. Table 3 is a list of the coal fields.

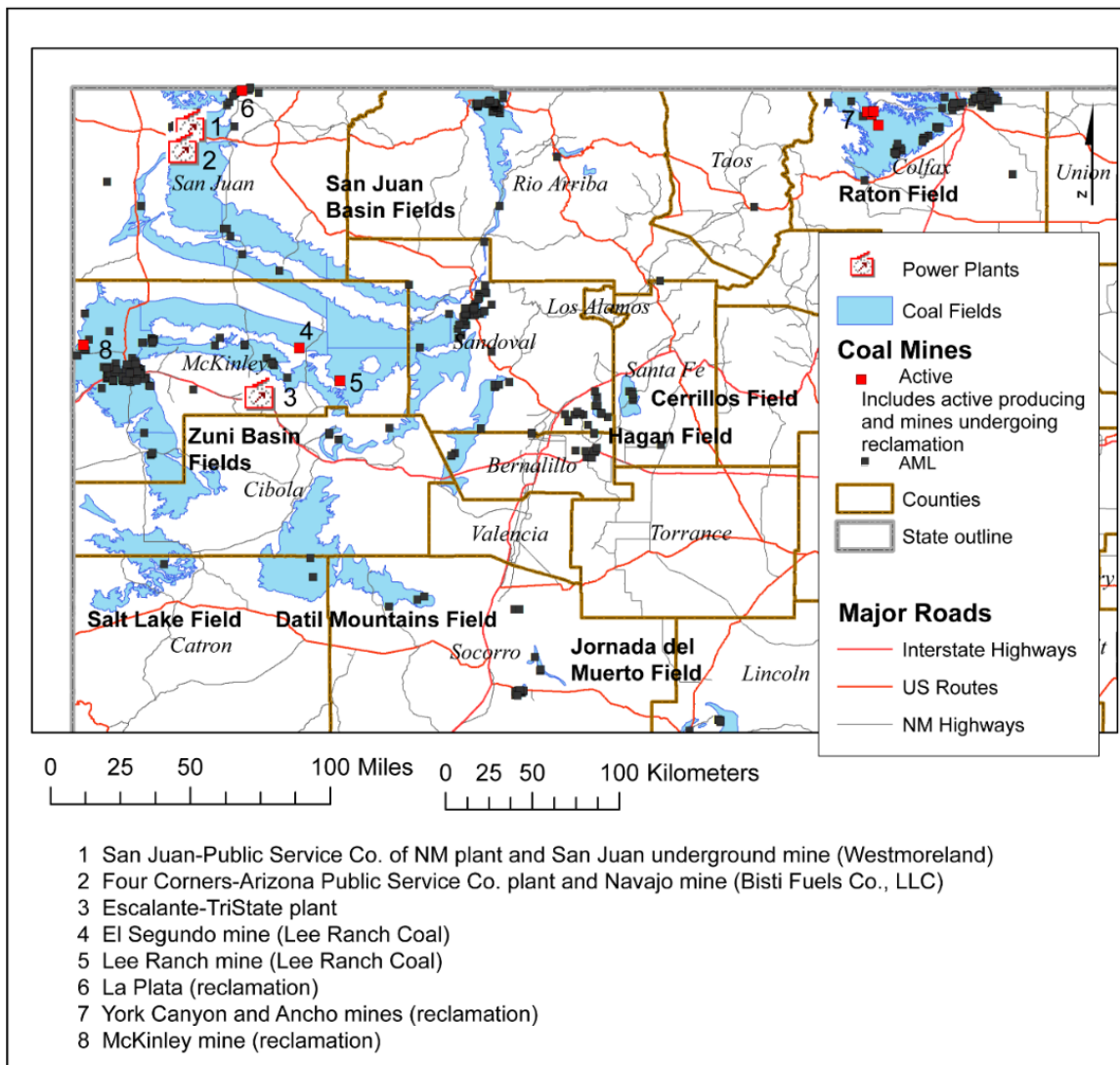


FIGURE 1. Coal fields, active mines, AML (abandoned mine lands) sites, and power plants in the San Juan and Raton Basins.

TABLE 3. Coal fields in the San Juan and Raton basins, studied in this project, delineated by Hoffman (1996, 2017). District Id is from the New Mexico Mines Database (McLemore, 2010a, 2017). Representative samples will be collected from each coal field. Each field sample will be prefixed with an abbreviation representing each coal district. Each drill core sample will be

identified by the hole number and depth. At least 3 samples will be collected from each coal field. Approximately 130 samples will be collected each year.

District id	District	Year of Discovery	Year of Initial Production	Year of Last Production	Estimated Cumulative Production	Formation	No of samples collected
DIS257	Barker Creek coal field	1882		1905		Menefee	
DIS150	Bisti coal field	1961	1980	1988	\$40,075,148.00	Fruitland	2
DIS259	Chaco Canyon Coal Field	1905	1905			Menefee	
DIS260	Chacra Mesa coal field	1922		1945		Menefee	
DIS174	La Ventana	1884	1904	1983		Menefee	4
DIS118	Crownpoint coal field	1905	1914	1951	\$20,758.00	Crevasse Canyon	
DIS155	Fruitland coal field	1889	1889	2001	\$3,137,957,050	Fruitland	
DIS119	Gallup coal field	1881	1882	2001	\$121,522,629,885	Crevasse Canyon	
DIS156	Hogback coal field	1907	1907	1971	\$301,237.00	Menefee	
DIS146	Monero coal field	1882	1882	1970	\$5,277,552.00	Menefee	
DIS016	Mount Taylor coal field	1936	1952	1953	\$69,948.00	Crevasse Canyon	
DIS157	Navajo coal field	1933	1963	9999	\$4,714,689,147	Fruitland	2
DIS258	Newcomb coal field	1955				Menefee	
DIS021	Raton coal field	1820	1898	2002	\$954,470,032.00	Vermejo, Raton	17
DIS003	Rio Puerco coal field	1901	1937	1944	\$139,555.00	Crevasse Canyon	
DIS009	Salt Lake coal field	1980	1987	1987	\$100,000.00	Moreno Hill	2
DIS121	San Mateo coal field	1905	1983	2001	\$1,678,742,326	Menefee	
DIS261	Standing Rock coal field	1934	1952	1958		Menefee	
DIS158	Star Lake coal field	1907			\$0.00	Fruitland	7
DIS263	Tierra Amarilla coal field	1935	1955	1955		Menefee	
DIS159	Toadlena	1950			\$0.00	Menefee	
DIS124	Zuni coal field	1916	1908	1926	\$16,010.00	Crevasse Canyon	
	Other areas					Popotosa Formation	7
Total samples	July 14, 2022						41

Health and safety plan

HASP is complete (https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf).

Subtask 2.4 Collect Samples

Sampling was delayed due to poor weather, vacation schedules, closures of Federal land because of fire danger, and students not available because of school schedule. We started sampling in April.

We have logged 1,313 ft of core (13 holes). We have collected 41 samples (Table 3).

Subtask 2.5 Sample Characterization

Attended the DOE CORE-CM Characterization Working Group - Planning Meetings on April 11, 19, May 9, June 13, 2022

Subtask 2.6 Application of Machine Learning techniques for basin-wide resource assessment

There is no update on this subtask.

Task 3.0 Basinal Strategies for Reuse of Waste Streams***Subtask 3.1 Waste Streams Sampling and Characterization***

There is no update on this subtask.

Subtask 3.2 Coal Ash

There is no update on this subtask.

Subtask 3.3 Technology Development of Basinal Reuse Strategy

There is no update on this subtask.

Task 4.0 Basinal Strategies for Infrastructure, Industries and Businesses***Subtask 4.1 Infrastructure Investigation***

There is no update on this subtask.

Subtask 4.2 Competitiveness and Challenge

There is no update on this subtask.

Subtask 4.3 Life-Cycle Analysis

The project team is utilizing the cradle-to-grave concept, which would be adopted to set the boundary of energy and material flows for all the processes involved in the REE industry. Life-cycle analysis including energy and material analysis, environmental impact assessment, scalability assessment and detailed economic analysis shall be conducted to the current REE and CM supply chain and investigate the potential upgrading of the REE and CM process industry, in order to establish pathways toward net neutral carbon emission and the process engineering and design requirements to accomplish this. Typical REE production route is describe in Figure 2:

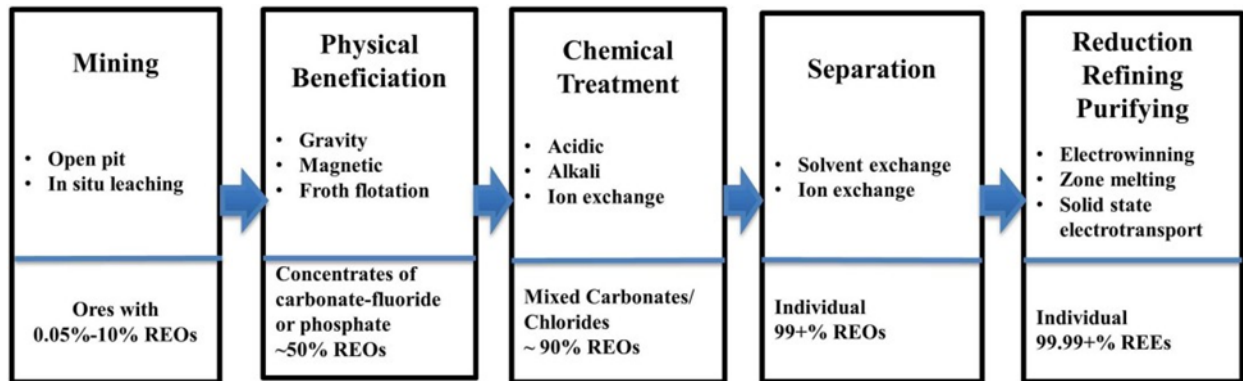


Figure 2. Generalize REE production flow chart

Proposed boundary for this task would be simplified as Figure 3.

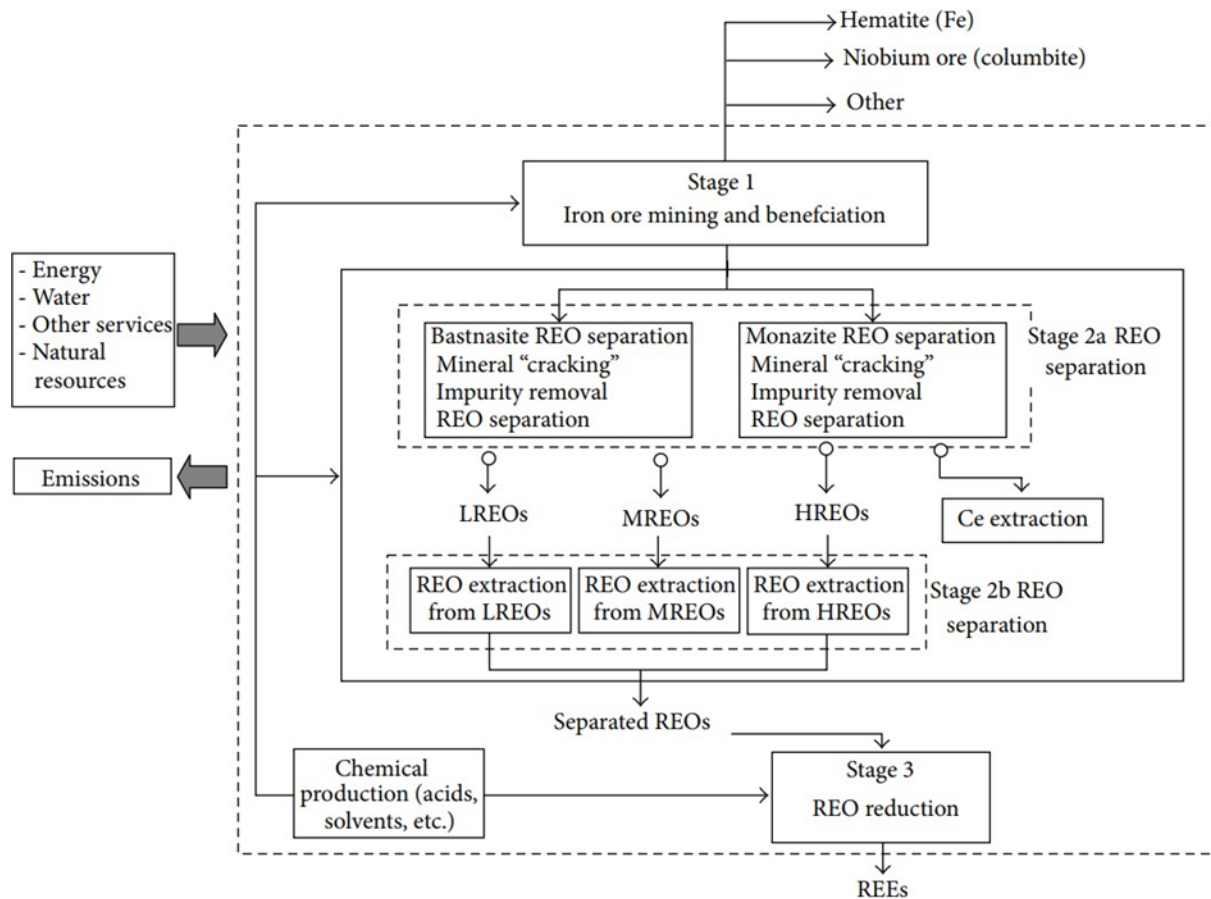


Figure 3. Simplified boundary. (To be modified with details of each unit processes for LCI)

We will continue the following topic to complete this task:

- Detailed description of processes involved in each unit of REE production (different technologies or techniques would be discussed)
- Life cycle inventory analysis: quantification of energy and material flows for all the processes involved in the REE industry.

- Life cycle impact assessment (Global warming will be a major impact for this study, however other impacts such as acidification, ecotoxicity, human toxicity etc. will be assessed)
- Techno-economic assessment.

Task 5.0 Technology Assessment, Development and Field Testing

Subtask 5.1 Identify and Assess Existing and Novel Technologies Specific to the Resource

There is no update on this subtask.

Subtask 5.2 Develop Plan for Field Testing

There is no update on this subtask.

Task 6.0 Technology Innovation Centers

Subtask 6.1 SonoAsh Center of Excellence

There is no update on this subtask.

Task 7.0 Stakeholder Outreach and Education

Subtask 7.1 New Mexico State and Regional Education

A short summary of the project was written for Gold Pan, NMIMT Alumni Newsletter. Working on a short summary of the project for Lite Geology.

The NMBGMR Rockin' Around New Mexico was in Farmington, NM July 6-8, 2022 (<https://geoinfo.nmt.edu/education/rockin/home.html>). Lectures on critical minerals and a tour of the Navajo coal mine were included (<https://geoinfo.nmt.edu/staff/mclemore/home.html>) .

Subtask 7.2 Lessons Learned and Narratives Constructed

There is no update on this subtask.

Subtask 7.3 Publications and presentations

New Mexico Geological Society abstract: Badonie, M.N. and McLemore, V.T., 2022, REE in coalbeds in the San Juan-Raton coal basins (abstr.): New Mexico Geological Society, Spring Meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2838>. Poster at <https://geoinfo.nmt.edu/staff/mclemore/documents/NMSG.Poster2022COPY2.pdf>.

Subtask 7.4 Training and Conferencing with SJC and Sonoash COE

There is no update on this subtask.

2. PRODUCTS

A. Publications, conference papers, and presentations

1st quarter

Kickoff presentation October 15, 2021

(<https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMfinal.pdf>)

DOE Division of Critical Minerals Program Plan Rollout on December 8, 2021

(https://geoinfo.nmt.edu/staff/mclemore/documents/CORE-CMprojectNMDOEsummary12_21.pdf)

2nd quarter

New Mexico Geological Society abstract: Badonie, M.N. and McLemore, V.T., 2022, REE in coalbeds in the San Juan-Raton coal basins (abstr.): New Mexico Geological Society, Spring Meeting, <https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2838>. Poster at <https://geoinfo.nmt.edu/staff/mclemore/documents/NMSG.Poster2022COPY2.pdf>.

3rd quarter

Rockin' 22 Critical Minerals presentation

(<https://geoinfo.nmt.edu/staff/mclemore/documents/McLemoreRockinCM22.pdf>)

Rockin' 22 Critical Minerals activities

(<https://geoinfo.nmt.edu/staff/mclemore/documents/Rockin22.pdf>)

B. Website(s) or other Internet site(s)

See project web page at <https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html>

C. Technologies or techniques

No update

D. Inventions, patent applications, and/or licenses

No update

E. Other products

1st quarter

Sampling plan

Health and safety plan (https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf)

SOP17 Drillhole logging

(<https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf>)

3rd quarter

Revised sampling plan

(https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v5.pdf)

REE in produced waters

(https://geoinfo.nmt.edu/staff/mclemore/ree_produced_waters_for_GIS.xlsx) and USGS coal chemistry (<https://geoinfo.nmt.edu/staff/mclemore/REEcoal.mpk>)

McLemore attended Mining and Metallurgical Society of America AML summit in Phoenix

April 6-7, 2022

Rockin' was held in Farmington July 5-8, 2022

3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

A. Individuals involved in project

New Mexico Tech

Dr. Navid Mojtabai (PI) is a professor and department chair in the Mineral Engineering Department at New Mexico Tech - Tasks 1, 3, 5, and 7.

Dr. Virginia McLemore (Co-PI) is the Principal Senior Economic Geologist for the NMBGMR - Tasks 1, 2, 3, 5 and 7.

Dr. Robert Balch (PM) is the Project manager for this project and is the Director of the PRRC – Task 1,

2, 4 and 7.

Dr. William Ampomah (Co-PI) is a Research Engineer and Section Head at PRRC – Task 1, 4, 5 and 7.

Dr. Sai Wang is a Research Associate at PRRC - Tasks 4.

Dr. William Chavez is a professor in the Mineral Engineering department at New Mexico Tech – Task 2 and 3.

Mr. Mark Leo is the NMBGMR database specialist - Task 2 and 3.

Mr. Mark Mansell: is the NMBGMR GIS specialist - Task 2.

Ms. Cynthia Connolly is the Education Outreach Manager at the NMBGMR – Task 7.

Dr. Shari Kelley is a senior field geologist and geophysicist at the NMBGMR – Task 2 and 7.

Mr. Christopher Armijo is the NMBGMR computer specialist - Task 1 and 2.

Mr. Brian Wheeler is the NMBGMR fleet manager - Tasks 2 and 3.

Ms. Gretchen Hoffman is the NMBGMR emeritus coal geologist - Task 2 and 3.

Sandia National Laboratories(SANL)

Dr. Jason Heath is a hydrogeologist at SANL. –Task 2 and 5.

Dr. Guangping Xu is an experimental geochemist at SANL - Tasks 2, 3 and 5.

San Juan College

Dr. John Burriss: is a Professor of Geology and Department Chair at San Juan College - Tasks 7.

Los Alamos National Laboratory (LANL)

Dr. Kirsten Sauer is a Scientist at LANL - Task 5.

Dr. Hakim Boukhalifa is a Senior Scientist at LANL – Task 5

Dr. Sam Clegg is Senior Scientist at LANL – Task 2

SonoAsh

Mr. Claudio Arato is the CTO of SonoAsh company - Task 3, 4, 5, 6 and 7.

Mr. Brad MacKenzie is the VP of SonoAsh company – Task 4 and 6

B. Change in support levels of key persons

Dr. Rajesh Pawar had shifted his responsibilities on this project to Dr. Kirsten Sauer.

4. SPECIAL REPORTING REQUIREMENTS: Mandatory

No update

5. BUDGETARY INFORMATION: MANDATORY

Spend Plan by Fiscal Year Format						
	FY 2022		FY 2023		Total	
	DOE funds	Cost Share	DOE funds	Cost Share	DOE	Cost Share
NMIMT	564,432	101,114	544,856	104,147	1,109,287	205,261
Los Alamos National Laboratory	93,750	-	93,750	-	187,500	-
Sandia National Laboratories	99,946	-	87,054	-	187,000	-
SonoAsh LLC	-	115,000	-	115,000	-	230,000
Total (\$)	758,128	216,114	725,660	219,147	1,483,787	435,261
Total Cost Share %		22.2%		23.2%		22.7%

Table for Actual Incurred Costs

Table for Remaining Balance

6. REFERENCES

7. APPENDICES

APPENDIX 1. List of SOPs and plans

(see <https://geoinfo.nmt.edu/staff/mclemore/REEinCoalWeb.html> for copies as they are completed)

Number	Name	Description
HASP	Health and Safety Plan (HASP)	Health and safety plan for field and laboratory work (https://geoinfo.nmt.edu/staff/mclemore/documents/HASP_v2.pdf)
FSP	Field Sampling Plan (FSP)	Field sampling plan (https://geoinfo.nmt.edu/staff/mclemore/documents/samplingplan_v3.pdf)
SOP 1	Data management	entering, reporting, verification, and validation of data to the database
SOP 2	Photography	procedures taking photographs in the field and laboratory
SOP 3	GPS surveying	Procedures for use of handheld GPS surveying
SOP 4	Sampling outcrops, rock piles, and drill core	field procedures for taking surface solid samples
SOP 17	Drillhole logging	procedures for drilling, logging, and sampling of subsurface samples (solids) (https://geoinfo.nmt.edu/staff/mclemore/documents/SOP17DrillholeLoggingupdated.pdf)
SOP 6	Soil paste pH and paste conductivity	laboratory procedures for soil paste pH and paste conductivity
SOP 7	Field measurements of water	field procedures for measuring water flow, pH, conductivity, alkalinity, temperature when collecting water samples
SOP 8	Surface water and seep sampling	field procedures for collecting samples of surface and seep water samples
SOP 9	Petrographic analysis	laboratory procedures for describing petrographic samples
SOP 10	Electron microprobe analyses	laboratory procedures use for analyses using the electron microprobe
SOP 12	X-ray diffraction (XRD) analyses	laboratory procedures for mineralogical analyses by x-ray diffraction (XRD)