



SCHOOL OF ENERGY RESOURCES



UNIVERSITY OF WYOMING

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Progress Report of the Rare Earth Element Research Program to the Joint Minerals, Business, and Economic Development Interim Committee October 1, 2015

This report provides a summary of the rare earth element (REE) research program in accordance with Budget Footnote 331(c)-(f) to the 2014 State Budget, House Enrolled Act No. 41, and amended by Budget Footnote 331(f)(iii) to the 2015 State Budget, House Enrolled Act No. 56. It provides background on the REE research program, status of research projects to date and program budget.

Background

The REE research program was created to stimulate research and development in the area of rare earth element production and processing in Wyoming. The objectives of this program are intended to focus on technologies that better identify and quantify sources of rare earth elements and optimize the economic benefit of the resource to the state of Wyoming.

In the 2015 general session, the Legislature of the State of Wyoming redirected \$324,517.90 of Abandoned Mine Land (AML) funds from two previously funded research efforts to the University of Wyoming for REE research. In the same session, the Wyoming Legislature also appropriated \$250,000 from the general fund to the University of Wyoming, School of Energy Resources (SER) that can only be expended if matched with an equal amount of non-state funds. Both the AML and general fund appropriations were intended to fund, "...applied research to promote processing developments that would improve the possibility that rare earth materials could be processed in Wyoming."¹ The REE research program legislation stipulates that the funds allocated for REE research revert June 30, 2016.

May 27, 2015 Stakeholder Meeting

On May 27, 2015, SER hosted a stakeholder meeting comprised of a member of the Wyoming House of Representatives; representatives from Rare Element Resources, a company proposing to mine rare earth elements in Wyoming; a representative from Idaho National Laboratory; and several University of Wyoming (UW) faculty and administrators. The objective of the meeting was to identify research topics of interest to stakeholders that satisfy the charge of the legislation. The stakeholder group identified the following three research focus areas:

1. Characterization, quantification and production of rare earth element supplies from "unconventional" sources in sustainable quantities. Such sources might include geothermal and produced waters and waste product streams such as coal fly ash.
2. Identification of novel processes to refine, concentrate, convert and purify "conventional," or mined, rare earth deposits known to exist in sustainable quantities within the State of Wyoming.

¹ Wyoming Original Senate File No. SF0001, Senate Enrolled Act No. 56, Section 331(f)(ii), 2015 General Session.

3. The use and application of rare earth element resources mined and processed within the state of Wyoming in industrial applications and functional products that could seed new industry and manufacturing within the State of Wyoming.

2015 REE Research Program Request for Proposals

On June 16, 2015, SER issued a request for proposals (RFP) for research focused on REE with the intent of deploying at least the \$324,517.90 of redirected AML funds. RFP respondents were encouraged to include demonstration of non-state matching funds in the hopes of generating a minimum of \$250,000 in combined match that would subsequently allow for deployment of the \$250,000 general fund appropriation.

The RFP asked for proposals for applied research in one or more of the three research focus areas identified by the stakeholder group. The RFP was open to all full-time UW faculty, academic professionals, research scientists and post-doctoral research associates. Collaboration with other non-UW entities (industry, national laboratories, other universities, etc.) was encouraged but not required.

Proposals in response to the 2015 RFP were submitted to SER by June 30, 2015. In accordance with the RFP, funds for successful proposals became available by August 1, 2015. All projects must be completed by June 15, 2016. The RFP specifies that successful proposals are required to submit a progress report by September 15, 2015 and a final report by June 15, 2016.

Proposals were reviewed by SER in consultation with stakeholder representatives. The overriding criterion for proposal funding was demonstration of applied research with direct relevance to one or more of the three research focus areas listed above and demonstration that the proposed work can be completed by June 15, 2016.

The projects that were funded through the 2015 RFP are listed below and summarized in Table 1.

1. “Unconventional Rare Earth Elements in Wyoming from Coal Fly Ash and Oil and Gas Production Water: A Technical and Economic Feasibility Study,” submitted by University of Wyoming Carbon Management Institute (CMI), Fred McLaughlin, Principal Investigator (PI). The total project budget is \$351,902. No matching funds were identified for this project.

Objectives: This project provides a technical assessment of the potential for REE recovery from waste streams associated with Wyoming’s energy industry (coal fly ash and oil and gas production water). Tasks include characterization and quantification of REE’s, identification of separation and treatment technologies, and an economic evaluation of recovery scenarios.

Current Status: Research accomplishments to date include hiring of graduate and undergraduate students to assist with the technical and economic analyses; establishment of relationships with industry partners to obtain coal by-product and produced water samples; development of sampling collection and analysis protocols; procurement of sampling equipment; evaluation of national and worldwide economic trends in REE extraction, production, imports/exports, and prices. In addition, this research serves as a platform for a proposal submitted by a University of Wyoming-led effort for \$750,000 of funding from the US Department of Energy (DOE) focused on REE extraction from western coal by-products. The University of Wyoming-led team includes researchers from the University of Wyoming, Idaho National Laboratory, Oak Ridge National Laboratory, and the University of Alaska.

Deliverables: The results of this project will identify the REE resources that can be obtained from by-products generated at coal-fired power plants (fly ash) and oil and gas fields (produced water) in Wyoming. Along with an engineering design for recovery of REE's from these two unconventional sources, the final report will include an economic feasibility assessment of recovering REE resources from Wyoming coal and produced water.

2. "Rare Earth Element Recovery from Roll-Front Uranium Deposits in Wyoming: An Unconventional Source of Rare Earth Elements," submitted by University of Wyoming Department of Geology and Geophysics, Susan Swapp, Principal Investigator. The total project budget is \$137,690, including matching funds in the amount of \$45,000 committed by the University of Manitoba.

Objectives: This project explores the possibility of extracting REE's as a byproduct of already established in-situ recovery (ISR) uranium mining. Past and current research in this area has identified uranium deposits as potential valuable unconventional sources of REE's. The uranium deposits that are currently being mined in Wyoming have significant concentrations of REE's (at least 10 to 50 times of that found in crustal abundances). These REE's are likely associated with uranium mineralization, which is currently being extracted by ISR mining methods. Objectives include working to determine the host material of REE's in uranium deposits and tracking the movement of REE's through the ISR process by analyzing production water, exchange resins and returned water.

Current Status: Researchers on this project have partnered with Cameco Resources and Uranium One and identified and obtained samples from three different mines throughout Wyoming for analysis. Sample analysis has begun and the results are forthcoming.

Deliverables: This project will produce a report describing the abundance of REE's in uranium roll-front deposits, identification of the minerals hosting these deposits, and where REE's are ultimately deposited in the ISR mining process. If REEs are shown to be extracted in the ISR mining fluids, it may be possible to concentrate them as a by-

product of the uranium mining process. There are significant potential economic benefits associated with extracting REE's as a by-product of ISR uranium mining. First, the mining operation is already well established so development costs would be minimal. Second, one of the most significant challenges in REE mining processes world-wide is disposal of the radioactive elements that are inevitably also extracted in the process. Since the primary objective of ISR uranium mining is extraction and recovery of the uranium, there is no added waste management burden to recovering REE's at the same time.

3. "Electrochemical Conversion of Rare Earth Oxides to Metals/Alloys in Molten Salts," submitted by Idaho National Laboratory, Eric Peterson, Principal Investigator. The total project cost is \$204,000 including matching funds in the amount of \$100,000 committed by the DOE Critical Materials Institute.

Objectives: This research proposes to develop an electrolytic process for obtaining REE metals and their alloys in a powder form using molten salts. Typically, REE metals are consolidated into ingots which require an additional pulverization step prior to fabrication to other components. The production of metals in a powder form requires less process energy and is directly amenable to further processing for component fabrication, eliminating the cost and time for pulverization.

Current Status: A research contract is still under negotiation between the University of Wyoming and Battelle Energy Alliance (BEA), the contracting entity for the DOE and Idaho National Laboratory. As a representative of the DOE and INL, BEA requires that their contract template be used as the research agreement. This requires review by the University of Wyoming, Office of General Counsel and the Office of Research and Economic Development to ensure the terms and conditions of funding proposed by BEA are acceptable to the University of Wyoming. Work to be paid by the REE Research Fund cannot commence until a contract is signed by both parties; however, the matching funds offered by the DOE Critical Materials Institute are currently being used to develop REE metal reduction equipment and processes for the project. It is anticipated that a contract can be fully executed by October 31, 2015.

Deliverables: The funding from the REE Research Program will be used to develop processes that are of specific interest to companies looking to mine REE's in Wyoming. The final report from this project will detail initial methods for performing electrochemical conversion of rare earth oxides to metals and alloys in molten salts.

Status of REE Funding

Given that the funded projects were not able to cumulatively demonstrate \$250,000 of non-state of Wyoming matching funds, the \$250,000 general fund appropriation was not available for funding. Therefore, the \$327,517.90 of redirected AML funding (which does not require

matching funds) was used to fund the projects. The total funding request from the REE research program for the three projects exceeds the \$327,517.90 of available funding. SER felt the three projects that were selected for funding solidly met the requirement of applied research and stand to provide valuable information on potential sources of REE's in Wyoming. SER has decided to contribute an additional \$269,074.10 from its Matching Grant Fund account to the project focused on recovery of REE's from coal fly ash and oil and gas product water (McLaughlin, PI). Use of SER's Matching Grant Fund for the McLaughlin project aligns well with the intent of the Matching Grant Fund program, which is to provide UW researchers assistance with leveraging external grant funding. The McLaughlin project has submitted a proposal for \$750,000 to the DOE for continuing the research funded by the REE research program. Table 2 shows a funding allocation summary for the three research projects.

Table 1: Funded Rare Earth Element Research Projects

Proposal Title	Submitted By	Funding Requested	Outside Match	Outside Match Source	Total Funds	Focus Area
Unconventional Rare Earth Elements in Wyoming from Coal Fly Ash and Oil and Gas Production Water: A Technical and Economic Feasibility Study	University of Wyoming - McLaughlin	\$351,902	\$0	---	\$351,902	Unconventional REE's
Rare Earth Element Recovery from Roll-Front Uranium Deposits in Wyoming: An Unconventional Source of Rare Earth Elements	University of Wyoming - Swapp	\$137,690	\$45,000	University of Manitoba, Canada	\$182,690	Unconventional REE's
Electrochemical Conversion of Rare Earth Oxides to Metals/Alloys in Molten Salts	Idaho National Laboratory - Peterson	\$104,100	\$100,000	DOE – Critical Materials Institute	\$204,100	Processing of Conventional REE's
Totals:		\$593,692	\$145,000		\$738,692	

Table 2: AML Fund Allocation Summary

Available REE AML Funding	\$ 324,517.90
Projects to Fund from REE AML Funds	
Susan Swapp, UW Geology/Geophysics	\$ 137,690.00
Eric Peterson, INL	\$ 104,000.00
Total Cost	\$ 241,690.00
Remainder of AML Funds	
	\$ 82,827.90
Funding Sources for McLaughlin Project	
Remaining AML Funds	\$ 82,827.90
SER Matching Grant Fund Contribution	\$ 269,074.10
McLaughlin Project Total	\$ 351,902.00