Rare Earth Element Extraction and Concentration at Pilot-Scale from North Dakota Coal-Related Feedstocks

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Team Members

Project Team Members
• UND Institute for Energy Studies
• Microbeam Technologies Inc.
• Barr Engineering Co.
• Rare Earth Salts LLC
• MLJ Consulting LLC
• North Dakota Geological Survey

Project Sponsor Representatives/Executive Advisory Team
• U.S. Department of Energy NETL
• Lignite Research Program
• North American Coal
• Great River Energy
• Minnkota Power Cooperative
• BNI Energy
• Great Northern Properties
• Critical Materials Institute
• North Dakota University System
• Valley City State University
Presentation Overview

• Technology and Project Background
• Project Objectives and Scope
• Accomplishments to Date
• Project Next Steps
• Questions
Technology Background

• Extracts REE from low rank coals (LRCs) utilizing weak acids
  – Weak organic associations, rather than mineralized forms (carboxylic acid)

• Utilizes the pre-combustion coal for the feedstock
  – Generates a reduced-ash unique byproduct
    • Usable for AC, humic acid
    • Low fouling ash for boilers
Lignite Background - REE

- Lignite often identified with high HREE/LREE ratios
  - Economically favorable distributions for usage

- Process developed produces other CM
  - High-value Ge and Ga concentrates

Modified from Seredin and Dai, 2012
Project Objectives

• As outlined by DOE – NETL in FOA 2003:
  – Development of pilot scale near 5-25% of commercial capacity of >2% REO concentrates utilizing coal-based resources of >300 ppm concentration TREE
    • Utilizing at least 500 kg/hr coal input and producing 50-100 grams/hr of REO concentrate
  – Economic and environmentally-friendly extraction of REEs from coal

• Goal is to validate the REE extraction from low rank coal technology at a relevant scale for commercial deployment
Accomplishments Completed

• Pilot Design Study
• Preliminary Feasibility Study
• Coal Acquisition
• Procurement of Pilot Components
• Development of Control Software
• Bench Testing Progress
• MREO Concentrate Purification
Continuous Pilot Design Summary

• Included within the continuous scope of the pilot:
  – Coal crushing and preparation (to topsize of -4 mesh)
  – Coal spiraling and mineral-rich tailings disposal
  – Leaching of REE and filtration/washing of coal
  – Solution purification and REE precipitation
  – Wastewater treatment of spend waste

• REE concentrates will be fired to oxides batch-wise as produced (kg/day)

• All processing permits (industrial safety, air, water) have been issued
• Three major process steps (after coal handling)
  • Leaching of REE/CM
  • Removal of Impurities from liquid
  • Recovery of REE/CM into solids
Feasibility Study - Economics

• Plant Scope: 5.5 ton/hr AC feed for REE extraction
  – Includes CAPEX and OPEX of AC plant
    • Salables: AC, REE Concentrates, Ge, Ga
    • Consumables: Acid, Base, Oxalic Acid, Coal Feed, Labor, Electrical/Heat, Maintenance, and REE/CM refining costs
  – Discounted payback at 6.2 years
  – Produces up to 25 tons/yr of REE concentrate

• Utilizes data from bench-scale data (DE-FE0027006)
  – REE Recovery
  – Consumable Usage
Coal Acquisition

• Blended, cleaned coal basis utilized for process feed
  – Blend of TREE-rich coal and HREE-rich coal seams
  – Coal spiraling utilized as coal cleaning process to remove mineral-rich tailings

• Up to 150 tons of >300 ppm material gathered to date on cleaned-coal basis
Procurement of Pilot Components

• All major pilot components purchased, some components awaiting delivery
  – Received:
    • Tanks, Mixers, and VFDs
    • Pumps, VFDs, and Piping and Valving
    • Conveyors, air blowers, and cyclones
    • Coal handling system (completed)
    • Coal spiral
    • Control system, sensors, and wiring components
  – Waiting on delivery
    • Leached coal filter presses (May 2021)
    • Filter bag housings for polishing (May 2021)
Control Software for Pilot

• Utilizing National Instruments LabVIEW™ software
  – Contains >20 PID control loops
    • To be tuned during commissioning
  – Utilizes over 200 independent variables
  – Developed with process area emergency shutdowns
    • Includes plant-wide shutdown
  – Able to successfully manage all programming with less than 100 ms delay
Bench Testing – Parametric

• Testing:
  – Chemical and physical operating parameters
    • Coal size
    • Leaching pH
    • Base type and concentration targets
    • Oxalic acid dosage
    • Use of seed crystals
Parametric Results – Leaching pH

- Moderate pH (not lowest nor highest, identified as optimal point)
  - Includes significant Sc leaching from B to C
  - Further REE recovery at expense of acid, base consumption

Note – Ce removal process added, limiting recovery
MREO Concentrate Purification

- Firing, dissolving, and separating impurities from ~65% pure concentrate using ion exchange resins
  - IDA and AMP resins chosen from ~10 options
  - Selective stripping using Na₂CO₃ for REE
  - Can produce ~85% pure (cation basis) REO concentrate
  - Ce excluded by firing to tetravalent form, insoluble in dissolution step
Project Next Steps

- Bench-Scale parametric and production testing
- Pilot Construction, Commissioning, and Testing
- MREO Concentrate Separation at RES
- Feasibility Study Update
Bench-Scale – Testing

• Complete testing of parameters for remaining process steps
  – Impurity Removal
    • Base Type
    • pH
  – REO Concentrate Production
    • Oxalic Acid Concentration
    • Seed Crystal Dosage

• Bench-Scale Production Testing – 0.5 tons of coal blend
  – Anticipated completion – August 1st, 2021
Pilot Schedule

• Pilot system anticipated to be complete for testing by September, 2021
  – Will include PID loop tuning, safety checks, and personnel training
  – 24-hr testing, with week-on/week-off scheduling planned
    • Parametrics to use 2-3 day-weeks, production of 5 day-weeks
Pilot Construction

- Coal handling systems have been constructed for the plant, including staged crushing
  - Topsize of 1/8", with fines rejection (by cyclone) of -150 US Mesh
  - Able to crush up to 5 tons/hr

- Other construction to begin upon final equipment delivery
Pilot Commissioning

• Upon construction, “cold” commissioning to start
  – Without chemical additions (acids/bases)
  – Needed to tune flow PID loops for tank level control, estimate filter times
  – Leak-check all pipelines and determine flowability problems (using slurries)

• “Hot” commissioning
  – Addition of acids/bases to tune respective PID controls
  – Gather preliminary data on processing and effective residence times of the system
Pilot Parametric Testing

• Utilizing >300 ppm blended lignite feed
  – Brief parametric testing based on results of bench-scale testing
    • Only choose optimal point and one other (closest economic point) for each process area
    • Focus on unit ops of greatest impact (largest economic difference per unit change)
  – Further trains personnel on pilot operation and handling
    • Reduces personnel risks with production testing, where majority of >300 ppm coal will be utilized
Pilot Production Testing

• Production testing aimed at producing at least 15 kg of MREO concentrate at a purity of >85-90%
  – Can produce as much as 6-8 kg of REE’s per 24-5 week, assuming stable operation
  – Determination of data required for AACE Class 4-3 study for future economic preparation
    • Including pilot-scale ZLD wastewater treatment plant to evaluate for scale-up
MREO Separation

- At least 10-15 kg of MREO concentrate to be delivered to partner RES for inter-lanthanide separation
  - Major element targets of Sc, Pr, Nd, Dy, and Tb
  - Goals to produce 99+% pure individual oxides of all target elements by end of project (July 2022)
    - Bench-scale processing of UND-based concentrates underway with ~25 grams of concentrate delivered
Feasibility Study Update

• Complete project with TEA and Feasibility Study update based upon pilot data and estimate refining costs
  – Include sections on potential lignite resources identified over the course of the project
  – Include environmental costs and impacts of the plant/project based upon pilot data
  – Furnish in NI-43-101 Preliminary Economic Assessment (PEA) format for industrial release
    • May not meet exact legal requirements of NI-43-101 PEA
Summary

• Pilot design and preliminary HMB/economic modeling complete for testing purposes

• Pilot procurement near-complete, with testing start aimed for September 1st, 2021

• MREO Separation to pure lanthanides underway at RES with bench-materials
  – To be combined with bench and pilot production testing products
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Questions?

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