

GOVERNMENT BANKROLLS INITIAL EFFORTS TO EXTRACT RARE EARTHS FROM COAL WASTE

The Department of Energy is funding coal research that could help yield metals of critical military and strategic importance by 2020, but to do so must meet strict regulations and face entrenched Chinese competition

BY JESSE MORTON, TECHNICAL WRITER

The day may come when a coal miner processes waste and overburden to commercially produce rare earth elements (REEs) for domestic and foreign markets. If the government, a handful of academics, and some dedicated companies have anything to do with it, that day may arrive within a half-decade. Meanwhile, high in the Mohave desert, an idled open-pit mine stands testament to a different future. A researcher of the Molycorp Mountain Pass REEs mine bankruptcy says that government involvement in REEs extraction from coal amounts to little more than a political stunt, some well-meaning theater to benefit beleaguered energy sector players that once contributed to political campaigns. Both camps, however, acknowledge that if REEs can be economically produced from coal, then the black rock will suddenly be doing more than lighting the night. It might save America from a massive power grab by the totalitarian Chinese.

REEs are not particularly rare. With the right technology and systems in place, they could be a byproduct of a number of mines, to include those producing iron, uranium and phosphate. REEs are so known because while they may not be uncommon, they are often found in traces and, yearly, are produced in comparatively limited quantities globally. They are used in most modern computerized electronics. REE-based polymers make up the circuitry and electrical components of your in-cab computer, for example. And no matter where on Earth they are mined, those components are the product of a value chain owned almost exclusively by China. Specifically, two cities, Baotou and

Ganzho, are referred to as “rare earth cities,” where oxides are transformed into magnets, lasers, and alloys for circuits and chips.

For easy access to those parts, American companies set up or contract factories in China. Chinese companies then have easy access to American intellectual property to craft cheap knock-offs. Some within the U.S. government are increasingly concerned about a U.S. military entirely dependent on a value chain owned and located in China. Of equal concern should be America’s addiction to technology.

A scan of the daily headlines reveals a country headed toward automated everything, to include some aspects of government. If all things remain equal, that automated future will be brought to Americans by China. China has deep-seated totalitarian tendencies, to include automated blanket surveillance and censorship, and an emergent citizen digital rating system, where the government rates each citizen based on both public (and, soon, private) information. That rating can be referenced by employers, creditors, insurers, hospitals, educators and permitting bodies. When the Pentagon contracts for cruise missiles or fighter jets, it imports a bit of that. And when you equip your mine for Industry 4.0, you do too.

REEs in Coal

Coal is now proposed as one of the first stepping stones on the path to self-sufficiency regarding raw REEs supply. Indeed, bound in coal, alongside other elements, are some heavy REEs that have military and strategic applications. Various university studies reveal that, while

concentrations vary, both heavy and light REEs are found in coal mines around the country.

A white paper released this year by a team from Southern Illinois University titled *Chemical Extraction of Rare Earth Elements From Coal Ash* reported “14 coal samples of different coal ranks, from lignite to anthracite, originating from all over the country indicated a maximum coal ash REE content of more than 700 parts per million (ppm) for the highest rank coal sample.” Most of the REEs were light. “A maximum of 27% of (heavy) REEs was found in a low volatile bituminous coal sample.” Higher rank coals contain more of the heavy REEs, which see higher demand than the light elements. Acid leaching and solvent extraction tests revealed possible processes for recovery.

A paper by a team from the University of Kentucky released this year and titled *Process Evaluation and Flowsheet Development for the Recovery of Rare Earth Elements From Coal and Associated Byproducts* reported that samples from three operating coal processing plants revealed REE concentrations “from around 300 ppm to as high as 1,308 ppm on an ash basis. The values ranged from \$121 to \$315 per ton of feedstock[.]” An ultrafine particle concentrator raised that to 17,500 ppm, a ratio of 53:1. “The REEs contained in mixed-phased particles, also known as middlings, from the three coal seams were found to be effectively recovered by leaching using nitric acid at pH zero under atmospheric pressure and a solution temperature of 75°C,” the group reported. A recovery rate of 80% was reported “for middlings from the Fire Clay coal seam.” The group

arrived at a flowsheet for a processing facility to produce a REE oxide concentrate “from the waste streams of an existing coal preparation plant.”

A related group produced a paper this year titled *Concentration of Rare Earth Minerals From Coal by Froth Flotation* based on an SEM-EDX analysis of Fire Clay fine coal refuse. It reported, “Unliberated monazite particles with an REE content of around 60% were discovered having particle sizes less than two microns.” Flotation release analysis found heavy REEs “were likely associated with finely dispersed ash materials within the organic matrix. (M)aximum REE content occurred in particles with an ash content of around 80%.” The group recommended column flotation at a pH of nine and grinding for 60 minutes.

Such reports add to a growing body of knowledge on the possibility of profitable REE extraction from coal. Concurrently, the federal government observed, conducted its own research, and is increasingly putting skin in the game.

Government Involvement

Recently, the Department of Energy’s (DOE) National Energy Technology Laboratory (NETL) announced the results of multiple in-house projects centered on sampling and processing optimization.

One of the highlights was the successful development of a procedure to arrive at accurate concentration data. Conventional methods were assessed for determining the markers, overlays, and interferences that caused a couple of the elements, such as scandium, to be reported at inaccurate concentrations, Mary Anne Alvin, REE technology manager, NETL, said. “Depending on what laboratory you go to, you may get the same concentrations for cerium, lanthanum, gadolinium or other REEs plus or minus some variation,” she said. “NETL worked out a better set of procedures to be able to obtain the best concentration data relative to whatever your sample is.” Those procedures are available to researchers and miners on the NETL website.

A separate NETL project arrived at a REE recovery process for acid mine drainage. “External researchers are re-

covering nearly 100% of all the REEs,” Alvin said. “When you think about cleaning up or adding value to a waste product, extracting REEs out of acid mine drainage sludge, you’ve got to see that as a win.”

Currently, NETL is developing computational fluid dynamics modeling for REEs extraction from clays using ammonium sulfate, Alvin said. “You can design your reactor, change the parameters of your reactor, change your feed and process conditions,” she said. “And by doing this, you can save time and cost, ironing out many of the problems before you actually go into full design, construction and operation.”

NETL assigns its projects a technical readiness level, a score based on degree of development of the subject technology or process. “The fundamental work being done at NETL’s in-house research is more on the lower TRL levels, maybe two or three, possibly four,” she said. The DOE funding opportunities now available are for projects that would end at a five or six, she said.

In June, the DOE’s Office of Fossil Energy announced three funding opportunities for research into processing technologies potentially capable of producing salable REEs from coal, byproducts and waste. Targeted are REEs from the lanthanide series (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu), including scandium and yttrium, Jess Szymanski, DOE spokeswoman, said. “Of particular interest are the REEs that have been defined as critical elements: Nd, Eu, Tb, Dy and Y.”

Three grants valued at roughly \$1 million each are available to three corporate entities. Equinox Chemicals was selected to conduct lab testing and produce a technical design for a plant to process byproducts from an existing eastern Kentucky coal preparation plant. Inventure Renewables was selected to do the same using coal-related materials from an eastern Pennsylvania anthracite mine. Marshall Miller & Associates was selected to do the same with byproducts from a West Virginia coal preparation plant. Success brings increased competition for a possible second round of funding to further develop initial plans.

The focus is to validate the feasibility of prototype REE separation and extraction systems, Szymanski said. The goal is to have an operational plant within a couple of years. “Validation is to demonstrate production of 10 pounds per day of at least three rare earth elements, as oxides, that are present in concentrations that are 90%-99% pure,” she said. “After that, advancements and improvements in efficiency and optimization of either the equipment, technologies and/or overall systems will follow.”

Many of the technologies and systems are already established. Inventure Renewables, for example, will be using an ion exchange process that is based on the one used to separate uranium for the Manhattan Project. “What our partners have done is refine that process from a batch process to a continuous process,” Anthony Marchese, chairman, Texas Mineral Resources Corp. (TMR), said. TMR is part of the consortium that includes Inventure, K-Technologies and Penn State. “What it does is it saves a tremendous amount of time, and it is way more efficient to do it on a continuing basis rather than a batch process.”

TMR will process coal overburden into a purified liquid solution, which will serve as a feedstock for continuous ion exchange, continuous ion chromatography (CIX/CIC). The primary target is scandium. Currently, roughly 10 tons of scandium are produced globally per year. Commercial applications include laser crystals and minor aerospace components. “We will also target the REEs that have higher market values, which tend to be the magnet-related elements, things like dysprosium and neodymium,” Marchese said. “When we actually process it, we will determine which material we want to selectively extract.” Currently, TMR likes its prospects, he said. “We are using a process that has been tested over time,” Marchese said. “We are confident that if we can produce a purified liquid solution, we can separate it and extract the REEs.”

The Actinides Problem

At the same time Marchese was being interviewed for this article, the CEO of American Elements Corp., Michael Silver,

was lobbying the Trump administration to nationalize Mountain Pass, the shuttered open-pit REEs mine located roughly half way between Los Angeles and Las Vegas. The mine was once America's only potentially large-scale REEs mine. Silver said his goal is to turn the plant at the

mine into a national lab capable of processing ore from mines around the continent and by U.S. allies into REE oxides.

Once owned by Chevron, the mine was purchased in 2008 by a consortium spearheaded by Goldman Sachs that went to market as Molycorp. The latter

then systematically deceived the public before eventually filing for bankruptcy in 2015, according to James Kennedy, REEs sector consultant, former iron mine owner, and author of *Earths In Review - A Decade of Decline and Deception*. Kennedy is the subject of a new book, *Sellout: How Washington Gave Away America's Technological Soul and One Man's Fight to Bring it Home*. Coincidentally, last month, Mountain Pass passed to a consortium backed by China's Leshan Shenghe Rare Earth Shareholding Co. Rival bidder Tom Clarke, owner of ERP Strategic Minerals, said he will challenge the sale in court.

The reality that REEs supply is of national security and strategic importance is what fueled the wave of investors onboarding with Molycorp in 2007 and 2008, Kennedy reported. Molycorp promoted itself "as the best company to challenge China's monopoly." At the time, there were hundreds of REEs miners seeking startup money. Molycorp attracted investors like moths to a flame, Kennedy reported. "The financial, technology and defense press coverage verged on euphoric."

After being ranked as one of the year's top investments, reality set in. Ultimately, the mine contained only lower value REEs, Kennedy reported. "These facts were concealed from investors, Congress and the Pentagon by promoting an over-simplistic narrative," he reported. "Wall street and the Pentagon bet the bank on Molycorp." The company never produced or supplied heavy lanthanides or commercial quantities of yttrium oxide, he reported.

There are a number of reasons for the resulting bankruptcy, most having to do with the economics of processing REEs. For one, China owns the value chain, which likely cannot be reproduced stateside without a major government initiative. That is no accident, and China strategically manipulates the REEs markets to sink potential competitors, Kennedy said. Another reason is what Kennedy called the actinides problem. "That means your rare earths are tied up mineralogically with thorium and uranium," Kennedy said. "That material is classified as source material. Consequently, the liabilities associated



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with processing that make the material unrealistic.”

Liabilities means handling what is effectively nuclear waste in accords with the United States Nuclear Regulatory Commission's 10 CFR 40 Part 75, Safeguards on Nuclear Material. Due to it, heavy mineral sand miners “currently dispose of massive amounts of high-value heavy rare earths every single day on purpose,” Kennedy said. “The entire REEs supply and value chain was terminated worldwide because of this regulation. China picked up all the production because China is not a member of the NRC or the IAEA.”

Prior to the regulation, America's supply of REEs came from heavy mineral sands, phosphate or iron deposits, Kennedy said. “It was always this free byproduct from some other commodity,” he said. “When this 1980 regulation came along, the suppliers and end users realized that they had been dealing with source material for decades and that if somebody inquired about their historical disposal practices they may end up being a superfund site and being sued out of business.”

For this reason, Kennedy said he views the DOE's funding opportunity

as strictly political. “It reflects a legitimate desire of congressmen and senators in coal states to relieve some pain,” he said. “From an economic and a viability standpoint, it is unrealistic.” That is because concentrating REEs means concentrating actinides. “Coal-based rare earth extracts will also have a source material issue,” he said. “Why would a coal company that is already financially struggling take on a nuclear source material liability?”

Marchese, however, disagrees. “Not all REE deposits have radionuclides,” he said. “Based on the testing we've done of the coal overburden, the uranium and thorium are virtually undetectable.” TMR will design an environmentally responsible plant, he said. “The process is very efficient, with a minimal environmental footprint.”

Silver said not all REEs are mineralogically bound to actinides. “You're failing to mention the ionic clays in Southern China that are not radioactive” that contain heavy REEs, he said.

Currently, DOE is conducting research seeking to solve the actinides problem, Szymanski said. “DOE's research addresses the production and

management of waste products, like the potential generation of radioactive elements uranium and thorium.”

Making America Autonomous Again

Clearly, the stage is set for a hero to emerge. Somebody will arrive at a solution that starts to unwind China's global REEs value chain hegemony. It could come from a private/public partnership involving the DOE, academia and American coal miners. It might come from a nationalized processing lab. It might come from the Kennedy team's lobbying efforts for a multinational cooperative to root a REEs value chain stateside. The three camps are not mutually exclusive.


Whatever solution emerges, it will have to survive whatever China does in response, Kennedy said. China has demonstrated willingness to flood the market to bankrupt a competitor, he said.

Accordingly, the acquisition of Mountain Pass by a group backed by a Chinese firm appears to be either psychological warfare or an egregious purchasing error, Kennedy said. “I hope they like their desert real estate,” he said. “Good luck building condos there.”

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