POWERLINE NEWS

Fly Ash Residuals are a Strategic Mineral Resource

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Long considered an industrial byproduct with limited applications, coal fly ash is now emerging as a potential domestic source of rare earth elements (REEs)—critical materials essential to modern technologies ranging from smartphones to electric vehicles and advanced defense systems.

From Cement Additive to Strategic Resource

Fly ash, the fine particulate residue left after coal combustion, has traditionally been used as a supplementary cementitious material in concrete, enhancing strength and durability. It also finds use in bricks, tiles, and road base. Despite these applications, over 60% of the estimated 100 million tons of fly ash produced annually in the U.S. is still landfilled.

However, recent research by the U.S. Department of Energy (DOE) suggests that this industrial waste may hold untapped economic potential. The DOE estimates that millions of tons of rare earth elements—valued at over $50 billion domestically—could be recovered from coal ash across the country. This compares to the $13.5 billion dollar current global market for fly ash as a concrete additive

The Strategic Importance of REEs

Rare earth elements, a group of 17 chemically similar metals, are indispensable in the manufacture of high-performance magnets, batteries, lasers, and other advanced technologies. The REEs commonly found in coal byproducts include:

- Light REEs: Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Samarium (Sm)
- Heavy REEs: Gadolinium (Gd), Dysprosium (Dy), Terbium (Tb), Yttrium (Y), Europium (Eu)

Although these elements are called Rare Earth metals, they are relatively abundant in the Earth's crust. But, they are found in low concentrations making extraction difficult. Interestingly, the concentrations in fly ash—typically ranging from 300 to 1000 mg/kg—are comparable to those in some natural ore bodies.

Geographic Variability and Resource Mapping

The distribution of REEs >300 mg/kg in coal ash varies significantly by region:

- Northern Appalachian Basin: High concentrations of neodymium, dysprosium, and yttrium
- Central Appalachia: Rich in praseodymium, samarium, and gadolinium
- Rocky Mountains: Mixed REE profiles with moderate concentrations

This variability necessitates detailed geochemical mapping and site-specific extraction strategies.

DOE-Led Innovation in Extraction Technologies

To unlock this potential, the DOE has issued a report and launched multiple research initiatives and pilot projects. At its Battelle National Energy Technology Laboratory, researchers have demonstrated the feasibility of acid leaching—a hydrometallurgical process that uses sulfuric acid to dissolve REEs from fly ash. The process involves:

- Pre-treatment: Drying, grinding, and magnetic separation to remove iron oxides.
- Leaching: Application of acid to solubilize REEs and associated metals.
- Solid-liquid separation: Filtration or centrifugation to remove particulates.
- Solvent extraction or ion exchange: Selective separation of REEs from base metals.
- Precipitation and calcination: Conversion of REEs into oxides.

While aluminum is relatively easy to remove, zinc presents a challenge due to its chemical similarity to REEs and requires specialized extractants.

Technological Challenges

The DOE has pointed out that advanced methods of extraction will be needed to accomplish efficient and environmentally safe extraction. One promising technology aiding in REE purification is the VSEP (Vibratory Shear Enhanced Process) system developed by New Logic Research. VSEP uses acid-resistant nanofiltration (NF) membranes to purify sulfuric acid leach solutions, enabling:

- Purification and recycling of spent acid, reducing chemical consumption and spent acid storage
- Selective separation of REEs from interfering ions
- High suspended solids tolerance, due to vibratory shear of the membrane

For a Neodymium mining project in Australia, VSEP achieved over 90% recovery of REEs in just two NF filtration passes. The system's ability to handle high suspended solids makes it ideal for processing complex acid leach solutions from coal ash.

Toward a Domestic REE Supply Chain

The DOE has concluded that REE recovery from coal ash is economically viable and is supporting early-stage commercialization. Several universities and private enterprises are now working to scale these technologies, integrate AI for process optimization, and ensure environmental compliance. If successful, these efforts could transform coal ash from a waste liability into a strategic domestic resource, reducing U.S. dependence on foreign REE imports and strengthening national supply chains.

New Logic Research has been a trusted provider of filtration treatment solutions for the power industry since 1987. To explore how VSEP technology can support cleaner coal operations: VSEP Power. To speak directly with an experienced VSEP engineer: info@vsep.com