### Overview

#### Goal

Develop a bench-scale rare earth element (REE) extraction process for coal by-product materials utilizing a proprietary technology involving leaching processes and metal sorption media with the ability to process one kilogram batches and deliver a product meeting or exceeding DOE requirements

#### Objectives

- Identification/selection of coal by-product sources
- Develop leaching procedure for selected by-products*
- REE sequestration and recovery*
- Radioactive material separation*
- Waste water treatment for metal removal
- Scale-up of process to 1-kg coal by-product per batch

* These objectives have been successfully demonstrated at laboratory scale by Tusaar using other source materials.

### Technology

#### Background

- Rare earth elements (REEs) in a fly ash digest liquor. At pH 1.5, REEs separation is minimal while U/Th separation is maximized.

#### U/Th Removal

- Activated carbon media is modified by oxidizing agents and metal coordinating ligands to significantly increase metal sequestration
- Benzotriazole derivatives on the carbon surface coordinate specific metals at selective pH by forming a strong ion pair effectively removing target metal(s) from solution by displacing the original H⁺ and enhancing selectivity of metals
- Low pH disrupts the ion pair, altering the aromatic cloud which releases the paired metal into solution for removal and regeneration of media

### REE Concentration

Tusaar media eluent containing concentrated, well separated REEs during extraction of metals from ligand modified activated carbon surface.

### Coal By-Product Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Total REE+Y (ppm)</th>
<th>Thorium (ppm)</th>
<th>Uranium (ppm)</th>
<th>Outlook Ratio*</th>
<th>% Critical Elements</th>
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</table>

* Outlook Ratio of Total REE+Y and Thorium.