Coal Ash- Understanding a Valuable Commodity
NCC Annual Fall Meeting
October 4-5, 2016
Milwaukee, WI
RCRA 1976 – Energy Goal & Objective

- RCRA -42 U.S. Code § 6902 - Objectives and national policy
- Objective “The objectives of this chapter are to promote the protection of health and the environment and to conserve valuable material and energy resources by”... “providing technical and financial assistance to State and local governments and interstate agencies for the development of solid waste management plans (including resource recovery and resource conservation systems) which will promote improved solid waste management techniques (including more effective organizational arrangements), new and improved methods of collection, separation, and recovery of solid waste, and the environmentally safe disposal of non-recoverable residues;”
- “The Congress finds with respect to materials, that ... millions of tons of recoverable material which could be used are needlessly buried each year” and that “the recovery and conservation of such materials can reduce the dependence of the United States on foreign resources and reduce the deficit in its balance of payments.”
CCP Resource Recovery

• Coal Ash History Meets The Goal of RCRA- Best Resource Recovery Story - “Untold”

• 2014 Data - 129.7M Ton Produced; 62.4M Ton Utilized – 48%

• Resource Produced For Construction
  – Sand & Gravel - 914 Million Ton (up 7.5%%)
  – Cement - 89.1 Million Ton (up 9.1%)
  – Gypsum - 33.7 Million Ton (up 4.7%)
  – CCPs - 129.7 Million Ton (up 13% due to Scrubbers)

• Strategic Material Resource Value- REE
CCR Resource Impacts

• Regulatory Climate & E&P Tech Have Rapidly Changed The CCR Resource Markets

• Focus Today Is On Regulatory Impacts
  – MATS, MACT, CCR, ELG, CPP Etc.
  – 2015 & 2016 Hard Hit Years On Plant Closings
  – 60 GW Reduction By EOY 2016
  – 19.6 GW Announced For Shutdown by 2025
  – Compliance Costs & Methods Indirectly Reduce Ash Quality & Resource Recovery
Capacity Reductions Impact CCRs

- Total 310 GW Current Capacity
- 48-60 GW Closing - Primary MATS & MACT
  - Capacity Factor <45%
  - Units < 200MW
  - Av Age 54 Yr
  - Most w/o SO2 Controls
- Announced Unit Closing - 19.6 GW - CCR & ELG Regulation – Ash Volume 8M TPY Reduction

Source: EIA Annual Energy Outlook 2014 Reference Case and Annual Electric Generator Report
CCP Production & Use History

- CCP Production 129.6 MM Ton - Fly Ash, Bottom Ash & FGD
- Fly Ash & Bottom Ash Production Down - FGD Production Up
- Utilization Rebounding After Regulatory Clarity - Subtitle D
- EPA Support For Fly Ash In Concrete & Gypsum In Wallboard

SOURCE: American Coal Ash Association Production and Use Survey
Utilization of CCPs has increased during recessions, but dropped during a period of regulatory uncertainty.

Figure 2. Regulatory uncertainty led to a decline in CCP markets.

SOURCE: ARTBA CCP Production and Use Historical Analysis, 2015
Traditional Value Impacts & Uses

- CCP Value - $6-$14B/Year
- CCPs – 3%-New Home Costs- <½ $$ Of Replaced
- Cement-$80-$110
- Fly Ash- $20-$90
- Gypsum - $5-$35
- Life-cycle Costs Decrease w/ CCPs
- Highway Concrete Lifespan Extension

- Ready Mixed Concrete
- Wallboard
- Roofing Shingles
- Carpet Backing
- Lightweight Plastics
- Lightweight Aggregates
- Agriculture Sulfur Source
- Oil & Gas Drilling
Fly Ash Production & Use

- 2014 Fly Ash Use In Concrete – 13.1 M Ton vs. 12.3M Ton (6.5% Inc)
Bottom Ash Resource Use

• De-icing Skid Control
  ➢ Salt Replacement
  ➢ $5-$15 vs $50-$70

• Bottom Ash LWA
  ➢ Processed to replace LWA
  ➢ Typical Block - 35 – 38 lb
  ➢ Bottom Ash LWA Block – 28-32 lb
  ➢ Product priced in $15-$30/t
  ➢ Replaced product - $30-$50/t
  ➢ Avoids Mine Operation
  ➢ Avoids Kiln Operation
  ➢ Avoids Disposal
Gypsum Utilization

- Wallboard Manufacture
  - 50% Of Production
  - $1-$10/Ton

- Cement Manufacture
  - 5% Added to All Cement
  - Set Control
  - $1-$10/Ton

- Agriculture Application
  - Sulfur Nutrient Deficiency
  - Crops Consume 16-18 lb/ac
  - 90% Purity vs Mined @ 70-80%
  - $15-$35/Ton
FGD Gypsum Production & Use

• Half Of Wallboard Manufactured In US Utilized Recovered CCP Gypsum
2015 Projected CCP Production

- Coal Remains ~30% Fuel Mix – Announced Closings Equate To 5M TPY
- Production Volume & Reclaimed CCPs Offer Resources For Needs
- Certain Markets Impacted By Loss Of Plants Or CCP Quality

SOURCE: ARTBA CCP Production and Use Historical Analysis, 2015
Future Resource Applications

- Beneficiated Ash – Traditional Construction Markets
- Strategic Resource Applications-REE
  - REE Demand Within Green Energy & Technology Applications Continues
  - China Supplies 80%+ Of World Supply
  - Supply Concentration Has Caused Political Related Price Volatility- China 2010 Restrictions On Exports Caused Wild Increases Followed By Innovation And Price Collapse By 2012 – Honda 2016 – Magnets w/o REE @ 10% Cheaper & 8% Lighter
  - Long Term-Higher Demand – Supply Concentration Needs Solution- CCRs May Be One Option
# Rare Earth Elements

## 17 REE-15 Lanthanides – 2 Types

<table>
<thead>
<tr>
<th>Light REE (more Abundant)</th>
<th>Major End Use</th>
<th>Heavy REE (Less Abundant)</th>
<th>Major End Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lanthanum</td>
<td>Hybrid Eng, Metal Alloys</td>
<td>Terbium</td>
<td>Phosphos, Perm Magnets,</td>
</tr>
<tr>
<td>Cerium</td>
<td>Auto Catalyst, Petro Refining, Metal Alloys</td>
<td>Dyprosium</td>
<td>Perm Magnets, Hybrid Eng</td>
</tr>
<tr>
<td>Praseodymium</td>
<td>Magnets</td>
<td>Erbium</td>
<td>Phosphors</td>
</tr>
<tr>
<td>Noedymium</td>
<td>Catalyst, Petro Refining, Hard Drives, Hybrid Eng</td>
<td>Yttrium</td>
<td>Red Color, Fluorescent lamps, ceramics, metal alloy agent</td>
</tr>
<tr>
<td>Samarium</td>
<td>Magnets</td>
<td>Holmium</td>
<td>Glass coloring, lasers</td>
</tr>
<tr>
<td>Europium</td>
<td>TV &amp; Computer Screens</td>
<td>Thulium</td>
<td>Medical X-Ray Units</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lutetium</td>
<td>Catalyst in Petro Refining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ytterbium</td>
<td>Lasers, steel alloys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gladolinium</td>
<td>Magnets</td>
</tr>
</tbody>
</table>

**Use 500kg/kw capacity**

Source: DOI, USGS Circular 930-N
REE – Strategic-Political & Regulatory Risk

– DOE Research - Currently 10 Phase I Projects – 6 Bench Scale & 4 Pilot; Goal 4 Projects Advance
– Enriched REE Concentrations In Ash & Coals- 2X To 4X Crustal; Approach 60% Of Commercial Deposits (1,000 mg/kg)
– Access To Reserves Required For Both Traditional & Future Uses
– Policies & Regulations Must Provide Pathway To Access
– Regulatory Constraints On Access Need Alignment
## US DOE R&D Projects – December 2015

<table>
<thead>
<tr>
<th>Type of Project</th>
<th>Research Host</th>
<th>Location</th>
<th>Materials</th>
<th>Process</th>
<th>DOE ($000s)</th>
<th>Private ($000s)</th>
<th>Total ($000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Scale</td>
<td>University of Wyoming</td>
<td>Laramie, WY</td>
<td>PRB Coal Ash</td>
<td>CO2, FeChloride under Supercritical Conditions</td>
<td>660</td>
<td>221</td>
<td>881</td>
</tr>
<tr>
<td>Bench Scale</td>
<td>Duke University</td>
<td>Durham NC</td>
<td>Various CCB</td>
<td>Solvent Extract &amp; Membrane Filtration</td>
<td>720</td>
<td>183</td>
<td>903</td>
</tr>
<tr>
<td>Bench Scale</td>
<td>West VA University</td>
<td>Morgantown WV</td>
<td>NApp Coal Mine Drainage</td>
<td>Extraction from AMD &amp; AMD Sludges</td>
<td>750</td>
<td>201</td>
<td>951</td>
</tr>
<tr>
<td>Bench Scale</td>
<td>Neumann Systems Group</td>
<td>Colorado Sp, CO</td>
<td>PRB/E Bit &amp; Anthr Coal &amp; Ash</td>
<td>Supercritical CO2/Solvent &amp; Acid-Base Extr</td>
<td>750</td>
<td>237</td>
<td>987</td>
</tr>
<tr>
<td>Bench Scale</td>
<td>Batelle</td>
<td>Columbus OH</td>
<td>OH Coal &amp; Ash</td>
<td>Closed Loop Digestion</td>
<td>710</td>
<td>190</td>
<td>900</td>
</tr>
<tr>
<td>Bench Scale</td>
<td>University of North Dakota</td>
<td>Grand Forks, ND</td>
<td>ND Lignites &amp; Refuse</td>
<td>Separate, Extr &amp; Concentrate</td>
<td>749</td>
<td>188</td>
<td>937</td>
</tr>
<tr>
<td>Pilot Scale</td>
<td>University of KY</td>
<td>Lexington KY</td>
<td>Central App Prep Refuse</td>
<td>Qtr TPY Physical &amp; Chemical Seaparation</td>
<td>1,000</td>
<td>320</td>
<td>1320</td>
</tr>
<tr>
<td>Pilot Scale</td>
<td>Physical Sciences, Inc</td>
<td>Andover MA</td>
<td>Ash E KY Fire Clay &amp; Antracite Refuse</td>
<td>1-5 TPD Physical-Chemical Separation</td>
<td>999</td>
<td>251</td>
<td>1250</td>
</tr>
<tr>
<td>Pilot Scale</td>
<td>Southern Res Institute</td>
<td>Birmingham AL</td>
<td>Cent App &amp; E Bitum Coal</td>
<td>Plasma Based Testing on Ash</td>
<td>1,000</td>
<td>290</td>
<td>1290</td>
</tr>
<tr>
<td>Pilot Scale</td>
<td>Tusaar Inc</td>
<td>Lafayette, CO</td>
<td>KY &amp; OH Coal Ash</td>
<td>Extraction &amp; Metal Sorption</td>
<td>984</td>
<td>246</td>
<td>1230</td>
</tr>
</tbody>
</table>
Summary Impacts On CCP

• Coal Use Will Be Impacted By Cheap Natural Gas (Capacity Factor) & Regulatory Impacts (Closures)

• CCP Use As A Valued Resource Continues
  – Volumes Impacted In Certain Markets
  – Quality Impacted By Regulation
  – Beneficiation Technologies Applied To Reclaim
  – Reclaim Of Impoundment & Landfill Ash Ensures Long Term Availability With Beneficiation
  – Transportation Longer Distances Required
  – At 30% Of Fuel Mix – Volumes Meet Demands

• Future Uses Include REE Options
QUESTIONS
### 2014 ACAA CCP Survey Data

#### Beneficial Utilization versus Production Totals (Short Tons)

<table>
<thead>
<tr>
<th>2014 CCP Categories</th>
<th>Fly Ash</th>
<th>Bottom Ash</th>
<th>Boiler Slag</th>
<th>FGD Gypsum</th>
<th>FGD Material Wet Scrubbers</th>
<th>FGD Material Dry Scrubbers</th>
<th>FGD Other</th>
<th>FBC Ash</th>
<th>CCP Production / Utilization Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total CCPs Produced by Category</td>
<td>50,422,238</td>
<td>12,478,765</td>
<td>2,094,056</td>
<td>34,123,920</td>
<td>12,596,291</td>
<td>1,255,775</td>
<td>344,551</td>
<td>15,780,766</td>
<td>120,684,142</td>
</tr>
<tr>
<td>Total CCPs Used by Category</td>
<td>23,181,723</td>
<td>6,063,028</td>
<td>1,706,621</td>
<td>16,750,990</td>
<td>1,163,434</td>
<td>275,995</td>
<td>0</td>
<td>13,285,766</td>
<td>62,427,561</td>
</tr>
</tbody>
</table>

1. Concrete/Concrete Products/GROUT
   - 13,126,900
2. Blended Cement/Feed for Clinker
   - 3,391,272
3. Flowable Fill
   - 84,734
4. Structural Fills/Embankments
   - 2,855,515
5. Road Base/Sub-base
   - 365,856
6. Soil Modification/Stabilization
   - 176,112
7. Mineral Filler in Asphalt
   - 68,707
8. Snow and Ice Control
   - 0
9. Blasting Grout/Roofing Granules
   - 0
10. Mining Applications
    - 1,392,935
11. Gypsum Panel Products
    - 0
12. Waste Stabilization/Solidification
    - 279,323
13. Agriculture
    - 62
14. Aggregate
    - 0
15. Oil/Gas Field Services
    - 512,100
16. Miscellaneous/Other
    - 978,165

#### Summary Utilization to Production Rate

<table>
<thead>
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<th>FGD Other</th>
<th>FBC Ash</th>
<th>CCP Utilization Total</th>
</tr>
</thead>
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<tr>
<td>Totals by CCP Type/Application</td>
<td>23,181,723</td>
<td>6,063,028</td>
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Category Use to Production Rate (%): 48%

2014 Cemospheres Sold (Pounds): 4,662,561

Notes:
These are estimates for entire U.S. utility and IPP sectors calculated by dividing the survey respondents data by the portion of the overall industries coal burn they represent, as reported in the July 2015 EIA Electric Power Monthly (58%).

Charah