What are CUBs?

- **Coal Utilization Byproducts**
  - Includes Fly ash, Bottom ash, FGD solids
  - Many other acronyms: CCBs, CCPs, CCW, FFCW, CCR ...

- **Utilization includes:**
  - Combustion
  - Gasification & Hybrid systems

- **Byproducts because:**
  - $ from electricity sales >> $ from CUB sales
  - “Products” when sold or beneficially used
  - “Wastes” when sent to a permanent disposal site
  - Can still become “products” after disposal
### U.S. CUB Production and Use – 2004
(Data from American Coal Ash Association)

<table>
<thead>
<tr>
<th>2004</th>
<th>Fly Ash</th>
<th>Bottom Ash</th>
<th>FGD Gypsum</th>
<th>Other Wet FGD</th>
<th>Boiler Slag</th>
<th>Dry FGD</th>
<th>FBC Ash</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production (million tons)</td>
<td>70.8</td>
<td>17.2</td>
<td>12.0</td>
<td>17.5</td>
<td>2.2</td>
<td>1.8</td>
<td>0.9</td>
<td>122.5</td>
</tr>
<tr>
<td>Total Use (million tons)</td>
<td>28.1</td>
<td>8.2</td>
<td>9.0</td>
<td>1.2</td>
<td>2.0</td>
<td>0.2</td>
<td>0.5</td>
<td>49.1</td>
</tr>
<tr>
<td>Percent of production utilized</td>
<td>39.6%</td>
<td>47.4%</td>
<td>75.7%</td>
<td>6.8%</td>
<td>89.6%</td>
<td>9.7%</td>
<td>54.6%</td>
<td>40.1%</td>
</tr>
</tbody>
</table>

**Overall Utilization in 2004**: >40%
Near-term Goal for CUB Utilization

- Increase overall beneficial utilization of CUBs to 50% by 2010
  - Will require collaborative effort by Government & Industry
  - Must overcome economic, perceptual & regulatory barriers
Many Uses for Coal Utilization Byproducts

- Drywall
- Cement & Concrete
- Structural fill
- Bowling balls
- Wall paints
- Carpeting
- Synthetic tiles
- AMD control
- Soil amendments
Trends in Fly Ash Production & Use

Fly Ash Production
- Production (black diamonds)

Total Use
- Total Use (purple squares)

Disposal
- Disposal (yellow triangles)

Million tons

Years:
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004

U.S.-India Coal Working Group Meeting, November 18, 2005
Trends in Fly Ash Production & Use

Cement, concrete, grout
Structural fill
Waste stabilization & solidification
Raw feed for cement clinker
Mining applications
Road base & sub-base
Other
Trends in Bottom Ash Production & Use

Bottom Ash

- Production
- Total Use
- Disposal

Production, Total Use, and Disposal of Bottom Ash from 1996 to 2004.
Trends in Bottom Ash Production & Use

- Structural fill
- Cement, concrete, grout
- Other
- Soil modification
- Snow and ice control
- Raw feed for cement clinker
- Road base/subbase
Trends in FGD Byproduct Production & Use

FGD Byproducts

Million tons

- Production
- Total Use
- Disposal


NETL
Trends in FGD Byproduct Production & Use

- Wallboard
- Mining
- Structural fill
- Raw feed for cement clinker
- Cement, concrete
- Agriculture
- Other
### FGD Byproducts: Use by Type (2004)

#### FGD Gypsum
- **Wallboard**
- **Raw feed for cement clinker**
- **Cement, concrete, grout**
- **Disposal**

#### Other Wet FGD
- **Raw feed for cement clinker**
- **Structural fill**
- **Mining applications**
- **Agriculture**
- **Other**
- **Disposal**

#### Dry FGD
- **Cement, concrete, grout**
- **Flowable fill**
- **Mining applications**
- **Agriculture**
- **Aggregate**
- **Disposal**

#### FBC Ash
- **Structural fill**
- **Soil modification**
- **Mining applications**
- **Waste stabilization**
- **Other**
- **Disposal**
Multiple Benefits of Using CUBs

- **Environmental**
  - Reduced greenhouse gas emissions
    - 1 ton of fly ash as cement replacement = 0.8 tons of CO2 avoided
  - Reduced land disposal requirements

- **Economic**
  - Avoid disposal costs
  - Revenue from sale of byproducts

- **Performance**
  - Enhance physical and chemical characteristics, e.g., increased strength, improved workability
Barriers to CUB Utilization

- **Economic**
  - Transportation costs
  - Processing costs (carbon in fly ash)
  - Competing with other low-cost materials

- **Perceptual**
  - “Waste” stigma

- **Regulatory**
  - Uncertain status under RCRA; Variations in state regulations
  - New air emission regulations affect CUB amounts & characteristics
EPA Regulations Introduce Additional Challenges to CUB Utilization

• RCRA Subtitle D Rules (Landfills, impoundments)
• Minefill: is it Utilization or Disposal? (NAS Study)
• CAIR = More FGD Byproducts
  – Will wallboard market continue to absorb excess?
  – Can new large-volume markets be developed?
  • PRB coal = dry FGD (unsuitable for wallboard)
• CAIR = More Low-NOx burners, SCR, SNCR
  – Will additional carbon/NH₃ in fly ash disrupt or prevent expansion of current cement/concrete markets?
• CAMR: Additional Hg in CUBs
Coal Combustion Products Partnership (C²P²)

- Government-Industry partnership to promote the beneficial use of Coal Combustion Products (CCPs)
  - Led by U.S. EPA Office of Solid Waste
    - U.S. Agency Charter Members: DOE and FHWA
    - Industry: American Coal Ash Association, Utility Solid Waste Activities Group

- Major Activities
  - Awards program: “C²P² Partners”
  - Regional Workshops

- Website: http://www.epa.gov/c2p2/
CUB Reuse: Economics 101

- **Producer (Utility) Perspective:**
  - Recycling occurs when cost of reuse < Cost of disposal
    - In theory: new technology reduces cost of reuse
    - In practice: reuse becomes “economical” when disposal costs rise

- **User Perspective:**
  - Recycling occurs when cost of reuse < cost of alternative materials
    - Need specifications for reuse (not always available)
    - Need consistent supply and quality of material
    - Need support from material supplier
CUBs in Fossil Energy’s R&D Programs

**Clean Coal Technology & the President's Initiative**
DOE is implementing President Bush's $2 billion, 10-year initiative to develop an improved generation of coal-based electric power and pollution control technologies that will be environmentally superior to the technologies used in today's power plants. Read More > **Large-scale Demonstrations**

**Pollution Control Innovations for Today's Power Plants**
With the President's Clear Skies Initiative calling for major reductions in power plant air emissions, DOE is developing new pollution control technologies that can meet tighter standards without resulting in major cost increases for ratepayers. Read More > **Basic and Applied R&D (small scale)**
Program Implementation: National Energy Technology Laboratory (NETL)

- One of DOE’s 17 national labs
  - Government owned / operated
- Funding: DOE Office of Fossil Energy
  - Other Federal agencies & private collaborators
- Sites in PA, WV, OK, AK
- R&D Implementation
  - External contracts & grants
  - In-house research
Innovations for Existing Plants

Extramural Funding, FY03–05 ~ $49M

- Hg Control ~49%
- Air Quality ~16%
- NOx ~9%
- Water ~8%
- Other ~7%

- Hg Control: $24.4M
- Air Quality: $8.0M
- NOx: $4.5M
- Water: $3.9M
- Other: $3.5M
- CUB: $5.4M

Total Extramural Funding: $49M
CUB R&D Priorities: Environmental vs. Utilization
NETL IEP-CUB Funding, FY03-05

Environmental vs. Utilization

- Environmental ~63%
- Utilization ~34%
- Other ~3%

* Does not include In-house or CBRC Projects
Potential Impact of Power Plant Mercury Emission Regulations on CUBs

Fly Ash
- Loss of all reuse applications $\leq 908 \text{ M impact}$

FGD Solids
- Loss of all reuse applications $\leq 213 \text{ M impact}$

Hazardous designation of all by-products could cost more than $11 \text{ billion/year}$
Mercury Partitioning Across Coal Power Plants
(Annual Nationwide Estimates based on 1999 EPA ICR Data)

Typical Control Technologies

Sorbent Injection
Enhanced Scrubbing

Boiler
Particulate Control
FGD System

After Coal Cleaning

Pre-CAMR: ~75T Hg
Bottom Ash: ~5T Hg
Fly Ash: ~22T Hg
FGD Byproduct: ~73 T Hg

In 2018: ~94T Hg

Stack

15T Hg CAMR Phase II
48T Hg
Environmental Release of Hg from CUBs

**NETL Extramural R&D Projects**

- Complete list of projects and relevant reports can be found on the NETL CUB Web site:

<table>
<thead>
<tr>
<th>Project Title</th>
<th>Lead Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUB Analysis from ACI Mercury Control Field Testing</td>
<td>ADA-ES and Reaction Engineering</td>
</tr>
<tr>
<td>Characterization of Coal Combustion By-Products for the Re-Evolution of Hg into Ecosystems</td>
<td>CONSOL Energy</td>
</tr>
<tr>
<td>Hg and Air Toxics Element Impacts of Coal Combustion By-product Disposal and Utilization</td>
<td>UNDEERCE</td>
</tr>
<tr>
<td><strong>Fate of Hg in Synthetic Gypsum Used for Wallboard Production</strong></td>
<td>US Gypsum</td>
</tr>
<tr>
<td>Characterization of CUBs from Phase II Hg Control Field Testing</td>
<td>Frontier GeoSciences Inc.</td>
</tr>
</tbody>
</table>
Fate of Mercury in Synthetic Gypsum Used for Wallboard Production (USG Corp.)

- Measure mercury concentrations in solid, liquid, and gaseous streams at 3 operating wallboard manufacturing plants
Estimated Nationwide Hg Emissions from FGD-Wallboard Industry

- Based on ACAA 2004 CCP Production and Use Survey
  - 8,148,078 Tons of FGD Gypsum Used in Wallboard Production

<table>
<thead>
<tr>
<th>Task</th>
<th>Mercury Emitted in grams per ton of dry gypsum processed</th>
<th>Estimated Industry Release (pounds/yr) based on Task results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant A (w/SCR)</td>
<td>0.045</td>
<td>808.49</td>
</tr>
<tr>
<td>Plant A (w/o SCR)</td>
<td>0.083</td>
<td>1491.22</td>
</tr>
<tr>
<td>Plant B</td>
<td>0.09</td>
<td>1616.99</td>
</tr>
<tr>
<td>Plant C</td>
<td>Below</td>
<td>Below</td>
</tr>
</tbody>
</table>
NETL In-House Research: Hg Release from CUB

- Determine the stability of Hg and other metals in CUB under simulated end-use environments
- Explain the chemistry underlying metal stability
- Preliminary Results:
  - All Hg in FGD gypsum remains in iron-rich residues
  - Iron-containing phase, probably introduced to FGD via limestone, is responsible for Hg sorption & retention in disposal environments
Utilization Research: Combustion Byproducts Recycling Consortium (CBRC)

- Cooperative Agreement with West Virginia University (1999 – 2007) under IEP Program
- Proposals are reviewed and selected by regional and national technical committees
  - Industry, academia, state and Federal gov’ts
- 42 projects since 1999; wide variety of topics
  - Total project funding: $10.75M
    - DOE - $5.97M; Cost share - $4.78M

Website: http://wvwri.nrcce.wvu.edu/CBRC/
Clean Coal Technology Demonstration Projects

- **Manufacture of Lightweight Aggregates Using Spray Dryer Ash**
  - Awarded in November 2002 to Universal Aggregates, LLC
  - Total project funding: $19.58M
    - DOE - $7.22M; Cost share - $12.36M

- **Multi-product CUB Processing Plant**
  - Awarded in November 2004 to University of Kentucky Research Foundation
  - Total project funding: $8.98M
    - DOE - $4.48M; Cost share - $4.50M
 Manufacture of Lightweight Aggregates Using Spray Dryer Ash

Flue gas from boiler → Spray Dryer → FGD Sorbent Ca(OH)₂ → ESP or FF → Stack

Fly ash + FGD byproduct
Spray Dryer Ash
Manufacture of Lightweight Aggregates Using Spray Dryer Ash

- 115,000 tpy ash → 167,000 tpy aggregates
- Aggregate properties tailored toward end-use markets
- Operation began in Spring 2004

Birchwood Power Partners
King George County, VA
Multi-product CUB Processing Plant

- Uses fly & bottom ash from disposal ponds at Ghent Power Station, Ghent, KY

- Hydraulic classification & froth flotation used to create multiple products:
  - Pozzolan for Portland cement replacement
  - Lightweight aggregate
  - Graded sand = construction fill
  - Unburned carbon = supplemental boiler fuel
  - Ultrafine spheres = polymer filler

- Startup: scheduled October 2007
For More Information

- DOE Office of Fossil Energy: Coal & Natural Gas Electric Power Systems
  - http://fossil.energy.gov/programs/powersystems/
- DOE-FE Innovations for Existing Plants Program
- DOE-FE Clean Coal Power Initiative
  - http://www.netl.doe.gov/coal/CCPI/
- Coal Combustion Products Partnership (C²P²)
  - http://www.epa.gov/c2p2/
- Combustion Byproducts Recycling Consortium
  - http://wvwri.nrcce.wvu.edu/CBRC/