The Value of Coal Combustion Products:  
An Economic Assessment of CCP Utilization for the U.S. Economy  

Revised Second Edition  

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Prepared by  
John Ward Inc.  

American Coal Council  
1101 Pennsylvania Ave., NW, Ste. 600  
Washington, DC  20004  
202-756-4540  
www.americancoalcouncil.org ~ info@americancoalcouncil.org
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Executive Summary

Coal Combustion Products (CCPs) – including fly ash, bottom ash, and flue gas desulfurization (FGD) material – represent a strategic resource for the United States that has been steadily growing in utilization since the 1950s.

CCPs are produced during the generation of electricity at coal-fueled power plants. In 2008, 136.1 million tons of CCPs were produced in the United State – of which 44.5% was utilized in a beneficial manner. The largest portion was fly ash, accounting for 72.5 million tons, 41.6% of which was beneficially used.

This study identifies the following annual economic benefits from the utilization of these materials as an alternative to disposing of them as waste:

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues from the Sale of CCPs for Utilization</td>
<td>$1,028,761,000</td>
</tr>
<tr>
<td>Avoided Costs of Disposal</td>
<td>$412,800,000</td>
</tr>
<tr>
<td>Savings from Use as Sustainable Building Materials</td>
<td>$5,000,000,000 to $10,000,000,000</td>
</tr>
</tbody>
</table>

Total Economic Impact: $6.4 billion to $11.4 billion

Utilization of CCPs also creates significant benefits in the form of improved performance for products incorporating them.

Utilization of CCPs also creates significant annual environmental benefits such as the reduction in energy consumption commensurate with the energy consumed by 1.7 million homes, water savings equal to 31% of the annual domestic water use in California, and reductions in greenhouse gas emissions comparable to removing 2 million automobiles from the roadway.

The remainder of this study discusses the history, characteristics, production and handling of coal combustion products. It includes descriptions of the myriad beneficial uses and product standards for the materials.

Finally, this study discusses the outlook for future utilization of this resource based on emerging technology and regulatory factors that could help – or harm – one of the nation’s largest recycling success stories.
Section 1 - Introduction

Coal Combustion Products (CCP) use gradually evolved into a multi-billion dollar industry in the United States without fanfare as the result of regulatory, technical and market-based developments. Whether the industry will continue to grow is a function of how well those three legs of the stool remain balanced.

In 2005, the American Coal Council published the first detailed analysis of the economic scope of the coal ash industry. That 128-page report was a snapshot of the coal ash industry largely based on 2003 data concerning the production and use of fly ash, bottom ash, boiler slag and synthetic FGD gypsum. The study identified more than $2.2 billion in annual direct economic impact from the use of these products in a variety of construction and manufacturing applications, as well as a total economic impact of nearly $4.5 billion annually.

This publication is an updated and expanded version of that report, incorporating the most up-to-date production and use statistics for 2007 and 2008 and featuring expanded analysis of how the coal ash industry got to where it is and what the future may have in store.

The first uses of coal ash as a construction material occurred in the United States beginning in the 1940s. Engineers with the U.S. Bureau of Reclamation were seeking a way to mitigate the heat of hydrating cement in mass concrete placements such as dams. Construction of the Hungry Horse Dam in Montana beginning in 1948 utilized 120,000 tons of coal fly ash. Six more dams utilizing coal fly ash were built during the 1950s.

Increasing environmental regulations in the 1960s, culminating with the Clean Air Act of 1970, forced electric utilities to begin collecting substantially all of the fly ash produced by coal combustion. Utilities initially moved to dispose of substantially all of the ash, but drawing on the Bureau of Reclamation’s experience, an ash marketing industry emerged to begin utilizing the resource for construction materials. The National Ash Association – forerunner of the current American Coal Ash Association – was organized in 1968.

Over the four decades commencing in 1966, utilization of coal ash increased steadily. Utilization increases have been attributed to advances in technological knowhow, education of users and specifiers of construction materials, and development of logistics resources to deliver materials to markets.
Utilization rates of coal ash increased more dramatically beginning in 2000. That year, the U.S. Environmental Protection Agency issued its Final Regulatory Determination that coal ash did not warrant regulation as a hazardous waste, concluding more than 20 years of study and prior rulings on the topic. Since that Final Determination was issued in 2000, utilization rates for coal ash have increased from 30% to 43% – a growth rate made even more impressive by a steadily increasing volume of coal ash supply.

The industry’s ability to continue increasing the amount of coal ash used beneficially as an alternative to disposal may not be assured, however. New technical and regulatory developments are serving to both encourage and potentially discourage utilization.

Technically, the coal ash universe is expanding as never before. In the early days of coal ash industry history, the technical focus was largely on demonstrating the material’s usefulness as a component of construction materials and on establishing standards for its composition. Today, coal ash users are exploring techniques for utilizing increasingly higher quantities of ash. Meanwhile, a new industry segment has emerged to supply technologies to coal ash producers to help them improve and maintain the quality of material bound for utilization.

On the regulatory front, a mixed bag of incentives and disincentives may be facing the industry. On the plus side, national climate change legislation is expected to establish ambitious targets for reducing greenhouse gas emissions. Utilization of coal fly ash as a partial replacement for cement in producing concrete is an important contributor to this goal. More than 15 million tons of carbon dioxide emissions from cement production were avoided in 2007 alone through the use of coal ash.

On the negative side, however, the EPA has indicated that it may rescind its Final Regulatory Determination of 2000 and seek to regulate coal ash as a hazardous waste when disposed. Although EPA has indicated that it intends to continue supporting beneficial uses of coal ash such as fly ash in concrete, the mixed regulatory signals – hazardous for disposal, but not hazardous for use in concrete in your neighborhood – could seriously harm continued utilization of the resource.

Terminology

The term “Coal Combustion Products” or “CCP” is used throughout this report to refer to the class of materials produced when burning coal, chiefly for the purpose of generating electricity. Often referred to generically in the news media as “coal ash,” these materials do include fly ash and bottom ash. But CCP also refers to non-ash products of combustion, including boiler slag and the output of Flue Gas Desulphurization equipment used to control emissions.

In addition to the generic term “coal ash,” CCP is sometimes referred to by other terms. “Coal Combustion Wastes” (CCW) and “Coal Combustion Byproducts” (CCB) are two terms that occur frequently in historical records of the CCP industry and remain in use by some government agencies. Also, personnel of the U.S. Environmental Protection Agency have recently begun referring to the materials as “Coal Combustion Residues” (CCR) in documents related to development of new disposal regulations.¹

However, U.S. EPA continues to refer to the materials as Coal Combustion Products in the agency’s Coal Combustion Products Partnership (C2P2) program, which was created to encourage increased utilization as an alternative to disposal. Inasmuch as the utilization of CCP is the prime focus of this report, the CCP terminology is adopted throughout.

Data Sources

This report utilized data from numerous sources, most of which are footnoted at the appropriate section of the report. Key data sources include:

- U.S. Department of Energy, Energy Information Administration
- U.S. Environmental Protection Agency
- U.S. Department of Transportation, Federal Highway Administration
- American Coal Ash Association
- Electric Power Research Institute
- Portland Cement Association

Baseline data for the 2005 edition was largely obtained from EIA 767 annual reports for 2001, 2002 and 2003. The Energy Information Administration has since terminated the Form EIA-767. Beginning with calendar year 2007 data, two other surveys, the Form EIA-860 (Annual Electric Generator Report) and the Form EIA-923 (Power Plant Operations Report), began collecting most of the data formerly collected on the Form EIA-767. The New Form EIA-923 combined:

Form EIA-906 - Power Plant Report
Form EIA-920 - Combined Heat and Power Plant Report
Form EIA-423 - Monthly Cost and Quality of Fuels for Electric Plants
FERC Form 423 - Monthly Report of Cost and Quality of Fuels for Electric Plants
Form EIA-767 - Steam-Electric Plant Operation and Design Report

Utility CCP Revenues – Obtained from EIA 767 annual reports for 2001, 2002 and 2003 and from EIA 923 annual report for 2007. No assumptions were made for revenues; actual reported values were utilized. Revenues reported as “Fly Ash / Bottom Ash Intermingled Revenues” were proportionately distributed to the fly ash and bottom ash categories.
Section 2 – Coal Overview

Uses and Forecast

Coal is the largest energy source for producing electricity in the United States, accounting for 48.5% of electricity generated in 2007.\(^2\) Despite increasing concerns over coal’s environmental characteristics, the resource is expected to continue to fuel a significant portion of America’s electricity generation for decades to come. The U.S. Department of Energy predicts that over the next 20 years only a modest decrease in coal’s share of electricity generation will occur – from 48.5% in 2007 to 47% in 2030. Meanwhile, the amount of coal consumed is expected to increase because of the rising demand for electricity. Total electricity generation at coal-fueled power plants in 2030 is expected to be 19% higher than the 2007 total.\(^3\)

Total U.S. consumption of coal in 2007 was 1,128.0 million short tons.\(^4\) Most of that coal – 1,045.1 million tons – was used to generate electricity. The remainder was used to produce coke for steel making or in other industrial plants such as cement kilns and pulp and paper mills. Imported coal accounts for a small portion of total U.S. consumption, approximately 36 million tons.

Coal Types

Coal is classified into four main types, or ranks (lignite, sub-bituminous, bituminous, anthracite), depending on the amounts and types of carbon it contains and on the amount of heat energy it

---
\(^1\) U.S. Energy Information Administration, *Electric Power Annual 2007*
\(^2\) U.S. Energy Information Administration, *Electric Power Annual 2007*
\(^3\) U.S. Energy Information Administration, *Annual Energy Outlook 2009 with Projections to 2030*
\(^4\) U.S. Energy Information Administration, *Annual Coal Report 2007*
can produce.\(^5\) The rank of a deposit of coal depends on the pressure and heat acting on plant debris as it sank over millions of years during the coal’s formation. For the most part, the higher ranks of coal contain more heat-producing energy.

- **Lignite** is the lowest rank of coal with the lowest energy content (between 6,300 Btu/pound and 8,300 Btu/pound.) Lignite coal deposits tend to be relatively young coal deposits that were not subjected to extreme heat or pressure. Lignite is crumbly and has high moisture content. There are 20 lignite mines in the United States, producing about 7% of U.S. coal. Most lignite is mined in Texas and North Dakota. Lignite is mainly burned at power plants to generate electricity.

- **Sub-bituminous** coal has a higher heating value than lignite (between 8,300 Btu/lb and 11,500 Btu/pound.) Sub-bituminous coal typically contains 35-45% carbon, compared to 25-35% for lignite. Most sub-bituminous coal in the U.S. is at least 100 million years old. About 44% of the coal produced in the United States is sub-bituminous. Most of that coal is located in the Powder River Basin (PRB) of Wyoming and Montana.

- **Bituminous coal** contains 45-86% carbon, and has heating value higher than lignite (between 10,500 Btu/pound and 14,000 Btu/pound.) Bituminous coal was formed under high heat and pressure. Bituminous coal in the United States is between 100 to 300 million years old. It is the most abundant rank of coal found in the United States, accounting for about half of U.S. coal production. Bituminous coal is used to generate electricity and is an important fuel and raw material for the steel and iron industries. West Virginia, Kentucky, and Pennsylvania are the largest producers of bituminous coal.

- **Anthracite** contains 86-97% carbon, and has a heating value slightly lower than some bituminous coal (approximately 13,500 Btu/pound.) Anthracite production accounts for less than one-half of a percent of the coal mined in the United States. The majority of anthracite is produced in the northeastern U.S. and is most commonly used as metallurgical coal.

In addition to the four noted classes of coal, some energy plants burn waste coal fuels, commonly known as culm and gob. Culm and gob are not naturally occurring coals, but are mining wastes from coal-cleaning activities. However culm and gob may contain significantly high amounts of coal which make them desirable for certain types of combustion. Culm is waste or rejects generated from the processing of bituminous coal at the mine or tipple. Gob is the waste or rejects generated from the processing of bituminous coal or anthracite at the tipple or a coal preparation plant. Both culm and gob are high in ash content (45 – 70%), and low in heating values (between 2,500 Btu/pound and 6,500 Btu/pound.) If used for producing energy, most culm and gob are combusted in fluidized bed combustion (FBC) boilers.

**Production Regions**

Coal is produced in three main regions of the United States:

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\(^5\) U.S. Energy Information Administration, *Energy Facts* publication
Appalachian Coal Region:
- More than one-third of the coal produced in the U.S. is produced in the Appalachian Coal Region.
- West Virginia is the largest coal-producing state in the region, and the second largest coal-producing state in the U.S.
- Large underground mines and small surface mines.
- Coal mined in the Appalachian coal region is primarily used for steam generation for electricity, metal production, and for export.

Interior Coal Region:
- Texas is the largest coal producer in the Interior Coal Region, accounting for almost one-third of the region’s coal production.
- Mid-sized surface mines.
- Mid- to large-sized companies.

Western Coal Region:
- Over half of the coal produced in the U.S. is produced in the Western Coal Region.
- Wyoming is the largest regional coal producer, as well as the largest coal-producing state in the nation.
- Large surface mines.
- Some of the largest coal mines in the world.

Figure ESL. Coal Production by Coal Producing Region, 2007
(Million Short Tons and Percent Change from 2006)
Regional totals do not include refuse recovery
U.S. Total: 1.146.6 Million Short Tons (+1.4%)

Section 3 – Coal Combustion Products Overview

CCP Types

CCPs are engineering materials that are similar in use to virgin, processed and manufactured materials. CCPs are the residuals produced from the combustion of coal.

Ash is the non-combustible mineral portion of coal. Purchasers of coal typically specify the maximum percentage of ash that will be allowed in delivered coal. After the coal is combusted, the residual ash must be collected and either disposed or used for a beneficial purpose. Ash content varies from one coal source to another independent of coal rank. Higher rank coals typically contain higher percentages of ash at the mine mouth, but are often “washed” to reduce ash content prior to delivery to utilities. Post combustion ash takes the form of:

- **Fly Ash** - ash that exits a combustion chamber in the flue gas and is captured by air pollution control equipment, such as electrostatic precipitators (ESPs), baghouses and wet scrubbers. Fly ash is the consistency of powder and is typically a pozzolan. A pozzolan is defined as “Siliceous or siliceous and aluminous materials that in themselves possess little or no cementitious value but will, in finely divided form and in the presence of water, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.”

Concrete-quality fly ash is classified into two types as outlined below.

- **Class C Fly Ash** - fly ash, which meets criteria defined in ASTM C 618, for use in concrete. Specifically, the combined total of Silicon Dioxide, Iron Oxide and Aluminum Oxide is higher than 50% for a Class C designation. Most Class C fly ash is derived from sub-bituminous coal. It is often brown or tan in color. Some Class C fly ashes also exhibit self-hardening properties in the presence of moisture.

- **Class F Fly Ash** - fly ash, which meets criteria defined in ASTM C 618, for use in concrete. Specifically, the combined total of Silicon Dioxide, Iron Oxide and Aluminum Oxide is higher than 70% for a Class F designation. Most Class F fly ash is derived from bituminous and lignite coals. It is normally gray or black in color.

- **Bottom Ash** - agglomerated ash particles formed in pulverized coal furnaces that are too large to be carried in the flue gases and impinge on the furnace walls or fall through open grates to an ash hopper at the bottom of the furnace. Bottom ash is typically grey to black in color, is quite angular and has a porous surface structure. Bottom ash is used as an aggregate, as feed stock for cement manufacturing or in construction applications in lieu of other constituents (such as sand and gravel).

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7 U.S. Office of Surface Mining
In addition to ash, other solid residuals may be produced during the coal combustion process. These include:

- **Boiler Slag** - a molten ash collected at the base of slag tap and cyclone furnaces that is quenched with water and shatters into black, angular particles having a smooth, glassy appearance. Boiler slag is in high demand for beneficial use (blasting grit, roofing granules, etc.), but supplies are decreasing because of the retirement from service of aging power plants that produce boiler slag.

- **FGD material** – a product of a flue gas desulphurization process typically using a high-calcium sorbent, such as lime or limestone. Sodium-based sorbent and high-calcium coal fly ashes are also used in some FGD systems. The physical nature of these materials varies from a wet thixotropic sludge to a dry powdered material, depending on the process.

  Wet thixotropic sludge is usually produced from a lime-based reagent wet scrubbing process and is predominantly calcium sulfite. It is the end product of dewatering equipment, such as vacuum filters or centrifuges, although it can be the end product of a sedimentation pond. This dewatered end product is usually stabilized by mixing it with lime and fly ash or other materials for disposal in landfills. (There are systems where the end product is not dewatered but is highly concentrated in solids as the underflow from a thickener. It is then mixed with fly ash and another material and pumped to a surface impoundment for disposal.)

  The wet product from a limestone-based reagent wet scrubbing processes is predominantly calcium sulfate, which is gypsum. This material readily dewatered and there are systems in use where the slurry is transported to a pond and construction equipment is used to excavate and stockpile the gypsum.

  The production of commercial grade FGD gypsum used for wallboard manufacturing usually requires forced oxidation either in or external to the scrubbers, followed by dewatering with filtration equipment such as vacuum filters or centrifuges and placement in sedimentation ponds. The dry material from dry scrubbers that is captured in a baghouse along with fly ash consists of a mixture of sulfites and sulfates. This powdered material is referred to as dry FGD ash, dry FGD Material, lime spray dryer ash, lime spray dryer or lime spray dryer residue.
CCP Chemical Characteristics

The relative concentrations of the various chemical compounds found in CCPs vary considerably. Factors affecting the concentrations of the various chemical compounds are coal type and source, coal preparation processes, boiler design and combustion conditions, collection and handling methods, and the characteristics of any additives. Thus, while the general nature of a given source of CCPs will be known, specific characteristics will vary from source to source as well as over time from a single source. This situation is analogous to changes in other common engineering and manufacturing materials, such as sand, gravel and portland cement, which also vary from source to source and over time at a given source.

Ash is comprised largely of silicon, aluminum, iron, oxygen and calcium, together with smaller quantities of magnesium, titanium, potassium, phosphorus, sulfur and alkali compounds. These ash-forming constituents consist of inherent impurities that are present in the coal and are derived either from the original organic material or from an external source of sediments.

Impurities in the coal can also occur through the mining process by taking fragments of the roof or bottom of the coal seam with the coal. The aluminum, silicon and titanium oxides are derived from external sources such as sand, clay and shale. The iron oxide is derived mainly from iron pyrites and the calcium and magnesium from carbonates and sulfates.

The ash resulting from the combustion of the coal weighs less than the inorganic matter from which it is produced because of the loss of volatile constituents and other changes during the combustion process. For example, carbon dioxide is released when the carbonates are decomposed and sulfur dioxide is released when the iron pyrite decomposes to ferric oxide.

A portion of the fly ash is comprised of hollow, gas-filled, glassy microspheres called cenospheres. Cenospheres are formed when CO₂ and N₂ fill the semi-molten material in the coal-fueled boiler. Cenospheres are usually less than 1% of the total mass of CCPs produced. They are generally gray-to-buff in color and are comprised primarily of silica and alumina. They resemble fine sand in grain size and will usually float on water. Cenospheres float to the surface of ash ponds and are gathered by skimming. They can be very valuable as fillers for use in the manufacture of paints, plastics, ceramics, adhesives and metal alloys. The light weight and small size of cenospheres also provide excellent insulating properties.
Fly ash is a solid, inert material. A microscopic view of fly ash particles shows that it is a spherical, fused material, similar in size to portland cement and lime.

An elemental analysis of bituminous fly ash shows that it is very similar to clay soils found in the eastern United States. Both fly ash and clay soils primarily consist of silicon dioxide, aluminum oxide and iron oxide. Both materials also contain trace amounts of other metallic oxides.

**TYPICAL ELEMENTAL ANALYSIS**

*Conventional Fly Ash & Typical Clay Soil*

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>FLY ASH</th>
<th>SOIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO2</td>
<td>46</td>
<td>42</td>
</tr>
<tr>
<td>Al2O3</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>CaO</td>
<td>3.8</td>
<td>2.8</td>
</tr>
<tr>
<td>SO3</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>K2O</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>TiO2</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>MgO</td>
<td>1.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Na2O</td>
<td>0.6</td>
<td>1.8</td>
</tr>
<tr>
<td>P2O5</td>
<td>0.3</td>
<td>2.1</td>
</tr>
</tbody>
</table>

American Coal Ash Association, Innovative Applications of Coal Combustion Products (CCPs); 1998
CCP Quality

Quality requirements for CCPs vary depending on the intended use. CCP quality is affected by fuel characteristics, boiler type, generation characteristics for the generation facility (base loaded versus load following) and various aspects of the combustion and flue gas cleaning/collection processes. CCPs must pass a battery of tests to qualify for use in various applications. Among the types of tests administered:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Physical</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Leachate Analysis</td>
<td>2. Fineness - % passing No. 325 sieve</td>
</tr>
<tr>
<td>3. pH</td>
<td>3. Specific Gravity</td>
</tr>
<tr>
<td>4. Loss on Ignition</td>
<td>4. Moisture Content</td>
</tr>
<tr>
<td>5. Flash Point</td>
<td>5. Particle Shape and Texture</td>
</tr>
<tr>
<td>6. Oil and Grease Solids</td>
<td></td>
</tr>
<tr>
<td>7. % Volatile Solids</td>
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</tr>
<tr>
<td>8. Corrosivity</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineering</th>
<th>Stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Compaction</td>
<td>1. Compressive Strength</td>
</tr>
<tr>
<td>2. Shear Strength</td>
<td>2. Durability</td>
</tr>
<tr>
<td>3. Compressibility</td>
<td>3. Permeability</td>
</tr>
<tr>
<td>4. Permeability</td>
<td>4. Age Hardening</td>
</tr>
<tr>
<td>5. Pozzolanic Activity</td>
<td></td>
</tr>
<tr>
<td>6. Age Hardening</td>
<td></td>
</tr>
<tr>
<td>7. Bulk Density</td>
<td></td>
</tr>
<tr>
<td>8. California Bearing Ratio</td>
<td></td>
</tr>
</tbody>
</table>

Variations in Ash Produced  Variations in Storage
1. Within a Unit               1. Dry Storage/Stockpile
2. Between Units               2. Wet

One of the key issues with concrete quality fly ash is the carbon content as measured by the Loss on Ignition test (LOI). High carbon contents cause problems with organic air entrainment agents used to protect the finished concrete from damage caused by freeze-thaw cycles. Excessive or variable LOI renders the air entrainment agents ineffective and generally takes the fly ash out of the high value concrete market.

Gypsum quality is another area that affects the market value. Wallboard manufacturers generally are very strict in the gypsum content, 98% to 99% pure, moisture content, and the chloride content of the synthetic gypsum. The latter item causes problems with the delamination of the paper from the gypsum cake.
**CCP Toxicity**

The following table details typical results from the testing of leachate from fly ash. Comparing concentrations of various parameters in fly ash leachate to the hazardous waste regulatory limits and drinking water standards, it is clear that CCPs are not hazardous materials. In almost all cases, leachate from fly ash meets or is near drinking water standards.

### Typical Toxic Characteristic Leaching Procedure (TCLP) Analysis of Fly Ash

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>0.01</td>
<td>5.0</td>
<td>0.05</td>
</tr>
<tr>
<td>Barium</td>
<td>5.2</td>
<td>100.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.002</td>
<td>1.0</td>
<td>0.01</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.005</td>
<td>5.0</td>
<td>0.05</td>
</tr>
<tr>
<td>Lead</td>
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Source: ACAA; Innovative Applications of Coal Combustion Products (CCPs); 1998

Data compiled in 2009 by the Electric Power Research Institute (EPRI) provides a more detailed view of CCP composition and toxicity. Data was collected comparing total composition of coal ash and gypsum to soil and rock, foundry sands, metal slags, fertilizer, and biosolids.

EPRI’s data shows that the general composition of fly ash is very similar to geologic materials, particularly volcanic rock and shale.

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8 Ladwig, Ken; *Sustainable Management of Coal Combustion Products - Recent EPRI Research*; October 16, 2009
Trace elements contained in coal ash collectively comprise less than 1% of the total volume of the material. Most trace constituent concentration ranges are on the high end of the ranges for rocks, suggesting slight enrichment. Arsenic was always higher in fly ash. Other trace constituents that tended to be higher in fly ash were antimony, beryllium, and boron.
In the case of FGD gypsum produced by power plant scrubbers, most trace constituents are within or below the levels found with mined rock gypsum.

**Total Composition of Trace Constituents in FGD Gypsum Compared to Mined Gypsum**

The mere presence of trace constituents in any material does not indicate toxicity. Trace constituents must have a pathway out of the material to create potential for human exposure. For most trace constituents in CCPs, only a small fraction of the total composition is leachable. CCPs rarely fail the Toxic Characteristic Leaching Procedure hazardous waste leaching criteria.

**Coal Ash Leachate Compared to Hazardous Waste Regulatory Limits**

Data Sources: USGS, 2008; EPRI, 2009
In preparing this leachate data during 2009, the Electric Power Research Institute collected 80 fly ash samples from 33 power plants. None of the samples exceeded federal hazardous waste test (TCLP) limits. (To provide perspective on this sample size, in launching a major revision of Steam Electric Power Generating Effluent Guidelines in 2009, the U.S. Environmental Protection Agency collected and analyzed samples to characterize wastewater streams at six coal-fueled power plants.9)

The EPRI testing also demonstrated that coal fly ash leachate is very similar to other non-hazardous wastes from industries with largely inorganic wastes. Ranges for non-hazardous metal slag and foundry sand leachates are similar to fly ash leachate.

### Coal Ash Leachate Compared to Non-Hazardous Inorganic Waste Leachate

![Graph comparing coal ash leachate to non-hazardous inorganic waste leachate](image)

EPRI also conducted research to compare potential risks from leachates from coal ash landfills and impoundments with risks from leachates from municipal solid waste landfills, which are not considered hazardous waste. The results show that using standard screening level risk assessment protocols, the risk from fly ash leachate is several orders of magnitude lower than municipal solid waste leachates for non-cancer, cancer, and ecologic risks.

The high municipal solid waste risk is largely driven by dioxins and furans, which have high risk levels even at very low concentrations. If dioxins and furans are excluded from the analysis, fly ash leachate risk is still about a factor of 10 lower than municipal solid waste leachate.

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EPRI also performed analyses of 24 proven and 39 potential “damage cases” related to surface and groundwater contamination linked to coal ash disposal facilities. These damage cases have been cited by environmental activists and regulators as justification for revising coal ash disposal regulations. The EPRI analysis concluded that groundwater damage cases are typically related to older sites with limited exposure risk. Between 65% and 90% of the disposal facilities implicated began operation before 1980 when installation of containment liners was uncommon. According to the Environmental Protection Agency and Department of Energy in 2006, 98% of new coal ash disposal sites are lined.

Furthermore, the EPRI damage case analysis showed that the incidents were characterized by low toxicity constituents – mostly sulfate, manganese, and boron – and limited exposure risk. Only approximately one-third of the sites had potential for groundwater receptors and remediation had begun at 22 of the 24 proven damage cases. (No information was available on the other two.)

Other issues commonly mentioned as risk factors for CCPs and addressed by previous EPRI research include:

- **Arsenic.** EPA modeling in 2007 found relatively high individual risk associated with arsenic at disposal sites, as high as 1 in 50 for an individual living immediately down gradient of an unlined co-management site. EPRI commented extensively on technical aspects of the risk assessment modeling, which used highly conservative inputs. However, even if the results are accepted, an analysis of potentially exposed individuals suggests that the population risk is relatively low. This was done by considering hydrogeologic position, estimating the number of potential receptors living within one mile of the 245 sites modeled by EPA using Google Earth, and multiplying by the EPA modeled risk for that site. The population risk, expressed as number of lifetime cancer
occurrences, was orders of magnitude lower than the “acceptable” population risk for the EPA’s arsenic in drinking water rule.

- **Mercury.** Mercury in CCPs is found in low concentrations, usually less than 1 mg/kg, and is very stable at ambient temperatures. No significant risk has been demonstrated to public from beneficial use in wallboard, concrete, or geotechnical fills.

- **Radioactivity.** Radioactivity is not significantly enriched in ash relative to soil or rocks, or conventional concrete or building materials.\(^\text{10}\) For an ash storage site worker, radiation exposure from fly ash is about 2% of background radiation exposure.

- **Windblown ash.** Fugitive dust from ash operations is easily controlled with wetting and cover materials. Power plant worker exposure is not above health criteria and public exposure is significantly less.

Section 4 – CCP Production and Handling

CCP Production Overview

CCPs are produced in electric power plants by the burning of coal in steam boiler furnaces. The furnace is equipped for continuous combustion and the coal is injected or conveyed into the furnace where the mixture ignites and burns to completion. When complete combustion of the coal takes place, the CCP, or non-combustible portion of the coal, remains to be collected at the bottom of the boiler or exits the boiler in the flue gas stream to be captured using dust collection devices.

Typical Power Plant Configuration

Utility Boilers

There are several different manufacturers of coal combustion steam boiler furnaces, each with different design features. However, the basic types of coal combustion steam boilers can be grouped into the following categories:

- pulverized dry-bottom boiler
- pulverized wet-bottom boiler
- cyclone boiler
- stoker-fired boiler
- fluidized bed combustion boiler
Additionally, several new coal combustion technologies are being commercialized and may be utilized in new coal-fueled power plants to be constructed in the future. These technologies include:

- integrated gasification combined cycle
- supercritical pulverized boiler
- ultra supercritical pulverized boiler

Overview of Existing Boiler Types

Pulverized coal boilers make up the majority of the coal-fueled boilers used by electric utilities. With pulverized coal boilers, the coal is pulverized to a fine powder (70% < 75 μm) and injected in the boiler with preheated air for combustion. In a pulverized coal furnace, the ash particles are formed in suspension and approximately 80% of the ash, known as fly ash, remains entrained in the flue gas and exits the furnace, where it is collected by mechanical collectors, ESPs or baghouses. The remaining approximate 20% of the ash exits the bottom furnace and is known as dry bottom ash, sand-sized particles with granular characteristics.

In a slag-tap furnace up to 50% of the ash forms on the walls of the boiler. The molten ash falls to the bottom of the furnace where it is quenched with water and shatters into a hard slag that is black and glassy. The other 50% of the ash exits the furnace through the flue gas as fly ash.

The cyclone boiler is capable of burning a wide variety of fuels. Coals from low volatile bituminous to lignite may be combusted. In addition, other solid fuels such as wood, bark, coal char and petroleum coke may be fired in combination with coal. Coals burned in cyclone boilers need to be crushed but do not need to be pulverized. Due to this larger particle size, the cyclone furnace retains 70% to 80% of the ash as slag that is removed from the bottom of the furnace, with the remainder of the ash exiting the cyclone furnace as fly ash entrained in the flue gas and captured by dust collectors.

Stoker-fired boilers are one of the earliest types of boilers used for the combustion of coal in energy production. The coal is sized to a two-inch or smaller mesh and fed into the boiler using a chain grate or other conveying device. The coal is retained in the boiler on the conveying device until combustion of the coal is complete. Because the coal in a stoker is not pulverized, the combustion is not as efficient compared to other boiler types. Therefore, the ash typically has a high unburned carbon content, usually greater than 10% and as high as 60%. The fly ash and bottom ash are formed and removed from the boiler in the same manner as a pulverized coal boiler. Because of the sizing of the coal, the fly ash is typically coarser than fly ash from other boilers. Fly ash production is typically 80% of the ash produced by a stoker boiler with the remainder being bottom ash.

Fluidized bed combustion (FBC) boilers are being utilized for the combustion of coal in increasing numbers due to stricter emission standards. FBC boilers can be used to burn high-sulfur fuels with efficiency while maintaining the low levels of SO₂ air emissions required by regulatory agencies. Typically with FBC boilers, coal is sized to one-half of an inch or less and injected into the boiler with limestone or some other form of calcium carbonate. The calcium reacts with the sulfur in the boiler and is prevented from forming an SO₂ gas. The compounds of sulfur and calcium, typically calcium oxide (CaO), calcium sulfate (CaSO₄), calcium sulfite
(CaSO₃), and calcium hydroxide (Ca(OH)₂), remain in a solid form and are removed from the boiler with the ash. The finer particles, FBC fly ash, are removed from the flue gas stream by a baghouse or ESP and the coarser, heavier particles, known as FBC bed ash, are removed at the bottom of the boiler.

FBC boilers are also used to combust fuels with low heating values such as culm and gob. These fuels have BTU values as low as 2500 Btu/pound and have ash contents of as high as 70%. Because of the combustion chamber design and fuel-handling capabilities of an FBC boiler, these fuels can be burned efficiently with low emission levels for the production of power.

**Overview of Emerging Coal Combustion Technologies**

Most coal-fueled electricity generated in the U.S. today comes from older, “subcritical”, pulverized coal power plants. While this technology has proven to be highly reliable at generating electricity at a low financial cost, its low efficiency and high emissions rate for various pollutants has left it out of favor among electricity utilities looking to build new, base load power plants. If new coal-fueled facilities are to be built in the future, they are likely to utilize more advanced coal technologies such as supercritical and ultra-supercritical pulverized coal, or integrated gasification combined cycle (IGCC).¹¹

The next technological step beyond subcritical pulverized coal is the development of “supercritical” technology. While this technology has been around for decades, it is only in recent years that some of its difficulties have been resolved. Most new coal power plants being proposed or constructed in the U.S. are to use supercritical technology. The main benefit of this technology is that it has the potential to operate at efficiencies as high as 45%, reducing the amount of coal and consequent emissions of harmful pollutants needed to generate each kilowatt-hour of energy.

The next step beyond supercritical technology is “ultra-supercritical” pulverized coal power plants. Few of these plants operate around the world today and few are being planned, largely because the benefits from the increased efficiency of the technology does not outweigh the increased cost of constructing and operating the more advanced technology power plant. A next generation ultra-supercritical pulverized power plant could potentially achieve an efficiency of 50% but would likely require the use of more exotic materials in the construction of the power plants core components which would drive up the cost of the power plant.¹²

Unlike advanced pulverized coal technologies which can be seen as a refinement of the well-established subcritical technology, IGCC technology involves a markedly different method of generating electricity from coal. The value of IGCC lies in its potential to significantly reduce many of the persistent problems associated with pulverized coal combustion. IGCC technology begins with pulverized coal being “gasified”, broken down into largely carbon monoxide and hydrogen, in a high-pressure, steam-filled boiler. As a high-pressure gas, all the contaminates in the coal gas, or syngas, can be removed before the combustion process, improving the percentage of harmful pollutants that can be removed from the energy generation process while also significantly reducing the costs of achieving these reductions. Once cleaned, the

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¹¹ North Carolina Sustainable Energy Association
¹² Viswanathan, R; Coleman, K; Rao, U. “Materials for ultra-supercritical coal-fired power plant boilers” 2006.
syngas can then be fully combusted in order to drive a gas turbine. The hot gas leaving the gas turbine can then used to generate steam for use in a steam turbine to generate additional electricity. This combined cycle process allows for IGCC technology to achieve efficiencies above 40% with the potential for efficiencies as high as 45% or even 50%.

Supercritical and ultra-supercritical pulverized coal boilers produce ash products identical to those produced by the pulverized coal generating fleet in place now. IGCC plants produce a different type of solid byproduct, however. Coal ash remaining after gasification takes the form of a vitrified slag that is not soluble in water. Limited beneficial uses for IGCC slag have been identified, but many companies are undertaking product development in the expectation of increased availability of this material.

According to a 2007 analysis by Emerging Energy Research, nearly 4,000 megawatts of IGCC projects are currently operating in the U.S., Europe and Asia and over 50 IGCC projects totaling over 25,000 megawatts have been announced or are in planning worldwide. In North America, utilities AEP, Southern Company and Duke have all initiated coal IGCC projects, while independent power producers including Hydrogen Energy, NRG and Edison Mission are also active players. The Emerging Energy analysis identified 27 projects in 16 states at some stage of development with a combined capacity of more than 15,000 megawatts.

However, even if all of these plants were constructed – which is highly unlikely given difficulties in permitting coal fueled generating facilities and financing new technologies – 15,000 megawatts of generating capacity would represent less than 5% of the current U.S. coal-fueled generating capacity of 312,738 megawatts. Therefore, ash from pulverized coal boiler is expected to remain the dominant form of combustion byproduct for decades to come.

Ash Production Characteristics of Boilers

At any given power plant, the design and operation of the boilers and the characteristics of the coal that is burned will determine the amounts of fly ash, bottom ash or boiler slag that is produced.

For relative comparison, consider a typical 500 megawatt coal-fueled power plant which is assumed to burn 1.5 million tons of coal annually. If the coal contains 12% ash, the plant would produce 180,000 tons of CCPs. If the plant utilized any one of the following common furnace types, CCPs would be produced in differing amounts in each case.

- Pulverized coal furnace - 36,000 tons of bottom ash and 144,000 tons of fly ash
- Slag tap furnace - 90,000 tons of boiler slag and 90,000 tons of fly ash
- Cyclone furnace -126,000 tons of boiler slag and 54,000 tons of fly ash

Using a sulfur content in the coal of 1.5%, with forced oxidized FGD scrubbers for $\text{SO}_2$ control at the power station, the plant can generate up to another 250,000 dry tons per year of FGD

13 Acosta, A; Aineto, M; Iglesias, I; et Al. “Physic-Chemical Characterisation of Slag Waste Coming from IGCC Thermal Power Plant”, Date Unknown
residue products. A dry FGD system would produce about 20% to 25% more material than the fly ash, by volume. The volume of material added to the process in the form of lime or other sorbents is only about 20% to 25% more than the total residue in the flue gas stream.

Collection Systems

Fly ash is removed from the flue gas stream using one or a combination of three types of particulate collection devices: ESPs, fabric filters or baghouse, and mechanical collectors.

ESPs are available in a broad range of sizes for utility and industrial applications. Collection efficiency can be expected to be 99.8% or greater of inlet dust loading. ESPs work by electrically charging the ash particles in the flue gas to collect and remove them. Because their materials are not as sensitive to maximum temperatures, ESPs are less sensitive to plant upsets than are fabric filters.

The unit comprises a series of parallel plates through which the flue gas passes. Charging electrodes between the plates charge the fly ash particle with a negative charge. The negatively charged particles are attracted toward the grounded collection plates and accumulate on the plates. The ash layer is removed by “rapping” which consists of suddenly striking the collection surface, thus dislodging the particles. The particles fall into collection hoppers directly below the collection plates.

Fabric filters, commonly known as baghouses, collect the dry particulate matter as the cooled flue gas passes through the filter material. As the gas passes through the porous bag material, the fly ash particles are separated from the flue gases. An outlet device collects the cleaned flue gas and directs it toward the induced draft fan and stack. The individual bags are closed at one end and connected to an assembly at the other end to allow the gas to pass through. As the particulate accumulates on the bags, the pressure drop increases across the filter and the bags must be cleaned.

Bag cleaning methods distinguish the types of fabric filters, with the three most common being reverse air, shake/deflate and pulse jet. Cleaning is done by reversing the air flow through the filter, either gently as in the reverse air and shake deflate systems or more forcefully as used in the pulse jet applications. The ash cake dislodged during cleaning falls into a hopper directly below the bags and is removed by the ash transfer system. Applications of fabric filters include industrial and utility power plants using coal or solid wastes, plants using sorbent injection and dry scrubbing FGD and fluidized-bed combustors. Collection efficiency can be expected to be at least 99.8% or greater. Baghouses have the potential for enhancing SO₂ capture in installations downstream of sorbent injection and dry scrubbing systems.

Mechanical dust collectors, often called cyclones or multiclones, have been used extensively to separate large particles from a flue gas stream. The cyclone flow of gas within the collector and the centrifugal force on the ash particulate drive the particulate out of the flue gas stream. Hoppers below the cyclones collect the particulate and feed an ash removal system. The mechanical collector is most effective on particles larger than ten microns. For smaller particles, the collection efficiency drops considerably below 90%. These collectors are frequently used for
re-injection to improve unit efficiency on stoker firing of coal and biomass. With stricter emissions regulations, mechanical collectors are no longer used as primary control devices.

FGD emission control systems may be a part of one of the aforementioned types of boilers, particularly pulverized, stoker and cyclone boilers. FGD systems incorporate the injection of calcium products (lime or limestone) or other sorbents (e.g., sodium, magnesium oxide, ammonia) into the flue gas stream for the removal of sulfur dioxide (SO₂). FGD systems are manufactured by several different companies using many variations of designs; however, the basic types of FGD systems are wet scrubbers, spray dryers and lime or limestone injection.

With wet FGD systems, the fly ash is usually removed from the flue gas stream prior to the flue gas entering the scrubber vessel. Hydrated lime is added to water to produce a lime solution/slurry. The reagent slurry from the vessel is then added to a reaction tank or scrubber basin where it is mixed with recycled slurry from the scrubber. In the wet scrubber vessel are spray towers from which the recycled lime slurry is sprayed into the flue gas stream. Within the loop, a surge tank is used to control slurry flows and a thickener is used to remove solids.

In spray drying, lime is added to water to produce a lime solution/slurry. The solution is sprayed as a fine mist into flue gas, which still contains the fly ash particulate. The mist reacts with SO₂ and dries to a fine particulate. The particulate laden flue gas then passes to a baghouse or ESP where FGD residue and fly ash are collected.

Spray dryers, or dry scrubbers, have several advantages over a wet scrubber FGD system. The former produces a dry waste, minimizing the complex handling and storage problems of large volumes of sludge produced in wet FGD systems. Spray dryer waste can be processed or disposed of without dewatering. Spray drying requires a highly reactive absorbent (e.g., lime) to attain high SO₂ removal efficiencies. This alkaline absorbent material is more costly than that of a wet FGD system.

In a direct injection system, lime or limestone, is injected directly into the boiler for SO₂ control. The lime particles chemically combine with SO₂ and oxygen to form calcium sulfate (CaSO₄), unreacted lime (CaO) and small amounts calcium sulfite (CaSO₃). The calcium and sulfur compounds are removed with the fly ash in a baghouse or ESP.

Product Storage and Distribution

The most common method of conveying fly ash is pneumatic conveyance of the dry material. Fly ash is dry when collected in precipitators and bag houses. Due to its fine particle size, it is easily conveyed and stored in a dry condition. For utilization applications, such as cement admixtures, the material can be shipped in bulk pneumatic tankers and stored in silos similar to other dry, fine materials like flour and portland cement.

For applications such as fills where the ash is to be handled like soil or aggregate, about 20% moisture is added to the fly ash. This process is called conditioning. Water is normally added as the ash is loaded from silos to truck. The conditioning process may be performed using a pugmill, rotating drum or other form of rock mixer.
Fly ash is frequently handled wet when conveyed to storage ponds near power plants. In these situations, the ash is slurred with large quantities of water and sluiced to settling ponds for dewatering. Utilization of ash sluiced to ponds requires drainage and drying prior to use for most applications.

Class C fly ash from sub-bituminous coal and lignite is most commonly handled dry. Because these materials normally react with water to form cementitious compounds, the ash is generally handled and stored dry until used or disposed of so that hardening reactions are prevented.

Bottom ash and boiler slag are most commonly handled wet and conveyed to storage areas by sluicing. The coarse grain size of the material allows relatively easy drainage in ponds or in bins. The material is commonly handled in a damp or moist condition for utilization.

FGD material from wet scrubbers is in a slurried state and often requires dewatering before use or disposal. In some cases, wet scrubber FGD materials are sluiced and stored in ponds. Dry FGD materials are conditioned with water to facilitate handling, utilization and disposal.
Section 5 – CCP Utilization Options

Decades of experience and numerous successful utilization projects have fostered commercial and governmental acceptance and knowledge of the use of CCPs as construction materials. The principal use of fly ash has been in concrete. Substantial amounts have also been used in structural fills, soil stabilization, asphalt mixes and cement manufacturing. Bottom ash has been used as pavement base, pipe bedding, skid control and in block manufacturing. Boiler slag applications include sand blasting grits, roofing granules, skid control and as a raw material in cement manufacturing. More recently, FBC materials and FGD materials have been used in structural fills, pavement base and backfills. FGD gypsum produced via a wet-limestone, forced-oxidation scrubber can be used as a direct replacement for mined gypsum in the production of wallboard and/or as a post-kiln additive in cement production.

The American Coal Ash Association CCP Production and Use Survey annually reports the volumes of material utilized in various applications. (See table on following page.)

In 2008, 136.1 million tons of CCPs were produced in the U.S. The largest portion was fly ash, accounting for 72.5 million tons, 41.6% of which was beneficially used. Bottom ash production was 18.4 million tons, 43.82% of which was beneficially used. FGD material production was 33.6 million tons, of which approximately 35% was beneficially used.

The largest and most valuable use is fly ash in the production of concrete, concrete products and grout (12.6 million tons in 2008). Fly ash offers these applications significant performance, environmental and economic benefits. Concrete made with fly ash is stronger, less permeable (and therefore more durable) than concrete made with portland cement alone. In addition to avoiding landfill disposal of the ash, environmental benefits include displacing the manufacturing of cement with its attendant natural resources consumption and greenhouse gas emissions. Finally, because cement sells in many markets for more than $100 per ton, the market allows for absorbing significant distribution costs for fly ash while still reaching the consumer at less than the cost of the competing material. In addition to being the most valuable coal ash use application, environmental regulators also consider it among the safest uses because metals in the fly ash get bound within the concrete and the likelihood of leaching into groundwater is minimized.

Over 8 million tons of fly ash (and nearly 3 million tons of bottom ash) were used in structural fill applications in 2008. (Another 1.8 million tons of fly ash and bottom ash was used in the construction of road base and sub-base.) These applications are typically less valuable than fly ash in concrete because rather than competing with $100 per ton cement, the materials are competing with less expensive locally available soils and gravel.

A beneficial use similar to structural fills is the practice of filling abandoned mines and quarries. Approximately 1.2 million tons of coal ash went to this application in 2008. Additionally, about 8.6 million tons of coal ash mixed with limestone from Fluidized Bed Combustion units was used in mine reclamation in 2008.

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16 American Coal Ash Association, Annual CCP Production and Use Survey, 2008
Approximately 8.5 million tons of FGD gypsum was used in 2008 in the manufacturing of wallboard.
Source: American Coal Ash Association

Over 3.1 million tons of fly ash (plus approximately 1 million tons of bottom ash and FGD material) was used in 2008 as raw feed for cement manufacturing.

Over 2.9 million tons of fly ash was used in 2008 for stabilizing wastes and solidifying wet soils.

Dozens of other applications account for the remainder of coal ash beneficially used in 2008. Other applications include, but are not limited to the production of flowable fills, blasting grit, snow and ice control products, shingles, paints, other mineral fillers and several agricultural applications.

More detailed descriptions of various CCP uses include:

**Concrete Production Applications**

The largest volume use of CCPs is in cement and concrete applications. Fly ash is used as a mineral admixture for ready mixed concrete production and in the manufacture of cements, aggregates, blocks, precast pipes, panels and other structures, aerated concrete, asphalt and concrete pavements, base and sub-base construction. Bottom ash is used in cement-treated base and sub-base, and as an aggregate for concrete block. Boiler slag is used in the manufacture of asphalt for flexible pavement systems.

**Mineral Admixture in Concrete**

Coal fly ash, like cement and volcanic ash, is comprised of oxide compounds found in limestone, iron ore, silica sand and clay. The amount of fly ash in typical structural concrete applications ranges from 10% to 40%, by weight of total cementitious material, with amounts up to 70% in massive walls, girders and dams. Fly ash for use in concrete is available in virtually every location in the United States, including Hawaii and Puerto Rico. Fly ash also is traded internationally.

Fly ash as a concrete admixture can be added during the concrete batching process or directly to the cement. When utilized in the concrete batching process, fly ash is added along with portland cement, sand, gravel and water to the specific proportions determined in the concrete mix design. Fly ash is typically used as a replacement for 10% to 40% of the cement content. Class F fly ash is sometimes added to portland cement at the cement manufacturing plant to produce Type IP, portland-pozzolan cement (see below).

**Cement Manufacturing**

Fly ash, bottom ash and boiler slag have all been used as raw materials in the manufacture of cement. Fly ash is used because it contains silica, alumina, calcium and iron oxides needed in portland cement feed stocks. Portland cement is prepared in a two-step process. Initially, raw materials are heated to around 3000°F, blended and fused in a cement kiln to produce a substance called clinker. Next, the clinker and additives are ground to a fine powder to produce portland cement. Fly ash may be added at either step in the manufacturing process. Certain FGD products can also added into the finished cement as a replacement for natural gypsum.
In the case where the fly ash is added to cement clinker during or after the grinding process, portland-pozzolan cement is produced. The resulting product, Type IP cement, must conform to ASTM standard C 595 and may contain 15% to 40% fly ash. The composition, properties and behavior of the cement determine the proportions blended. Pozzolans are compounds that react with lime that is generated during the cement hydration process to produce additional cementitious compounds. These reactions increase strength and impart other beneficial properties to the concrete.

Concrete Block and Other Precast Concrete Product Manufacturing

Fly ash is used in manufacturing concrete blocks to add plasticity to the concrete mixture and improve the quality of the blocks. Ash addition produces blocks with better texture, better corners and increased mold life. Typically, ash is added to replace 20% to 30% of the cement. However, at block plants where steam curing is used, ash addition rates may be as much as 50%.

CCPs can be used as lightweight aggregate for the production of precast concrete products, such as concrete masonry units and other concrete, where a low density material is beneficial in reducing weight or loading. The principal use of lightweight aggregates is for block and structural or precast concrete where low unit weight of the end product may be an important factor in the design of the structure. Lightweight aggregate normally has a density of around 50 to 70 pounds per cubic foot. These aggregates typically need to be non-staining and non-reactive because of their use in structural and architectural applications where appearance is important. Conformance to ASTM C 330 or ASTM C 331 is usually a requirement.

Bottom ash is a common source of lightweight aggregate for use in concrete blocks. Select, screened, low-density material that is durable and will not degrade during handling is often used in this application. Many bottom ashes conform to the density and gradation requirements of ASTM C 331.

Fly ash lightweight aggregates are commercially produced from firing or chemical-bonding processes. Exceptionally durable and lightweight aggregate has been produced from fly ash and municipal wastewater sludge or paper mill sludge, providing a viable outlet for multiple materials that would otherwise be disposed. Lightweight aggregate has been produced from high calcium fly ash that has been conditioned, spread and allowed to cure. After initial curing the material is excavated and graded prior to additional curing and use.

Aerated Concrete

This versatile building material, currently produced at approximately 240 plants in 40 countries, is now being introduced into the United States. When fly ash is utilized, the product, consisting of roughly 70% fly ash plus water, cement, lime and aluminum powder, is a porous, lightweight material that offers excellent insulating properties and strength and is resistant to fire, sound, mildew and insects. It can be easily sawed, drilled, screwed and nailed with ordinary carpentry tools. Given the international acceptance this product has received, aerated concrete could become a significant outlet for the beneficial use of fly ash in the U.S.
Paving (Concrete and Asphalt)

CCPs have been successfully used for decades as a component in both portland cement concrete pavements and asphaltic concrete pavements. The materials can be utilized through the entire pavement structure from the sub-base course to the topping course. The use of CCPs provides a superior performing structure, as well as a cost-effective measure for state departments of transportation. In most states, the use of CCPs in the construction of pavements is a normal part of the standard construction specifications.17

Lime-fly ash (LFA) mixtures are blends of hydrated lime and fly ash mixed in-situ with native materials or blended with crushed stone or other aggregate. LFA mixtures have been used as base and sub-base beneath flexible asphalt pavements. The mixtures are blended in a central mixing plant or in place, compacted, cured and topped with an asphalt wearing surface. The superior strength and durability of LFA mixtures as compared to aggregate alone, allows LFA mixtures to serve as an economic alternative to conventional pavement in many situations. These pavements have been most widely used by state and local highway departments in the Midwestern United States.

Cement treated bottom ash has been used as a substitute for conventional crushed stone or gravel base course for secondary roads. This product has been especially useful in locations where bottom ash is plentiful and natural aggregates are relatively scarce or expensive. Though not as widely used as LFA mixtures, this product has proven to be a practical application of CCPs in some locales.

Fly ash performs as a mineral admixture in portland cement concrete paving in the same manner as ready mixed concrete.

Asphalt pavement normally consists of a blend of asphalt, coarse aggregate and a fine grain-sized additive, commonly referred to as mineral filler. Fly ash has been used since the early 1930s as a mineral filler in asphalt mixes. Many fly ashes have chemical and physical characteristics, particularly low plasticity, which are suitable for use in this application. Specifications normally allow up to 12% carbon content and a grain size of 70% to 100% passing a #200 sieve. Often, fly ashes which do not meet specifications for use in concrete or other applications, will comply with these requirements, and be acceptable for use as mineral filler in asphalt.

Blends of boiler slag and cationic emulsified asphalt have been demonstrated as a practical surface pavement for service road and low volume secondary roads in rural areas. This material has the advantage of low cost and flexibility. It can be mixed and stockpiled for later use, even during periods of cold and inclement weather when conventional asphalt may not be available.

Fly ash mixed with lime or portland cement has been used as a binder to recycle secondary road pavements. The pulverized, recycled pavement is combined with the fly ash mixture, compacted to ten inches or more, and then covered with a thin asphalt or tar and chip surface.

This process offers the benefit of significant cost savings over conventional methods because additional aggregate is not imported to reconstruct the pavement.

**Manufacturing Applications**

CCPs have been used as ingredients in producing manufactured products as raw materials, as aggregates and as additives to the final products. Principal uses in this category are as fillers, lightweight aggregates or components in the manufacture of various products.

**Roofing Granules**

A major use of boiler slag is roofing granules – the hard, fine aggregate used to surface shingles and other roofing products. Several properties of boiler slag make it a preferred material for this use, including natural dark color, hardness and resistance to ultraviolet radiation. Its glassy composition makes it durable and resistant to oxidation and weathering, thus producing a long-lasting surface.

**Wallboard**

Gypsum (CaSO\(_4\)•2H\(_2\)O) based wallboard is a common building material in the United States for residential and commercial construction. Generally, wallboard is manufactured by pulverizing natural gypsum rock and laminating the gypsum with a multi-layered paper surface. While natural gypsum is mined in many areas of North America, its supply is limited.

FGD residues from wet lime and limestone scrubbers have been effectively utilized for the production of wallboard. FGD residues from these installation are primarily gypsum (CaSO\(_4\)•2H\(_2\)O), although some FGD residues will contain impurities, such as fly ash, carbon, calcium sulfite (CaSO\(_3\)) and other compounds of calcium and sulfur.

The wallboard industry takes into account several critical variables when considering synthetic gypsum, such as FGD residue, for use in their product. The criteria includes: 1) FGD gypsum should contain from 98% to 99% gypsum (CaSO\(_4\)•2H\(_2\)O); 2) calcium sulfite (CaO\(_3\)) is not desirable because in substantial quantities it can change the crystallization and adversely modify the stucco-slurry fed to the wallboard manufacturing line; 3) crystal shape and size should be short and stubby with lengths approaching 100 microns; 4) water soluble salt components should be limited to prevent delamination of the paper layers from the gypsum core; and 5) fly ash content should be limited to 2% to prevent discoloration, adverse crystallization and improper board forming as a result of the fly ash’s pozzolanic properties.

FGD residues from wet lime scrubbers may have the proper chemical makeup to meet these criteria; however, the FGD residue from this type of installation requires substantial drying before use. FGD residues from other calcium-based scrubber systems typically have high levels of calcium sulfite (CaSO\(_3\)). Forced oxidation technologies exist to convert the calcium sulfite (CaSO\(_3\)) to calcium sulfate (CaSO\(_4\)).

**Filler in Paints, Plastics and Ceramics**
Fly ash, particularly cenospheres, has been used in blends of plastics and paints as a mineral filler to enhance mixture properties and/or to reduce the cost of materials. Cenospheres are primarily hollow fly ash spheres and are often referred to as “floaters” because, with a specific gravity in a range from 60% to 80% of that for water, they are naturally buoyant. Cenospheres can reduce the weight of manufactured products. They also can reduce the cost of some products by reducing the amount of resin that is needed, due to their low ratio of surface area to volume. Industries that have benefited from the use of cenospheres as fillers are sporting goods, specialty cements and PVC flooring, among others.

The fly ash that is used as filler may be processed or unprocessed, depending upon the properties needed for a specific product. The major advantage that fly ash and cenospheres have over other fillers is their spherical shape which enables them to fill and flow much more readily than other fillers such as clay or calcium carbonate. Due to the high temperatures at which these CCPs are produced, they are better able to withstand high-temperature manufacturing processes. Ash has been used in a wide range of plastic products for industrial, commercial and domestic purposes.

Fly ash, other than cenospheres, has a specific gravity in a range from 1.8 to 2.8 times that of water. Compared to cenospheres, a typical fly ash used in filler applications has diameters in a more narrow range, that are smaller on average. Due to their solid spherical nature, fly ash fillers can withstand extreme pressures. Industries that have benefited from the use of fly ash as a filler are adhesives, grouting, plastics, paints, explosives and automotive.

The use of fly ash in the plastics industry is expanding. Incorporating fly ash in the manufacture of polyvinyl chloride (PVC) pipe improves the productivity factors and lowers the raw material cost. It is the spherical nature of fly ash that improves production rates in these pipe extrusions. Automobile manufacturers also take advantage of the properties of fly ash by introducing the material into their products. The durability and strength of vinyl floor coverings are improved with fly ash, the weight of the finished product is decreased and the raw material costs are reduced.

Cenospheres are utilized in low-density paints for exotic applications, including aircraft carrier deck coatings and as filler in automobile undercoatings. In addition to reduced material costs, the crucial properties of improved flowability and very light weight provide specific advantages.

Some of the more innovative developments for cenospheres and solid fly ash particles are emerging in the aerospace industry. For example, silver-coated cenospheres are used to fill voids which create radar echoes in the stealth aircraft. Lightweight composites utilizing fly ash provide the needed weight reduction with no loss in rigidity or strength.

Metallurgical Applications

CCPs are used by the steel industry for many applications. Coal fly ash and bottom ash can be used as insulating cover material to retain heat in ladles of molten steel. These ladle insulators should be flowable and coarse, have a low bulk density and have a wide particle-size distribution. Fly ashes with such characteristics generally are produced by coal-fueled stoker boilers.
Most of the newer steel mills in the United States use electric arc furnaces to melt scrap iron and refine it for making specialty products. These furnaces use carbon electrodes charged with an electric current to heat the scrap in a refractory-lined furnace. Both the carbon rods and refractory material are consumed in the process and are very expensive to replace. To prolong the life of these components, a coarse high-carbon fly ash is injected into the slag, an accumulation of impurities that float at the surface of the molten steel. The combustion of the carbon in the ash generates carbon monoxide and other gases that “foam” the slag. Foamy slag prolongs the life of the carbon rods and the refractory by insulating the region on the carbon rods and refractory where the surface of the molten steel meets the atmosphere. Additionally, foamy slag promotes the movement of impurities from the molten steel into the slag. Important characteristics for slag foamers are carbon content greater than 50%, a low percentage of fines, a high degree of coarseness, a good particle-size distribution and a bulk density of greater than 40 pounds per cubic foot. Small coal-fueled stoker boilers readily produce ash of this quality.

The high melting point and strength characteristics of CCPs make them highly suitable for applications as sintered tiles. Cenospheres as well as denser fly ashes, are used to produce insulating refractory compounds for the steel industry.

Composites of aluminum and fly ash particles have been developed using standard foundry techniques. Additions of solid and hollow particles of fly ash have been successful in reducing the material cost and density of aluminum castings while increasing their performance. Mechanical properties of aluminum-fly ash composites show that the composite possesses superior abrasion resistance, higher hardness, higher compressive strength and elastic modulus, compared to the parent matrix. Composites containing up to 55% fly ash on a volume basis have been developed. Additionally, cast composites of aluminum and fly ash have been successfully extruded using commercial technology, suggesting even more opportunities for use. The production of fly ash and aluminum composites could make existing foundries more competitive by increasing the market potential for aluminum in applications that traditionally have been dominated by steel. Examples of such markets include both the automotive and the electromechanical machinery industries.

Explosives Manufacturing

Another application for cenospheres is in explosive manufacturing. Cenospheres provide a stable medium for introducing controlled air voids, a requirement for reliable detonation.

Geotechnical Applications

Geotechnical applications for CCPs for projects such as highways, airports, commercial land developments and public infrastructure systems constitute a substantial portion of construction activities. In addition to concrete, CCPs have been successfully used in geotechnical projects in several ways, including flowable fill, grouts, roller compacted concrete, soil stabilization, construction bedding, backfill and structural fill/embankments.

Flowable Fill
MIXTURES OF FLY ASH, CEMENT AND WATER HAVE BEEN USED AS CONSTRUCTION BACKFILL IN AREAS WHERE CONVENTIONAL BACKFILLING MAY BE DIFFICULT OR UNDESIRABLE. THESE FLUID MIXTURES FLOW INTO AREAS TO BE FILLED AND RESULT IN A FILL WITH PROPERTIES EQUAL TO, OR EXCEEDING, TRADITIONAL BACKFILL MATERIALS. A MIXTURE OF FLY ASH, WATER, SAND AND A SMALL AMOUNT OF CEMENT IS TYPICAL. IN SOME CASES WHERE CLASS C FLY ASH IS USED, NO CEMENT IS REQUIRED. THE SAVINGS IN USING FLOWABLE FILLS RESULTS FROM THE REDUCTION IN TIME, EQUIPMENT AND MANPOWER NEEDED, AND THE SUPERIOR PERFORMANCE, AS COMPARED TO CONVENTIONAL MATERIALS. FLOWABLE FILLS ARE ESPECIALLY USEFUL IN RESTRICTED AREAS WHERE ACCESS FOR PLACEMENT AND COMPACTION IS DIFFICULT, AND WHERE MINIMAL SUBSEQUENT SETTLEMENT IS DESIRED. FLOWABLE FILLS ARE PARTICULARLY WELL SUITED FOR FILLING UTILITY TRENCHexcavations under streets in urban locations, and other applications where quick set times and load bearing is important.

**Grouting**

Grout is used to strengthen or decrease permeability of structures and subsurface strata by filling voids, and cementing cracks, fissures and other openings. Fly ash adds several useful properties to grout mixes. The fine, uniform particle size, spherical shape and pozzolanic activity of fly ash are all useful qualities. Grouts containing fly ash have been employed in filling abandoned mine openings to prevent ground subsidence and in oil wells. Ash use in oil well grouting dates back to 1949. In this application, pumpability, less bleeding and lower heat of hydration with fly ash grouts are particularly desirable properties. The American Petroleum Institute has a standard specification for this use of fly ash.\(^{18}\)

**Roller Compacted Concrete**

Roller compacted concrete (RCC) is a fill material that is placed using conventional earthmoving equipment, such as dump trucks, bulldozers and vibratory compactors. RCC mixes are used for mass concrete in dams, thick pavement bases and similar applications. These mixes are used in mass concrete applications where material is placed using earth moving equipment to reduce the placement and forming costs that are normally associated with standard concrete construction methods. RCC mixes have a lower water content and higher ash content than conventional concrete mixes.

Fly ash, as well as other CCPs, is a major component of roller compacted concrete and contributes to the strength and cost-effectiveness of the material. Prominent RCC dam building projects utilizing fly ash include the U.S. Bureau of Reclamation’s Upper Stillwater Dam in Utah and the San Diego Water Authority’s Olivenhain Dam in California. Almost 200,000 tons of Class F fly ash was used in the Utah project and approximately 150,000 tons was used in the California project.

**Soil Stabilization**

Fly ash has been used to supplement or replace portland cement or lime in soil stabilization applications. When ash is used as an ingredient, standardized mix design procedures have been developed. Design specifications typically include compaction moisture content, strength and dimensional stability criteria. Procedures for curing, placement and other considerations are

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\(^{18}\) American Petroleum Institute, Specification Number 10.
typically included. Specifications for fly ash use in soil stabilization have been adopted by several government agencies, including the Federal Aviation Administration, Federal Highway Administration, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation and many state departments of transportation.

Construction Bedding

Bottom ash is widely used as fill to provide support beneath slabs and small structures, and as pipe bedding. Bottom ash is often the preferred material for these uses because it is easily spread and compacted, is not sensitive to moisture content variations, drains readily and forms a stable base.

Backfill

The qualities that make bottom ash a preferred material for construction bedding also make it desirable as a backfill material for small areas. Bottom ash is uniform, well graded, drains readily, is not sensitive to moisture variations and is relatively lightweight compared to many natural materials. Bottom ash can be handled, placed and compacted using the same techniques as other natural granular materials.

Structural Fills/Embankments

CCPs are a lightweight material for constructing fills. In this application, CCPs have been used to convert sites with unsuitable topography into valuable, productive property. These materials can be placed, spread and compacted using the same equipment as conventional fill materials. Placement to a controlled density and configuration can produce stable fills for site developments, roadways, parking areas and building construction.

In the United States, the use of CCPs in structural fills dates back to at least 1971. Since then, several million tons have been used in successful land development projects. These sites include housing developments, shopping malls, industrial parks and other types of commercial, residential and industrial developments. Transportation costs and material availability normally determine if CCPs are a practical alternative to competing native materials. When available in sufficient quantities within competitive haul distances, CCPs have proven to be an excellent material for creating structural fills. The most common material used for structural fills has been Class F fly ash. Class C fly ash, bottom ash, FBC ash, stabilized FGD materials and other types of CCPs have also been successfully used as structural fills.

ASTM E 2277-03 “Standard Guide for Design and Construction of Coal Ash Structural Fills,” is a specification standard covering the use of CCPs in structural fill applications. The standard provides a guideline to assure that CCPs used as in structural fills conform to a specified range of physical and chemical properties, and behavior. Conformity assures that a consistent, high quality product is produced.

Many state transportation departments are taking advantage of the beneficial properties and low cost of CCPs to construct roadway embankments, eliminating the need for traditional cut-and-fill designs which often involve excavation. After concrete, structural fills are now the largest volume use of CCPs in the United States.
Use of CCPs in highway embankments has been more prevalent in Europe and in urban projects in the United States where availability of local virgin borrow materials are limited.

**Agricultural Applications**

Large quantities of CCPs can be utilized for applications in the agricultural industry. The chemical and physical characteristics of CCPs provide many properties that are needed for the production of crops. CCPs could be used to replace or augment some of the fertilizers and additives used by farmers today.

**Soil Amendment**

CCPs can be used to improve agricultural soils utilizing both chemical and physical properties of the materials. Chemical benefits result from supplying essential plant nutrients for growth (such as supplying boron to a boron-deficient soil) or by changing the chemical nature of the soil to make it a more favorable medium for plant growth (such as increasing soil pH or decreasing aluminum toxicity). Examples of physical benefits include increases in water-holding capacity when fly ash is added to coarse-textured soils and increased water infiltration and soil aggregation resulting from the application of FGD gypsum.

Many CCPs have appreciable levels of elemental calcium and sulfur, nutrients essential to the growth of all plants and crops. FGD residue may be pelletized for efficient handling and distribution onto the fields. Crops such as peanuts, sweet and Irish potatoes and evergreens can benefit from the application of FGD residue. The FGD residue is made up primarily of calcium sulfate (CaSO₄) and calcium sulfite (CaSO₃), which are soluble forms of calcium, and is available in a product which is pH-neutral, neither acidic nor alkaline. In the case of peanuts, large amounts of available calcium are required by the plant during a certain period of growth known as pegging. If the calcium is not available during this period, the harvest of peanuts will have “pops”, or vacant shells, thus severely detracting from the value of the crop.

**Conversion of Salty Soils**

Gypsum (CaSO₄•2H₂O) from an FGD system can be used in the conversion of salty soils to more productive soils. The gypsum is used for exchanging Ca²⁺ for Na⁺ on the soil exchange complex and removing bicarbonates from soil solution. Several tons of gypsum per acre are usually used. The gypsum must be thoroughly mixed with the soil and not simply plowed under.

**Potting and Landscape Soils**

Fly ash and FGD residues can be used in the production of potting soil mixtures. When used in this application, CCPs may provide air- and water-holding capacity, micro- and macro-nutrients and improved texture. These CCPs can be added to peat moss, humus, compost or pine bark mixtures to produce high quality soils.

**Soil from Stabilized Wastewater Biosolids**
Dewatered biosolids from wastewater treatment plants can be combined with high calcium oxide (CaO) CCPs or a mixture of Class F CCPs and cement kiln dust, lime or lime kiln dust to produce a safe and high quality soil. CCPs fine particle size and the available alkalinity of the CaO provide the characteristics to dry the biosolids, pasteurize pathogens, reduce odors and provide a granular soil-like consistency. The stabilized product has valuable levels of calcium carbonate, nitrogen, organics, micro- and macro-nutrients and residual bio-activity. The stabilized product has many applications in the agricultural industry as liming material, soil conditioner, fertilizer and landscaping soil.

Feedlot Applications

CCPs in several forms have been used to demonstrate improved soil conditions at livestock feedlots. Soil stabilized with fly ash and FGD materials have been used to improve the feedlot environment, reducing animal stress and improving health.

Environmental Management Applications

The physical and chemical characteristics of many CCPs, along with their availability in dry, conditioned or slurry form, make CCPs useful in certain applications dealing with environmental and waste management.

Coal Refuse and Mine Fire Abatement

In several coal-mining regions, spontaneous combustion and other factors, such as lightning strikes, have created challenges with smoldering coal refuse piles and deep-mine fires. Fly ash slurry is often used to fill voids and to isolate and cool combustion areas in burning refuse piles. Both ponded ash and conditioned ash have been used in this application. Ash is mixed with additional water at the site to form a slurry and injected into the fire zone through pipes and boreholes.

For deep-mine fires, dry fly ash pneumatically injected has commonly been used to directly extinguish burning areas and to create barriers of incombustible material.

Mine Subsidence and Acid Mine Drainage Mitigation

Large quantities of fly ash have been used to stop or prevent surface subsidence above mined areas. Dry fly ash injected pneumatically, slurried fly ash and fly ash/cement grouts have all been used to fill sub-surface voids from abandoned mines to protect industrial, commercial, public and residential developments from mine subsidence damage. When alkaline ash is used in these applications, a reduction or elimination of acid mine drainage may also result. Alkaline fly ash, and mixtures of fly ash and FGD materials, have been used successfully in projects to control acid mine drainage from deep mines.

Surface Mine Reclamation

Surface mined areas and mine refuse piles have several characteristics that make reclamation difficult. Various properties of these spoil materials interfere with plant growth, including
coarse texture and poor water-holding capacity, dense compacted surfaces, the presence of acidic materials and the lack of sufficient nutrients. These problems are aggravated when erosion and accelerated surface runoff further prevent the successful establishment of vegetation on the disturbed area.

Direct application of fly ash has several beneficial properties that can aid in the successful establishment of vegetation as part of a reclamation program. The addition of fly ash to surface soils improves the physical characteristics of the soil; the fine material in the fly ash creates a better-graded soil texture. This change improves the water-holding capacity of the soil and serves as a medium for supporting vegetation. Fly ash also provides nutrients and, in the case of alkaline fly ashes, neutralizes acidity. Fly ash typically is added at the rate of 100 to 400 tons per acre to mine spoils as part of revegetation programs.

**Landfill Cover**

Fly ash and bottom ash are used at some municipal waste landfills as daily and intermediate cover, and as a component of final cover. The fine grain size of these materials makes them a practical substitute cover material in locations where suitable natural soil materials are unavailable or scarce.

**Waste Stabilization**

Fly ash is an excellent material for use in stabilizing and solidifying biological and industrial sludges, as well as liquid wastes from industrial processes and wastewater treatment. Sludges and liquids from hazardous waste management and site cleanups have also been stabilized using fly ash. Liquid wastes and sludges are difficult to handle and transport due to their unstable nature. Addition of dry fly ash alone, or in combination with lime, kiln dust or portland cement, dries, thickens and stabilizes these materials, and makes them more manageable. Cementitious reactions that occur upon curing are also a benefit of using fly ash as a solidifying and stabilizing agent. These reactions tend to reduce the leachability of metals and other substances that may be contained in the sludge and pose environmental concerns. Pozzolans, such as fly ash, have been recognized by the U.S. Environmental Protection Agency as the preferred material for stabilizing certain metal-bearing wastes.

**Miscellaneous and Emerging Applications**

Several important applications of CCPs are not readily categorized and many more exist at various stages of development:

**Skid Control**

One of the major uses of bottom ash and boiler slag is as an agent to prevent skidding on icy roadways in winter. These CCPs are widely used by highway departments for this purpose in regions where inclement winter weather makes driving hazardous. The dark color of bottom ash and boiler slag aids in the melting process and tends to keep the abrasive particles on the icy surface where they are needed. Bottom ash and boiler slag are superior to sand or crushed stone for this use. The free-draining nature of boiler slag reduces problems of freezing and
clumping in stockpiles. Also, bottom ash and boiler slag are non-corrosive to vehicles, roadway structures and pavements, and are not environmentally sensitive like chemical de-icing agents.

**Blasting Grit**

Processing boiler slag to produce roofing granules also generates a well-graded material suitable for grit used in sand blasting. The hard, durable and angular nature of boiler slag, combined with its relatively low cost, makes it an ideal material for use as an abrasive. The processing provides a range of gradations that conform to various grit specifications. Due to the hardness and durability of boiler slag particles, and the low free silica content, as compared to sand, boiler slag is widely used in this application. Low silica content also helps reduce health risks to workers who may otherwise be exposed to development of silicosis.

**Marine Applications**

CCPs processed in several forms have been used in demonstration projects for marine rehabilitation. Stabilized blocks of fly ash and FGD materials have been used to construct artificial reefs suitable for supporting marine life. Other materials formed into small saucer-shaped units have been used to promote the development of oyster beds.

**Pond Liners**

CCPs in several forms have been used in demonstration projects to construct pond liners made of natural soils and fly ash or FGD materials for the construction of waste storage ponds at utility sites.

**Emerging Applications**

A wide array of potential beneficial use applications for CCPs have been demonstrated in projects of various sizes, including: Mitigating explosions from ammonium nitrate explosives by using FGD gypsum and other FGD residues; Removing nutrients from storm water using bottom ash; Horticultural applications combining bottom ash with yard waste to amend heavy clay soils; Artificial aggregates for road base and construction applications manufactured utilizing Class C ash; Lightweight aggregates for concrete manufactured utilizing spray dryer ash; Re-vegetation of mine sites utilizing FGD gypsum and some ashes; Odor control of poultry and swine wastes utilizing FGD gypsum; and others.
Section 6 – CCP Product Standards

A wide array of specifications and use guidelines have been adopted by standard setting organizations and regulatory agencies, placing CCPs on par with virgin and manufactured materials for product acceptability.

Industry Standard Setting Organizations

Both the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO) have developed CCP related standards. Key specifications and use guidelines include:

- **ASTM C 618** and **AASHTO M 295** are the standards for the use of fly ash as a concrete additive when cementitious or pozzolanic properties are desired. These standards provide a guideline to assure that fly ash used as a concrete admixture conforms to a specified range of physical and chemical properties and behavior. Conformity assures that a consistent, high quality product is produced.

- Particle size of fly ash is normally determined using the standard procedures of **ASTM D 422** or **AASHTO T 88**. The specific gravity of fly ash ranges from 2.1 to 2.9; boiler slag and bottom ash specific gravity normally ranges from 2.3 to 3.0. The procedures of **ASTM D 554** or **AASHTO T 100** are commonly used to determine fly ash specific gravity. Compacted fly ash and bottom ash usually have dry densities in the range of 70 to 110 pounds per cubic foot. Standard test procedures **ASTM D 698 and D 1557** and **AASHTO T 99 and T 180** are commonly used to define the compaction behavior of fly ash.

- There are numerous ASTM standards that establish CCP specifications and characteristics for specific manufacturing and engineering uses. While the following list is not all-inclusive, it typically represents ASTM standards that are widely recognized by designers, specifiers and regulators:
  - **ASTM C 593** - Standard specification for fly ash and other pozzolans for use with lime.
  - **ASTM C 595** - Standard specification for blended hydraulic cements.
  - **ASTM C 1157** - Standard performance standard for blended hydraulic cement.
• **ASTM D 5759** - Standard guide for characterization of coal fly ash and clean coal combustion ash for potential uses.

• **ASTM E 2277-03** – Standard guide for Design and Construction of Coal Ash Structural Fills.

• **ASTM E 2278** – Standard guide for the use of CCPs for Surface Mine Reclamation, Revegetation and Mitigation of Acid Mine Drainage.

• **ASTM E 2243-02** – Standard guide for the use of CCPs for Surface Mine Reclamation, Recontouring and Highwall Reclamation.

Additionally, the American Concrete Institute (ACI) maintains several technical committees and related reports addressing the use of both Class F and Class C fly ash in cement and concrete applications.

### Federal Agency Use Support

The U.S. federal government has promoted CCP utilization as a construction material through a variety of initiatives, including:

- **Initial Procurement Guidelines.** In 1983, the U.S. Environmental Protection Agency promulgated the first federal procurement guideline requiring agencies using federal funds to implement a preference program favoring the purchase of cement and concrete containing fly ash. EPA also published a summary of information pertaining to CCP use in an environmental fact sheet, *Guideline for Purchasing Cement and Concrete Containing Fly Ash*.19

- **Executive Order.** In 1993, President Clinton issued Executive Order No. 12873, *Federal Acquisition, Recycling and Waste Prevention*,20 directing federal agencies to develop affirmative procurement programs for environmentally preferable products and requiring EPA to issue guidance on principles agencies should use in making determinations for the preference and purchase of environmentally preferable products.

- **Comprehensive Procurement Guidelines.** In 1997, as part of its continuing program to promote the use of recovered materials, the EPA adopted the “Comprehensive Guideline for the Procurement of Products Containing Recovered Materials”21 and its companion piece, the “Recovered Materials Advisory Notice” (RMAN). The CPG designates 24 recycled-content products for which government procuring agencies need to develop affirmative procurement programs. The RMAN provides recommendations for purchasing products designated in the CPG. These guidelines

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19 EPA/530-SW-91-086, January 1992
20 58 Federal Register 54911, October 22, 1993
21 Federal Register November 13, 1997 (Volume 62, Number 219) Page 60961-60974
require all federal agencies and all state and local government agencies and contractors that use federal funds to implement a preference program favoring the purchase of such environmentally preferable products. Concrete and cement containing coal fly ash were the first of these products designated for federal purchasing in 1983.

- **Environmental Protection Agency Coal Combustion Products Partnership.** In 2003, the U.S. Environmental Protection Agency created the Coal Combustion Products Partnership – or C2P2 – program to actively promote the beneficial use of CCPs and the environmental benefits that result from their use. Through the program, EPA has set a goal of 50% utilization of CCPs by 2011. More than 200 companies and organizations have joined the C2P2 program, which conducts workshops, publishes technical materials and case studies, reviews state regulations and standards for CCP management, sponsors an awards program for best practices, and undertakes other activities. More information about the C2P2 program can be found at www.epa.gov/epawaste/partnerships/c2p2/index.htm.

- **Department of Energy Research Support.** Beginning in 1985, the U.S. Department of Energy’s National Energy Technology Laboratory sponsored the Coal Ash Resources Research Consortium – an international consortium of industry and government representatives, scientists, and engineers focused on advancing coal ash utilization.

- **Federal Highway Administration Usage Guidelines.** The Federal Highway Administration – in cooperation with the U.S. Environmental Protection Agency and other organizations – has published two CCP use guidelines: *Fly Ash Facts for Highway Engineers* and *Using Coal Ash in Highway Construction: A Guide to Benefits and Impacts.*

- **Army Corps of Engineers Specifications.** The first large-volume use of CCPs was by the U.S. Army Corps of Engineers in construction of the Hungry Horse Dam in 1949. The Corps has since built several dams using fly ash and continues to perform research on utilization of fly ash. Many Army Corps specifications for military and civil construction projects provide for fly ash use in concrete. The Army Corps also allows fly ash use in sub-grade stabilization, embankments, flowable fill, soil amendment and asphalt filler.

- **Other Federal Agency Support.** Federal Aviation Administration standards allow fly ash use in certain concrete products. The U.S. Department of Agriculture conducts research on a variety of beneficial uses for CCPs. The Office of Surface Mining studies utilization of fly ash in mine reclamation. The U.S. Bureau of Reclamation was an early adopter of coal ash technology in the construction of concrete dams.

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22 Federal Highway Administration Report # FHWA-IF-03-019
23 Environmental Protection Agency Report # EPA-530-K-05-002
25 Standards for Specifying Construction of Supports, AC 150/5370-10A, February 17, 1989
Section 7 – CCP Utilization Benefits

Performance Benefits

As noted in Section 5 – CCP Utilization Options, CCPs frequently enhance the performance of the end products in which they are utilized. Concrete is the most prevalent example. The addition of fly ash produces concrete with higher ultimate strength, improved workability, reduced bleeding, reduced heat of hydration, reduced permeability, increased resistance to sulfate attack, increased resistance to alkali-silica reactivity (ASR), lowered costs, reduced shrinkage, and increased durability.26

The performance benefits of using coal fly ash in concrete are the result of both mechanical and chemical properties of the material. Mechanically, coal ash particles are small, glassy spheres of varying sizes, allowing them to fill tiny voids between aggregate and cement particles. In addition to filling the voids, the spherical shape of fly ash gives it a ball bearing effect, allowing concrete mixes to utilize less water.

Chemically, fly ash is a pozzolan which reacts with free lime produced during the hydration of cement to produce a greater volume of durable binder within the concrete mix. The combination of these mechanical and chemical properties creates concrete that is stronger, less permeable to water, and therefore more durable.

Environmental Benefits

Fly ash utilization, especially in concrete, has significant environmental benefits including: (1) increasing the life of concrete roads and structures by improving concrete durability, (2) net reduction in energy use and greenhouse gas and other adverse air emissions when fly ash is used to replace or displace manufactured cement, (3) reduction in amount of coal combustion products that must be disposed in landfills, and (4) conservation of other natural resources and materials.27

The Electric Power Research Institute during 2009 sponsored a study to quantify the environmental benefits from CCP utilization.28 The study – conducted by the Recycled Materials Resource Center at the University of Wisconsin at Madison – applied life cycle analysis methodologies to quantify the benefits of using CCPs in sustainable construction.

The analysis focused on fly ash, bottom ash, and FGD gypsum and their most common applications. Comparisons were made between energy consumption, water use, and greenhouse gas emissions associated with conventional materials and procedures and those employing CCPs.

26 U.S. Federal Highway Administration report FHWA-IF-03-019, *Fly Ash Facts for Highway Engineers*
27 Ibid.
The analysis showed significant societal benefits are obtained by using CCPs in sustainable construction in lieu of natural resources (e.g., limestone for portland cement, rock gypsum, etc.) Using 2007 CCP use data, energy consumption was reduced by 162 trillion BTUs, water consumption was reduced by 32 billion gallons, and GHG emissions were reduced by 11 million tons CO₂ equivalent.

In comparative terms, the reduction in energy consumption is commensurate with the energy consumed by 1.7 million homes (a large U.S. city), the water saved is equal to 31% of the annual domestic water use in California, and the reduction in greenhouse gas emissions is comparable to removing 2 million automobiles from the roadway.

The study also identified benefits achieved by avoiding disposal: 3.7 trillion BTUs of energy are saved (= 38,600 households) and CO₂ equivalent emissions are reduced by 0.3 million tons (= 46,300 automobiles) by not disposing CCPs in landfills.

Organizations that promote and establish standards for sustainable construction have recognized the role CCPs can play in improving the environmental performance of structures. Building with concrete that contains fly ash can contribute to earning points in the U.S. Green Building Council’s (USGBC) Leadership in Energy and Environmental Design (LEED) program, which recognizes sustainable use of materials, land, water, and energy, as well as ergonomics and innovative design.

**Economic Benefits**

The economic benefits of CCP utilization can be divided into three categories: Direct Utilization Industry Economic Activity; Avoided Cost of Disposal; and Economic Savings from Utilization of Recovered Materials.

**Direct Utilization Industry Economic Activity**

The 2005 edition of the American Coal Council Economic Assessment provides the core of this analysis. That publication gave the first comprehensive monetary view of the activities related to marketing and distributing CCPs for beneficial use. Comparative data from the 2005 report is provided here and methodologies have been maintained consistent to allow for conclusions about the growth of the industry.

Revenue generating activity occurs on several levels when CCPs are beneficially used. Revenue flows to producers of CCPs (typically utilities), marketing agents, and transportation service providers. Out of those revenues, numerous supporting industries and taxing agencies receive benefits.

**Revenues to CCP Producers**

Utilities and other producers of CCPs typically receive revenue from marketing the products as an alternative to disposing of them. These revenues have the effect of reducing electricity generating costs and are typically passed along to electricity ratepayers.
The tables below, derived from U.S. Energy Information Administration data, show the total reported revenues to utilities, as well as detailed information on revenues from specific CCP product types. The first three years on the tables were reported in the 2005 edition of this report. EIA did not collect data in 2006 and began using a new form for data collection in 2007 to gather the information presented here.

### Total CCP Utilization Revenues

<table>
<thead>
<tr>
<th>Year</th>
<th>Total CCPs Sold</th>
<th>Average Revenue $/Ton</th>
<th>Total Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>30,575,900</td>
<td>$3.71</td>
<td>$113,361,100</td>
</tr>
<tr>
<td>2002</td>
<td>31,138,600</td>
<td>$3.81</td>
<td>$118,706,100</td>
</tr>
<tr>
<td>2003</td>
<td>34,198,900</td>
<td>$4.16</td>
<td>$142,256,000</td>
</tr>
<tr>
<td>2007</td>
<td>48,352,600</td>
<td>$4.63</td>
<td>$223,822,000</td>
</tr>
</tbody>
</table>

Source: EIA Forms 767, 923

### Fly Ash Revenues

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Fly Ash Sold</th>
<th>Average Revenue $/Ton</th>
<th>Total Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>17,755,300</td>
<td>$4.45</td>
<td>$79,050,400</td>
</tr>
<tr>
<td>2002</td>
<td>17,987,900</td>
<td>$4.69</td>
<td>$84,296,200</td>
</tr>
<tr>
<td>2003</td>
<td>19,540,600</td>
<td>$5.06</td>
<td>$98,879,500</td>
</tr>
<tr>
<td>2007</td>
<td>29,556,400</td>
<td>$5.63</td>
<td>$166,506,000</td>
</tr>
</tbody>
</table>

Source: EIA Forms 767, 923

### Bottom Ash Revenues

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Bottom Ash Sold</th>
<th>Average Revenue $/Ton</th>
<th>Total Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>5,528,900</td>
<td>$1.48</td>
<td>$8,203,200</td>
</tr>
<tr>
<td>2002</td>
<td>5,183,200</td>
<td>$1.88</td>
<td>$9,735,600</td>
</tr>
<tr>
<td>2003</td>
<td>5,579,000</td>
<td>$2.49</td>
<td>$13,918,900</td>
</tr>
<tr>
<td>2007</td>
<td>8,849,800</td>
<td>$2.82</td>
<td>$24,932,000</td>
</tr>
</tbody>
</table>

Source: EIA Forms 767, 923

### FGD Revenues (Gypsum)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total FGD Sold</th>
<th>Average Revenue $/Ton</th>
<th>Total Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>6,634,900</td>
<td>$3.36</td>
<td>$22,285,000</td>
</tr>
<tr>
<td>2002</td>
<td>7,431,200</td>
<td>$2.78</td>
<td>$20,682,300</td>
</tr>
<tr>
<td>2003</td>
<td>7,422,700</td>
<td>$3.43</td>
<td>$25,446,700</td>
</tr>
<tr>
<td>2007</td>
<td>8,922,300</td>
<td>$3.32</td>
<td>$29,627,000</td>
</tr>
</tbody>
</table>

Source: EIA Forms 767, 923
### Other CCP Revenues

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Other CCPs Sold Tons</th>
<th>Average Revenue $/Ton</th>
<th>Total Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>656,800</td>
<td>$5.82</td>
<td>$3,822,500</td>
</tr>
<tr>
<td>2002</td>
<td>536,200</td>
<td>$7.44</td>
<td>$3,992,000</td>
</tr>
<tr>
<td>2003</td>
<td>1,656,580</td>
<td>$2.42</td>
<td>$4,010,900</td>
</tr>
<tr>
<td>2007</td>
<td>1,024,100</td>
<td>$2.69</td>
<td>$2,757,000</td>
</tr>
</tbody>
</table>

Source: EIA Forms 767, 923

Utility revenues from the sale of CCPs continue to increase rapidly, growing 63.5% between 2003 and 2007 to total $223.8 million.

Most of the growth came from increased sales of fly ash – which increased from 19,540,600 tons to 29,556,400 tons during the same period – and bottom ash – which increased from 5,579,000 tons to 8,849,800 tons. Average revenue per ton for these materials also increased – from $5.06 to $5.63 for fly ash and from $2.49 to $2.82 for bottom ash.

Revenues from FGD materials increased more modestly. FGD material sales increased from 7,422,700 tons in 2003 to 8,922,300 tons in 2007. The average revenue per ton declined slightly from $3.43 to $3.32.

### Revenues to CCP Marketing Agents

For the purposes of this report, CCP marketing agent revenues will be limited to the fly ash portion of CCP utilization. It is generally recognized in the CCP industry that marketing agents are utilized primarily for the sale of fly ash into the concrete and other high end applications, while the CCP producers may retain control over sales of the lower-end CCPs.

The price of fly ash varies widely between markets and prices in more costly markets often reflect long distance transportation costs. There are no construction materials indices that publish current prices for fly ash in various markets. The U.S. Federal Highway Administration in 2003 estimated the average retail value of fly ash in the concrete market at $25 to $30 per ton (excluding transportation.)

For this analysis, the low end of FHWA's estimate, $25 per ton, was adjusted for inflation at 2007 to yield $28.17 per ton as an estimated average retail price for fly ash sales.

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29 U.S. Federal Highway Administration, *Guidelines for the Use of Lithium to Mitigate or Prevent Alkali-Silica Reaction (ASR)*, PUBLICATION NO. FHWA-RD-03-047, July 2003
In 2007, CCP producers reported revenue-producing sales of fly ash totaling 29,556,400 tons. At $28.17 per ton, this yields an estimated retail market value of $832.6 million. After deducting the revenues reported by the CCP producers, an estimated net revenue value to CCP marketing agents is $608,782,000.

Revenues to Transportation Service Providers

Transportation costs vary widely between retail markets based on their distance from ash sources. Therefore, these costs are typically added to the costs of the resource and represent an additional revenue stream created by CCP utilization. CCPs are transported by both rail and truck.

Rail Transportation – Rail transportation estimates are based solely on fly ash tonnages. For the purposes of this report, all other CCPs reported as sold were of a retail value that precludes shipping any great distance. For lower value CCPs, competing against local materials that have marginal value cannot be accomplished if freight costs are incurred.

For the 2005 edition of this report, the American Coal Council surveyed railroads regarding fly ash shipping tonnage information based on Standard Transportation Commodity Code 40. Over a three year period, rail shipments of fly ash averaged 4,830,000 tons annually with an average hauling distance of 632 miles. Average per ton costs for shipments of this type, according to the Bureau of Transportation Statistics and U.S. Census Bureau’s 2002 Economic Census were $4.46 per ton. Assuming the same ratio of truck to rail shipping volume in 2007, the volume of rail shipments of fly ash can be estimated at 7,744,000 tons.

Therefore, a conservative estimate of annual total revenue from the rail movement of fly ash is $34,538,000.

Truck Transportation – The remainder of marketed fly ash is trucked to regional and local distribution points. After deducting for average annual volumes of fly ash shipped by rail, the amount of tonnage remaining for trucking in 2007 is 21,812,000 tons. Assuming average 80-mile hauls of 25-ton loads charged at $1.75 per mile, the total estimated value of fly ash shipments equals $122,147,000.

Because of their lower value, other CCPs are assumed to move a shorter distance. The combined volume of bottom ash, FGD, and other materials reported sold in 2007 was 18,796,200 tons. Assuming average 30-mile hauls of 25-ton loads charged at $1.75 per mile, the total estimated value of other CCP shipments equals $39,472,000.

The total estimated revenue of truck transportation for CCPs in 2007 was $161,619,000.

Summary of Direct Revenues from Utilization Industry
The following table summarizes the estimates of direct revenues produced from the utilization of CCPs:

<table>
<thead>
<tr>
<th>Revenue Segment</th>
<th>Total 2007 Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producers (Utilities)</td>
<td>$223,822,000</td>
</tr>
<tr>
<td>Marketers</td>
<td>$608,782,000</td>
</tr>
<tr>
<td>Transporters</td>
<td>$196,157,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1,028,761,000</strong></td>
</tr>
</tbody>
</table>

**Indirect Economic Benefits from Operations of Utilization Industry**

Numerous support businesses and taxing agencies benefit from the revenues directly produced by the CCP utilization industry. Although the dollars flowing to these entities are, in essence, expenses of the revenue generators listed above, their impact on local economies can be significant.

Major economic beneficiaries of the CCP utilization industry include:

- Federal, state and local taxing entities
- Suppliers of ash storage and material handling equipment
- Suppliers of truck and rail transportation equipment
- Local business support services

Because CCP sources and markets are widely dispersed across the United States, these benefits are realized in communities of all sizes.

**Avoided Cost of Disposal**

The 2009 Electric Power Research Institute sponsored study by the Recycled Materials Resource Center that applied life cycle analysis to determine environmental benefits of CCP use also used the methodologies to determine economic savings from avoiding landfill disposal.30

In the EPRI study, avoided landfill disposal costs were calculated using life cycle inventory (LCI) data generated for construction, operation, and maintenance costs for Subtitle D (non-hazardous municipal solid waste) landfills in EREF (1999).

Assuming all of the avoided disposal would have been conducted on-site at power plant facilities, the total life cycle cost for one year of materials would be $412.8 million. If the materials would have been disposed at a commercial industrial landfill, the total life

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cycle cost for one year of materials would be $1.4 billion, reflecting the addition of commercial landfill tipping fees.

**Economic Savings from Utilization of Recovered Materials**

The same EPRI study also calculated economic benefits associated with using CCPs to replace conventional materials in sustainable construction activities. The analysis focused on fly ash, bottom ash, and FGD gypsum and their most common applications. Comparisons were made between energy consumption, water use, and greenhouse gas emissions associated with conventional materials and procedures and those employing CCPs.

In addition to the significant environmental benefits discussed above, the analysis showed that utilizing CCPs in sustainable construction applications results in annual savings of between $5 billion and $10 billion.

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Section 8 – CCP Utilization Trends

Historic Production and Use

The modern usage of fly ash in concrete applications is a technology derived from ancient construction practices. The Egyptians learned to burn gypsum and the Greeks learned to burn lime in order to concentrate their calcium content. The Romans, a bit later, learned to combine burnt lime with other products – including volcanic ash – to make concrete and mortar. In fact, the term “pozzolan” is derived from the name of the Roman city “Pozzuoli” where volcanic ashes were obtained.

The best preserved building of the Roman Empire, the Pantheon, was rebuilt in 200 A.D. using pozzolanic concrete and pozzolanic mortar and brick. The dome of the Pantheon, with a span of 142.5 feet, was built with lightweight pozzolanic concrete consisting of pozzolan, lime and pumice.

As centuries passed, many other structures have been built with pozzolanic concrete, the ancient equivalent of fly ash-based concrete. For example, the Cathedral of Santa Sophia in Turkey was completed in 537A.D. using pozzolanic concrete foundations as well as pozzolanic mortars and bricks. The Kremlin, in Russia, as well as many fortresses, palaces and cathedrals in Eastern Europe were built between the 1500s and the 1700s using pozzolanic concrete foundations as well as pozzolanic-based mortars.

The development of portland cement (first using a type of stone quarried on the Isle of Portland in England) during the early 19th Century led to its ascendance as the dominant cementitious material for concrete construction. Portland cement enjoyed the advantage of utilizing common minerals as raw materials in its manufacture. The use of natural pozzolans such as volcanic ash became exceptionally rare.

Builders in the ancient world used pozzolanic concrete foundations and pozzolanic mortars because the technology was both strong and durable. Equally today, the use of fly-ash based concretes, mortars and stucco provides benefits to a builder far in excess of just using portland cement. It is these benefits, and not necessarily the environmental value of fly ash, that has led to its increasing use over the past 30 years.

The first uses of coal ash as a pozzolan occurred in the United States beginning in the 1940s. Engineers with the U.S. Bureau of Reclamation were seeking a way to mitigate the heat of hydrating cement in mass concrete placements such as dams. Construction of the Hungry Horse Dam in Montana beginning in 1948 utilized 120,000 tons of coal fly ash. Six more dams utilizing coal fly ash were built during the 1950s. Between 1940 and 1973, the Bureau used fly ash in

33 U.S. Bureau of Reclamation, Hungry Horse Project History, Eric A Stene, 1995
more than seven million cubic yards of concrete. The Bureau continues to specify the use of coal fly ash for its projects, and has used it in countless concrete pipe projects.

Other early users of fly ash in the United States included the U.S. Army Corps of Engineers and the Tennessee Valley Authority.

The Corps of Engineers has used fly ash as a partial replacement for portland cement in concrete since the 1950s. The U.S. Army Waterways Experiment Station in Vicksburg, Mississippi, began an investigation of pozzolans in 1950, and the Office of the Chief of Engineers authorized a study on the use of fly ash concrete in airfield pavement in 1956. Between 1957 and 1959, the Corps used fly ash in 611,000 cubic yards of concrete in the Sutton Dam on the Elk River in West Virginia. This project was part of the Corps’ Civil Works program, which now utilizes fly ash in concrete whenever it is economically available. The Corps’ Military Works program has used fly ash concrete in numerous projects since the 1950s.

Tennessee Valley Authority began using fly ash as a partial replacement for portland cement in the mid 1950s. TVA’s first use of fly ash in concrete dates back to 1956 at the Johnsonville Steam Plant, after which fly ash began to be used in all major construction projects. TVA used 10,600 tons of fly ash from its Gallatin Steam Plant in 94,000 cubic yards of concrete placed at the Normandy Dam in 1976. TVA also used fly ash in the construction of its Watts Bar Nuclear Plant.

Increasing environmental regulations in the 1960s, culminating with the Clean Air Act of 1970, forced electric utilities to begin collecting substantially all of the fly ash produced by coal combustion. Utilities initially moved to dispose of substantially all of the ash, but drawing on the experience of the government early adopters, an ash marketing industry emerged to begin utilizing the resource for construction materials. The National Ash Association – forerunner of the current American Coal Ash Association – was organized in 1968.

It is significant to note the evolution of terminologies used to formally describe “coal ash.” Originally defined as “Coal Combustion Wastes” (CCW), the materials began to be called “CoalCombustion Byproducts” (CCB) as beneficial use strategies began to take hold. Eventually, the term “Coal Combustion Products” (CCP) was adopted by most of the industry and the U.S. Environmental Protection Agency in its establishment of the Coal Combustion Products Partnership (C2P2) program in 2003. Recent public statements by some EPA officials referring to “Coal Combustion Residues” may signal another pending shift in perception. (See “Section Nine – Factors Affecting Future Utilization” for further discussion.)

Over the four decades commencing in 1966, utilization of CCPs increased steadily. The chart below illustrates increases in the supply, utilization and utilization rates of CCPs. Increases in CCP supply are attributable to increases in amount of coal consumed, increases in consumption of coal with higher ash contents, and the addition of FGD material as a new large volume class of CCPs.

34 University of North Dakota Coal Ash Research Center, Historical Timeline
35 http://www.epa.gov/epawaste/partnerships/c2p2/index.htm
36 American Coal Ash Association, Annual CCP Production and Use Survey
Utilization increases have been attributed to advances in technological knowhow, education of users and specifiers of construction materials, and development of logistics resources to deliver materials to markets. Numerous barriers to increased utilization have been identified in the technical, regulatory, economic, and perceived safety and health risk areas.\textsuperscript{37}

Since the U.S. Environmental Protection Agency issued its Final Regulatory Determination on CCPs in 2000 (see “Regulatory Trends” in this section), beneficial use rates for CCPs have increased from 30% to 43%.

Recent years have seen a slight downturn in CCPs utilization, particularly in the highest value application of fly ash in concrete. These downturns are attributable to an overall slowdown in construction activity that has created reductions in sales of all building materials. In fact, consumption of portland cement decreased 9.6\% in 2007 and 15.1\% in 2008.\textsuperscript{38} Declines in sales of fly ash for concrete applications were less, indicating continuing growth of utilization in comparison to cement.

\textsuperscript{37} U.S. Environmental Protection Agency Report to Congress, \textit{Study on Increasing the Usage of Recovered Mineral Components in Federally Funded Projects Involving Procurement of Cement or Concrete}, June 3, 2008

\textsuperscript{38} Portland Cement Association, \textit{Forecast 2010}, Concrete Products magazine, December 2009
Market Participants Overview

Today’s CCP industry consists of a group of stakeholders connected by common interests in the management and use of CCPs. Their combined efforts have produced an increasing trend in beneficial use of CCPs. Major participants in the coal ash market can generally be divided into the following categories:

- **Producers** – primarily integrated electric utilities and electricity generating companies operating coal-fueled power plants. Industrial and some institutional coal users also exist, but tend to produce lower quantities of coal ash at their facilities.

- **Marketers** – which contract with producers to manage and/or sell coal ash to end users. Marketers traditionally handle the sales, promotion and logistics related to CCP utilization. These marketing firms generally have a revenue-sharing arrangement with the utilities in which they provide a portion of the selling price to the utility as a revenue stream.

- **Technology Providers** – which develop and market technologies for ash quality improvement and material handling.

- **Researchers** – which include public and private institutions. Major research centers for coal ash include the University of Kentucky Center for Applied Energy Research, University of North Dakota Coal Ash Resource Center, University of New Hampshire / University of Wisconsin at Madison Recycled Material Resource Center, University of Wisconsin Milwaukee Center for By-Products Utilization, Southern Illinois University Coal Research Center, Electric Power Research Institute, Western Research Institute, and The Ohio State University.

- **Federal Agencies** – Key federal agencies involved in research and promotion of coal ash utilization include the Environmental Protection Agency’s Coal Combustion Products Partnership (C2P2), the Department of Energy’s National Energy Technology Laboratory, and the Department of Transportation’s Federal Highway Administration.

Market Trends

Producer attitudes toward coal ash have evolved steadily since the industry originated in the 1960s. Producers initially viewed coal ash as a waste product and would often give the materials to marketers for free or even pay them to take materials in an effort to reduce disposal costs. As coal ash markets developed over time, many producers began to see the materials as a valuable resource and began charging marketers and users for access to it.

Today, the majority of producers, however, have entered into supply agreements with either:

- Large volume consumers of coal ash, primarily cement kilns, which utilize the ash as raw feed; or
• Marketers which undertake the marketing and distribution of coal ash to a wide array of smaller users.

As standards for CCPs became established and user knowledge about the resource grew, the industry grew in both size and sophistication. Today, CCPs are utilized in every state and are delivered by both truck and rail to job sites and distribution terminals nationwide.

The mix of CCPs being marketed also has evolved over the past 30 years. With the advent of flue gas desulfurization emissions control equipment (also known as "scrubbers") at electric generating plants, an entire new class of CCPs was created. FGD material produced by these units is now the fastest growing CCP segment and expected to continue rapid growth as more scrubbers are placed in service over the next decade.

Technology Trends

Early technology developments in the CCP industry focused on developing knowhow regarding the use of the materials. This resulted in the development of the utilization options and product standards discussed in Sections Five and Six of this report.

As product knowledge grew, users began to change the perception of what was possible utilizing CCPs. For instance, early users of fly ash in concrete products considered 25% to 30% replacement of cement as an upper limit. Today, those replacement rates are common and “High Volume Fly Ash” replacements can be 40% to 50% or more.

Technology developments today come in several forms:

• Technologies enabling higher utilization rates of CCPs in existing applications.

• Technologies utilizing CCPs in new applications.

• Technologies intended to improve the quality or marketability of the CCPs.

Examples of each of these technology approaches have been provided by companies that responded to an American Coal Council survey in 2009. These technology profiles are included in Appendix 1 of this report.

Regulatory Trends

Federal Regulation

The principal federal statute under which hazardous and solid wastes are regulated is the Resource Conservation and Recovery Act (RCRA). RCRA establishes a comprehensive cradle-to-grave system for regulating hazardous wastes. Specifically, Subtitle C of RCRA and its implementing regulations impose requirements on the generation, transportation, storage, treatment and disposal of hazardous wastes. To trigger these requirements, a material must be a "solid waste," and the solid waste must be "hazardous." Subtitle D of RCRA pertains to State
or Regional Solid Waste Plans. Wastes that are not classified as hazardous under Subtitle C fall under Subtitle D and are subject to regulation by the states as solid waste. As originally drafted, RCRA did not specifically address whether CCPs fell under Subtitle C as a hazardous waste or Subtitle D as a solid waste.

In 1980, Congress enacted the Solid Waste Disposal Act amendments to RCRA. Under the amendments, certain wastes, including CCPs, were temporarily excluded from Subtitle C regulation. This regulatory exemption is commonly referred to as the "Bevill Exemption." As a result, CCPs fell under Subtitle D and became subject to regulation under state law as solid waste.

The amendments further directed that the EPA produce a report regarding CCPs and recommend appropriate regulation. EPA issued its Report to Congress in 1988 titled *Wastes from the Combustion of Coal by Electric Utility Power Plants*. The EPA report concluded that CCPs generally do not exhibit hazardous characteristics and that regulation of CCPs should remain under state Subtitle D authority.

A Regulatory Determination by the EPA became effective September 2, 1993. The regulation stated that regulation of CCPs generated by coal-fueled electric utilities and independent power producers as hazardous waste is unwarranted and that the EPA will continue to exempt these materials from regulation as a hazardous waste under RCRA. In its 1993 Report to Congress, EPA stated it “encourages the utilization of coal combustion wastes as one method for reducing the amount of these wastes requiring disposal and supported voluntary efforts by industry to investigate new possibilities for utilizing coal combustion wastes.”

The exemption, according to EPA, applies only to coal-fueled electric utilities and independent power producers. While it does not include CCPs generated through any other industrial activity, these wastes continue to be exempt from hazardous waste regulations until EPA issues the required regulatory determination.

In 1999 the EPA issued a second Report to Congress addressing low level wastes as required by the original Bevill determination. On May 22, 2000, EPA issued a Final Regulatory Determination, stating that fossil fuel combustion wastes “do not warrant regulation under Subtitle C of RCRA,” thereby retaining the Bevill exemption under RCRA. EPA further determined that there will be no regulation for CCPs when beneficially used and that EPA does “not wish to place any unnecessary barriers on beneficial use.” Along with the non-hazardous Bevill Determination, EPA announced that it would develop national standards under RCRA Subtitle D to address CCPs disposed in landfills and surface impoundments or placed in mines. EPA provided an unqualified endorsement of all beneficial uses other than mine placement.

**State Environmental Regulations**

Most states currently do not have specific regulations addressing all uses of CCPs. Requests for CCP uses are handled on a case-by-case basis or under generic state recycling laws or regulations. States without formal case-by-case CCP use regulations or guidelines often encourage the use of coal fly ash in cement and concrete applications, and in manufactured products. Additionally, state highway departments are required by the Federal Highway Administration to have
specifications conforming to federal procurement guidelines for cement and concrete containing coal fly ash for federally funded projects.

Several states have adopted laws and regulations or issued policies and/or guidance regarding CCP use. The CCP uses authorized, however, vary widely from state to state. Some states authorize liberal use of CCPs, while others authorize CCP use only in limited applications. In addition, the level of regulatory control and oversight varies significantly.

One of the functions of the Environmental Protection Agency’s Coal Combustion Products Partnership program has been to conduct reviews of state by state standards and practices. To date, reviews have been conducted in Florida, North Dakota, Pennsylvania and Texas.

Wisconsin is also frequently cited as a state that has enacted model regulations for CCP management. Previously, Wisconsin had the most proven and potential CCP-related environmental damage cases listed by the EPA. The state enacted non-hazardous disposal standards similar to those for municipal solid waste landfills in 1988 and subsequently enacted beneficial use regulations in 1997. The result has been environmentally protective disposal and a dramatic increase in CCP utilization.

**Wisconsin Ash Production and Utilization History**

![Graph showing Wisconsin ash production and utilization history](Data courtesy of We Energies)
Section 9 – Factors Affecting Future Utilization

Barriers Analyses

Three major studies examining barriers to increasing utilization of CCPs have been conducted by the federal government — two by the Department of Energy and one by the Environmental Protection Agency at the direction of the U.S. Congress.

The U.S. Department of Energy’s first report was completed in 1993 and culminated in a Report to Congress in 1994. A follow-up to that study was performed in 1998 as a means of updating the perceived barriers from the standpoint of those that improved, those that worsened and those that remained the same, as well as identifying new barriers.

In the 1993 report, barriers were categorized into three groups: institutional, regulatory and legal. These barriers were determined through a Barriers Workshop held at the DOE’s Morgantown, West Virginia offices in September of 1993.

Institutional barriers included:

- Lack of familiarity with potential ash uses.
- Lack of data on environmental and health effects.
- Restrictive or prohibitive specifications.
- Belief that fly ash quality and quantity are not consistent.
- Lack of fly ash specifications for non-cementitious applications, resulting in substitution in these applications of the more restrictive specifications for use of fly ash in cement and concrete.
- Belief that raw materials are more readily available and more cost-effective.
- Viewpoints of states that EPA procurement guidelines for fly ash in concrete are a rigid ceiling rather than general guidelines for use.
- Actions by environmental agencies that normally support beneficial ash uses in principle, but that frustrate the actual implementation by restrictive regulations.
- Restrictive regulation of fly ash as a solid waste in most states.
- Lack of state guidelines on beneficial ash use.
- Lack of clear federal direction on regulation of beneficial use.

The Regulatory barriers result from the EPA RCRA designation of CCPs as solid wastes, even when they are utilized rather than disposed of. This “waste” designation generally triggers case-by-case approval and permitting procedures that discourage the use of CCPs because of the cost and time involved in getting approval.

The Legal barriers were identified to be closely tied to the regulatory barriers. Environmental liability becomes a strong deterrent to the use of any by-product that is designated and regulated as a solid waste. Other legal barriers include uncertainties in applying commercial and contract law to the sale of CCPs and confusion as to how patent law applies to CCP applications.
The 1998 report updated the status of the barriers detailed in the 1993 report, and identified a number of new barriers.

The barriers that remained unchanged in 1998:

- **Legal Barriers** – The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), commonly known as Superfund, enacted by Congress on December 11, 1980, has remained unchanged with regard to CCPs.
- **Institutional Barriers**
  - Education – The need to educate a wide variety of groups and individuals was identified as a continuing issue. The groups requiring education include regulators, engineers, scientists and other professionals, and the public.
  - Changes to the CCPs produced due to the Clean Air Act Amendments (CAAA). NOx regulations have had the largest impact on the quality and quantity of marketable fly ash produced due to higher carbon contents in the fly ash.

The barriers identified as having been reduced or eliminated between 1993 and 1998:

- **Regulatory Barriers** – Federal and state regulation has been eased since the EPA Final Regulatory Determination of Four Large-Volume Wastes from the Combustion of Coal by Electric Utility Power Plants stating that fly ash, bottom ash, boiler slag and FGD emission control waste are non-hazardous industrial wastes and should therefore be regulated under Subtitle D of RCRA, was a positive step toward reducing the regulatory barriers and reducing concerns of users and the public that these materials must be hazardous.
- **Institutional Barriers**
  - Environmental and public perception – The need to reduce CO₂ emissions because of potential global warming has provided an opportunity for the CCP industry to promote the use of fly ash in concrete as an environmental benefit. The sales of fly ash into the cement replacement market has reduced the need for production of an equivalent quantity of cement. For every ton of cement that is replaced by fly ash there is one ton of CO₂ production avoided.
  - Economic – The perception that cost avoidance is the only economic advantage to CCP utilization remains in place at many utilities. It is now evident that utilities that participate actively in trade associations related to CCPs have a much better handle on the true economic benefits derived from CCP utilization. The 1998 report validated the premise that avoided costs are but a part of the overall economic benefits derived from CCP utilization and promotion.
  - Technical – Industry worked diligently since the 1993 report to develop standards and specifications for CCPs. Although this was a slow and tedious process, the end result guaranteed that utilization would be guided by adequate performance standards that further enhance utilization.

New barriers to CCP utilization identified in the 1998 update included:

- **Institutional and Technical Barriers**
Climate Change – The issue of global climate change and the need to reduce greenhouse gas emissions has the potential to impact coal-fueled utilities. It is anticipated that coal-fueled power plants may be required to substantially reduce CO₂ emissions in the near future. One approach is to incorporate biomass as a portion of the fuel; this will produce CCPs that likely will not meet the current standards.

Mercury Control – The biggest challenge coming from the potential mercury regulations is the use of Activated Carbon Injection for control. The presence of any activated carbon in fly ash prevents its use in concrete, thus requiring an increase in the production of cement to meet demand and also causing the 12 million plus tons of fly ash currently utilized in the cement market to be landfilled. Landfill costs may increase due to the presence of mercury in the ash, although EPRI has indicated that no significant changes for disposal should occur.

Regulatory Barriers

NORM – Naturally Occurring Radioactive Materials has been a past issue with CCPs and may surface again. It was a barrier due to the EPA inclusion of CCPs on the list of eight industrial materials that contain NORM and require some assessment.

TRI – Toxic Release Inventory was added to the burden that utilities have in reporting emissions. Fortunately, utilized CCPs are excluded from reporting under TRI and so this in fact increased the utility incentive for utilization. Unfortunately, the TRI reporting has put most utilities on the top of the state list of emitters.


The 2007 study focused on “recovered mineral components” – a broader class of materials that includes CCPs along with other materials such as ground granulated blast furnace slag, silica fume and foundry sands. The study identified barriers in economic, regulatory, technical, and institutional areas.

Notably, the 2007 Report to Congress concluded that: “A major regulatory impediment to the use of RMCs, particularly coal combustion products (CCPs), is their categorization as a waste by legislative and regulatory bodies.” (See the discussion of “Regulatory Factors” later in this section for EPA’s apparent perception of this conclusion two years later.)

Other CCP-specific conclusions of the 2007 barriers study were related to logistical issues. For instance, the study noted that “transportation costs also limit RMC use because of the distance between the source of materials and where they would ultimately be used... For example, the American Coal Ash Association (ACAA) notes that transportation costs are the primary economic impediment to the reuse of CCPs, and estimates that such costs generally limit the shipment of CCPs to a 50-mile radius around a power plant. In addition to the problems posed by distance, using railcars to transport materials also presents issues because railcar availability is limited and
rail transportation rates are high in certain markets. To complicate matters further, there are at least 50 different sets of transportation regulations for nonhazardous materials (EPA, 2005b).”

Overcoming logistical barriers to increased CCP utilization requires investment in infrastructure to correct for geographic and seasonal disparities between CCP production and use. CCP production is centered at large electric generating stations often located distant from construction markets. Those base load generating stations operate around the clock all year long, while the demand for CCPs is frequently seasonal – peaking during warm summer construction months. A robust system of transportation assets and product storage facilities is necessary to counter those logistical disparities.

Technology Factors

Many barriers to higher utilization can be met through the deployment of new technologies. Technologies are developed by a variety of entities ranging from private commercial companies to government-funded research.

For many years, the United States government was a significant funder of CCP research and development. The U.S. Department of Energy’s National Energy Technology Laboratory (NETL) – with locations in Pittsburgh, Pennsylvania, and Morgantown, West Virginia – coordinated funding for research projects through the Combustion Byproducts Recycling Consortium (CBRC). The CBRC was divided into three geographic areas (western, midwestern, and eastern), each of which was tasked with identifying priorities of high interest to their respective geographic areas. Proposals were reviewed against regional priorities and then against a set of national priorities, after which recommendations were made to DOE to fund research projects. Private matching funding of at least 50% was required for research projects. Projects addressed a wide variety of topics, including mine applications, the use of CCPs in new processed and formed structural products using ash as filler, in agricultural and land applications, high carbon ash utilization, transportation uses, FGD materials and leaching characteristics of CCPs in disposal setting, even setting where the material is in direct contact with groundwater. From its inception in 1998, the CBRC funded 52 research projects nationwide with a total value exceeding $10 million from federal, state, and private sources of support. However, federal funding for the program was phased out in 2007 and 2008.

Universities and states continue to conduct much of today's CCP research. A number of universities have established programs and/or centers of research and support for CCPs. The University of North Dakota has established the Energy and Environmental Research Center (EERC), and more specifically the Coal Ash Resources Research Consortium. The University of Wisconsin Milwaukee has the Center for Byproduct Utilization, and the University of Kentucky has the Center for Applied Energy Research (CAER). The Ohio State University, Pennsylvania State University, Texas A&M University, Southern Illinois University and West Virginia University all have nationally recognized CCP programs. These university programs examine the many uses, characteristics and impacts of CCPs in a variety of settings.

Several states have governmental offices that support coal utilization and CCPs use. Notable among these are Ohio and Illinois. These state programs look not only at mining coal but also at the variety of ways that CCPs can be used within their states for beneficial use. The partnerships
that have resulted from state participation have made the introduction of new CCP technology an element of the state's economic growth. Some technology being supported is rather unusual. For example, the State of Ohio has been supporting Energy Industries of Ohio, a small company in Cleveland, in their research for ways to reduce the weight of structural components in the automotive industry using cenospheres and off-specification fly ash. If successful, this may permit the reduction in metals needed for automobile chassis and frames in light trucks and sport utility vehicles. This, in turn, would lead to a reduction of vehicle weight and an increase in fuel economy.

The formation of partnerships can be one of the most effective ways to induce new technology or promote specific applications. The New South Boston highway project demonstrated that long term community and economic benefits can be derived from local partnerships with public agencies, CCP producers and marketers. The efforts by the EPA and FHWA to advance CCP utilization should help to reassure local and state government officials that CCP use can be environmentally sound and still meet required performance and design needs for construction projects.

Regional partnerships have been created where special issues unique or important to a geographic area can be addressed. The Midwest Coal Ash Association in Ohio, brings together marketers, producers and Ohio State environmental regulators to discuss applications and uses of CCPs in Ohio. Similarly, the Texas Coal Ash Utilization Group (TCAUG) meets periodically to discuss issues in Texas. However, issues in Ohio or Texas may not be unique, making broader geographical relationships important. The Western Region Ash Group (WRAG) includes members from companies, universities, and state agencies for the states West of the Mississippi River. This large region has a number of CCP issues that are unique to the dry, arid part of the U.S. Some of these issues are not found in the eastern U.S. For example, groundwater and leachate questions for CCP use in the eastern U.S. is significantly different than in the west where rainfall and snow melt is often 50% to 80% lower than in eastern and midwestern states.

Since 2005, the biennial “World of Coal Ash,” symposium has been held. This event combined the biennial American Coal Ash Association Symposium and the biennial University of Kentucky Symposium, and included the ACAA, University of Kentucky Center for Applied Energy Research, DOE and the Office of Surface Mining as organizers. North American and international participants present exhibits and scholarly papers on a wide array of subjects, ranging from sustainability to science to applications pertaining to CCPs. Other associations and organizations co-located their own workshops and meetings during the “World of Coal Ash” so that the combination of resources offered attendees a broad perspective on CCP related issues.

Collaborative relations are not limited to states and organizations within the U.S. International relationships are vital as well. For example, the ACAA and the Association of Canadian Industries Recycling Coal Ash (CIRCA) have initiated joint participation in several projects and the exchange of technical information on a variety of issues. Memorandums of understanding exist between ACAA and a number of international CCP organizations, including the European Coal Combustion Products Association (ECOBA) and the Center of Coal Utilization Japan (CCUJ). In March 2003, the Union of Business for Use of By-products of Coal Fired Power Stations in Poland (UPS) proposed to ACAA an agreement of cooperation that resulted in a closer relationship on all aspects of CCPs between both countries. These agreement promote information exchange, educational opportunities, work on common projects, joint funding of
research and other activities, and a variety of methods of working to improve the beneficial use of CCPs worldwide.

Key technology developments expected to support continued growth in the utilization of CCPs can be considered in relation to their place in the supply and demand chain:

**Technologies Affecting Supply**

A common misconception about the coal ash industry is that there is “bad ash” that is not useful for high value applications. Shifting economics and technology availability can make “bad ash” into “good ash,” however. As costs of disposal and market values for CCPs rise, economic incentives lead CCP producers and marketers to invest in ash quality technologies and logistics to bring the materials to users.

Examples of ash quality technologies and strategies include:

**For reduction neutralization of residual carbon in ash**

- Burnout systems
- Air separation systems
- Flotation systems
- Chemical passivation treatments

**For addressing particle size concerns**

- Size reduction processing systems
- Blending strategies

**Technologies Affecting Demand**

Similarly, higher utilization of CCPs can be stimulated by increasing demand for them by users. Current examples include:

**For increasing utilization in existing applications**

- Development of High Volume Fly Ash concrete mix designs
- Development of high performance concrete mixes using fly ash in connection with other supplementary cementitious materials (also known as “ternary mixes”)

**For creating utilization in new applications**

- High volume fly ash bricks, blocks and pavers
- High volume fly ash aerated concrete blocks and panels
- Synthetic aggregates from ash or FGD materials
- Mineral sequestration of carbon dioxide
Regulatory Factors

As noted in the U.S. Environmental Protection Agency’s 2007 Report to Congress on encouraging higher utilization of “recovered mineral components” such as CCPs: “A major regulatory impediment to the use of RMCs, particularly coal combustion products (CCPs), is their categorization as a waste by legislative and regulatory bodies.” Numerous federal regulatory actions now under way may have a significant impact on the future trajectory of CCP utilization:

Solid Waste Regulation

Background

On December 22, 2008, a containment dike at a Tennessee power plant’s coal ash disposal facility failed. Approximately 300 acres, several homes, and portions of two nearby rivers were flooded by more than a billion gallons of ash slurry. Fortunately, no one was injured. But the clean-up cost is now estimated to exceed $1.2 billion and the incident has touched off a flood of a different kind: Unprecedented attention to coal ash disposal by news media, environmental activists, elected officials and government regulators.

National news media coverage of the Tennessee incident commenced immediately and continues to this day. Newspaper, magazine, and network television reports have been replete with references to “toxic” and “poisonous” coal ash and have characterized the incident as “100 times bigger than the Exxon Valdez oil spill.” A broad array of environmental activist groups has enthusiastically encouraged these media portrayals. In the six months immediately following the incident, environmental groups released reports with titles such as “Disaster in Waiting – Toxic Coal Ash Disposal in Surface Impoundments” and “Waste Deep – Filling Mines With Coal Ash is Profit for Industry but Poison for People.” More than 100 environmental groups petitioned the EPA to regulate coal ash as a hazardous waste.

Congress has also become actively involved. Hearings have been held in several committees of both the Senate and House of Representatives. Press conferences and field visits have occurred regularly. An investigation by the Government Accountability Office was ordered and resolutions were introduced calling for EPA’s expedited review of coal ash disposal regulation.

Heeding calls for tougher coal ash disposal regulations, the U.S. Environmental Protection Agency (EPA) promised to propose new requirements by the end of 2009. As the agency looked for ways to obtain federal RCRA jurisdiction over coal ash disposal, discussions included the prospect of reversing EPA’s 2000 Final Regulatory Determination and classifying coal ash as a hazardous waste under Subtitle C with exemptions for specific beneficial uses.
A wide array of industry groups, led by the American Coal Ash Association (ACAA) and the Utility Solid Waste Activities Group (USWAG), vigorously engaged in informing EPA and other policymakers of the dangers of classifying coal ash as “hazardous” in any setting. ACAA submitted detailed analyses to EPA officials showing that continuing beneficial use of coal ash would be endangered if the Agency classifies coal ash as hazardous, even if for the limited purpose of regulating disposal operations. The construction materials standards setting organizations American Concrete Institute (ACI) and ASTM International were also among the dozens of organizations raising concerns, noting that allowing materials designated as “hazardous waste” in any setting may not continue to be allowed in building codes.

Industry and standards setting organization concerns were largely based on concerns over potential legal liability. Supply of coal ash for recycling would be restricted as power plants reconsider the potential risks of widely dispersing a material that would be considered “hazardous waste” if disposed on their own property. Demand for coal ash would be harmed by the “hazardous” stigma that could frighten potential users.

Numerous other mining and utility industry groups also worked to encourage development of responsible coal ash disposal regulations that protect the environment without jeopardizing the safe and environmentally beneficial use of coal ash resources. They have been joined by over 100 Members of Congress and by numerous state environmental regulators. At least 26 states and the Association of State and Territorial Solid Waste Management Officials have formally urged EPA to adopt a regulation program under RCRA’s non-hazardous Subtitle D. State highway department officials are now beginning to engage in the debate, worried that their supply of fly ash from concrete may be endangered. Copies of letters to EPA urging a non-hazardous approach to coal ash disposal regulation can be found at this frequently updated web site: http://www.uswag.org/ccbletters.htm.

**Current Status**

EPA did not meet its self-imposed deadline for proposing new coal ash disposal regulations under the Resource Conservation and Recovery Act by the end of 2009. A public release of proposed regulations is expected early in 2010 and is rumored to contain more than one potential regulatory approach. EPA’s favored approach appears to be some form of “hybrid” regulation in which ash disposal is designated a Subtitle C (hazardous) material giving EPA federal jurisdiction over disposal operations while specific beneficial uses are exempted from the subtitle C designation. It is unclear whether EPA will present this concept as a “lead option with several alternatives” or whether several alternatives will be presented without preference.

In any event, the public comment period on the draft proposed regulation can be expected to take several months, after which EPA would be required to create a Draft Final Rule subject to further public comment prior to enactment. The issue may not be resolved until 2011 or later.
Whether the final approach is through Subtitle C (hazardous) or Subtitle D (non-hazardous) it is clear that certain coal ash disposal practices will be modified. The practice of disposing of coal ash in wet ponds or impoundments will almost certainly be phased out in favor of dry disposal techniques.

Furthermore, a number of practices currently considered as “beneficial use” will likely come under regulatory scrutiny to determine whether they are “disposal by another name.” EPA officials appear to be devising a view of beneficial uses that differentiates between “encapsulated” applications and “non-encapsulated” applications. Encapsulated applications, in which the coal ash becomes tightly bound within a finished product – such as fly ash in concrete or FGD gypsum in wallboard – are likely to continue receiving regulatory support as beneficial uses. Non-encapsulated applications – such as coal ash being used for large volume structural fill and other geotechnical and agricultural applications – may become subject to further regulatory scrutiny.

The practice of “minefilling” – taking coal ash back to mines from which the coal originated – is likely to be the subject of further separate rulemaking conducted jointly by the Environmental Protection Agency and the Office of Surface Mining.

In addition to the high profile rulemaking effort under the Resource Conservation and Recovery Act, EPA has undertaken two other efforts to develop rules that would affect coal ash disposal:

- **CERLCA Financial Assurance Requirements.** In early January 2010, The U.S. Environmental Protection Agency issued an advance notice of proposed rulemaking (ANPRM) identifying additional classes of facilities for development of financial responsibility requirements under Section 108(b) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). CERCLA Section 108(b) requires certain classes of facilities to “establish and maintain evidence of financial responsibility consistent with the degree and duration of risk associated with the production, transportation, treatment, storage or disposal of hazardous substances.” Among the new industries targeted for regulation under this section were the petroleum and coal products manufacturing industry (NAICS 324), and the electric power generation, transmission and distribution industry (NAICS 2211).

  To qualify the electric power generation, transmission and distribution industry for potential financial assurance requirements EPA relied on Toxic Release Inventory data, 27 “damage cases” involving groundwater and surface water contamination from coal ash, and the large volume of coal ash that is disposed of in landfills and surface impoundments per year. EPA highlighted the estimated costs associated with the clean up the coal ash at the Tennessee Valley Authority’s facility in Kingston, Tennessee, to rationalize the need for CERCLA financial responsibility requirements for this industry.

  Moving forward, the agency will examine the “specific activities, practices, and processes involving hazardous substances at these facilities,” and the “Federal and State authorities, policies, and practices to determine the risks posed by these
classes of facilities and whether requirements under CERCLA Section 108(b) will effectively reduce those risks.”

- **Steam Electric Generating Effluent Guidelines.** In September 2009, the Environmental Protection Agency announced that it expects to revise federal rules governing effluent limitation standards for coal-fueled power plants to reduce pollution and better protect the nation’s waterways. Effluent guidelines are national standards, based on the performance of treatment and control technologies, for wastewater discharges to surface waters. These guidelines, authorized by the Clean Water Act, were last amended in 1982.

  Wet coal ash disposal ponds or impoundments usually comprise part of a utility’s effluent system and will therefore be affected by the pending rule revisions. The rulemaking effort is currently at the Information Collection Request phase. Information collection is expected to continue through the fall of 2010.

**Climate Change Regulation**

A regulatory issue that could significantly affect both coal and coal combustion product utilization is the development of legislation or regulations to address climate change.

Anti-coal environmental sentiment is pushing strongly to significantly reduce or eliminate the consumption of coal in the United States. The largest part of this debate focuses on coal combustion’s role in producing greenhouse gases linked to climate change.

To eliminate coal use would require the nation to replace fully half of its electricity generation with some combination of nuclear, natural gas, wind, solar, and conservation strategies. The aforementioned U.S. Department of Energy forecast predicting continuing growth in demand for coal through 2030 indicates that this may be an insurmountable task.

Longer term analysis by the MIT Joint Program on the Science and Policy of Global Change predicts that if carbon capture and storage is successfully adopted, coal utilization will likely continue to expand through 2050 and beyond. MIT concludes that adoption of carbon capture and storage will depend on regulatory signals that provide cost incentives.

Climate change legislation now evolving in the U.S. Congress provides some indication of what those regulatory signals will be. On June 26, 2009, the U.S. House of Representatives approved by a narrow margin the “American Clean Energy and Security Act” – also commonly referred to as the “Waxman-Markey” bill. This 1,200-page bill

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calls for widespread changes in American energy policy, including the establishment of a carbon “cap and trade” system to address greenhouse gas emissions linked to global climate change.

Waxman-Markey is the most substantive step yet toward creation of a U.S. climate change regulatory system. However, in order to generate enough votes to pass the bill, Democratic leaders substantially softened it from earlier proposals. For instance:

- The target for reducing greenhouse gas emissions was lowered from 20% to 17% (below 2005 levels) by 2020.
- A cap and trade program beginning in 2012 is included, but 85% of the allowances under the program would initially be issued for free to electric utilities and other large industrial operations. (President Obama originally proposed auctioning all of the allowances. Under the House plan, the number of allowances auctioned would increase over time.)
- The bill sets a ceiling price on carbon at $28 per ton.
- The bill includes a renewable portfolio standard and efficiency standards for electric utilities, but the programs have been softened to provide more flexibility for utilities.

Despite the efforts taken to reduce the bill’s economic impact on electric utilities and other large energy producers and users, the bill is unlikely to be received warmly in the U.S. Senate. Several Senate committees are working on their own approaches to climate change legislation and may produce a Senate bill with even greater concessions to industry. This could cause some important environmental constituencies – which are already upset about the weakening of the House provisions – to oppose the eventual legislation as too lax.

Further complicating the political landscape is the difficulty Congress is experiencing in addressing health care reform, which has been prioritized above climate change. Delays in the health care reform debate pushed further consideration of the climate change bill into 2010 and may delay its substantive consideration until after mid-term elections.

Administration officials and environmental groups continue to push Congress for action, however. The White House is actively lobbying Congress for climate change legislation on an almost daily basis. The administration is also working through the Environmental Protection Agency on a parallel strategy. Earlier this year, EPA issued an “Endangerment Finding” that greenhouse gas emissions constitute a threat to human health – thereby enabling EPA to develop regulations under the Clean Air Act with no further action by Congress. Implementation of such regulations would no doubt be delayed by years of litigation by industry, but the development of such regulations keeps the heat on industry and Congress to come to a legislative solution.

While the prospects for completion of climate change legislation in 2010 are starting to move from the “toss-up” to the “unlikely” category, there is no question that the
momentum has shifted. An administration committed to climate change legislation and a Congress with solid Democratic majorities in both houses makes enactment of a climate change measure much more likely in 2011.

Whenever it gets enacted, the final climate change package is almost certain to include a cap and trade program for greenhouse gas emissions. For electric utilities and large industrial entities subject to the system, the devil will be in the details. If the details include restrictions and safety valves like those ultimately included in Waxman-Markey, then cap and trade implementation will likely be costly, but manageable for electric utilities and overall coal utilization likely will not decline.

A carbon cap and trade program could come with a silver lining for CCP utilization. The use of coal ash to decrease the need for cement manufacturing by replacing cement in concrete could provide the basis for establishing and verifying tradable carbon offsets. This could create additional economic incentives to invest in operations and infrastructure that support marketing of fly ash instead of disposal.

Mercury Regulation

In March 2005, the Environmental Protection Agency issued the Clean Air Mercury Rule to permanently cap and reduce mercury emissions from coal-fueled power plants for the first time ever. In February 2008, the District of Columbia Circuit Court vacated the rule. EPA is now moving to develop new mercury emissions reduction rules consistent with the Court’s opinion. Meanwhile, several states are also implementing mercury reduction requirements of their own.

A leading technology for capturing mercury from power plant emissions involves the use of activated carbon sorbent to absorb mercury from the flue gases. If activated carbon is allowed to comingle with the power plant’s fly ash, however, it can render that ash unmarketable for certain high value uses.

Residual carbon in fly ash can interfere with a concrete producer’s ability to properly entrain air in concrete products. Because of its fineness and high surface area, activated carbon is a particularly aggressive form of carbon in this environment.

Understanding of the threat of activated carbon to the marketability of fly ash, the industry has developed a range of strategies for mitigating or eliminating the problem. These include:

- Equipment designs that introduce activated carbon only after the bulk of fly ash collection has occurred.
- Development of alternate “ash safe” sorbents that do not cause problems with air entrainment during concrete production.
• Development of chemical admixtures that can be used during concrete production to mitigate the effects of excess or active carbon.

• Alternate power plant strategies for capturing mercury, such as modified utilization of existing scrubber equipment installed for capturing sulfur dioxide.

The process of adapting to new mercury controls is similar to adjustments made by the ash marketing industry when another emissions control strategy – installation of “Low NOx” burners – led to increases in residual carbon in ash during the 1990s. While the installation of mercury controls continues to be discussed as a potential threat to the marketability of fly ash, the strategies listed above are highly likely to avoid any lasting damage to the practice of marketing coal fly ash for use in concrete.
Section 10 – Findings & Conclusions

- Coal consumption will continue at high levels in the United States through 2030 and beyond because of growing demand for electricity and inability of alternative energy resources to supplant coal’s role as the largest generator of base load electricity. Increasing regulatory pressure on coal will increase the cost of coal-fueled electricity in relation to other resources, but the resource will continue to be utilized.

- Pulverized coal power plants will continue to generate the majority of coal-fueled electricity. New combustion technologies such as Integrated Gasification Combined Cycle will be introduced, creating a different form of solid byproduct, but will account for only a fraction of the volume of byproducts produced.

- Rates of Coal Combustion Products utilization have increased steadily over the past 30 years; in 2008, 136.1 million tons of CCPs were produced in the United State – of which 44.5% was utilized in a beneficial manner. The largest portion was fly ash, accounting for 72.5 million tons, 41.6% of which was beneficially used.

- Fly ash utilization has declined recently in response to the weakened U.S. economy, but declines have been less than the declines in portland cement consumption – indicating continuing growth of fly ash utilization in concrete.

- The following annual economic benefits are realized by the utilization of Coal Combustion Products as an alternative to disposing of them as waste:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues from the Sale of CCPs for Utilization</td>
<td>$1,028,761,000</td>
</tr>
<tr>
<td>Avoided Costs of Disposal</td>
<td>$412,800,000</td>
</tr>
<tr>
<td>Savings from Use as Sustainable Building Materials</td>
<td>$5,000,000,000 to $10,000,000,000</td>
</tr>
</tbody>
</table>

  **Total Economic Impact:** $6.4 billion to $11.4 billion

- Utilization of CCPs also creates significant benefits in the form of improved performance for products incorporating them.

- Utilization of CCPs also creates significant annual environmental benefits such as the reduction in energy consumption commensurate with the energy consumed by 1.7 million homes, water savings equal to 31% of the annual domestic water use in California, and reductions in greenhouse gas emissions comparable to removing 2 million automobiles from the roadway.

- Emerging environmental regulatory policy in the areas of solid waste disposal, mercury emissions, and climate change will affect the trajectory of increases or decreases in the
utilization of Coal Combustion Products. To the degree that ash disposal becomes more costly utilities may have incentive to expend capital on logistics infrastructure and technology improvements necessary to support larger marketing efforts. However, some regulatory measures under consideration may stigmatize coal ash with a “hazardous waste” designation, which could lead to significant decreases in utilization of the resource.
Section 11 – About the ACC & About the Author

American Coal Council

The American Coal Council (ACC) represents the collective interests of the American coal industry, from the hole in the ground to the plug in the wall. The Association is dedicated to advancing the development and utilization of coal as an economic, abundant/secure and environmentally sound energy fuel source. The ACC promotes the lawful exchange of ideas and information regarding the coal industry. It serves as an essential resource for companies that mine, sell, trade, transport or consume coal. The ACC provides educational programs, advocacy support, peer-to-peer networking forums and market intelligence that allow members to advance their marketing and management capabilities.

The Association’s primary objectives are to:
• Support the business, marketing and management capabilities of American coal suppliers, coal consumers, coal transporters, coal traders and coal support service companies.
• Advocate for coal as an economic, abundant/secure and environmentally sound fuel source.
• Support the activities and objectives of associations and organizations involved in advancing coal supply, consumption, transportation and trading.

American Coal Council
1101 Pennsylvania Ave., NW, Ste. 600
Washington, DC  20004
202-756-4540
www.americancoalcouncil.org  ~ info@americancoalcouncil.org

Author John Ward

John N. Ward is President of John Ward Inc. -- a marketing and public affairs consultancy focusing on energy issues. He was formerly Vice President, Marketing and Government Affairs, for Headwaters Incorporated -- a leading provider of pre-combustion and post-combustion clean coal technologies and services. John is a former board member and past president of the American Coal Council. He served on the National Coal Council as appointed by the U.S. Secretary of Energy. He also served on the National Mining Association's Coal-to-Liquids Coalition. John is formerly chairman of the Government Relations Committee of the American Coal Ash Association and participates in numerous industry groups related to the manufacturing and use of construction materials.

John has special expertise in the fields of clean coal public policy, coal related tax credits, coal to liquid fuels technology and commercialization, heavy oil upgrading technology and commercialization, and coal combustion products management and commercialization.

John Ward Inc.
314 West 300 South, Suite 200
Appendix 1 – Technology Provider Profiles

Technology Provider Profile:

Ceramatec Inc.
2425 S 900 W
Salt Lake City UT 84119
801-972-2455
www.ceramatec.com

Ceramatec is internationally recognized with an extensive patent portfolio covering its achievements in the fields of solid-state ceramics, fly ash beneficiation, and aqueous ionic electrochemical technologies. Ceramatec's pursuit of innovative products and new business focuses in several major technological areas capitalizing on our core competencies including three decades of experience in solid state ceramic materials and structures. Many of Ceramatec’s novel technologies are applicable to the energy/utility industries, including the beneficial re-use of fly ash and other coal combustion waste products. Ceramatec is primarily a Research and Development company, and we are currently working on research projects to remediate fly ash containing Hg-laden activated carbon for continued use in the concrete industry. We are also doing research to develop several new markets for the beneficial use of fly ash waste materials.
Technology Provider Profile:

CleanCoal Briquettes Inc.
8745 W 14th Ave., Ste 240
Lakewood, CO 80215
720-833-5592
www.cleancoalincorporated.com

CleanCoal Briquette, Inc. (CCBI) has developed a proprietary technology that combines two industrial waste streams into an engineered fuel briquette. The process has been demonstrated at a commercial scale and will provide a variety of benefits to the coal-burning power industry:

- Reduction of power generation costs,
- Reduction of required coal tonnage,
- Elimination of fly ash as a problematic waste stream,
- Cleaner air emissions, and
- No modification to existing regulatory permits.

Our fuel briquette is composed of a combination of fly ash and biomass. Fly ash is a waste product from the combustion of coal in a stoker fired coal power plant, and biomass is a general term for plant material – most commonly trees, grasses or agricultural crops. We have completed the process design for briquette production, including product evaluation, feasibility testing, equipment specification, and plant layout. A commercial-scale production run and test burn were then conducted with a truck-load of briquettes, as well as a lab analysis to determine the fuel content and emissions potential of the briquettes.

CCBI develops and operates manufacturing plants, co-located at coal-burning power plants, to provide briquettes under long-term production agreements. CCBI technology works best with stoker-fired power plants that allow briquettes to be manufactured and burned with virtually no mechanical or permit modifications at the host site. CCBI technology can be cost-effectively deployed where power plants are producing fly ash with high Carbon content (typically over 4000 BTUs/lb) or sources of coal fines from coal processing operations, and a ready source of biomass located in the near vicinity.

Revenues for the facility include the sale of briquettes, share of the savings to the power plant from not having to dispose the fly ash, renewable energy credits and carbon credits plus any federal, state and local incentives for bio-energy. CCBI does not require clients to provide any financial investment or incur any project expenses. They will, however, enjoy an operational cost savings, make progress towards their renewable energy goals, reduce coal consumption and reduce their carbon footprint and emissions.
Technology Provider Profile:

DustMASTER Enviro Systems
190 Simmons Ave.
Pewaukee, WI 53072
262-691-3100
www.dustmaster.com

DustMASTER Enviro Systems, A Division of Mixer Systems, Inc. is a specialist in the design, manufacture and marketing of mixers, and material handling equipment for the industrial and environmental markets.

The Company is the largest pan mixer manufacturer in North America. Its brand name for this product is the “Turbin Mixer.” There are over 2,500 Turbin Mixers in the marketplace today. The Turbin Mixer has been produced for almost 40 years. The “Low Profile” Turbin introduced in August 1983 is the third generation improvement on this established product. It was the result of three and one-half years of design and field testing. It features improved mixing, increased productivity, reduced maintenance and easier accessibility. The Turbin Mixer is the heart of our DustMASTER environmental product line.

Our engineering department is staffed with mechanical, electrical and design engineers. In addition, we have electronic technicians that assist in the design and building of all of our control systems. We have 100% in-house metal fabrication and machining capabilities. The 85,000 sq.ft. manufacturing facility is complete with electronically controlled Plasma cutting, steel rolling for both plate and channel plus other related equipment. A complete machine shop and modern painting equipment are featured for added quality. All of our welders are AWS certified. Our spare parts department is computerized and we ship over 90% of our orders in the first 24 hours.

As a result of our company staffing and structure we are capable of designing, manufacturing and installing complete turn key systems for the processing of hazardous and non-hazardous waste.

DustMASTER design and builds equipment for the environmental market. In some cases, we are able to process materials for recycling back into an existing manufacturing process. Our mixing design is a complete automatic batch system. All solid material weights are controlled by load cells and liquid additions by flow meters or weight. Particle size or weight per cubic foot does not affect the 99% mixing efficiency of the Turbin Mixer. If chemical reagents are required for stabilization we can design the system and write the program to add each reagent automatically with the correct amount batch after batch. All times within the sequence of events can be adjusted to meet production or chemical changes. This gives complete flexibility of the system. In addition, the control has 100% manual override in the event of automatic mode failure. We also provide as an option recording by weight of each batch ingredient printed out and time dated documentation.

DustMASTER stresses quality products, strong service support and prompt parts availability plus innovative product design.

Our goals are to establish contact with officials involved in environmental issues, leaders in the industrial sector requiring environmental equipment for their manufacturing facilities.
Technology Provider Profile:

EnviRemed
6408 Beach Dr. SW
Ocean Isle Beach, NC 28469
888.575.3573
www.EnviRemed.net

Headquartered in Ocean Isle, NC, with offices in Atlanta, GA and Washington, DC, EnviRemed is a consortium of top biochemists, scientists, engineers and businessmen who united to offer the best available technologies to provide safe, natural solutions for governmental authorities, corporations and private citizens to create a cleaner future for our planet.

Our team of scientists works tirelessly to develop breakthrough, economical environmental solutions to remediate hazardous contaminants. EnviRemed remediates waste water industries, waste industries, energy, mining, manufacturing and agricultural industries.

EnviRemed solutions will remediate a vast number of heavy metals and radioactive materials from water and soil including but not limited to: Arsenic, Aluminum, Atimony, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Nickel, Phosphorus, Radium, Selenium, Strontium, Thorium, Uranium, Vanadium, and Zinc. The reagents used have an excellent trace metal and metalloid binding capacities and, equally importantly, elements that are bound when the material is used to treat contaminated water or soil are held very tightly. Furthermore, the longer the spent Virotec reagents are left to age after use, the more tightly the bound elements are held. As the residue ages some new metal-trapping capacity develops.
Technology Provider Profile:

Full Circle Solutions, Inc.
35 North Main Street, Suite A
Jasper, Georgia, 30143
(706) 253-1051
www.fcsi.biz

Full Circle Solutions, Inc. (FCSI) brings together the challenges of one industry with the needs of another to provide a “full circle of solutions” by marketing and managing coal combustion products (CCPs) and other industrial by-products for use in construction and agricultural applications. Through extensive research and field experience, FCSI has developed an extensive array of utilization options to offer CCP and industrial by-product generators. By partnering with these generators, FCSI is able to optimize their current CCP or by-product management program and focus on recycling the material into ecologically beneficial applications for society demonstrating the generator’s commitment to sustainability and preservation of the environment.
Technology Provider Profile:

GAI Consultants, Inc.
385 East Waterfront Drive
Homestead, PA  15120-5005
412-476-2000
www.gaiconsultants.com

Transforming ideas into reality for over 50 years, GAI is a 650-person, employee-owned, multi-disciplined engineering and environmental consulting firm, serving our clients worldwide in the energy, transportation, real estate, water, municipal, government, institutional, and industrial markets from offices throughout the Northeast, Midwest, and Southeastern United States. We bring value to our clients in the following disciplines: environmental engineering and studies; civil engineering; land development; transportation engineering and studies; geotechnical engineering; structural engineering; cultural resources; construction engineering and inspection; surveying; geographic information systems; landscape architecture; electrical engineering; mechanical engineering; and water resources management.

One of GAI’s niche services is providing coal combustion product (CCP) disposal and utilization services to electric utilities, independent power producers, and manufacturers. We specialize in developing innovative solutions to CCP disposal problems that reduce the overall cost of CCP disposal. GAI is nationally recognized for our state-of-practice reports and design manuals on CCP utilization and disposal. We have conducted applied research and demonstration projects for EPRI, FHWA, ACAA, and private clients.

Our effective marketing efforts for CCP management programs have allowed many clients to increase their CCP utilization rate to over 90%. Our market research methods have been applied and proven effective in New York, Pennsylvania, Florida, Kentucky, Ohio, Indiana, Virginia, West Virginia, South Carolina, Nevada, Utah, Wyoming, and Washington.

GAI has extensive disposal site experience having designed and permitted more than 50 landfills, impoundments, and pond-to-landfill conversions. This experience has been built by our current staff -- experts who have been recognized by industry leaders for engineering excellence.

With GAI, many clients realize the advantages of CCP utilization, such as avoiding disposal costs, lowering the cost of generation, increasing the life of disposal facilities, and lessening the impact of new environmental regulations. The key to developing and implementing a CCP utilization program is a thorough potential market assessment with essential information regarding potential market size, economic marketing radii, utilization constraints, and competing materials price and availability.
Technology Provider Profile:

Groundwater & Environmental Services, Inc.
800 Commonwealth Drive, Suite 201
Warrendale, PA 15086
800-267-2549 ext. 3639
www.gesonline.com

GES has provided client-focused environmental and remediation services since 1985. Founded to serve the needs of the oil industry, we have since developed a diverse client roster of businesses requiring the technical expertise, regulatory knowledge and safe performance that are hallmarks of GES. Our experienced team manages thousands of sites under federal, state and local regulations across the country for clients in the energy generation and distribution and petroleum sectors. We are trusted partners of many of the world’s most prominent companies. Our clients range from mid-sized manufacturers to Fortune 100 companies. We emphasize hands-on consulting, creative approaches, and service efficiencies that combine to reduce project life cycle and achieve our clients’ objectives, safely – with a commitment to health, safety, security and the environment. Our investment in the research, development and utilization of innovative technologies has helped our clients expedite site investigation, remediation and closure. GES champions highly-effective innovative methods that include our patented in situ chemical oxidation and reductive remediation technologies.

Services for the coal ash industry:

- Industrial landfill services
- Technical field services
- Innovative technologies
- Geochemistry of metals and other redox species
- Regulatory negotiation
- Data analysis and management
- Conceptual site model development
- Evaluation of sampling protocols
- Remedy selection and implementation
- Life-cycle cost analysis
**Technology Provider Profile:**

**Headwaters Resources, Inc.**  
10653 S. River Front Parkway, Suite 300  
Salt Lake City, UT 94095  
801-984-9400  
[www.flyash.com](http://www.flyash.com)

Headwaters Resources is America’s largest manager and marketer of Coal Combustion Products – serving more than 100 power plants from coast to coast.

Headwaters provides an array of CCP-related services – including:

- **Fly Ash for Concrete.** Headwaters is the undisputed leader in supplying fly ash to the concrete industry. Fly ash is a valuable additive that makes concrete stronger, more durable and easier to work with. Fly ash sources in 31 states are linked to a nationwide network of terminals and transportation equipment – ensuring customers receive quality material when they need it.

- **Fly Ash for Building Products.** Through its Headwaters Construction Materials division, the company utilizes fly ash in concrete blocks, architectural stone veneer, and other building materials that have not traditionally used CCPs.

- **New CCP Utilization Technologies.** Headwaters is also a leader in developing new technologies to increase utilization of ash products. For instance, FlexCrete fiber reinforced aerated concrete is a cost-effective, easy to use building material that features high fire resistance and excellent thermal and acoustic insulation capabilities. The company is also a leader in utilization of CCPs for soil and waste stabilization.

- **New CCP Quality Technologies.** Headwaters has commercialized technologies for carbon fixation and ammonia removal that maintain and improve the marketability of ash that may be affected by installation of emissions control equipment at power plants.

- **Utility Services.** Headwaters provides services including landfill permitting, design, construction and operation, as well as conversions from wet to dry disposal.
Technology Provider Profile:

Mineral Resource Technologies, Inc. – a CEMEX company
920 Memorial City Way, Suite 100
Houston, TX 77024
713-650-6200
www.mrtus.com

Mineral Resource Technologies Inc., (MRT) is a full service Coal Combustion Products (CCPs) management and marketing organization serving the construction, concrete pipe, infrastructure and coal-fired power generation utility industries. With its network of distribution terminals, external purchases and contracts with over ten utilities, MRT manages nearly 2 million tons of CCPs on an annual basis and is growing.

Founded in 1995, MRT was acquired by CEMEX in 2003, giving MRT access to CEMEX’s large internal demand for CCPs, as well as CEMEX’s vast distribution network. One of the world's leading building materials suppliers, CEMEX provides cement and concrete products to construction projects in every sector: industrial, commercial, residential and municipal. CEMEX’s U.S. network includes 14 cement plants, over 50 strategically located distribution terminals, more than 100 aggregate quarries and hundreds of ready-mix concrete batch plants.
**Technology Provider Profile:**

**Synthetic Materials, LLC**  
6009 Brownsboro Park Blvd.  
Louisville, KY 40204  
502-895-2810  
[www.synmat.com](http://www.synmat.com)

Synthetic Materials (Synmat) specializes in the finance, design, construction and operation of facilities that dewater synthetic gypsum slurry. Synmat is the largest supplier of synthetic gypsum in the United States with a market share of approximately 20%. Synmat is a key raw material supplier to several North American gypsum board manufacturers and portland cement producers.
Technology Provider Profile:

U.S. Minerals
2105 North Winds Drive
Dyer, IN 46311
219-864-0909
www.us-minerals.com

U.S. Minerals is a leading marketer of boiler slag.
Appendix 2 – Glossary of Terms

This glossary is reprinted in its entirety from the ACAA document titled “GLOSSARY OF TERMS CONCERNING THE MANAGEMENT AND USE OF COAL COMBUSTION PRODUCTS (CCPs)” April 2003.

acid mine drainage (AMD) - water exhibiting a pH of less than 6.0 and in which total acidity exceeds total alkalinity, discharged from an active, inactive or abandoned coal mine and reclamation operation or from an area affected by surface coal mining and reclamation operations.

acid mine water - (See AMD)

activator - a material that causes a catalyst to begin a function, which in the case of a coal combustion product based flowable fill or controlled low strength material (CLSM), causes cementitious reactions to occur.

admixture - a material other than water, aggregates, hydraulic cement and fiber reinforcement, used as an ingredient of concrete or mortar, and added to the batch immediately before or during its mixing. Fly ash is used as an admixture in concrete.

advanced sulfur control products (ASC) - products generated from advanced coal conversion technologies including Fluidized Bed Combustion (FBC) and products from advanced environmental emissions cleanup technologies such as duct injection and lime injection multiphase burners (LIMB). The type of product is technology dependent and could be a bed ash and high lime fly ash for an FBC technology.

aeration - the process of exposing a substance or area to air circulation; the process of mixing air with a pulverized fuel or a powdered material such as fly ash in a transport pipe or storage bin. Example: the aeration of the fly ash in a silo to facilitate flow, aeration equipment in a fly ash silo.

aggregate - granular material such as sand, gravel, crushed stone, crushed hydraulic-cement concrete, iron blast furnace slag, or coal bottom ash and boiler slag used as a component in concrete or mortar with a hydraulic cementing medium to produce either concrete or mortar.

lightweight aggregate (LWA) - aggregate of low density used to produce lightweight concrete or concrete products. Examples of LWA include coal bottom ash, pumice, scoria, volcanic cinders, tuff, and diatomite; expanded or sintered clay, shale, slate, diatomaceous shale, perlite, vermiculite, or slag; and bonded or sintered coal combustion products (CCPs) used to produce lightweight concrete or component products.

air entraining - the capability of a material or process to develop a system of microscopic bubbles of air in cement paste, mortar or concrete during mixing.
**air entrainment** - the incorporation of air in the form of microscopic bubbles (generally smaller than 1 mm) during the mixing of concrete or mortar.

**air-entraining agent (AEA)** - an addition for hydraulic cement; also an admixture for concrete or mortar which causes air to be entrained in the concrete or mortar during mixing, usually to increase workability and frost resistance. The quantity of unburned carbon in fly ash can affect the dosage of the AEA in the concrete and the quality of the concrete.

**air separator** - an apparatus that separates various size fractions of ground material pneumatically; fine particles are discharged as product; oversize is returned to the mill as tailings.

**alkali** - salts of alkali metals, principally sodium and potassium; a hydroxide or carbonate of an alkali metal.

**alkali metal** - a metal in Group 1A of the Periodic Table, that is, lithium, sodium, potassium, rubidium, cesium, and francium.

**alkalinity** - the capacity of water to neutralize acids, a property imparted by the water’s content of carbonates, bicarbonates, hydroxides and occasionally borates, silicates and phosphates. It is often expressed in milligrams per liter of equivalent calcium carbonate.

**alkali-silicate reaction (ASR)** - the reaction between the alkalis (sodium and potassium) in Portland cement and certain siliceous rocks and minerals, such as opaline chert, strained quartz, and acidic volcanic glass, present in some aggregates; the products of the reaction may cause abnormal expansion and cracking of concrete in service. Class F fly ash is used in concrete to reduce the occurrence of ASR.

**alkali-silicate reactivity (ASR)** - another name for alkali-silicate reaction.

**ammoniated ash** - ash that contains ammonia and/or ammonium salts as a result of the addition of ammonia or ammonium salts to the flue gas at the power plant for purposes that include removing Nitrogen Oxides (NOx) from the combustion flue gases, conditioning the flue gas in order to improve the performance of Electrostatic Precipitators (ESP) or to reduce the opacity of the emissions from the Stack. Ammonia levels occurs primarily in the fly ash due to the adsorption of the ammonia on the surface of the fly ash particles in the ESP, although there could be some minor carryover of the ammonia to the scrubber residue when scrubbers are installed downstream of the ESP. Ammonia levels in fly ash has been reported to exceed 800 ppm for gas conditioning applications and to be less than 100 ppm for the Nitrogen Oxides removal applications.

The latter applies to the Selective Catalytic Reduction (SCR) process only. Fly ash with ammonia levels of less than 100 ppm has been reported to be used in concrete that is placed in a closed environment (building enclosure) without causing health and safety concerns (this is based on the European experience). Also fly ash with ammonia levels of as much as 300 ppm has been reported to be used in concrete without affecting the structural performance of the concrete.
ammonia slip - the unreacted ammonia that occurs in the flue gas downstream of the Selective Catalytic Reduction (SCR) reactor and from the Selective Non-Catalytic Reduction (SNCR) Nitrogen Oxides control technologies. An ammonia slip results in the adsorption of the ammonia onto the surface of the fly ash particles in the ESP. An ammonia slip of 2 ppm yields 100 ppm adsorbed onto the fly ash based on the European experience with SCR. This 100 ppm level of ammonia in fly ash has allowed for the unrestricted use of this ammoniated fly ash in concrete in Europe.

angle of repose - the maximum angle from horizontal at which a given material (such as fly ash, bottom ash, or fixated FGD material) will rest on a particular stationary surface without sliding or rolling.

aquifer - a geologic formation, group of formations, or part of a formation that is saturated with water and capable of providing a significant quantity of water.

ash - the incombustible inorganic matter in fuels such as coal.

ash free basis - the method of reporting fuel analysis whereby ash is deducted and other constituents are recalculated to 100%.

ash fuel - the use of high carbon ash to produce energy.

ash pond - an impoundment or surface impoundment used to store or dispose of ash primarily from the combustion of coal. A type of waste management facility consisting of an excavated, a dammed or diked reservoir in which CCPs are stored for future removal or disposed of as a slurry or sludge. The CCPs solids settle out and leave relatively clear water at the surface that is discharged through a designed and managed outlet structure to a nearby stream, surface water or plant process water system. Ash pond designs reflect local site conditions, federal and state regulations and whether fly ash, bottom ash, boiler slag or a combination of CCPs are disposed in the ash pond. While some electric utility generating power companies combine the ashes during storage or disposal, other power companies use separate ash ponds for fly ash, bottom ash and boiler slag. The ash pond is referred to as a bottom ash pond, fly ash pond, boiler slag pond when it receives one type of ash. Also a large ash pond is referred to as an ash impoundment, ash reservoir, or surface impoundment. (See surface impoundment and ponded ash)

ash pond water outlet works - this consists of either a stop-logged vertical riser or sloping shaft within the pond, a pipe or conduit that runs from the base of the riser inside the pond to a receiving stream or other plant process water system and which is used to decant the ash transport water and normal precipitation; the skimming device at the vertical riser or sloping shaft, within the pond that prevents the floating fraction of ash or other material to enter the discharge from the pond.

ash processing facility - a facility that uses technology to enhance the physical characteristics of boiler slag, bottom ash or fly ash in order to meet specifications for the particular market that it is targeted. The initial ash processing facilities were boiler slag screening plants that produced materials for use as blasting grit and roofing granules.
**bag filter** - a device/equipment containing one or more cloth bags for recovering particles (fly ash) from the dust laden gas or air which is blown through it. Bag filters are used in the fly ash transport system in series with mechanical equipment (dust collectors and referred to as primary and secondary dust collectors) to remove fine particulate fly ash from the conveying air. The bag filter dust collector is usually referred to as a tertiary dust collector in this case. This fly ash is generally less than 10 microns, an ideal size for use as a mineral filler.

**baghouse** - a facility constructed at some coal-fueled power plants to remove particulate matter (fly ash) from the flue gas by the use of fabric filter bags that mechanically trap particulate (fly ash) carried in the flue gases; a facility that removes fly ash from the flue gas by the use of fabric filter bags.

**basin ash** - another name for ponded ash. *(See ponded ash)*

**batch** - quantity of either concrete, mortar, ash grout or flowable fill mixed at one time.

**bed ash** - the spent bed material that is produced by Fluidized Bed Combustion Generating Plants. The bed ash is usually collected separately and can be considered as being equivalent to bottom ash in a Dry Bottom Furnace or a Wet Bottom Wall Fired Furnace. The bed ash is comprised of calcium oxide (35% or greater by weight), calcium sulfate (30% or greater by weight), fly ash (26% or greater by weight), calcium carbonate (5% or greater by weight) and carbon (4% or greater by weight). Also because of the free lime content, heat is evolved when water is added. The collected bed ash is conveyed to a silo (which may only store the bed ash or may store a combination of bed ash and fly ash) from where it is loaded into trucks or other vehicles and transported to ground storage for reuse or to a disposal site.

**beneficial use of a CCP** - the use of or substitution of the coal combustion product (CCP) for another product based on performance criteria. For purposes of this definition, beneficial use includes, but is not restricted to, raw feed for cement clinker, concrete, grout, flowable fill, controlled low strength material; structural fill; road base/sub-base; soil-modification; mineral filler; snow and ice traction control; blasting grit and abrasives; roofing granules; mining applications; wallboard; waste stabilization/solidification; soil amendment and agriculture.

**beneficiation** - improvement of the chemical or physical properties of a raw material or intermediate product by the removal or modification of undesirable components or impurities. The removal of unburned carbon in fly ash is an example of beneficiation of the raw fly ash.

**Bevill exclusion** - an exemption from regulation as hazardous wastes of all wastes or residues that result from the combustion of coal and other fossil fuels.

**biomass** - a synonym for biological solids. All material that originated from the growth of agricultural crops (including food crops), trees, grasses, aquatic plants and their residues or waste materials. Includes residues from crop harvesting, forest maintenance, road or land clearing, utility line maintenance, as well as post-consumer materials such as used wood, food processing, paper mill sludge industrial byproducts and other waste materials that may result from the processing of these goods. Also typically refers to agricultural and forest products or residues derived from living plants.
biomass coal co-firing - the firing of two dissimilar fuels at the same time in the same boiler, coal and biomass.

blended fly ash - fly ash resulting from the combustion of a mixture of different classification coals such as bituminous and sub-bituminous coals. Also the mixing of ash from different sources. (See fly ash sub-bituminous/bituminous coal blends)

boiler slag - a molten ash collected at the base of slag tap and cyclone furnaces that is quenched with water and shatters into black, angular particles having a smooth, glassy appearance. Boiler slag is in high demand for beneficial use (blasting grit, roofing granules, etc.), but supplies are decreasing because of the removal from service of power plants (due to their age) that produce boiler slag.

boiler slag fines - the small boiler slag particles that are produced as a result of dry or wet boiler slag screening processes whose end product is directed to several markets that include use as a blasting grit. Beneficial use of the fines include its use in the glass industry.

borrow - an area designated as a source for soil in construction or mine reclamation projects; a source or sources of material other than the required excavation.

bottom ash - agglomerated ash particles formed in pulverized coal furnaces that are too large to be carried in the flue gases and impinge on the furnace walls or fall through open grates to an ash hopper at the bottom of the furnace. Bottom ash is typically grey to black in color, is quite angular, and has a porous surface structure. Bottom ash is used as an aggregate, as feed stock for cement manufacturing or in construction applications in lieu of other constituents (such as sand, gravel).

bottom ash dewatering bin/tank - an elevated sedimentation tank that is designed with baffles and other devices to receive the bottom ash slurry, settle out and store hours or days of bottom ash production, and discharge the stored and dewatered bottom ash into trucks. This tank is usually in series with a separate tank or tanks that settles out the very small bottom ash particles. Bottom ash dewatering bins are used where there are space limitations at a coal-fueled power plant and where other process or site requirements do not allow for the use of ponds.

bottom ash fines - the small bottom ash particles that is produced as a result of dry or wet bottom ash screening processes whose end product is an aggregate.

bottom ash pond - an impoundment or surface impoundment used to store or dispose of bottom ash primarily from the combustion of coal. (See ash pond.)

bulk density - the mass of a material per unit volume including voids. Bulk density is usually reported on a dry basis.

bulk density of aggregate - the mass of a unit volume of bulk aggregate material (the unit volume includes the volume of the individual particles and the volume of the voids between particles).
byproduct - a material that is not one of the primary products of a production process and that is not solely or separately produced by the production process.

byproduct utilization - the recycling or use of coal combustion wastes.

cake - the solids discharged from dewatering equipment such as rotating drum vacuum filters, where the material is then referred to as filter cake.

calcium carbonate equivalent (CCE) - the content of carbonate in a liming material or calcareous soil calculated as if all the carbonate is in the form of CaCO3.

calcium sulfate dihydrate (CaSO4) ·2H2O) - gypsum; the primary byproduct of a forced oxidation wet flue gas desulfurization system in which additional air is introduced and lime or limestone is used as the reagent. (See FGD gypsum and gypsum.)

calcium sulfite (CaSO3) - the primary product (or byproduct) of a wet flue gas desulfurization system where there is no forced oxidation and lime or limestone is used as the reagent.

cap - a layer of clay, or other impermeable material installed over the top of a closed landfill to prevent entry of rainwater and minimize leachate.

captive facilities - facilities that are located upon lands owned by the generator of coal combustion byproducts or coal combustion/flue gas cleaning wastes and which are operated to provide for the treatment or disposal solely of the generator’s byproducts or wastes. (Example: captive landfill)

carbon - element. The principal combustible constituent of all fuels.

carbon dioxide (CO2) - a colorless, odorless, incombustible gas formed during combustion in fossil-fuel electric generation plants.

carbon in ash (unburned carbon in ash-UBC) - the unburned carbons in fly ash include both carbon carried over as uncombusted “inertinite” and chars or cokes resulting from the incomplete combustion of thermoplastic, largely vitrinite-derived phases. The latter include “isotropic coke” and “anisotropic coke”.

carbon reduction process – a process to reduce the concentration of carbon (Loss On Ignition or LOI) in high-carbon fly ash. The reduction in the overall carbon content of a fly ash can be achieved through one or more of several different methods including thermal reduction, tribo-electric separation, flotation, classification, etc. In general, the goal in a carbon reduction processes is to remove carbon without significantly altering the hydraulic/pozzolanic properties of the fly ash – thereby making the material suitable for use in concrete applications. These processes are often proprietary and there are several firms that specialize in carbon reduction.

cell - a portion of a landfill which is isolated, usually by means of soil or an impermeable barrier, from its surroundings.
**cementitious ash** - fly ash, which hardens irreversibly when mixed with water. Also referred to as self-cementing ash.

**cementitious material** (hydraulic) - an inorganic material or a mixture of inorganic materials that sets and develops strength by chemical reaction with water by formation of hydrates, and is capable of doing so under water.

**cementitious mixture** - A combination of more than any one of the following materials to make a cement paste: hydraulic cement; Portland cement; coal fly ash; FBC ash; lime; ground granulated blast furnace slag; lime kiln dust; cement kiln dust. It may be used by itself for grout, or used to bind aggregates or fine materials to make concrete or controlled low strength materials (CLSM), or used for soil stabilization and solidification.

**cenospheres** - a portion of fly ash, that was once referred to as the floating fraction of the fly ash because of its occurrence on the surface of fly ash ponds and from where it was and still is harvested for beneficial use. Cenospheres are lightweight (23 to 28 pounds per cubic foot), inert, hollow, essentially thin-walled glass spheres (10 - 350 microns) comprised largely of silica and alumina and filled with air and/or gasses. Cenospheres are formed from the ash when it is in a molten state. The thickness of cenosphere walls may be very small and the resultant bulk densities are less than 1 gm/cm³. Cenospheres that are harvested from the surfaces of ash ponds are processed (drying, classifying, etc) and marketed as a high value product in applications for performance enhancement of products such as paints, coatings, adhesives etc. Cenospheres are also now extracted from dry fly ash by companies with proprietary processes and marketed under registered trade names. The proportion of 1gm/cm³ cenospheres that exists in fly ash has not been quantified definitively but the literature indicates a %age of about 2% maximum. (See Microspheres)

**char** - the solid carbonaceous residue that results from incomplete combustion of organic material which includes coal. It can be burned for heat or if pure, processed for production of activated carbon for use as a filtering medium. In the electric generation industry the term applies to the fixed carbon in the coal and current usage in coal combustion will be ‘the time to burn out the char’. Also it can apply to the unburned portion of the coal and would have the same usage as unburned carbon in ash.

**char/fly ash** - another term for the carbon in the fly ash which is now commonly referred to as unburned carbon (UBC) in ash.

**cinders** - an old term, in ash marketing, for the ash from utility stoker boilers and which were used as an aggregate especially in concrete block manufacturing and hence the term cinder blocks. This term is still used in ash marketing to refer to bottom ash and boiler slag especially. However the usage of this term by the American Boiler Manufacturers Association is for “particles of partially burned fuel from which volatile gases have been driven off, which are carried from the furnace by the products of combustion”.

**class C fly ash** - fly ash, which meets criteria defined in ASTM C 618, for use in concrete.

**class F fly ash** - fly ash, which meets criteria defined in ASTM C 618 for use in concrete.
clean coal combustion - the burning of coal, coal culm, or coal fines in a furnace designed to operate to minimize emissions (that is a fluidized bed or aerated fluidized bed, etc.) or coal burned in the presence of alkaline materials, which combine to reduce emissions.

clean coal technology - a government and industry co-funded effort to demonstrate a new generation of innovative coal utilization processes in “showcase” projects conducted across the country.

clean coal technology combustion products - products generated from any technology including technologies applied at the pre-combustion, combustion, or post combustion stage, at a new or existing facility which will achieve significant reductions in air emissions of sulfur dioxide or oxides of nitrogen associated with the utilization of coal in the generation of electricity, or process steam which was not in widespread use as of November 15, 1990.

clinker - a hard compact congealed mass of fused furnace refuse usually slag. Bottom ash and boiler slag usually contains clinker.

cement clinker - the fused particles or pellets produced from the sintering or burning zone (22000F to 27000F) of a rotary kiln in the cement manufacturing process. Raw materials (limestone, shale, iron ore, sand) are proportioned and ground to a powder and blended before being processed through the rotary kiln.

closure - the decommissioning of a disposal facility.

closure plan - a written plan that describes the steps the owner or operator of the disposal facility will take to close the facility in accordance with regulatory or other requirements.

coal - a brown to black combustible sedimentary rock (in the geologic sense) comprised principally of consolidated and chemically altered plant remains; solid hydrocarbon fuel formed by ancient decomposition of woody substance under conditions of heat and pressure. All solid fuels are classified as anthracite, bituminous, sub-bituminous or lignite by ASTM and in ASTM D388-77.

CCPs - a collective term referring to any solid materials or residues (such as fly ash, bottom ash or boiler slag) produced primarily from the combustion of coal. Collective term referring to any materials or residues produced directly from the combustion of coal and especially from coal-fueled power plants. It is much like volcanic ash. It consists of limestone, iron, aluminum, silica sand and clay. In addition it contains trace quantities (in the parts per million range) of the oxidized forms of other naturally occurring elements. These same elements exist in soil, rock and coal. The coal can be bituminous, sub-bituminous, lignite or a mixture of these coals. The residues of mixtures of small quantities of other fuels such as petroleum coke, fuel oil, etc. with coal are also referred to as CCPs. Current usage of the CCPs collective term is synonymous with the term coal combustion ash and coal combustion residue (CCR). Also CCPs is a component of the term coal combustion byproduct (CCB) covering only the materials or residues associated with the combustion of coal and not the residues from flue gas cleaning. (See coal combustion ash, CCR, and CCBs.)
CCPs landfills - a landfill that receives only CCPs. It is usually regulated by a State Governmental Agency and subjected to the waste management practices and alternative disposal practices of the particular state. (See mono-fill)

coal combustion ash - collective term referring to any materials or residues produced from the combustion of coal. (See CCPs and CCR)

ccoal combustion byproducts (CCBs) - collective term referring to fly ash, bottom ash, boiler slag, fluidized bed combustion ash or flue gas desulfurization (FGD) material resulting from the combustion of coal and the cleaning of the stack gases. Also a collective term referring to any large volume material or residue produced from the combustion of coal or the cleaning of the stack gases regardless of ultimate commercial application or disposal. Coal combustion products (CCPs) have replaced the term coal combustion byproducts and this usage is intended to clearly identify the products from the combustion of coal or the cleaning of the stack gasses that are manufactured or processed to meet standards, guidelines etc. and used commercially. However many government agencies (Federal and State) and other organizations continue to use the term CCBs. In addition federal regulations also use the term coal combustion wastes (CCWs) and fossil fuel combustion wastes (FFCWs) in the same context as the term CCBs.

As a result of the interchangeable use of these terms (CCBs, CCPs, CCWs & FFCWs) there is an industry movement to provide clarity based on use of the products. This clarification, based on current usage by the Department of Energy (DOE), National Energy Technology Laboratory (NETL) is that the term “Products” applies when the material is used and “Wastes” applies when the material is discarded. (See coal combustion products)

ccoal combustion products (CCPs) – fly ash, bottom ash, boiler slag, fluidized-bed combustion (FBC) ash, or flue gas desulfurization (FGD) material produced primarily from the combustion of coal or the cleaning of the stack gases. Also a collective term referring to fly ash, bottom ash, boiler slag, fluidized bed combustion (FBC) ash or flue gas desulfurization (FGD) material produced primarily from the combustion of coal and the cleaning of the stack gases and are manufactured either as a part of the coal-fueled power plants operating processes or otherwise to meet standards, guidelines etc. and used commercially. (Examples include but are not limited to the production of FGD gypsum; the production of specification fly ash either as a part of the power plants normal basis of operation or through the use of beneficiation processes; the production of commercial materials through screening, drying, classifying of bottom ash, boiler slag or fly ash.) Coal combustion products (CCPs) have replaced the term coal combustion byproducts (CCBs).

ccoal combustion residue (CCR) - collective term referring to any materials or residues produced from the combustion of coal. CCR has been a term used in scientific literature and by the US Environmental Protection Agency (EPA) and environmental groups; but used little by the CCPs industry. (See CCPs)

ccoal combustion wastes (CCWs) - a collective term for materials or residues produced from the combustion of coal or the cleaning of stack gases that are disposed of as a solid waste. This term is used in federal and state regulations by environmental groups. (See CCBs and FFCWs)
coal fly ash - a product of burning finely ground coal in a boiler to produce electricity. It is removed from the plant exhaust gases primarily by ESPs or baghouses and secondarily by wet scrubbers. Physically, fly ash is a very fine, powdery material, comprised mostly of silica, and nearly all particles are spherical in shape. Coal fly ash is a pozzolan. (See fly ash)

fly ash-bituminous coal – fly ash resulting from the combustion of a bituminous coal in a boiler for the production of electricity, it is generally low in lime (less than 2%); its chemistry would make it fall under but may not conform with the ASTM C 618 classification of a Class F fly ash; this fly ash does have pozzolanic characteristics.

fly ash-sub-bituminous/bituminous coal blends – the proportions of the coal blends affects the lime content of the fly ash; for example a 70% sub-bituminous powder river basin: 30% bituminous coal blend can result in a lime content of the fly ash that can range from 11 to 13%; the chemistry of the fly ash depending on the proportion of the blend could make it fall under, but may not conform with, the ASTM C618 classification of either a Class C or a Class F fly ash while having a lime content that exceeds that normally associated with a Class F fly ash.

clean coal mine - an area of land and all structures, facilities, machinery, tools, equipment, shafts, slopes, tunnels, excavations, and other property, real or personal, placed upon, under, or above the surface of such land by any person, used in extracting coal from its natural deposits in the earth by any means or method, and the work of preparing the coal so extracted, including coal preparation facilities. The British term is “colliery”. Coal combustion products are sometimes used in construction projects at coal mines and coal combustion byproducts are sometimes disposed in coal mines.

clean coal mine drainage –water discharge from coal mines, ranging in composition from acidic to alkaline typically with elevated concentrations of sulfate, iron, manganese, and aluminum as well as common elements such as calcium, sodium, potassium and magnesium. The pH is most commonly either in the ranges 3 to 4.5 or 6 to 7, with fewer intermediate or extreme values.

clean coal mine waste - the coal processing waste and underground development waste.

clean coal processing waste – the earth materials which are separated and wasted from the coal during cleaning, concentrating, or other processing or preparation of coal.

clean coal refuse - waste products of coal mining, cleaning, and coal preparation operation (for example culm, gob, etc) containing coal, matrix material, clay and other organic and inorganic material. This does not include overburden from surface mines.

clean coal utilization byproducts (CUB) – a collective term that is being used be the US Department of Energy (USDOE) to refer to byproducts from the utilization of coal and it includes coal combustion byproducts and byproducts from coal gasification.

clean co-firing - the term that is applied to the firing of two dissimilar fuels, such as biomass and coal, at the same time in the same boiler.
coke - a carbonaceous solid produced from coal, petroleum or other materials by thermal decomposition with passage through a plastic state; fuel consisting largely of the fixed carbon and ash in coal obtained by the destructive distillation of bituminous coal.

compaction - the densification of a soil or coal combustion product by means of mechanical manipulation; reduction in bulk volume of solid waste by rolling and tamping. Also, reduction in bulk volume or thickness of a body of fine-grained sediments in response to increasing weight of overlaying material.

compliance coal - a coal or a blend of coals that meets sulfur dioxide emission standards for air quality without the need for flue gas desulfurization.

compost - relative stable decomposed organic material, often associated with agriculture or gardening soil enrichment. Sometimes ash is blended with materials such as leaves, wood chips, peanut shell, poultry waste, etc to form compost.

composting - an aerobic process involving the biological stabilization of sludge and other wastes by microorganisms. Generally the process comprises of spreading or windrowing the material; sometimes the sludge or other waste is mixed with a bulking agent such as CCPs to maximize air contact.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) - A Federal law enacted in 1980 that governs the cleanup of hazardous, toxic, and radioactive substances. The act and its amendments created a trust fund, commonly known as Superfund, to finance the investigation and cleanup of abandoned and uncontrolled hazardous waste sites. Under this act the Department conducts remedial investigations and feasibility studies to determine the sources and extent of contamination and ultimately the cleanup alternatives.

conditioned ash - ash that has been moistened with water during the load out process at the temporary storage silo at the power plant to allow for its handling, transport, and placement without causing fugitive dusting. The water that is added can vary from 5 to 30% by weight of the dry ash which can be fly ash from an Electrostatic Precipitators (ESP), fluidized bed material which could be a combination of fly ash and bed ash, and bag-house material from a dry scrubber that could be a combination of fly ash, unreacted lime (as calcium hydroxide), calcium sulfate and calcium sulfite. The water is added in a pugmill or pugmill type equipment as the ash is fed from the silo and loaded into open body trucks or other hauling equipment. The conditioned ash is usually designated for placing in a landfill, although it can be used in beneficial applications. (See Pugmill)

conditioned fly ash - dry fly ash that has been moistened with water during the load out process at the temporary storage silo at the power plant to allow for its handling, transport and placement without causing fugitive dusting. The water that is added can vary from 5 to 30% by weight of the dry fly ash. Water contents of 5 to 10% is sometimes added for high lime fly ashes because of the quick setting that occurs and to allow a designated time that the hauling equipment can easily discharge the conditioned ash without it all sticking in the truck bed. Water contents for low lime fly ash is generally from 10 to 30%. The water is added in a pugmill or pugmill type of equipment (dustless unloader) as the dry fly ash is fed from the silo and
loaded into open body trucks or other hauling equipment for placing in a landfill or for beneficial use. (See dustless unloader and pugmill)

**consolidation** - the reduction in volume of a fill caused by movement of water out of the fill mass. Consolidation generally occurs due to an increase in the vertical stress on a fill. It is the movement of water rather than the compression of air filled voids that distinguishes consolidation from compaction.

**continuous emission monitoring (CEM)** - the measurement on a continuous basis of pollutants emitted into the atmosphere in the exhaust of gases for combustion processes or as the byproduct of industrial processes.

**controlled low-strength material (CLSM)** – a flowable fill conforming to ACI 229 R

**culm** - anthracite tailings, especially prevalent in Eastern Pennsylvania, that are a source of energy which could be used for example in fluidized bed boilers.

**cyclone** - a cone-shaped air-cleaning apparatus that operates by centrifugal separation and is used in particle collecting and fine-grinding operations. Cyclone particle collection equipment is widely used in CCPs handling and storage systems.

**cyclone boiler** - a type of coal-fueled boiler. The coarsely pulverized coal undergoes slagging combustion in a cylindrical (cyclone) burner. Some wet-bottom boilers are not cyclone-fired. The primary byproduct is a glassy slag referred to as boiler slag, which is in great demand for beneficial use, but the supplies are declining because of the retirement from service of cyclone boiler electric power generating plants.

**cyclone dust collector** - a type of particle collection equipment that is used in particle transport systems and is usually in series with other types of dust collection equipment such as a baghouse dust collector. It is used in CCP handling and storage systems.

**deep mine injection** - placement of materials such as ash and flue gas cleaning material into underground depleted mine cavities, through boreholes, either pneumatically or hydraulically. Proper filling may help control acid mine drainage by reducing oxidation of pyrite, addition of alkalinity or reducing groundwater flow through the mine. This is a beneficial use of CCPs when performed for mine subsidence control.

**density** – the mass per unit volume; weight per unit volume, expressed as grams per cubic centimeter or pounds per cubic foot for solids and liquids and usually as grams per liter for gases.

**dewatering** - a physical process which removes sufficient water from a sludge, FGD material or ponded ash and FGD solids so that its physical form is changed from essentially that of a fluid to that of a damp solid. Some major types of equipment and facilities used are: rotary drum vacuum filters, centrifuges, horizontal belt filters, lagoons, ponds, etc.

**dike** - an embankment or ridge of either natural or synthetic materials used to contain or hold a liquid, slurry, sludge or other material in ponds.
**discharge** - the release of any solid, liquid or gas waste stream or any constituent thereof to the environment. (Example: a coal combustion byproduct surface impoundment will have a water discharge that has a permit issued by a state or federal agency.)

**disposal** - the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may not enter the environment or be emitted into the air or be discharged into any waters including groundwater.

**disposal facility** - a facility or part of a facility at which waste is intentionally placed into or on any land or water, and at which waste will remain after closure; the necessary equipment and associated land area which serves to receive and manage waste. The facility may have available one, many or all of a large number of disposal methods. A coal combustion byproducts (CCBs) disposal facility is usually either a landfill or surface impoundment and may be located on site or off site from the power plant that produced the CCBs. However some power plants have elected to use abandoned mines for ash and/or FGD materials which could involve the placing of either material in excavated mine shafts or in depleted strip mines.

**double liners** - a combination of two synthetic and/or natural buffers acting independently to separate waste from underlying soil and groundwater.

**drainage blanket** - a uniform layer of permeable material such as sand, crushed stone, or bottom ash/boiler slag installed with properly designed filter media at the base of a structural fill to maintain the fill in a drained condition.

**dredging** - an excavation practice employed by the electric power generation industry to remove coal combustion byproducts from a temporary storage to a long term disposal facility.

**dry ash removal** - the method of accumulating and removing dry ash from a dry bottom pulverized fuel fired furnace.

**dry bottom furnace** - a pulverized fuel fired furnace in which the ash particles (bottom ash) are deposited on the furnace bottom in a dry non adherent condition.

**dry fly ash** - fly ash that has been collected by the particulate removal equipment such as Electrostatic Precipitators (ESP), Baghouses, Mechanical Collectors or Fabric Filters at coal-fueled power plants. The collected fly ash is in a dry state, less than 3% moisture, and it is transported via an ash removal system to either a silo for temporary storage or to a wetting water eductor for sluicing to an ash pond. The fly ash in the silo is loaded out through specially designed equipment either in its present dry state into pneumatic or bulk carriers (truck or rail) for beneficial reuse or moistened with water for disposal and/or beneficial reuse. Also high lime fly ash, especially Class C fly ash, that is not beneficially used are sometimes transported by pneumatic bulk trucks to a facility where the ash is mixed with water to form a slurry and then discharged into a pond – the pond is then dewatered and the hardened material is excavated and placed in a landfill or beneficially used. (See fly ash)
**Dry fly ash removal systems** - the equipment system used to remove and to convey the fly ash from the hoppers of the particulate collection equipment, ESP or other, to a silo including the silo aeration and unloading equipment or to a wetting water eductor.

**Dry fly ash disposal system** - the overall fly ash transport and storage systems that involve the dry fly ash removal system at the coal-fueled power plant, the truck (vehicular) transport of the conditioned fly ash and the placing of the conditioned fly ash in a landfill.

**Dust** - particles of gas borne solid matter larger than one micron in diameter.

**Dustless unloader** - a term used by the American Boiler Manufacturers Association for a device for wetting dust so the particles are adherent to each other, to prevent dissipation by atmospheric current while conveying. The typical usage is for the pugmill type equipment used to wet (condition) fly ash as it is being removed from a silo and loaded into trucks or other vehicles. (See conditioned fly ash)

**Economizer** - a heat recovery device designed to transfer heat from the products of combustion to a fluid, usually feedwater.

**Economizer ash** - ash which is collected in the economizer section of a boiler. It is the ash, which is collected in the ash hoppers that are located below the economizer. The majority of the economizer ash is plus 200 mesh and it is referred to as having a popcorn consistency. Generally the economizer ash is removed from its hopper(s) as a part of the fly ash removal system and it is conveyed along with the fly ash to a silo (for dry removal systems) and to a pond (for wet removal systems). However the size of the economizer ash particles when combined with the dry fly ash in a silo can cause the fly ash to be out of specification with standards for use in concrete. As a result the economizer ash is conveyed either to the bottom ash transport system and combined with the bottom ash or to a dedicated silo.

**Effluent** - the final discharge from any process such as from an ash impoundment.

**Electrostatic precipitator (ESP)** - a facility that removes fly ash from the flue gas by producing an electric charge on the fly ash and collecting it electrostatically.

**Encapsulation** - complete coating or enclosure of a toxic particle by an additive so as to sequester that particle from any environmental receptors that may otherwise have been negatively impacted by that particle; the complete enclosure of a waste in another material in such a way as to isolate it from external effects such as those of water or air.

**Ettringite** - a high–calcium sulfoaluminate mineral \((Ca_6Al_2(SO_4)_3(OH)_{12}·26H_2O)\) that is expansive because of its crystal structure; a mineral comprised of hydrous basic calcium and aluminum sulfate that expands when wet upon forming its crystalline structure.

**Ettringite formation** - the phenomenon that leads to the formation of ettringite and can occur in fly ash/lime/sulfur mixtures. Ettringite is formed by the combination of aluminum from the fly ash, lime and sulfates from the scrubber process and water. These four substances are required for ettringite to form. Swelling problems due to ettringite formation have occurred with fly ash
that contains scrubber or FBC residue. Swelling problems rarely occur with fly ash that does not contain scrubber or FBC residue.

**exothermic** - a process or chemical reaction which is accompanied by the evolution of heat, for example combustion reactions.

**ex situ** - a Latin term meaning off-location. (Example: ex situ oxidation (Wet FGD Scrubbers))

**facility** - all contiguous land, and structures, other appurtenances and improvements on the land used for treating, storing, or disposing of wastes. The US EPA defines a facility for the purposes of TRI reporting as – “all buildings, equipment, structures and other stationary items which are located on a single site or contiguous or adjacent sites and which are owned or operated by the same person (or any persons which controls, is controlled by, or under control with such person)”.

**filler** - a substance added to a system or product to increase bulk, weight, viscosity, opacity, or strength and often used to reduce cost. CCPs are used as fillers in many applications, for example in solidification/stabilization of wastes; in concrete, flowable fills/controlled low strength materials. Also fly ash in particular is being used as a mineral filler.

**final closure** - the measures which are specified by the permitting agency of a waste management facility and implemented by the owner of the facility to render a part of or the entire facility environmentally innocuous when it is no longer used to accept waste for treatment, storage or disposal.

**final cover** - cover material that is applied upon closure of a landfill or surface impoundment.

**financial assurance** - demonstration by an owner of a waste management facility to the permitting governmental agency of financial assets to guarantee closure and post closure care.

**fineness** - the %age by weight of a standard sample of a pulverized material which passes through a standard screen of specific mesh when subjected to a prescribed sampling and screening procedures. It is an important quality factor for the use of fly ash in concrete. The fineness of a particular fly ash is related to the operating condition of the coal crushers and the grindability of the coal itself. It is a measure of the % retained on the number 325 sieve. A coarser gradation can result in a less reactive fly ash.

**fixated CCPs** - CCPs that are blended with a cementitious binder to induce or enhance a pozzolanic reaction.

**fixation** - a physical immobilizing of particulates achieved by the development of chemical cementation bonds. This term is used by the US EPA to mean either solidification or stabilization.

**fixed carbon** - the part of the carbon that remains behind when coal is heated in a closed vessel until all of the volatile matter is driven off.
flowable fill - a material that flows like a liquid, is self-leveling, requires no compaction or vibration to achieve maximum density, hardens to a predetermined strength and is sometimes a controlled low strength material (CLSM). Coal Combustion Products (CCPs) are used in manufacturing flowable fills. The proportion of the CCPs in the flowable fill mixture can be 100% for an all ash flowable fill that consists of a combination of a Class C (high lime) fly ash and a Class F fly ash and water. It can be a major portion of a mixture that consists primarily of fly ash or fly ash and bottom ash and a small amount of cement or cement and lime. Also it may consist of only a high lime Class C fly ash (derived from the burning of Powder River Basin sub-bituminous coal) and sand with no addition of cement. The term flowable fill also applies to Fixated FGD material that is enhanced with added lime or cement and that is used in underground mine filling applications.

flue gas conditioning - the process of adding chemicals such as sulfur trioxide or ammonia to the flue gas in order to improve the performance of the electrostatic precipitator (ESP) or reduce the opacity of the emissions from the stack.

flue gas desulfurization (FGD) - removal of gaseous sulfur dioxide from boiler exhaust gas. Primary types of FGD processes are wet scrubbers, dry scrubbers, and sorbent injection. Sorbents include lime, limestone, sodium-based compounds, and high-calcium coal fly ash

dry FGD - an FGD system in which calcium or sodium based sorbents, usually hydrated lime are introduced to the flue gas. Dry FGD systems use less water than wet systems, usually remove fly ash and sulfur dioxide simultaneously and generate a dry byproduct. Spray dryer systems are the most common design. In a spray dryer, slaked lime slurry is sprayed into the flue gas and the resulting byproduct, dried by the heat of the flue gas is collected in a particulate control device with the fly ash. Other dry systems inject dry sodium sorbent directly into the boiler exhaust duct. The byproduct of a dry FGD system is referred to by various names that include dry FGD ash, dry FGD material, dry scrubber material.

dry sodium injection - (See dry FGD)

ex situ oxidation (wet FGD) - forced oxidation that occurs outside of the scrubber and used to produce FGD gypsum.

forced oxidation - a process employed to supply additional air in wet FGD systems, resulting in a predominantly calcium sulfate dihydrate (gypsum) byproduct with improved storage characteristics as well as greater commercial potential.

in situ oxidation (wet FGD) - a process in which both SO2 absorption and oxidation are carried out within the scrubber.

spray dryer - a type of dry FGD system. (See dry FGD)

wet FGD - an FGD system which uses a wet scrubber to introduce an aqueous solution of either slaked lime (calcium hydroxide) or limestone (principally calcium carbonate) into the flue gas in a spray tower. The sorbent reacts with or oxidizes the sulfur dioxide in the flue gas and coverts it to a byproduct that is referred to as scrubber sludge, scrubber material, wet FGD material.
scrubber - any of several forms of chemical/physical devices that remove sulfur compounds formed during coal combustion and especially from coal-fueled power plants. (See wet FGD and wet scrubbers)

FGD material – a product of an FGD process typically using a high-calcium sorbent such as lime or limestone. Sodium-based sorbent and high-calcium coal fly ashes are also used in some systems. The physical nature of these materials varies from a wet thixotropic sludge to a dry powdered material depending on the process. The wet thixotropic sludge is usually from a lime-based reagent wet scrubbing process and is predominantly calcium sulfite. It is the end product of dewatering equipment such as vacuum filters or centrifuges, although it can be the end product of a sedimentation pond. This dewatered end product is usually stabilized by mixing with lime and fly ash or other materials for disposal in landfills. (There are systems where the end product is not dewatered but is highly concentrated in solids as the underflow from a thickener - it is then mixed with fly ash and another material and pumped to a surface impoundment for disposal). The wet product from limestone based reagent wet scrubbing processes is predominantly calcium sulfate which is gypsum. This material readily dewater and there are systems in use where the slurry is transported to a pond and construction equipment is used to excavate and stockpile the gypsum. The production of commercial grade FGD gypsum used for wallboard manufacturing usually requires forced oxidation in the scrubbers or external to the scrubbers and dewatering by filtration equipment such as vacuum filters or centrifuges and sedimentation ponds. The dry material from dry scrubbers that is captured in a baghouse along with fly ash consists of a mixture of sulfites and sulfates in addition to fly ash. This powdered material is referred to as dry FGD ash, dry FGD Material, lime spray dryer ash, lime spray dryer, or lime spray dryer residue.

dry FGD ash – (See dry FGD material)

dry FGD material – the product that is produced from dry FGD systems and consists primarily of calcium sulfite, fly ash, portlandite (Ca(OH)2), and/or calcite. Lime based sorbent systems dry FGD material main constituents are calcium sulfite and dry fly ash, along with minor quantities of calcium sulfate. Sodium based sorbent systems main constituents are sodium sulfite and dry fly ash along with minor quantities of sodium sulfate. Dry FGD material is being used in construction, engineering and agricultural applications; however most of the material is stored in landfills.

FGD byproducts - the term for the byproducts from wet and dry FGD systems. (See Wet and Dry FGD byproducts)

FGD gypsum – gypsum formed from an oxidizing and calcium-based flue gas desulfurization process. Also precipitated gypsum formed through the neutralization of sulfuric acid in flue gas desulfurization processes at coal-fueled power plants. This gypsum can vary in purity, which is defined as the %age of CaSO4·2H2O and generally is over 94 % for use in wallboard manufacturing. The less pure gypsum can be stockpiled (gypsum stacking), placed in ponds or captive landfills or utilized in Agriculture or construction. The nearly pure or pure FGD Gypsum is utilized beneficially. The pure FGD Gypsum is manufactured to meet the specifications of wallboard manufacturing companies and is used for wallboard manufacturing, for cement production and as plasters. Large quantities of FGD Gypsum are produced and utilized. See gypsum and synthetic gypsum.
**FGD material dry scrubbers** - the dry powdered material from dry scrubbers that is collected in a baghouse along with fly ash and consists of a mixture of sulfites, sulfates, and fly ash. *(See dry FGD ash)*

**FGD products** - another term for the byproducts from wet and dry FGD systems.

**FGD sludge** - another name for scrubber sludge, wet FGD material or filter cake. *(See wet FGD material)*

**filter cake** - the material produced by filtering equipment such as vacuum filters for dewatering wet FGD material. *(See wet FGD material)*

**fixated FGD material** - a designed mixture of dewatered FGD sludge that is primarily calcium sulfite with either a high lime (class C) fly ash, or a low lime fly ash (Class F), combined with a cementitious material (such as cement kiln dust, lime kiln dust or FBC ash). FGD sludge is also known as scrubber sludge, scrubber material, FGD solids, filter cake or centrifuge cake. The designed mixture is produced in a mixing facility that is sometimes referred to as a Sludge Treatment Plant (STP), transported by a belt conveyor to an area where it is stockpiled for a number of hours or days to undergo an initial chemical set. The stockpiled material is then excavated, loaded unto trucks or other earthmoving equipment for placement as a fill in beneficial use applications or for placement in a Landfill for storage or disposal where it undergoes a further chemical set. After placement, the fixated material forms a stable, monolithic mass of low permeability.

**fixated scrubber sludge** - another name for fixated FGD material.

**lime spray dryer ash** - the residue from a spray dryer FGD system. The resulting byproduct is dried by the heat of the flue gas and it is collected in a particulate control device with the fly ash. *(See dry FGD material)*

**lime spray dryer residue** - another name for lime spray dryer ash.

**wet FGD material** - the byproduct of wet FGD processes or systems. It is comprised primarily of water, calcium sulfite/sulfate solids and small quantities of fly ash. It has the consistency of a sludge when allowed to settle in a pond or when the water is removed by filtering equipment such as vacuum filters. It is commonly referred to as scrubber sludge. Depending on the composition of the injected lime or limestone, some byproducts will also contain magnesium sulfite and/ or sulfate and possibly traces of barium sulfite or boron in sulfate addition to some trace metals.

**scrubber sludge** - another name for wet FGD material. *(See wet FGD material)*

**stabilized FGD material** - another name for fixated FGD material. *(See fixated FGD material)*

**fixated FGD material pad area** - the engineered area that receives the fixated FGD material from the processing facility (Sludge Treatment Plant) where the filter cake is mixed with fly ash and lime or other material, via a belt conveyor and radial stacker. The material is stockpiled on this
pad and allowed to cure (hours or days). The cured material is then excavated, loaded onto
trucks or other transportation equipment for beneficial use or disposal.

**fluidized-bed combustion (FBC) boiler** - a type of coal boiler which accomplishes coal
combustion by mixing the coal with a sorbent such as limestone or other bed material. The fuel
and bed material mixture is fluidized during the combustion process to allow complete
combustion and removal of sulfur gases. Atmospheric FBC (AFBC) systems may be bubbling
(BFBC) or circulating (CFBC). Pressurized FBC (PFBC) is an emerging coal combustion technology.

**fluidized bed combustion (FBC) ash** – the fly ash and bed ash produced by an FBC boiler. FBC fly
ash is collected in the flue of an FBC boiler using a baghouse filter or ESP. FBC bed ash is the
residue that is removed from the bottom of the FBC boiler. Some FBC fly ashes exhibit self-
hardening properties in the presence of moisture.

**fluidized-bed combustion (FBC) bed ash** – the spent bed material that is produced by an FBC
boiler. The bed ash is usually collected separately and can be considered as being equivalent to
bottom ash in dry bottom or wet-bottom wall-fired furnace.

**fluidized bed combustion (FBC) materials** - the unburned coal, ash, and spent bed material
produced by an FBC boiler. The bed ash is usually collected separately and can be considered as
being equivalent to bottom ash in dry bottom or wet-bottom wall-fired furnace.

**fluidized-bed combustion (FBC) products** - the unburned coal, ash, spent bed material, and
unreacted sorbent produced by an FBC boiler.

**fluidizing** - the causing of a mass of finely divided solid particles to assume some of the
properties of a fluid, as aeration. (Example: the fly ash in a silo is usually fluidized to facilitate its
flow and allow for the loadout of the ash from the silo.)

**fly ash** - ash that exits a combustion chamber in the flue gas and is captured by air pollution
control equipment such as ESPs, Baghouses, and wet scrubbers. Fly ash is typically a pozzolan.
Some fly ashes also exhibit self-hardening properties in the presence of moisture. (See coal fly
ash)

**fly ash–high lime** - fly ash resulting from the combustion of sub-bituminous and some lignite
coal that contains a significantly higher %age of calcium compounds than the fly ash resulting
from the combustion of bituminous coal; its chemistry would make it fall under, but may not
conform with, the ASTM C 618 classification of a Class C fly ash; it may contain in excess of 20%
CaO.

**fly ash–low lime** – fly ash resulting from the combustion of anthracite or bituminous coal and it
is relatively low in lime (less than 2%); its chemistry would make it fall under, but may not
conform to the ASTM C 618 classification of a Class F fly ash. This fly ash does have pozzolanic
characteristics.

**fly ash-lime content** – the total calcium content of fly ash including reactive and non-reactive
calcium species expressed as calcium oxide (CaO).
forced oxidation - a process employed to supply additional air in wet FGD systems, resulting in the production of gypsum.

fossil fuel combustion wastes (FFCWs) - a collective term utilized by the EPA for materials or residues produced from the combustion of coal or the cleaning of stack gasses. (See coal combustion wastes (CCWs), coal combustion byproducts (CCBs))

free lime - reactive lime and hydroxide species available to react with a pozzolan to form a cementitious product, usually expressed as a %age by total weight of the product.

friable - easily crumbled or pulverized. (Example: some coal bottom ashes are reported to be friable)

fuel switching - a pre-combustion process whereby a low-sulfur coal is used in place of a higher sulfur coal in a power plant to reduce sulfur dioxide emissions.

fugitive emissions - emissions other than those from stacks or vents. (Example: dust emissions from unpaved roads, from the surfaces of landfills, etc.)

gasification - the conversion of coal to a combustible gas, volatiles, char, and ash/slag; any of various processes by which coal is turned into low, medium, or high Btu gases. Byproducts from gasification systems vary widely. Gasification is a clean coal technology.

grab sample - a single sample of material or liquid taken at neither set time nor rate.

ground granulated blast furnace slag (GGBFS) - the granular material formed when molten iron blast furnace slag is rapidly chilled (quenched) by immersion in water. It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, hydrates like Portland cement. GGBFS use as a mineral admixture in concrete and water is covered by ASTM C 989-82 and AASHTO M302.

Portland blast furnace slag cement - the blended cement that is made by intergrinding blast furnace slag with cement clinker.

ground water - that part of the subsurface water that is in the saturated zone; water directly below the earth’s surface that is in the saturation zone.

grout - a mixture of cementitious material and water, with or without aggregate, sometimes incorporating CCPs, proportioned to produce a pourable consistency without segregation of the constituents. It is used for filling voids and spaces. Grouts can be considered as a controlled low strength material (CLSM) as defined by ACI 229 R when the compressive strength is less than 1200 psi. Grouts are referred to by various names depending on the mix design and constituents of the mixture that includes but is not limited to high strength grout, fluid grout, stiff grout, production grout, barrier grout, sand grout, FGD grout, ash grout, low strength grout etc. Mix designs are formulated to meet specific design considerations and are referred to by various names.
**gypsum** - name for calcium sulfate dihydrate (CaSO₄·2H₂O); the common name for the mineral consisting primarily of fully hydrated calcium sulfate, CaSO₄·2H₂O or calcium sulfate dihydrate. Gypsum occurs naturally in many areas, and is produced by some wet Flue Gas Desulfurization (FGD) processes. (See FGD gypsum and Synthetic gypsum)
gypsum stacking - the method used in the phosphate fertilizer industry and applied to the power industry for stacking the wet FGD byproduct (material) that is predominantly calcium sulfate (gypsum). It involves placement of the FGD byproduct slurry in an impoundment and stacking of the reclaimed settled solid in two operations. The primary operation accepts the FGD byproduct slurry directly from the scrubber in a diked or bermed ponding area (settling ponds). These settling ponds provide for primary settling of the FGD solids. The effluent from the ponds are decanted from the pond and either recycled back to the scrubber operation or sent to treatment and discharge. The solids that are settled in the primary/ponding operation are periodically excavated and placed into piles or stacks typically adjoining the ponds to minimize the distance for transporting the dewatered material. Draining/excavating and stacking/drying operations alternate between diked areas to enable continuous storage and excavated material is used to raise dikes and to increase the site capacity.

heat of hydration - heat evolved by chemical reactions with water such as that evolved during the setting and hardening of Portland cement, Class C fly ash, dry FGD material, quicklime with or without pozzolans.

high volume waste - a regulatory term for fly ash, bottom ash, boiler slag and flue gas desulfurization wastes.

highwall – the unexcavated face of exposed overburden and coal in a surface mine or in a face or bank on the uphill side of a contour mine excavation.

hygroscopic - the term describing a compound that can absorb water vapor from the atmosphere, for example some high lime fly ashes when stored in buildings will absorb moisture in the air.

impoundment - the restraint of a flowable material such as a slurry or sludge behind a structural barrier, such as a dam, dike etc. (See ash pond)

in situ - a Latin term meaning in place.

landfill - a disposal facility where waste is placed in or on land; a facility where “dry” (actually moistened) coal combustion or flue gas cleaning byproducts (CCBs) are placed for disposal in or on land. CCBs are transported to this facility directly from the coal-fueled plant after they are produced or after they are dredged from storage impoundments that are used as interim facilities. The disposed CCBs remain in the landfill after closure. Also these CCBs are dry (moistened) and have the consistency of soil. As a result dikes are not required to provide stability. Most large landfills are divided into sections or cells and the CCBs are placed in layers that are referred to as lifts that can vary in thickness. Typically captive CCBs landfills are designed and permitted to receive only CCBs and are classified as mono-fills.

leachate - the liquid including any suspended components in the liquid that has percolated through or drained from a pile or cell of solid materials; the liquid stream which issues from a pile (stockpile of ash, coal, etc) or cell of solid materials (an ash landfill) and which contains water, dissolved solid and decomposition products of the solids. Leachate may enter the groundwater and contaminate drinking water supplies.
leaching - the operation, natural or designed, of producing leachate.

lift - the construction/earth moving industry term for placing or spreading soil and other materials in layers in a fill; the depth of soil and other materials placed in an embankment or fill that can be compacted to the specified density with the available equipment.

light weight aggregate – (See aggregate)

lime - calcium oxide (CaO); also loosely, a general term for the various chemical and physical forms of quicklime, hydrated lime and hydraulic hydrated lime.

liner - a structure of natural and/or manufactured products that serve as a barriers to minimize leachate from reaching or mixing with the groundwater.

Loss on Ignition (LOI) - the weight change of a material when it is heated under prescribed conditions; a measurement of unburned carbon (coal) remaining in fly ash and is perhaps the single most critical characteristic of fly ash when used in concrete. Higher carbon contents can result in significant air-entrainment problems and can adversely affect the performance of concrete incorporating the ash. The carbon level found in coal combustion products (primarily fly ash) is determined in accordance with ASTM D 3178, Instrumental Method.

Low NOx Burners (LNB) - a combustion technology for reducing the emissions of nitrogen oxides (NO and NO2, collectively referred to as NOx) from coal-fueled power plants. The principle of LNB involves decreasing the amount of air introduced into the primary combustion zone, thereby creating a fuel-rich, reducing environment and lowering the temperature both of which suppress NOx formation. The remaining air required for complete burnout of combustibles is added after the primary combustion zone, where the temperature is sufficiently low so that additional NOx formation is minimized.

manufactured aggregates from CCPs - a commercial product made by the intentional size-enlargement and hardening of fine-particulate coal combustion products (CCP) for use as a substitute for crushed stone, sand and gravel, and lightweight aggregate in the construction materials industry. The commercial products that use CCPs all have trade names.

microspheres - micrometer-sized fly ash particles that are formed from the fly ash when it is in the molten state. In this state, a spherical shape is formed because it minimizes surface tension. These ash particles have diameters near or less than about 5µm. Although they may contain gas bubbles, in which case they would be considered cenospheres, it is usually the case that microspheres are solid in form. Their bulk densities approach or are equal to that of the pure compounds. Microspheres are recovered from fly ash by air classification and other techniques. Microspheres have a high intrinsic value and have many known applications. (See cenospheres)

milligrams per liter (mg/l) - essentially the same as parts per million when applied to water solutions whose specific gravity is 1.

mill rejects - the waste product from a pulverizer mill, which consists of coal, rocks and pyrites. The mill rejects are sometimes combined with the bottom ash. (See pyrites)
**mine subsidence** – the downward displacement of the natural land surface in response to the removal of underlying supporting material by mining.

**mono-fill** - a landfill that is comprised of a single material. (Example: a fixated FGD material landfill or an ash landfill)

**national pollutant discharge elimination system (NPDES)** - the national program for issuing, modifying, revoking, and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under the Clean Air Act.

**naturally occurring radioactive (NORM)** - the trace quantities of naturally occurring radionuclides 238U, 232Th and 40K as well as their associated decay chain products that are emitted from coal and as a result its ash. The US EPA considers fly ash to be a diffuse naturally occurring radioactive material – its most benign classification. The US Geological Survey (USGS) fact sheet FS – 163-97 states that “the vast majority of coal and the majority of fly ash are not significantly enriched in radioactive elements or in associated radioactivity, compared with common soils or rocks”.

**new source performance standards (NSPS)** - uniform national US EPA air emission and water effluent standards which limit the amount of pollution allowed from new sources or from modified existing sources.

**non-point sources** - diffuse pollution sources (i.e., without a single point of origin or not introduced into a receiving stream from a specific outlet). The pollutants are generally carried off the land by storm water. Common non-point sources are agriculture, forestry, urban, mining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.

**non-self-cementing fly ash** - a coal combustion product resulting from the combustion of anthracite or bituminous coal and some lignite coal in a boiler for the production of electricity or steam. This fly ash does have pozzolanic characteristics; it is usually relatively low in lime (less than 2%); its chemistry would make it fall under the ASTM C 618 classification of a Class F fly ash; generally it will not harden or gain strength over time following contact with water.

**off-gases** - vapors and gases (including air) given off during a process. (Example: ammonia gas that is given off when ammoniated fly ash is mixed with cement and water)

**organic** - chemical compounds which contain carbon and hydrogen; chemicals associated with living entities.

**outfall** - the point at which a sewer, ash impoundment or drainage channel discharges to a river or other body of work. Also, the narrow part of a stream, lake, or other body of water where it drops away into a larger body.

**particle size** - this term refers in this context to the composition of the solid particles of the products from coal combustion or flue gas cleaning. The smaller the particle, the greater will be the exposed surface area of a given volume.
particulate matter - the solid and liquid matter of organic or inorganic composition that is suspended as the result of stack or fugitive emissions. The matter may be individual elements and/or compounds and may or may not be emitted along with gaseous contaminants.

parts per billion (PPB) - $1 \times 10^{-9}$ a proportion by weight measurement equivalent to one unit weight of analyte per billion unit weights of matrix. In water treatment terminology, one pound per one billion pounds of water.

parts per million (PPM) - $1 \times 10^{-6}$ - a proportion by weight measurement equivalent to one unit weight of analyte per million unit weights of matrix. In water treatment terminology, one pound per one million pounds of water or one milligram per liter of water.

permissible exposure limit (PEL) - the workplace exposure limit established by Occupational Safety and Health Administration (OSHA) for each of 600 industrial chemicals.

permits - the official approval of and permission to proceed with an activity controlled by the permitting authority. Permits may be required from several government agencies for landfills and surface impoundments at coal-fueled power plants.

permit to install (PTI) - a permit that is issued by some states regarding the construction of CCBs storage and disposal or waster water facilities.

petrographic analysis - the determination of the structural, mineralogical and chemical character of coal, ash or slag.

petrology - the branch of geology that deals with rocks, in particular their formation and chemical and physical structure.

petroleum coke (pet-coke) - the solid carbonaceous residues remaining in oil refining stills after the distillation process and sometimes used in combination with coal at some coal-fueled power plants. The fly ash from pet-coke/sub-bituminous coal blends where the %age of pet-coke in the blend was less than 3 per cent by weight have been marketed for use in fly ash concrete. The carbon in the fly ash from the blend consisted primarily of unburned pet-coke.

pH - the logarithm of the reciprocal of the hydrogen ion activity in aqueous solutions. A measure of the strength or intensity of a water’s acidity or alkalinity. Water with a pH of 7.0 is neutral. A pH less than 7.0 indicates an acidic water, while a pH greater than 7.0 indicates an alkaline water.

pneumatic conveying - the transportation of a powdered material which would include ash, through a conduit by air.

point source - a stationary location or fixed facility from which pollutants are discharged; any single identifiable source of pollution. (Example: a pipe from an ash pond)

ponded ash – ash that is in an ash pond or that has been excavated from an ash pond. The ash pond is usually prepared to facilitate excavation of the ash by removing the surface water and lowering the water table within the pond. The ash, if it is predominantly fly ash still retains
moisture in excess of 30% unless construction practices of removing the ash in layers, and stockpiling the ash are followed. The ponded ash tends to be segregated by particle size in the pond with the coarser ash particles being located in the environs of the discharge of the ash transport pipeline(s) and the finer ash particles being located in the environs of the outfall from the pond. Also the ponded ash may contain other materials that are transported to the ash pond as a part of the wastewater sedimentation process for the particular coal-fueled power plant. The other materials could include coal fines from the coal pile runoff control system, solids from the cooling tower blowdown and wastewater collection systems.

**ponded bottom ash** - bottom ash that has been excavated from an ash pond.

**ponded fly ash** - fly ash that has been excavated from an ash pond.

**pozzolan** – primarily siliceous or siliceous and aluminous materials that will in finely divided form and in the presence of moisture, chemically react with calcium oxide at ordinary temperatures to form compounds possessing cementitious properties

**pozzolanic activity** - the phenomenon of strength development that occurs when lime and certain aluminosilicates react at ambient temperatures in the presence of water.

**pozzolanic-activity index** - an index that measures pozzalinic activity based on the strength of cementitious mixtures containing hydraulic cement with and without the pozzolan, or containing the pozzolan with lime.

**processed ash** - ash that has been put through a cleaning, sieving or other commercial manufacturing process to make the ash meet specifications for a particular beneficial use or to make a proprietary product that is marketed for niche or other applications. (Example: the fly ash produced from the commercial processes of removing carbon from fly ash in order to make it conform to ASTM C618)

**product** - any object possessing intrinsic value, capable of delivery either as an assembled whole or as a component part or parts and produced for introduction into trade or commerce.

**pugmill** - a mixer having a stationary cylindrical mixing compartment, with the axis of the cylinder horizontal, and one or more rotating horizontal shafts to which mixing blades or paddles are attached. Pugmill type equipment is used at coal-fueled power plants for mixing fly ash and water, FGD cake/lime/fly ash or other to facilitate the handling of the CCBs without creating fugitive dusting and/or providing for stabilizing of FGD material in particular.

**pulverized coal (PC) combustion** - refers to any combustion process that uses very finely ground (pulverized) coal in the process. Pulverized coal combustion processes usually result in the production of bottom and fly ashes.

**pulverized fuel ash (PFA)** - another name for fly ash and used primarily in the United Kingdom.

**pulverizer** - a machine which reduces a solid fuel such as coal to a fineness suitable for burning in suspension.
**pyrite** - a common mineral that consists of iron disulfide with a pale brass-yellow color and metallic luster which is usually rejected by coal pulverizers at the coal-fueled power plant and discarded. The present usage in the electric generation industry is that it is the waste product from a pulverizer mill, which consists of coal, rocks and pyrites. This mixture is now commonly referred to as “mill rejects”. Generally there is a separate pyrites (mill rejects) collection and transport system. In some of the newer vintage power plants the pyrites are conveyed to a dedicated collection tank/dewatering bin or pond from where it is removed for final disposal or reuse. In many power plants the practice is to convey the pyrites to the bottom ash collection tank from where it is conveyed as a part of the bottom ash handling system to either a bottom ash-dewatering bin or to a pond for temporary storage. The bottom ash pyrites mixture is removed on a frequent basis (daily or less than a week) for the dewatering bin system and on an infrequent basis (monthly or yearly) for the pond. The levels of pyrites in the bottom ash or boiler slag can affect reuse because of the staining that occurs due to iron pyrites or because of the low pH in the leachate.

**ready-mixed concrete** - concrete manufactured for delivery to a purchaser in a plastic and unhardened state. The use of fly ash in ready-mixed concrete is one of the largest markets for fly ash in the US.

**reagent** - a substance used, because of its chemical activity, typically to reduce emissions or improve opacity from coal-fueled power plants. Examples of reagents include lime and limestone used for wet scrubbing of the combustion flue gas to remove sulfur dioxide. Also it is a term applied to the substances used in solidification or stabilization of wastes. These materials may include liquids or solids such as sodium silicate, cement, fly ash, etc.

**reclamation** – actions taken to restore mined land to a post mining land use approved by the regulatory authority.

**reuse** - the utilization of a coal combustion product as is or slightly refurbished by a different company from the generator of the CCPs.

**rim ditching** - a method for stacking gypsum that uses a combination of ditches and berms to make the gypsum slurry flow along an elevated ditch around an inside perimeter dike of a surface impoundment. Coarse particles settle in the ditch around the rim and finer particles are directed to the center of the impoundment. As the coarse materials settle in the rim ditch it is excavated from the ditch and continually used to construct the rim berm. After the rim berm is constructed the rim ditch is dammed to allow the ditch to fill with material. The operation then moves to the center of the impoundment to develop another rim ditch and berm. The process continues, as the material is stacked higher and closer to the center of the impoundment.

**run-off** - water which, having fallen on a landfill (or other) surface, flows across the surface, picking up materials and will, if not collected, continue into a watercourse. Also any rainwater, leachate or other liquid that drains over land from any part of a facility

**sample, composite** - a sample that is constructed by combining equal portions of grab or regular samples.
sample, grab - a single sample of a material or liquid (coal combustion product, coal combustion byproduct, coal combustion waste) taken at neither set time nor rate. (Example: a grab sample is taken in a single operation from a conveyor delivering fly ash to bulk storage)

sample, regular - a sample that is constructed by combining equal portions of grab samples that were taken at predetermined times or locations from any single lot.

scrubber – (See flue gas desulfurization)

scrubber cake - another name for scrubber sludge. (See flue gas desulfurization)

scrubber material - another name for scrubber sludge. (See flue gas desulfurization)

scrubber sludge - another name for FGD material. (See flue gas desulfurization)

sedimentation - gravitational settling of solid particles in a liquid system. This is a widely used method in wet ash or flue gas cleaning material handling and disposal.

selective catalytic reduction (SCR) - a post combustion technology for control of nitrogen oxides (NOx) emissions from coal-fueled boilers, gas fired industrial and utility boilers and combustion turbines. The SCR process consists of injecting ammonia (NH3) into boiler flue gas and passing the flue gas through a catalyst bed where the NOx and NH3 react to form nitrogen and water vapor. Unreacted ammonia will pass through the SCR reactor with the flue gases with most of it being deposited on the fly ash in the ESPs. The levels of ammonia in the fly ash have an effect on ash quality, especially its use as a pozzolan.

selective non catalytic reduction (SNCR) - a post combustion technology for control of nitrogen oxides (NOx) emissions from coal-fueled boilers, gas fired industrial and utility boilers. The process consists of the injection of ammonia (NH3) or Urea in an optimal temperature window (850°C to 1,100°C) to produce a non-catalytic reaction between NH2 radicals and NOx. Ammonium bisulfate precipitation on the fly ash occurs with this process and this can have an effect on disposal and beneficial use of the fly ash.

self-cementing coal fly ash - fly ash resulting from the combustion of lignite or sub-bituminous coal in a boiler for the production of electricity or steam. Such fly ash in addition to having pozzolanic characteristics hardens and gains strength over time following contact with water. Self-cementing fly ash as described here does not include fly ash from fluidized bed combustion boilers, nor fly ash from boilers that inject lime or other sorbents (either wet or dry), nor does it include fly ash collected with a flue gas desulfurization material. (See cementitious ash)

silo - a storage vessel, generally tall relative to its cross section, for dry solids such as fly ash, FBC ash, etc. The dry solids are fed into the top of silo and withdrawn from the bottom through a controlled mechanism. Silos are extensively used in dry fly ash removal/storage systems. They may be flat bottomed or cone bottomed and may be made of concrete or steel.

silo aeration and unloading equipment - the collective term for the equipment used especially in flat bottomed fly ash silos for fluidizing the fly ash to facilitate flow and for removing the fly ash from the silo in either a conditioned or dry state.
slag - the nonmetallic product resulting from the interaction of flux and impurities in the smelting and refining of metals. Also the molten or fused ash in the furnace of a coal-fueled power plant. (See boiler slag)

sludge - any solid or semisolid or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant or air pollution control facility (wet scrubbers) or any other such waste having similar characteristics and effect.

slurry - a mixture of water and any finely divided insoluble material (fly ash, slaked lime, etc) in suspension.

soil cover - the clean earth fill, or combination of earth and other materials capable of supporting vegetation that is used to cover the surface of a completed landfill, surface impoundment or other waste management facility.

soil modification - a change to the physical or chemical characteristics of soils; any change to in situ soils that results in immediate effects that can expedite construction operations. These changes can be measured in terms of moisture reduction, improved California Bearing Ratio (CBR) and/or decrease in plasticity. CCPs are used to modify soils in applications such as surface mine land reclamation, soil stabilization and base stabilization.

solidification - the conversion of, liquids, slurries or sludges into a material that can be more easily handled or compacted for disposal or use; a process for converting a liquid waste to a solidified material. Also a process in which materials are added to the waste to produce a solid. In the Solidification/Stabilization Industry this process is usually monitored for completion by applying the “paint filter test” and engineering tests such as unconfined compressive strengths; fly ash is often used as a reagent or filler.

sorbent - the term applied in some combustion systems, to the chemical compounds that are added to the gas side of the steam generator to reduce (sorb) emissions. (Example: Limestone is used in fluidized-bed steam generators to reduce sulfur dioxide emissions.)

spoil - material overlying a coal seam that is removed during a surface coal mining operation.

stabilization - a process for treating a waste to minimize an undesirable attribute of that waste. In the Stabilization/Solidification Industry, typically the stabilization process is monitored for completion by applying leachate testing; “Stabilization” of biological wastes may infer the elimination of pathogens (or their minimization); fly ash is used as a reagent or filler. In the power generation industry, typically the terminology is applied to the treating of solids from wet scrubbing or other air pollution control processes.

soil stabilization - a permanent change to in-situ soils which improves their physical characteristics. Soil stabilization allows the soil layer to be assigned a structural support value as an integral part of a pavement structure. CCPs are used as reagents in soil stabilization.

stabilized CCPs - CCPs that are blended with a cementitious binder to induce or enhance a pozzolanic reaction. (Example: wet FGD material mixed with fly ash and lime). See fixated CCPs
stoker boiler - a type of coal-fueled boiler in which the combustion of coal takes place on a grate, which may be stationary or moving.

structural fill - an engineered fill with a projected beneficial end use that is typically constructed in layers of uniform thickness and compacted to a desired unit weight in a manner to control the compressibility, strength, and hydraulic conductivity.

subsidence - the downward displacement of the overburden (rock or soil or both) lying above an underground excavation or adjoining a surface excavation. The sinking of the earth’s crust. The lowering of the natural land surface in response to: earth movements; lowering of fluid pressure; removal of underlying supporting material by mining; or added load on the land surface. CCPs are used in a grout or flowable fill to reduce subsidence.

subtitle C - the portion of RCRA that regulates hazardous waste management facilities and units.

subtitle D - the portion of RCRA that regulates non-hazardous waste management facilities and units.

sulfate attack - either a chemical or physical reaction or both between sulfates usually in soil or ground water, and concrete and mortar; the chemical reaction is primarily with calcium aluminate hydrates in the cement – paste matrix, often causing a deterioration.

sulfate resistance - ability of concrete or mortar to withstand sulfate attack. Fly ash concrete helps to reduce sulfate attack. (See alkali-silicate reaction (ASR))

sulfur - one of the elements present in varying quantities in coal that contributes to environmental degradation when coal is burned. EIA classifies coal, in terms of pounds of sulfur per million Btu as low (less than or equal to 0.60 pounds of sulfur), medium (between 0.61 and 1.67 pounds of sulfur), and high (greater than or equal to 1.68 pounds of sulfur). When coal is sampled, sulfur content is measured as a % by weight of coal on an “as received” or “dry” (moisture-free) basis. Sulfur occurs in coal in three forms: (1) iron sulfides (pyrite and marcasite), (2) secondary sulfates (gypsum and hydrous ferrous sulfate), and (3) organic sulfur chemically bonded to the coal forming plant material.

surface impoundment - a facility or part of a facility which is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials) which is designed to hold an accumulation of liquid wastes or materials containing free liquids and which is not an injection well; a type of waste management facility consisting of an excavated, a dammed or diked reservoir in which coal combustion and flue gas cleaning wastes are disposed of as a slurry or sludge. (See ash pond)

surface mine - a coal mine that is usually within a few hundred feet of the surface. Earth and rock above or around the coal (overburden) is removed to expose the coalbed, which is then mined with surface excavation equipment such as draglines, power shovels, bulldozers, loaders, and augers. Surface mines include: area, contour, open-pit, strip, or auger mine.
**surfactant** - a material added to a liquid usually water to reduce its surface tension enabling it to wet a solid surface effectively rather than running of the surface in droplets; a substance that affects markedly the interfacial or surface tension of solutions even when present in very low concentrations. Surfactants are added at some installations, to the water in the fly ash loadout process from a silo to wet the conditioned fly ash more effectively.

**supernatant** - the liquid remaining above a layer of settleable solids after the solids collect at the bottom of a pond or vessel. (Example: the clear water at the outlet area/water discharge structure of an ash pond.)

**suspended solids** - solids that either float on the surface of or are in suspension in water, wastewater or other liquids and which are largely removed by laboratory filtering. Also the quantity of material removed from wastewater in a laboratory test as prescribed in “Standard Methods for the Examination of Water and Wastewater” and referred to as nonfilterable residue.

**suspended solids, total (TSS)** - the sum of all insoluble particles suspended in a water.

**synthetic gypsum** - a precipitated gypsum formed through the neutralization of sulfuric acid in an industrial process. (Examples are Phosphorus (phospho) gypsum from phosphoric acid production, titano gypsum from titanium oxide production, citro gypsum for citric acid production, flue gas desulfurization (FGD) Gypsum from flue gas cleaning of utility boilers.) In North America there are large quantities of synthetic gypsum such as phospho-gypsum that are being produced and stockpiled and not being used. The exception is FGD Gypsum where large volumes are being generated and utilized in wallboard manufacturing, cement production and plasters. (See gypsum and FGD gypsum)

**thickener** - a vessel or apparatus for reducing the proportion of water in a slurry. Thickeners are used in Wet FGD Systems.

**thickener underflow** - the settled solids that are extracted from the bottom of a thickener as a slurry and measured in %age solids by weight. The thickener underflow in a wet FGD process is either conveyed for dewatering to equipment such as vacuum filters or to a pond.

**thixotropic** - the property of a material that enables it to stiffen in a relatively short time on standing, but upon agitation or manipulation to change to a very soft consistency or to a fluid of high viscosity, the process being completely reversible. Some CCPs are thixotropic.

**top ash** - another name for fly ash. (See fly ash)

**toxic** - term describing a harmful effect by a substance as the result of physical contact, ingestion, or inhalation.

**toxicity characteristic leaching procedure (TCLP)** - a laboratory procedure that is designed to simulate leaching under actual disposal conditions. The concentrations in the effluent produced by this test are compared to a list of 14 toxic metals and 25 organic constituents and their respective maximum containment levels (MCLs), as measured against primary drinking water
standards (PDWS) established by the Safe Drinking Water Act. Effluent at concentrations equal to or greater than the given limit are classified as toxic.

**toxic release inventory (TRI)** - collection of annual reports on chemical releases that regulated companies must file under the Superfund Amendments and Reauthorization Act (SARA), Title 111.

**trace element** - an element present in extremely small quantities. Metals are the predominant, naturally occurring trace elements in coal; they are also in its ash. Most of the trace elements in FGD sludge/cake originate from the small amounts of fly ash that elude the particulate collection device.

**treatment** - any method, technique, or process designed to change the physical or chemical or biological character of a waste to neutralize the waste, render it less hazardous, make it safer to transport or manage, or reduce its volume.

**triboelectric separation process** - an electrostatic technology with patented processes to remove carbon from high Loss on Ignition (LOI) fly ash and to produce a concrete grade fly ash.

**unburned carbon (UBC) in fly ash** - the unburned carbon in fly ash includes both carbon carried over as uncombusted “inertinite” and chars or cokes resulting from the incomplete combustion of thermoplastic, largely vitrinite-derived phases. The latter include “isotropic coke” and “anisotropic coke”; a measure of the actual amount of carbon found in coal fly ash or other coal combustion products determined by a mineral analysis of the material. UBC levels can affect the beneficial use of fly ash. (*See loss on ignition*)

**waste** - material that has no identifiable future use for which suitable disposal must be found. Wastes would include: inorganic solutions/solids/sludges, organic wastes, sewage sludge, animal wastes, waste contaminated soils, wastewater treatment sludge, complex mixtures, sludges from air pollution control facilities. CCPs are used in the stabilization/solidification of wastes.

**wet ash removal systems** - the overall system of mixing the ash and water, and transporting the ash via a slurry tank(s), pump(s) and pipeline(s) to a pond, surface impoundment or dewatering bin/tank (for bottom ash only).

**wet ash disposal system** - the overall CCP transport and storage system that involves the conveying of the ash in a fluid (slurry) state by pipeline to a surface impoundment or a holding pond for future excavation.

**wet bottom furnaces** - a pulverized fuel fired furnace in which the ash particles are deposited and retained on the floor thereof and molten ash is removed by tapping either continuously or intermittently.

**wet disposal systems** - the overall coal combustion and/or flue gas cleaning byproducts (CCBs) transport and storage systems that involve the conveying of the CCBs in a fluid (slurry) state by pipeline to a surface impoundment.
**wet fly ash disposal system** - the overall fly ash transport and storage systems that involve the conveying of the fly ash in a fluid (slurry) state by pipeline to a surface impoundment.

**wet scrubbers** - equipment that is used to remove ash from the combustion flue gas of coal-fueled power plants, where fuels are burned in suspension, by collecting it with a suitable liquid. Also equipment used to remove sulfur oxides from the combustion flue gas of fossil-fueled power plants in a gas-liquid contactor using lime, or limestone. The use of wet scrubbers for particulate removal results in the collected fly ash being in a slurry form that requires as a general practice, wet disposal of the fly ash and very limited opportunity for beneficial use. (See FGD)

**wetland** - those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

**XRD** - x-ray diffraction.