Materials Characterization Paper
In Support of the
Proposed Rulemaking –
Identification of Nonhazardous Secondary Materials That Are Solid Waste
Coal Refuse

March 18, 2010

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1. Definition of Coal Refuse

This paper focuses on coal refuse that is a by-product of coal mining (mining rejects).[1] Coal refuse is generally defined by a minimum ash content combined with a maximum heating value, measured on a dry basis (ARIPPA, p. 1 and EPA 2002, p. 2-2). Coal refuse mining rejects are a low BTU-value material generated by the coal mining process. The material consists primarily of non-combustible rock, with some attached carbon material that could not be effectively separated due to its small size. Large volumes of these materials were accumulated at mining sites from the time mining first began in the Appalachians through the late 1970s. Beginning in the late 1970s, laws were enacted that, for the first time, required stabilization and reclamation of mining sites, including coal refuse disposal piles and fills (ARIPPA, p.1). Current mining operations continue to generate the material, though likely at lower rates than in previous decades (Neufeld p. 1). Mining rejects are referred to by various names, including: “gob” (garbage of bituminous) or “boney” in the bituminous coal mining regions of western Pennsylvania, West Virginia and elsewhere; and “culm” in the eastern Pennsylvania anthracite region. Coal refuse piles also may be referred to as slate dumps (Energy Justice 2007, p.1; WPCAMR 2001, p.2; NRC 2006, p.16).

2. Annual Quantities of Coal Refuse Generated and Used

(1) **Sectors That Generate Coal Refuse:**

- Coal Mining Rejects are generated by NAICS industry sector 212111 - Bituminous Coal and Lignite Surface Mining, 212112 - Bituminous Coal

[1] An additional source of coal refuse is coal mill rejects. Mill rejects are produced by coal-fired power stations that use roller mills to generate coal mill rejects. These rejects are the dense material in fuel coal that cannot be ground by the mills at a power plant to the desired size for burning in the boilers (EPA, 2008). Mill rejects appear to have limited fuel value. In a 1995 pilot test, when compared to clean coal the sulfur content of mill rejects increased from 1.43 percent to 6.1 percent, and ash content increased from 9.4 percent to 80.3 percent. The heating value of the original coal was 13,206 Btu/lb compared to that of the mill rejects of 1,931 Btu/lb (EPRI, 1998, p. 4-8). Most mill rejects are co-managed with coal combustion byproducts (CCBs) in landfills or impoundments. A 1996 EPRI survey of coal-fired power plants found that 55 percent of the 264 sites included in the survey co-managed mill rejects with CCBs in landfills or impoundments. An additional limited survey of 24 utilities representing 40 power plants for this project found that 75 percent of these plants co-managed mill rejects in landfills or impoundments. Mill rejects typically represent 0.003 to 0.005 percent of the total ash produced (EPRI, 1998, p.iv). As mill rejects appear to have limited fuel value, are typically landfilled, and are a relatively smaller waste stream, they were excluded from this analysis.

Underground Mining, and 212113 - Anthracite Mining. The U.S. Department of Energy categorizes the locations of these industries into three regions:

- Appalachian Region, which includes the states of Alabama, Kentucky (eastern), Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia;
- Interior Region, which includes the states of Arkansas, Illinois, Indiana, Kansas, Kentucky (western), Louisiana, Mississippi, Missouri, Oklahoma, and Texas; and
- Western Region, which includes the states of Alaska, Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, Washington, and Wyoming (USDOE 2007b, p.14).

(2) **Quantities and Prices of Coal Refuse Generated:**

One estimate reports that, annually, coal mines in the U.S. generate 109 million metric tons (120 million short tons) of coal refuse from 600 coal preparation plants in 21 coal-producing states (TFHRC post-1994, p.1).

A second estimate can be derived from other knowledge of coal production. In 2007 the amount of coal produced at U.S. coal mines reached an all-time high of 1,145.0 million short tons; this production data includes quantities extracted from surface and underground mines, and normally *excludes* secondary materials removed at mines or associated preparation plants (USDOE 2007a).[2] Thus, the amount of raw mining product is higher than this 1,145.0 million short ton total. The amount of mining reject resulting from this production is uncertain, but up to 50 percent of the raw mined product may end up as refuse depending on the rock and impurities in the coal (VCE 1996). This 50 percent estimate is most applicable where coal is mined from longwall mines or otherwise has relatively high rock, impurities, and partings content (VEC 1996, p.1). Treating this 50 percent value as an upper bound, no more than 1,145 million short tons of coal reject were likely to have been generated in 2007 (i.e., 50 percent of raw mined product is saleable product, while 50 percent is rejects). As an example of specific data from one state, fifteen million tons of mining reject are generated annually in Virginia (VCE 1996). Another estimate found that, since the 18th century, the refuse rate of coal was about 40 percent of the volume of coal mined in the U.S. (Neufeld p. 1). However, the same source cites that current coal preparation plants are more efficient, producing less coal waste, resulting in a refuse rate of about 25 percent in the 1990s.

Public comments submitted to EPA by the Council of Industrial Boiler Owners (CIBO) in response to the Advanced Notice of Proposed Rulemaking (ANPRM) indicate that approximately 1.1 billion tons of waste coal are located throughout the United States. CIBO reports that this material has an energy equivalency of more than 2 billion barrels of oil (assuming an average Btu value of 5,500 Btu per pound for the waste coal) (Bessette 2009).

[2] This amount does not include the recovery of coal refuse, which was 0.8 million short tons in 2007.

The combustor survey database developed by EPA for the 2009 proposal of the Commercial and Industrial Solid Waste Incinerator (CISWI) standards and the Industrial Boilers Maximum Achievable Control Technology (MACT) standards includes one source that reported burning approximately 308,000 tons of coal refuse per year (EPA 2009).[3]

Information on the price of coal refuse is limited, but can be expected to compare favorably with "virgin" energy sources in the applications where it is used.

(3) **Trends in Generation of Coal Refuse:**
Generation of coal refuse correlates with the production and use of coal. According to the DOE's *Annual Energy Outlook 2007 with Projections to 2030*, coal production is projected to increase in coming decades, particularly in the Powder River Basin of Wyoming. From 2005 to 2030, production in the Powder River Basin is projected to grow by 289 million tons. The Rocky Mountain, Central West, and East North Central regions are projected to show the largest increases in coal demand, by about 100 million tons each, from 2005 to 2030. Increasing coal use for electricity generation at existing plants and construction of a few new coal-fired plants lead to forecasted annual production increases that average 1.1 percent per year from 2005 to 2015. The forecasted growth in coal production is stronger from 2015 to 2030, averaging 1.8 percent per year, as new coal-fired generating capacity is added and several coal-to-liquids (CTL) plants are brought on line (USDOE 2007b). Overall, the generation of coal refuse will likely increase as the demand for coal-based energy grows; however, it is unclear how this increase will affect recapturing of existing coal refuse from stockpiles.

3. Uses of Coal Refuse

(1) **Combustion Uses of Coal Refuse:**

- There are 18 coal refuse plants (Fossil fuel electric power generation - NAICS 221112), and 13 more that use it as a secondary fuel, with bituminous coal as their primary fuel. Fourteen of the 18 coal refuse plants are in Pennsylvania, three are in West Virginia, and one is in Utah. Seventeen more plants have been proposed in Pennsylvania, West Virginia, Kentucky, Indiana, Illinois, Colorado, and Virginia (Energy Justice 2007, p.1).
- According to the Anthracite Region Independent Power Producers Association (ARIPPA), from 1988 to the end of 2003, coal refuse plants in Pennsylvania used 88.5 million tons of coal refuse, mostly from "legacy" refuse piles. ARIPPA's records show that the plants in the Commonwealth burn an average of about 7.5 million tons of coal refuse per year as fuel, mostly from "legacy" coal refuse piles (PADEP 2004a, p.2).

[3] Although we report coal refuse quantities from the database in tons, the database includes material quantities expressed in terms of heating values (Btu). To express this information as a tonnage, we assumed that coal refuse has a heating value of 7,750 Btu per pound, which is the midpoint of the 6,000 to 9,500 Btu per pound range reported by the National Research Council (NRC 2006). In addition, we suspect that the combustor survey database may under count the number of sources burning coal refuse, as such sources may have simply identified their fuel source as "coal".

- The type of process used for the combustion of mining rejects is circulating fluidized bed (CFB) combustion (also known as fluidized bed combustor (FBC) boiler technology) (Energy Justice 2007, p.1). CFB is an integrated technology for reducing sulfur dioxide (SO_2) and NO_x emissions during the combustion of coal. For the CFBs currently in use in all sectors, coal is the primary fuel source, followed by biomass and coal refuse. The heat input capacities of all industrial, commercial, and institutional (ICI) CFB units generally range from 1.4 to 1,075 MMBtu/hr. (EPA 2004, p.2-7).

(2) **Non-Combustion Uses of Coal Refuse**

Granular Base: For non-combustion applications, such as use for embankment fill, coal refuse is usually cleaned before use to remove carbonaceous material that has been known to spontaneously ignite. It may also be spread in thin, compact layers between earth fill to reduce oxygen exposure and therefore reduce the possibility of ignition (TFHRC post-1994). Coarse coal refuse can be used as aggregate in granular base applications. Proper compaction of coarse coal refuse to its maximum dry density is necessary to achieve stability within a pavement structure. Fine coal refuse slurry has little or no load carrying capability and is, therefore, unsuitable for use as a construction material (TFHRC post-1994, p.1). In addition, there has been occasional use of coal refuse in Alabama, Kentucky, Virginia, and West Virginia as an alternative material for bases and sub-bases (TFHRC post-1994, pp.1-2).[4]

A reference indicating the potential volume of coal refuse employed in non-combustion uses was not identified in the course of the preparation of this paper.

- ***Mine Reclamation Projects:*** Ash leftover from combustion in a CFB boiler is alkaline and used for mine reclamation projects. The ash is often hauled back to the same gob pile site, where it can be mixed with soils impacted by acid mine drainage around abandoned mines to neutralize acidity and immobilize heavy metals. The Commonwealth of Pennsylvania has certified CFB ash for beneficial use in mining reclamation projects, and the Department of Environmental Protection regulates and routinely tests it (WPCAMR post-2001, p.2). Following combustion of gob in the CFB boiler, the solids that remain are called ash.[5]

- ***<u>Stockpile Remediation</u>***: Some environmental groups advocate for the remediation of coal refuse stockpiles where they stand instead of burning them for fuel. Research has shown that beach grass can grow in the coal piles and can rebuild organic matter. Restored organic matter allows plant cover and eventually native species to take root (Energy Justice p. 2).

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[4] The Pennsylvania Department of Transportation has rejected anthracite refuse usage as aggregate for base and subbase courses because of high percent dissolution losses in the sodium sulfate (soundness test). West Virginia is evaluating the use of coal refuse as subbase material (TFHRC, post-1994, p.2).

[5] CFB Ash can be used for other kinds of reclamation projects. For example, one project will use CFB ash injected into the partially flooded underground voids of an abandoned mine to mitigate acid mine drainage that currently breaks out on the surface (WPCAMR).

(3) **Quantities of Coal Refuse Stockpiled/Stored**[6]

Comprehensive national data concerning the volume of legacy mining rejects was not identified during the course of this review. Before 1977, most mining rejects were stockpiled and abandoned since mining companies were not legally responsible for cleaning up mining waste. This resulted in thousands of abandoned coal refuse stockpiles. Pennsylvania alone has 820 abandoned piles constituting 258 million tons of coal refuse in the state (PA DEP 2004b p. 1). According to one source, upwards of 2.4 billion tons of coal refuse had been abandoned in Pennsylvania by 1977 (ARRIPA p.1). In 1977 the Surface Mining Control and Reclamation Act (SMCRA) was passed, requiring coal companies to reclaim the sites that they mine. At that time, state and federal governments began to clean up the abandoned stockpiles using the Abandoned Mine Lands Reclamation Fund established by SMCRA and continue to do so today. Many state reclamation projects suggest sending refuse piles to CFB plants. According to ARIPPA, from 1987 to the end of 2003, coal refuse plants in Pennsylvania consumed 88.5 million tons of the material, mostly from "legacy" refuse piles. ARIPPA's records show that the plants in the Commonwealth burn an average of about 7.5 million tons of coal refuse per year, mostly from "legacy" coal refuse piles (PADEP 2004a, p.2). In fact, many of the coal refuse plants have 10 to 15 years of fuel available (WPCAMR post-2001 p. 1).

Currently, mining rejects are managed on-site by the mining company, while few are abandoned. Although CFB boilers burning coal refuse appear to primarily utilize volumes from "legacy" stockpiles, coal refuse and selective overburden material from active mines are being utilized as fuel as well (Bessett 2009). Having particularly valuable refuse makes it more likely that a current generator will send ash to a coal refuse plant. Relatively low sulfur content, high energy value, and close proximity to the plant make coal refuse more appealing for a CFB (WPCAMR post-2001 p. 1).

4. Management and Combustion Processes

(1) **Types of Combustion Units:**

The two major technologies used to burn coal are pulverized coal combustion and fluidized bed combustion. Of the approximately 600 operating coal-fired power plants in the United States, about 160 utilize fluidized bed combustion (Goswami 2007). Although both technologies can be utilized to combust either normal coal or waste coal, fluidized bed boilers are noted for their capability to burn fuels with low carbon content. This is a result of the turbulent mixing process that takes place in the fluid beds, which creates good heat and mass transfer and allows the burning to take place at lower temperatures. Therefore, fluidized bed boilers are capable of combusting fuels, such as low-carbon waste coal, that do not have a high enough heating value to support combustion at high temperatures (Woodruff 2004).

(2) **Sourcing information:**

Sources of mining rejects include coal refuse or "gob/culm piles."[7]

[6] See the CCP Materials Characterization Paper for further information on CCP landfill volumes.

(3) **Processing Information:**

Coal refuse is regulated similarly to coal as a raw material. A coal refuse handler must receive a permit under the Office of Surface Mining and Control and Reclamation Act. Coal refuse that is reclaimed for secondary use is also subject to oversight by the Mining Safety and Health Administration (Bridgeford p. 4-5).

Following necessary licensing, the general process is as follows: material is hauled from mining areas (i.e., gob and culm piles) to coal-fired power plants, crushed into pieces smaller than ¼ inch for fluidized bed boilers or fine particles for pulverized coal combustion, and then burned for energy (Woodruff 2004).

For fluidized bed boilers, crushed limestone is injected into the bottom of the combustion chamber along with the fuel, where the calcium carbonate in the limestone is converted into calcium oxide. The calcium oxide then reacts with the sulfur in the coal refuse, thereby reducing the sulfur oxide emissions. The heavier fuel and limestone particles that cannot be retained in the circulating fluidized bed drop to the bottom of the chamber. This burned fuel, known as bottom ash, is removed from the combustion chamber along with any ash captured at the top, which is known as fly ash (PADEP 2004b, Ch 1, pp. 3-4). Ash leftover from CFBs may be hauled back to the same gob/culm pile site, where it can be mixed with soils around abandoned mines to neutralize acidity and immobilize heavy metals (WPCAMR post-2001, p.2).

Due to advances in coal preparation technology over the past century, the processing of coal has evolved over time such that materials that would have been considered mine rejects in the past are now handled and processed as coal. In the early twentieth century, coal preparation involved simple size segregation into lump coal for domestic use and intermediate-sized coal for industrial use. Coal fines were considered unfit for use and were disposed of as mine rejects in coal refuse piles. Today, however, coal preparation plants are much more capable of separating coal from mineral matter through processes such as density separation and froth flotation (NRC 2007). In the past, mines discarded coal pieces smaller than 0.5 millimeters, but technological improvements have allowed the size of rejected fines to decrease to those smaller than 0.04 millimeters (Yoon 2009).

(4) **Changes in Technology to Improve Use of Coal Refuse in Combustion:**

As noted, the advent of circulated fluidized bed (CFB) combustion boilers, along with higher fuel costs, has facilitated the combustion uses of coal refuse. In addition, certain technology advancements are in use or development that may serve to further improve the application of coal refuse in combustion:

[7] Based on the sources consulted in the development of this document, brokers or traders do not appear to be involved in sourcing the waste products to the power plants. It appears the utilities/power plants are supplying themselves with the waste pile materials.

- CSIRO-Liquatech hybrid coal and gas turbine system, developed in Australia, harnesses existing technologies in a 1.2 megawatt hybrid coal and gas turbine system that burns coal refuse and methane gas to generate electricity. The turbine system burns coal and methane in a kiln, producing hot air, which is then driven through a heat exchange unit and subsequently passed over a gas turbine to produce electricity. The electricity can either be used to power a mine's operations or be returned to the grid for general consumption. (CSIRO 2002, p.1).
- Radar Acquisitions Corp. is in the process of developing an engineered solid fuel (Re-Fuel™) for utilities. The primary component of Re-Fuel™ is coal refuse (gob piles and coal slurry pond material); the secondary component is biomass (i.e., agricultural material or sawdust). The goal of the RPS Fuels™ technology is to convert these two materials into a product that looks and acts like coal, but burns more efficiently and with reduced stack emissions (Radar, p.1).

(5) **State Status of Combustion as Beneficial Use:**
There are currently three states that have power plants that burn coal refuse as fuel (Pennsylvania, West Virginia, and Utah). There are currently five additional states that are proposing to build power plants that will burn coal refuse: Kentucky, Indiana, Illinois, Colorado, and Virginia.[8]

5. Coal Refuse Composition and Impacts

(1) **Composition of Coal Refuse**
The Btu value for this material is 6,000 to 9,500 Btu per pound (NRC, 2006). Nationally, this material has an average of 60 percent of the BTU value of normal coals (Energy Justice 2007, p.1). The ash contents of coal refuse is high: according to an ARIPPA-sponsored study, twelve Pennsylvania plants using coal refuse as a key ingredient of their fuel, burned over 8 million tons/year of refuse coal and generated in the process approximately 5 million tons of ash (Earthtech 2000, Vol. 1, p. iv).

Mining rejects have a higher concentration of mercury than normal coals. In West Virginia and nationally, gob has 4 times more mercury than bituminous coal. In Pennsylvania, gob has 3.5 times more mercury than bituminous coal. Culm has 19 percent more mercury than anthracite coal. Bituminous rejects also have higher levels of sulfur. Data on other metals in the material is sparse, but single metals tests on Pennsylvania culm and gob show both to have about four times more chromium and three times more lead (Energy Justice 2007, p.1)), and the content of arsenic is relatively elevated as well (Coleman and Bragg, 1990, in Earthtech, 2000, Vol. 1, pp. 15-16).

Exhibit 1, based on a 1999 EPA Information Collection Request (ICR), compares the mercury concentrations found in normal coal to those in waste coal nationally and for seven states.

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[8] Note that this information represents the results of preliminary research; we have not performed an exhaustive investigation of state activities and regulations for all states concerning coal refuse.

Exhibit 1: Mercury Content by Coal Type and Region

State	Coal Type	Mercury (ppm)
All	Anthracite and Bituminous	0.11
	Waste Anthracite and Bituminous	0.36
	Bituminous	0.11
	Waste Bituminous	0.46
PA	Anthracite	0.16
	Waste Anthracite	0.19
	Bituminous	0.20
	Waste Bituminous	0.69
KY	Bituminous	0.09
	Waste Bituminous	0.10
IL	Bituminous	0.08
	Waste Bituminous	0.08
MD	Bituminous	0.18
	Waste Bituminous	0.34
UT	Bituminous	0.05
	Waste Bituminous	0.12
WV	Bituminous	0.11
	Waste Bituminous	0.46
Source: EPA 1999		

The composition of coal mining rejects is similar for those mined from legacy piles and those generated from current mining activities, although the size of the fines produced has decreased over the years as a result of technology improvements. However, the ash concentrations and contaminant concentrations of coal mining rejects depend largely on the type of coal and location of the mine, rather than the year in which the rejects were mined (Yoon 2009).

(2) **Impact Information**

As noted, the typical process used for the combustion of mining rejects is circulating fluidized bed (CFB) combustion (Energy Justice 2007, p.1). CFB is an integrated technology for reducing sulfur dioxide (SO_2) and NO_x emissions during the combustion of coal. In a typical CFB boiler, crushed coal and inert material (sand, silica, alumina, or ash) and/or a sorbent (limestone) are maintained in a highly turbulent suspended state by the upward flow of primary air from the windbox located directly below the combustion floor. This fluidized state provides a large amount of surface contact between the air and solid particles, which promotes uniform and efficient combustion at lower furnace temperatures than conventional coal-fired boilers. The lower combustion temperature is below the threshold at which nitrogen and oxygen form NO_x and therefore leads to reduced emissions. Once the hot gases leave the combustion chamber, they pass through the convective sections of the boiler, which are similar or identical to components used in conventional boilers.

For the CFBs currently in use in all sectors, coal is the primary fuel source, followed in descending order by biomass, coal refuse, and municipal waste. The heat input capacities of all ICI CFB units generally range from 1.4 to 1,075 MMBtu/hr (EPA 2004, pp.2-7).

Concerning impacts related to emissions from this combustion process, the Pennsylvania Department of Environmental Protection (PADEP) required the owners of a Pennsylvania bituminous coal refuse fired facility to conduct extensive air toxics emissions stack testing to support its request to burn a 10 percent mixture of coal tar contaminated soil in combination with normal coal refuse. The coal refuse facility shows lower emissions for all of the toxic pollutants compared to a typical pulverized coal combustor. The dioxin levels were approximately 4 times lower, while most metals were about half, with the exception of mercury, which was 10 times lower per gigawatt-hour generated (PADEP post-2004, p.2). Based on stack testing of two CFB combustion plants, 99.7% to 99.8% of the mercury was captured in the ash (Earthtech, 2000, Vol. 1, p. vi). According to the same source (Earthtech, 2000, Vol.1, p. 1), there are several reasons for the general low emission levels of trace metals such as As, Cd, Cr, Hg, Pb, Ni and Se in the fluidized bed combustion process. Those include the significantly lower combustion temperatures (800-950 ^{0}C) as compared to pulverized coal combustion boilers (1200-1540 ^{0}C), Lower combustion temperatures allow mercury to condense as it is exhausted and therefore is more likely captured by emissions control devices downstream (Las Brisas Energy Center p. 1). The presence of a fabric filter baghouse (FF) also decreases mercury emissions in both CFB and PC units. Units with a FF produce fly ash with both a larger surface area and larger pore volume, and therefore allows for more complete fixation of mercury and lower emissions. The relative amount of mercury emitted can also depend on the type of coal burned (Yan et al. 2008).

The culm (reject anthracite coal) combusting facilities represent the majority of the coal refuse facilities in Pennsylvania and the data submitted to the Department shows that these facilities have been achieving a NOx emissions level of 0.15 lbs/MMBtu. In comparison, a typical pulverized coal facility without add-on selective catalytic reduction (SCR) controls, which is presently the majority of pulverized units, would emit NOx in the 0.3 to 0.5 lb/MMBtu range. This continuous emissions monitoring (CEM) data also shows that some of the coal refuse facilities have been achieving an SO_2 emissions rate of 0.20 to 0.25 lbs/MMBtu range using limestone injection. The pulverized coal-fired boilers typically emit in the range of 2 to 3 lbs. of SO_2 per MMBtu. The six Pennsylvania pulverized coal-fired units with SO_2 scrubbing operate in the 0.1 to 0.4 lbs. of SO_2 per MMBtu range (PADEP post-2004, p.2).

Pennsylvania coal refuse burning facilities are lower emitters of both NOx and SOx than the typical coal-fired utilities. However, it should also be noted that an SO_2 emission rate of 0.1 lbs/MMBtu is achievable for a newly built pulverized coal-fired unit that would be required to install an SO_2 scrubber under an SO_2 Best Available Control Technology (BACT) determination. Therefore, newly constructed electric generating combustors of either coal refuse or coal would emit at very comparable levels, because both would be employing very similar BACT for all pollutants. (PADEP post-2004, p.2).

Impacts related to the use of coal refuse are discussed qualitatively below. Note that a further discussion of the uses of coal combustion products (CCPs) as ingredients is provided in the CCP Materials Characterization Paper.

- ***Other Impacts Related to Mining Rejects:***
  The potential benefits of returning suitable FBC ash to abandoned or active mine lands for use in reclamation include:
  - The alkaline nature and encapsulating ability of the material make it useful for some mine reclamation applications. In particular, reclaiming coal refuse piles without the benefit of adding FBC ash does less to address the often-severe water quality problems that emanate from some of the piles.
  - The reclamation of abandoned mine land (AML) with FBC ash is often privately funded, freeing up state and federal government AML resources for other applications.
  - The ash from FBC plants has chemical and physical properties that limit the potential for the ash itself to become a source of environmental contamination (Earthtech, 2000, Vol 1, pp. v-vi; PADEP 2004b, Ch. 1, pp.6-7).
  - Reclaiming AML with ash serves to eliminate the safety hazard of abandoned mine highwalls and cropfalls.

  In addition, as indicated in public comments submitted to EPA in response to the ANPRM, the use of coal refuse as a fuel results in environmental benefits associated with (1) reducing abandoned mining waste piles, which threaten groundwater and air quality (through windblown fugitive emissions), and (2) reclaiming abandoned mine sites, thereby returning lands to productive use (Bessette 2009).

- ***Additional Avoided Impacts:***
  Exhibit 2 summarizes the air emissions associated with the combustion of coal refuse and the corresponding emissions from the combustion of coal. The exhibit also presents the cradle-to-gate emissions that may be avoided by using coal refuse as a substitute for coal. These cradle-to-gate environmental benefits may be offset by the environmental impacts associated with extracting coal refuse from coal refuse piles and processing this material, but data are not readily available on these impacts. Note that there may be alternative uses (e.g., aggregate, mine reclamation) that are environmentally preferable to combustion.

  Furthermore, use of coal refuse as a fuel serves the important benefit of removing the piles of gob and culm. The piles can be a fire hazard and a source of surface and ground-water pollution.

Exhibit 2: Emissions from Combustion of Coal Refuse and Extraction and Combustion of Traditional Coal

Pollutant	Coal Refuse	Coal	
	Combustion	Combustion	Combustion plus Upstream
	---------- *Lb./MMBtu* ----------		
Criteria Pollutants			
PM2.5	-	-	-
PM10	-	0.054	0.054
PM, unspecified	-	-	0.246
NOx	0.15	0.482	0.504
VOCs	-	0.006	0.014
SOx	0.20 - 0.25	1.446	1.469
CO	-	0.068	0.085
Pb	-	$8.93x10^{-6}$	$9.19x10^{-6}$
Hg	-	$2.05x10^{-6}$	$2.14x10^{-6}$
Greenhouse Gases			
CO_2	-	210.7	214.7
CH_4	-	0.007	0.458
N_2O	-	0.003	0.003
$MTCO_2E$/MMBtu	**-**	**0.096**	**0.102**

Sources:
PADEP post-2004, p.2; Franklin Associates 1998.
Note:
"-" signifies data not available; may equal zero.

The emission information presented in this table is derived from Life Cycle Inventory (LCI) data, as compiled by Franklin Associates. LCI data identifies and quantifies resource inputs, energy requirements, and releases to the air, water, and land for each step in the manufacture of a product or process, from the extraction of the raw materials to ultimate disposal. The LCI can be used to identify those system components or life cycle steps that are the main contributors to environmental burdens such as energy use, solid waste, and atmospheric and waterborne emissions. Uncertainty in an LCI is due to the cumulative effects of input uncertainties and data variability.

There are several life cycle inventory databases available in the U.S. and Europe. For this paper, we applied the most readily available LCI database that was most consistent with the materials and uses examined. These LCI data rely on system boundaries as defined by Franklin Associates, as described in the documentation for this database, available at: http://www.pre.nl/download/manuals/DatabaseManualFranklinUS98.pdf.

References

Anthracite Region Independent Power Producers Association (ARIPPA), "Coal Refuse," fact sheet, undated, accessed on August 21, 2008, at: http://www.arippa.org/coalrefuse.asp.

Bessette, Robert D., Public comment in response to EPA's Advanced Notice of Proposed Rulemaking for the Identification of Non-Hazardous Materials That Are Solid Waste, EPA docket EPA-HQ-RCRA-2008-0329, submitted on behalf of the Council of Industrial Boiler Owners (CIBO).

Bridgeford, Tawny A., Public comment in response to EPA's Advanced Notice of Proposed Rulemaking for the Identification of Non-Hazardous Materials That Are Solid Waste, EPA docket EPA-HQ-RCRA-2008-0329, submitted on behalf of the National Mining Association (NMA).

Coleman, SL and Bragg, LJ, 1990, "Distribution and mode of Occurrence of Arsenic in Coal"; In Recent Advances in Coal Geochemistry, ed. by LL Chyi and CL Chou, Geologic Society America Special Paper 248, pp. 13-26.

CSIRO Australia, "New System Uses Mine Waste to Generate Clean Power," Science Daily, August 12, 2002, accessed on August 20, 2008, at: http://www.sciencedaily.com/releases/2002/08/020812070617.htm.

Earthtech, Inc., "Occurrence and Fate of Selected Trace Elements in Circulating Fluidized Bed Combustion Byproducts" Volumes 1 and 2, September 19, 2000.

Electric Power Research Institute and Utility Solid Waste Activities Group, "Mill Rejects Characteristics and Management Options for Coal-Fired Power Plants," prepared by Tetra Tech, Inc., Ish Inc., and Energy and Environmental Research Corporation, November 1998.

Energy Justice.net. "Waste Coal" fact sheet, November 2007, accessed August 18, 2008 at: http://www.energyjustice.net/coal/wastecoal/factsheet.pdf.

Franklin Associates, "Franklin U.S. LCI 98 Library" 1998.

The Financial Express, "Coal Rejects Can Generate 7,000 MW Power by 2016," December 27, 2006, accessed August 19, 2008, at: http://www.financialexpress.com/printer/news/187901.

Goswami, D Yogi, and Kreith, Frank. 2007. Energy Conversion. Available at: http://books.google.com/books?id=qBB00M5pe84C&pg=PT211&lpg=PT211&dq=list+of+fluidized+bed+plants&source=bl&ots=w8Ukae6_NI&sig=zP2cLTxWSzcnNxvE7nq31URyCjk&hl=en&ei=uHsNSvGIAsjktgfM-JGcCA&sa=X&oi=book_result&ct=result&resnum=7

Las Brisas Energy Center, LLC. "Mercury Emissions," Undated, accessed on July 15, 2009 at: http://www.lasbrisasenergy.com/pdfs/Mercurywhitepaper.pdf.

National Research Council of the National Academies (NRC), "Managing Coal Combustion Residues in Mines," 2006, accessed on August 19, 2008 at: http://books.nap.edu/catalog.php?record_id=11592#description.

National Research Council of the National Academies (NRC), "Coal Research and Development," 2007, accessed on May 14, 2008 at: http://www.nap.edu/catalog.php?record_id=11977

Neufeld, Ronald D., Undated, "Coal Refuse to Energy," accessed on July 13, 2009 at: http://www.p2pays.org/ref/14/13880.pdf.

Pennsylvania Department of Environmental Protection (PADEP). Kathleen A. McGinty, Secretary, Testimony on Waste Coal Incentives to the Senate Environmental Resources and Energy Committee, September 8, 2004a, accessed on August 19, 2008 at: http://www.depweb.state.pa.us/dep/cwp/view.asp?a=3&q=474575.

Pennsylvania Department of Environmental Protection (PADEP). "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania," 2004b, accessed on August 19, 2008, at http://www.dep.state.pa.us/dep/deputate/minres/bmr/beneficial_use/Index.htm

Pennsylvania Department of Environmental Protection (PADEP). "Analysis of Emissions from Waste Coal-Fired Combustion Units in Pennsylvania," post-2004, accessed on August 20, 2008, at http://www.dep.state.pa.us/dep/DEPUTATE/AIRWASTE/AQ/emission/docs/emissions_analysis.pdf

Radar Acquisitions Corp., http://www.radar.ab.ca/s/Home.asp.

Turner-Fairbank Highway Research Center (TFHRC). post-1994, accessed August 18, 2008, at: http://www.tfhrc.gov/hnr20/recycle/waste/mwst3.htm and http://www.tfhrc.gov/hnr20/recycle/waste/mwst1.htm.

United States Department of Energy, Energy Information Administration (EIA). 2007a, accessed on August 21, 2008 at: http://www.eia.doe.gov/cneaf/coal/page/special/feature.html.

United States Department of Energy, Energy Information Administration (EIA). 2007b, "Annual Energy Outlook 2007 with Projections to 2030," Publication DOE/EIA-0383 (2007), February 2007.

United States Environmental Protection Agency (EPA). 2004, Economic Impact Analysis of the Industrial Boilers and Process Heaters NESHAP. EPA-452/R-04-001, February 2004.

United States Environmental Protection Agency (EPA). 2008, Email from Mike Galbraith, to Cynthia Manson, IEc, regarding a definition of coal mill rejects, August 15, 2008.

United States Environmental Protection Agency (EPA). 2009, Combustor survey database in support of the 2009 proposal of the Commercial and Industrial Solid Waste Incinerator (CISWI) standards and the Industrial Boilers Maximum Achievable Control Technology (MACT) standards, April 2009.

United States Environmental Protection Agency (EPA). 2002, Control of Mercury Emissions from Coal-Fired Electric Utility Boilers: Interim Report. EPA-600/R-01-109, April 2002.

United States Environmental Protection Agency (EPA). 1999, Information Collection Request for Electric Utility Steam Generating Unit Mercury Emissions Information Collection Effort. Summary table available at: http://www.energyjustice.net/coal/wastecoal/epa-icrdata.html

Virginia Cooperative Extension (VCE), "Reclamation of Coal Refuse Disposal Areas," Powell River Project, Reclamation Guidelines for Surface-Mined Land in Southwest Virginia, Virginia Cooperative Extension, publication #460-131, June 1996, accessed on August 21, 2008 at: http://www.ext.vt.edu/pubs/mines/460-131/460-131.html.

Western Pennsylvania Coalition for Abandoned Mine Reclamation (WPCAMR), "Burning Waste Coal in CFB Power Plants," Fact Sheet, post-2001, accessed on August 18, 2008 at: http://www.amrclearinghouse.org/Sub/landreclamation/cfb/wpcamr-cfbpower.htm

Western Pennsylvania Coalition for Abandoned Mine Reclamation (WPCAMR), "Coal Refuse Burning Power Plants," power point presentation, undated, accessed on August 19, 2008 at: http://www.amrclearinghouse.org/Sub/landreclamation/cfb/CoalRefuseBurningPowerPlants.pdf

Woodruff, Everett, Lammers, Herbert, and Lammers, Thomas. Steam Plant Operation, 8th Edition. 2004. Available at: http://books.google.com/books?id=TgsenZD5VwUC&pg=PA102&lpg=PA102&dq=pulverized+coal+combustion,+fluidized+bed+boiler+comparison&source=bl&ots=dSTb85muUS&sig=wohcvVcn6wU1IOGCRViCs44rK6M&hl=en&ei=X3oMSpqiE5Dg8wTHn_3PDw&sa=X&oi=book_result&ct=result&resnum=10#PPA101,M1

Yan, Cao, Cheng, Chin-Min, Chen, Chien-Wei, Liu, Mingchong, Wang, Chiawei, and Wei-Ping Pan. Institute for Combustion Science and Environmental Technology (ICSET), "Abatement of mercury emissions in the coal combustion process equipped with a Fabric Filter Baghouse," May 2008, accessed on July 15, 2009 at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V3B-4SRD21V-1&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=958439288&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=a579f8b95e93c33173e52b8d5f71f792.

Yoon, Roe-Hoan. Center for Advanced Separation Technologies (CAST), personal communication, 5/29/09.