NATIONAL SYNTHESIS REPORT ON REGULATIONS, STANDARDS, AND PRACTICES RELATED TO THE USE OF COAL COMBUSTION PRODUCTS

Final Report

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DISCLAIMER

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NOMENCLATURE

AC	activated carbon
ACAA	American Coal Ash Association
ACI	activated carbon injection
AFBC	atmospheric fluidized-bed combustors
ASR	alkali silica reactivity
ASTM	ASTM International
C^2P^2	Coal Combustion Products Partnership
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
$CaSO_3$	calcium sulfite
$CaSO_4$	calcium sulfate
CCB	coal combustion by-products
CCP	coal combustion products
CH_4	methane
CFB	circulating fluidized bed
CO	carbon monoxide
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
EPGA	Electric Power Generation Association
ESP	electrostatic precipitators
FBC	fluidized-bed combustion
FCG	Florida Electric Power Coordinating Group, Inc.
FDEP	Florida Department of Environmental Protection
FGD	flue gas desulfurization
FLDOT	Florida Department of Transportation
GLO	General Land Office
H_2	hydrogen gas
HB	House Bill
IGCC	integrated gasification combined-cycle
LOI	loss-on-ignition
NETL	National Energy Technology Laboratory
NO_x	nitrogen oxide
NRM	nonhazardous recyclable materials
OSM	Office of Surface Mining
PADOT	Pennsylvania Department of Transportation
PC	pulverized coal
RCRA	Resource Conservation and Recovery Act
RMDB	Recycling Market Development Board
SB	Senate Bill
SCR	selective catalytic reduction
SNCR	selective noncatalytic reduction
SO_2	sulfur dioxide
TAC	Texas Administrative Code
TCAUG	Texas Coal Ash Utilization Group
TNRCC	Texas Natural Resources Conservation Commission
TXDOT	Texas Department of Transportation

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EXECUTIVE SUMMARY

To better understand the status and development of different coal combustion product (CCP) utilization profiles across the United States, the University of North Dakota Energy & Environmental Research Center conducted a series of state reviews. For each state, an in-depth review of CCP management was performed in an effort to showcase keys to successful utilization, describe existing barriers, recommend actions that can be taken to overcome those barriers, and identify threats that could impact future CCP utilization. Each effort included a review of state regulations, standards, and practices related to the use of CCPs. Individual state reviews were conducted in Texas, Florida, and Pennsylvania. The final reports from the series of state reviews can be accessed online at www.undeerc.org/carrc/html/review.html.

Each state review followed the same methodology which was very effective for conducting a multiday site visit in a central location within the state reviewed. Panels of key stakeholders were assembled and interviewed during the course of each site visit. Information provided during the interviews was compiled and summarized in individual state reports. This synthesis report is a completion of the series of individual state reviews and was prepared to translate the results from the three in-depth state reviews into a national perspective. The preparation of this synthesis report was funded by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) National Energy Technology Laboratory. Additional individual reviews may take place in other states.

Each state had a different regulatory framework, political climate, infrastructure, economy, coal source, and geographic location. These characteristics contributed to differences in CCP production and use among the states reviewed. Despite these unique characteristics, several commonalities were identified and used to translate individual state review observations to a national perspective. The following is a brief summary of observations:

- Organized industry-led groups can be effective in working with government agencies and state legislators because each one represents a unified voice on behalf of its members and allows industry to pool its collective knowledge base and monetary resources to address key issues.

- State Department’s of Transportation (DOTs) often look to the American Association of State Highway and Transportation Officials and ASTM International for guidance on developing their own specifications. State DOT specifications typically set the bar for other CCP users in the state because the road-building industry generally views state DOT specifications as cautious and stringent, thus lessening the potential for failure and subsequent liability. Contractors are also familiar with DOT specifications, enhancing their acceptance and use in the construction industry. For these reasons, it is imperative that DOT specifications are noted because they set the tone for how CCPs are used across the state in road building and other applications.

- To comply with new federal and state air emission regulations, it is anticipated that the nation's coal-based power plants will employ a variety of technologies. Significant changes in the chemical composition, physical properties, and morphology of CCPs may occur as a result of the application of new emission control technologies. Universal concerns brought forth during the state reviews, either directly or indirectly, related to the impact these air emission regulations will have on CCP management are described.

- The National Academy of Sciences report entitled *Managing Coal Combustion Residues in Mines*[*] concluded that using CCPs for mine reclamation is a viable option, as long as precautions are taken to protect the environment and public health. Mine placement was not discussed at the Texas and Florida reviews, but those interviewed during the Pennsylvania state review generally agreed with this conclusion; however, they felt that the report was "middle of the road" and was a missed opportunity to showcase the benefits of using CCPs in mines.

- Several communication and perception barriers were discussed during the state reviews. These types of nontechnical barriers were found among the general public, end users, and within government agencies and electric generating companies.

- Different methods that could be taken to increase CCP utilization were discussed at the individual state reviews and included the need for state beneficial use policies, importance of state-led industry by-product recycling initiatives, promotion and acceptance of green building programs, CO_2 credits, and the exemption of Toxic Release Inventory reporting for beneficial use.

- Economics are a key factor in the beneficial use of CCPs. In most cases of beneficial use observed during the state review process, economics were the primary reason why CCPs were selected over virgin materials. Engineering performance was also considered, but the environmental benefits for using the material were rarely considered a reason to use CCPs.

[*] National Academy of Sciences. *Managing Coal Combustion Residues in Mines*; The National Academies Press: Washington, D.C., 2006.

NATIONAL SYNTHESIS REPORT ON REGULATIONS, STANDARDS, AND PRACTICES RELATED TO THE USE OF COAL COMBUSTION PRODUCTS

PURPOSE OF THIS REPORT

Over 49 million tons of coal combustion products (CCPs) are beneficially used in the United States each year, but over 73 million tons, or 59%, are still being disposed of in landfills or surface impoundments.[1] The U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) set goals to increase CCP utilization to 50% by 2011. As 2011 draws near, this goal appears to be more difficult to attain, particularly as new air emission regulations are implemented, resulting in larger quantities and changing qualities of CCPs produced. Given these challenges, both agencies are committed to reaching their utilization goals and are conducting research studies and working together to create and support programs that encourage CCP use. Such programs include the Coal Combustion Products Partnership (C^2P^2), Recycled Materials Research Center, Green Highways Partnership, Combustion Byproducts Recycling Consortium and U.S. Green Building Council Leadership in Energy and Environmental Design (LEED®) program. Other programs such as the newly formed Industrial Resources Council join industry associations together (CCPs, foundry sand, slags, pulp and paper products, construction and demolition debris, and rubber) to achieve similar goals.

Many of the technical barriers associated with CCP utilization have been addressed, but social and knowledge barriers still exist. One of the key nontechnical barriers is the broad range of state laws, regulations, policies, and guidelines regarding the use of CCPs.[2–4] Some states have worked to develop progressive and effective guidance for CCP utilization that encourages CCP utilization while being protective of the environment. However, some states still lack the resources and information to feel comfortable with the environmental appropriateness of using CCPs in certain applications, particularly nonconcrete applications. In addition, changing state laws, regulations, policies, and guidelines can be a lengthy process, taking a number of years to come to fruition, which often frustrates CCP industry stakeholders.

To better understand the status and development of different CCP utilization profiles across the United States, the University of North Dakota Energy & Environmental Research Center (EERC) conducted a series of state reviews. For each state, an in-depth review of CCP management was performed in an effort to showcase keys to successful utilization, describe existing barriers, recommend actions that can be taken to overcome those barriers, and identify threats that could impact future CCP utilization. Each effort included a review of state regulations, standards, and practices related to the use of CCPs. For the first pilot state, the effort was achieved with funds from EPA and Headwaters Resources, LLC. Texas was selected as the pilot state because of its progressive approach to CCP utilization. Additional funding was awarded by EPA and DOE National Energy Technology Laboratory (NETL) to conduct a second state review. Florida was selected as the second state to review, primarily because it was undergoing changes to its CCP regulations. The EERC subsequently received funding from EPA, DOE NETL, and the American Coal Ash Association (ACAA) to perform a review in a third state that exhibited a different CCP use scenario and geographic area than the previous two states. Pennsylvania was ultimately chosen as the third state. The final reports from the series of state reviews can be accessed online at www.undeerc.org/carrc/html/review.html.

Following the completion of the series of individual state reviews, this synthesis report was prepared to translate the results from the three in-depth state reviews into a national perspective on the status of CCP regulations, standards, and practices. The preparation of this synthesis report is funded by EPA and DOE NETL. Additional individual reviews may take place in other states.

BACKGROUND

U.S. Coal Production and Consumption

According to preliminary data from the Energy Information Administration (EIA), U.S. coal production reached a record level of 1161 million short tons in 2006.[5] Total U.S. coal production and number of mines by states are shown in Table 1. The table shows that in 2005, the United States produced 571,177 thousand short tons of bituminous, 474,675 thousand short tons of subbituminous, 83,942 thousand short tons of lignite, and 1704 thousand short tons of anthracite coal.[6] Although U.S. coal production rose in 2006, not all of the coal-producing regions shared in the increase. Exclusive of refuse production, the interior and western regions had an increase in their production levels in 2006 of 1.5 percent and 5.9 percent, respectively, while Appalachian coal production declined by 1.7%.[5] Similar trends in coal production are expected to continue. The Annual Energy Outlook 2007 predicts that in 2030, almost 68% of domestic coal production will originate from states west of the Mississippi—particularly in states close to the Powder River Basin supply region.[7]

In 2006, the U.S. electric power sector (defined by EIA as electric utilities and independent power producers) consumed 1026 million short tons of coal,[8] and coal consumption is expected to increase to more than 1772 million short tons in 2030, with significant additions of new coal-based generation capacity.[7] Recent EIA service reports have shown that steps to reduce greenhouse gas emissions through the use of an economy-wide emissions tax or cap-and-trade system could have a significant impact on coal use.[7] As illustrated in Figure 1, coal is predicted to remain the leading energy source in the United States. Additions to coal-based generating capacity in the Annual Energy Outlook 2007 reference case are projected to total 156 gigawatts from 2005 to 2030, including 11 gigawatts at coal-to-liquids plants and 67 gigawatts at integrated gasification combined-cycle (IGCC) plants.[7] The National Coal Council stated that of the 135 new proposed coal-based power plants, more than 110 are pulverized coal or circulating fluidized-bed (CFB) technology and 19 are IGCC.[9]

Description of Coal-Based Power Plants

There are three primary types of coal-based power plants employed by U.S. electric generating companies today: 1) conventional combustion, 2) fluidized-bed combustion, and 3) gasification. Below is a description of each of the technologies and the resulting by-products.

Table 1. Coal Production and Number of Mines by State[6, a,b]

Coal-Producing	Bituminous		Subbituminous		Lignite		Anthracite		Total	
State and Region[c]	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production
Alabama	53	21,339	-	-	-	-	-	-	53	21,339
Alaska	-	-	1	1454	-	-	-	-	1	1454
Arizona	2	12,072	-	-	-	-	-	-	2	12,072
Arkansas	1	3	-	-	-	-	-	-	1	3
Colorado	10	30,006	3	8504	-	-	-	-	13	38,510
Illinois	20	32,014	-	-	-	-	-	-	20	32,014
Indiana	29	34,457	-	-	-	-	-	-	29	34,457
Kansas	1	171	-	-	-	-	-	-	1	171
Kentucky Total	432	119,734	-	-	-	-	-	-	432	119,734
Eastern	404	93,322	-	-	-	-	-	-	404	93,322
Western	28	26,412	-	-	-	-	-	-	28	26,412
Louisiana	-	-	-	-	2	4161	-	-	2	4161
Maryland	16	5183	-	-	-	-	-	-	16	5183
Mississippi	-	-	-	-	1	3555	-	-	1	3555
Missouri	2	598	-	-	-	-	-	-	2	598
Montana	-	-	5	40,024	1	330	-	-	6	40,354
New Mexico[d]	2	13,409	2	15,110	-	-	-	-	4	28,519
North Dakota	-	-	-	-	4	29,956	-	-	4	29,956
Ohio	54	24,718	-	-	-	-	-	-	54	24,718
Oklahoma	9	1856	-	-	-	-	-	-	9	1856
Pennsylvania Total	198	65,849	-	-	-	-	68	1645	266	67,494
Anthracite	-	-	-	-	-	-	68	1645	68	1645
Bituminous	198	65,849	-	-	-	-	-	-	198	65,849
Tennessee	28	3217	-	-	-	-	-	-	28	3217
Texas	-	-	-	-	13	45,939	-	-	13	45,939

[a] Totals may not equal sum of components because of independent rounding.

continued…

b Energy Information Administration Form EIA-7A, "Coal Production Report," and U.S. Department of Labor, Mine Safety and Health Administration, Form 7000-2, "Quarterly Mine Employment and Coal Production Report."

[c] For a definition of coal-producing regions, see Glossary.

[d] One mine in New Mexico periodically produces both bituminous and subbituminous coal. When this occurs, it is double-counted as a subbituminous and bituminous mine but is not double-counted in the total.

Table 1. Coal Production and Number of Mines by State[6, a,b] (continued)

Coal-Producing	Bituminous		Subbituminous		Lignite		Anthracite		Total	
State and Region[c]	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production
Utah	13	24,521	-	-	-	-	-	-	13	24,521
Virginia	132	27,743	-	-	-	-	-	-	132	27,743
Washington	-	-	1	5266	-	-	-	-	1	5266
West Virginia Total	277	153,650	-	-	-	-	-	-	277	153,650
Northern	50	42,628	-	-	-	-	-	-	50	42,628
Southern	227	111,022	-	-	-	-	-	-	227	111,022
Wyoming	-	-	18	404,319	-	-	-	-	18	404,319
Appalachian Total	1162	395,022	-	-	-	-	68	1645	1230	396,666
Northern	318	138,379	-	-	-	-	68	1645	386	140,023
Central	790	235,297	-	-	-	-	-	-	790	235,297
Southern	54	21,347	-	-	-	-	-	-	54	21,347
Interior Total	90	95,510	-	-	16	53,655	-	-	106	149,165
Illinois Basin	77	92,883	-	-	-	-	-	-	77	92,883
Western Total	27	80,008	30	474,675	5	30,287	-	-	62	584,970
Powder River Basin	-	-	16	429,996	-	-	-	-	16	429,996
Uinta Region	21	53,641	3	8504	-	-	-	-	24	62,145
East of Miss. River	1239	487,905	-	-	1	3555	68	1645	1308	493,105
West of Miss. River	40	82,635	30	474,675	20	80,386	-	-	90	637,697
U.S. Subtotal	1279	570,540	30	474,675	21	83,942	68	1645	1398	1,130,802
Refuse Recovery	14	637	-	-	-	-	3	59	17	696
U.S. Total	1293	571,177	30	474,675	21	83,942	71	1704	1415	1,131,498

[a] Totals may not equal sum of components because of independent rounding.

b Energy Information Administration Form EIA-7A, "Coal Production Report," and U.S. Department of Labor, Mine Safety and Health Administration, Form 7000-2, "Quarterly Mine Employment and Coal Production Report."

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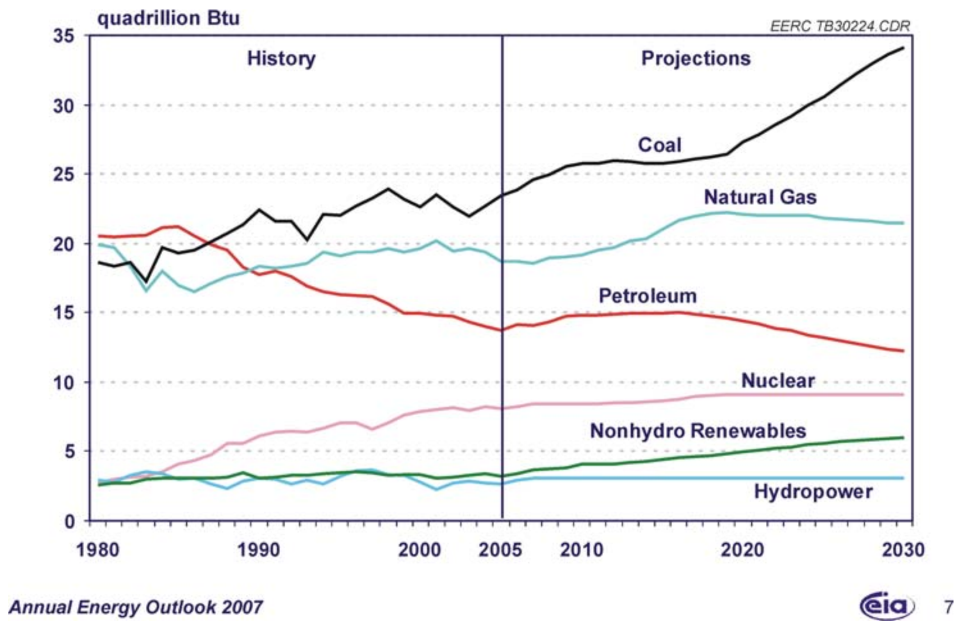

Figure 1. Energy production by fuel, 1980–2030.[7]

Conventional Combustion Systems

The most common utility combustion systems in place in the United States today are pulverized coal (pc) combustion, cyclone firing, and stoker firing, with pc-fired units outnumbering the cyclone and stoker units.[3] Figure 2 shows a simple schematic diagram for a typical pc combustion system. In this type of system, the coal is prepared by grinding to a very fine consistency for combustion. Typically, 70% of the coal is ground to pass through a 200-mesh per unit screen. There are several configurations for commonly used pc furnaces, which can impact ash formation, but the primary advantage of pc combustion is the very fine nature of the fly ash produced. In general, pc combustion results in approximately 65%–85% fly ash, and the remainder in coarser bottom ash (dry-bottom boiler) or boiler slag (wet-bottom boiler). Cyclone combustion uses coarsely pulverized coal (95% −¼ in.) and produces much higher percentages of bottom ash (up to 75%–90%, depending on coal type) and smaller amounts of fly ash. Stoker-fired units do not require the same level of coal grinding (e.g., −¾ in.) because the coal generally stays in the hot zone for an extended period of time, allowing complete combustion of larger coal particles.[3]

Electric generating companies use a variety of technologies to control air emissions, namely, particulate matter, SO_2, and NO_x. Technologies to control mercury and other air toxic elements as well as CO_2 emissions are also being investigated. Emission control technologies impact the quantity and quality of the CCPs produced. In addition, the use of multiple air emission technologies can impact the effect on emissions and by-products.

Particulate collectors are installed on 79% of all fossil-fueled steam-electric generators over 10 MW.[10] Particulate collectors are typically either electrostatic precipitators (ESPs) or

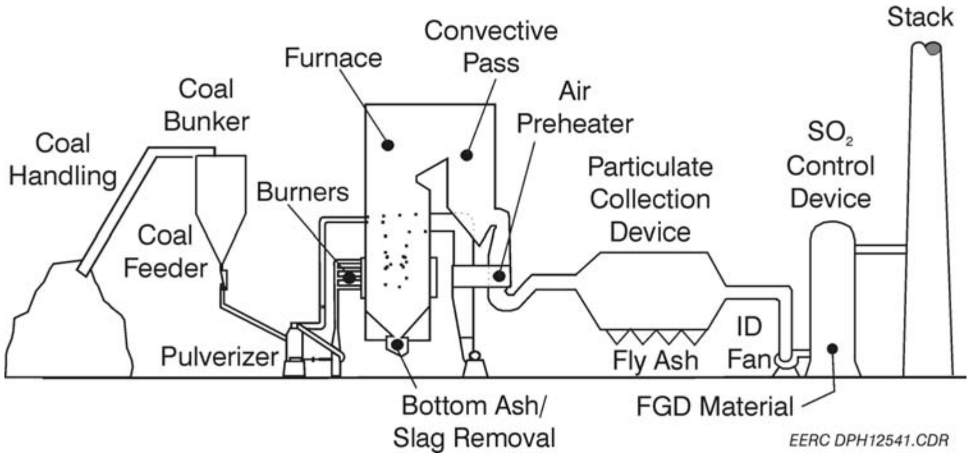

Figure 2. Typical pc combustion system.

baghouses/fabric filters, whose primary function is to collect fly ash, resulting in larger quantities of fly ash collected.

U.S. electric generating companies generally employ one of two strategies to control SO_2 in the flue gas stream: 1) use of compliance fuel (achieved by burning a low sulfur coal, coal blending or washing) or 2) install flue gas desulfurization (FGD) systems. FGD systems can be classified as either wet or dry, and both produce a by-product generically referred to as FGD material. As of 2005, 16% of fossil-fueled steam-electric generators over 10 MW had FGD systems installed.[10] In the United States, approximately 85% of FGD systems on coal-based power plants are wet, 12% are spray dryer absorber (SDA) systems, and 3% are dry injection systems.[11]

Control of NO_x emissions is complicated since these emissions are related both to the nitrogen content of the fuel and to the formation of various NO_x species during the combustion process. NO_x controls include combustion modifications such as use of overfire air or low-NO_x burners. Selective noncatalytic reduction (SNCR) and selective catalytic reduction (SCR) are used as postcombustion NO_x control.[3] As a result of the installation of these technologies, NO_x emissions decreased 51% from 1994 to 2005 at conventional and combined-heat-and-power plants.[10] However, these technologies have had a negative impact on the quality of fly ash produced, resulting in fly ashes with higher concentrations of unburned carbon.

Fluidized-Bed Combustion

Fluidized-bed combustion (FBC) systems use a heated bed of sandlike material suspended (fluidized) within a rising column of air to burn many types and classes of fuel. The result is a turbulent mixing of gas and solids, which provides effective chemical reactions and heat transfer. The technology burns fuel at temperatures of 1400°–1700°F, well below the temperature where NO_x forms (at approximately 2500°F).[5]

FBC systems fit into two major groups: atmospheric fluidized-bed combustors (AFBCs) and pressurized fluidized-bed combustors (PFBCs) and two minor subgroups, bubbling or circulating fluidized bed (CFB). These systems are described below:

- AFBCs use a sorbent such as limestone or dolomite to capture sulfur. Jets of air suspend the mixture of sorbent and fuel during combustion, converting the mixture into a suspension of red-hot particles that flow like a fluid. These systems operate at atmospheric pressure.[5]

- PFBCs also use a sorbent and jets of air to suspend the mixture of sorbent and fuel but operate at elevated pressures and produce a high-pressure gas that can drive a gas turbine. The compressed air used contains more oxygen per unit volume and, therefore, sustains a higher intensity of combustion, allowing for the design of smaller combustors.[5]

- CFB combustors use higher air flows to entrain and move the bed material, recirculating nearly all of the bed material with adjacent high-volume, hot cyclone separators. The relatively clean flue gas goes on to the heat exchanger. This approach simplifies feed design, extends the contact between sorbent and flue gas, reduces the likelihood of heat exchanger tube erosion, and improves SO_2 capture and combustion efficiency.[5]

The solids in FBCs are typically fuel ash, bed material, sorbent used to control pollutants, and reaction products formed by sulfur capture and other sorbent–fuel interactions. The characteristics of the solid by-products produced in FBCs depend on the bed material, fuel and ash compositions, unburned carbon, desulfurization by-products, and unreacted sorbents. The by-products can be collected from several locations in the system, including the bed offtake, primary cyclone, and final particulate control device. In most cases in the United States, the by-products are combined. High-calcium materials used for sulfur capture (i.e., limestone or dolomite) produce by-products containing high levels of calcium sulfate, free lime, and coal ash, which reflects the chemical characteristics of the sorbent and coal used. FBC systems operate at low temperatures which prevents significant fusion and melting of the ash particles, resulting in fly ash particles that are angular and very different from the spherical-fused ash particles produced in pc firing.[3]

Gasification

In the gasification process, carbon-based feedstocks (e.g., coal, biomass, petcoke, oil residual) are converted in the gasifier—in the presence of steam and air or oxygen at high temperatures and moderate pressure—to synthesis gas, commonly referred to as "syngas." Syngas is comprised primarily of carbon monoxide (CO) and hydrogen gas (H_2); however, depending on the gasification technology employed, significant quantities of water, CO_2, and methane (CH_4) can be present in the synthesis gas as well as several minor and trace components. These contaminants are cleaned using chemical and physical solvents. Once the synthesis gas is cleaned, various options exist for its utilization including production of electricity via IGCC or the production of chemicals, H_2, and reformable liquid fuels.[12]

In the IGCC process, the clean synthesis gas is sent to a combustion turbine, where it is combusted to produce electricity. The energy contained in the exhaust gas from the gas turbine is recovered in a heat-recovery steam generator for the production of additional electricity in a steam turbine. Approximately two-thirds of the total electricity produced in the IGCC plant is produced by the gas turbine.[12]

Commercial gasifiers differ widely in the way in which they produce by-products, and either a dry ash, an agglomerated ash, char, or slag may result. Sulfur removed from the syngas at IGCC plants will range in purity from 98.5% to 99.99%.[13] Sulfur can be captured as either elemental sulfur or sulfuric acid. Characteristics of gasification by-products are described in a previous EERC report available online at www.undeerc.org/carrc/Assets/IGCCandPFBC.pdf.[14]

CCP Terminology, Properties, Production, and Use in the United States

The combustion of coal to generate electricity results in the formation of a variety of solid materials, collectively referred to as CCPs. CCPs include any by-product from the combustion of coal and are primarily considered to be fly ash, bottom ash, boiler slag, and FGD material. FBC and IGCC plants also produce by-products and are considered to be CCPs. The term CCPs is used in this report to generically refer to coal ash as a whole; however, there are several other terms used to describe coal ash such as coal combustion by-products (CCBs), coal combustion wastes, coal utilization by-products, coal combustion residues, and fossil fuel combustion wastes.

As noted in Figure 3, the production and use of CCPs has grown steadily since ACAA began tracking statistics in 1966. In 2005, ACAA reported that 123.1 million short tons of CCPs were produced. Of that, 40.29% was beneficially used, and the remainder was disposed of in landfills or surface impoundments.[1]

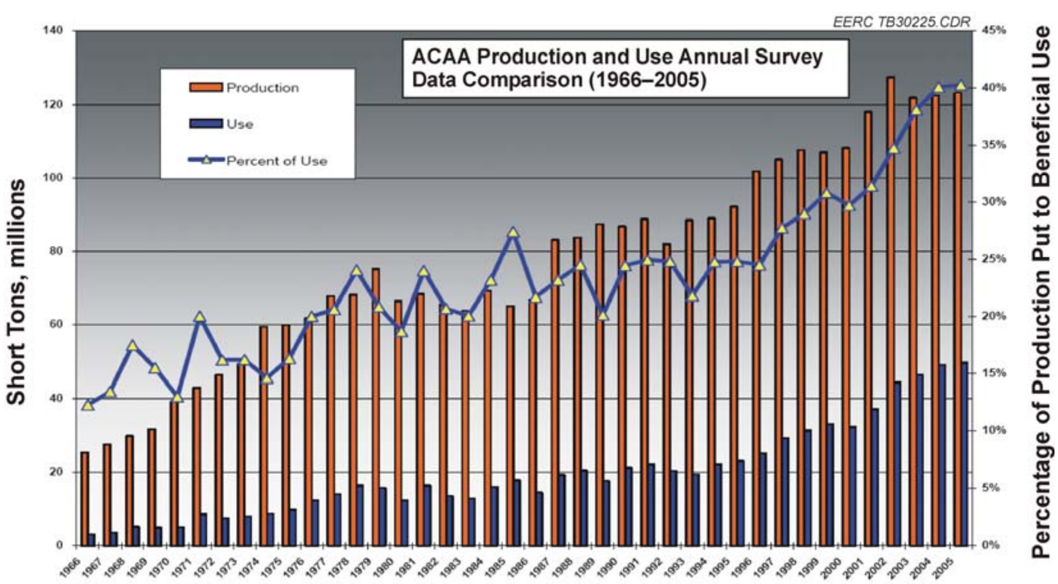

Figure 3. ACAA production and use annual survey data comparison (1966–2005).[1]

Fly Ash

Fly ash is the inorganic portion of finely pulverized coal that is carried out of the boiler with the flue gases and collected by an ESP or a fabric filter (baghouse). Depending on the efficiency of the particulate control device, a small portion of the smallest size fraction of the fly ash may exit the stack. Fly ash has the consistency of fine powder and varies in color from tan to dark gray. The chemical composition of fly ash depends primarily on the chemical properties of the coal burned but also on emission control equipment used. The coal grinding equipment, furnace, and combustion process impact phase association, morphology, and particle size. The primary chemical composition of fly ash, includes silicon, aluminum, iron, and calcium present in varying associations in both amorphous (glassy) and crystalline phases. The chemical composition is usually reported as oxides. Unburned carbon may also be present in fly ash and usually a loss-on-ignition (LOI) value is used to provide an indication of the amount of unburned carbon present, although the LOI test is not designed to differentiate between loss from carbon or other changes that can occur on exposure to elevated temperatures. Generally speaking, the higher the carbon content, the darker the fly ash.

ASTM International (ASTM) classifies fly ash into two categories—Class F and Class C. Class F fly ash is pozzolanic and is made up of primarily silicon, aluminum, and iron. A pozzolanic material will harden with water but only after activation with an alkaline substance such as lime. Class C fly ash, which is a cementitious material, also contains silicon, aluminum, and iron but is high in calcium (reported as CaO) and hardens when mixed with water.

Fly ash is the largest-volume CCP with respect to both production and utilization (71.1 and 29.2 million short tons in 2005, respectively). The overall utilization rate for fly ash in 2005 was 40.9%. The largest beneficial use (15 million short tons, or 21%) for fly ash was as a mineral admixture in concrete manufacturing. Other major beneficial uses for fly ash, listed in order of million short tons used, included structural fills/embankments, raw feed for cement clinker, waste stabilization/solidification, soil stabilization, and mining applications.[1]

Superior-quality fly ash is in high demand for concrete products, whereas lower-quality fly ashes that may not meet ASTM C618 specification for use as a mineral admixture in concrete may have limited demand. Low-quality fly ashes not meeting ASTM C618 specifications are typically used in large-volume, low-value applications such as structural fill. The value of fly ash varies significantly among producers depending on product quality, the plant's proximity to the market, and product availability.

Bottom Ash

Bottom ash falls to the bottom of the furnace and is removed as nonmolten particles (clinkers). It is composed of a range of fine to coarse angular particles, which are generally gray to black in color, with the bulk of the material resembling sand. Some may appear glassy, but, more commonly, the particles are porous. Bottom ash and fly ash are quite different physically; however, the bulk chemical composition of bottom ash is usually similar to fly ash, with the exception of sulfur trioxide. The trace element composition of bottom ash and fly ash produced from the same coal can be very different. Also, more carbon is generally associated with bottom ash.

In 2005, 17.6 million short tons of bottom ash was produced, and 7.5 million short tons (42.8%) was beneficially used. Major beneficial use applications for bottom ash, listed in order of million short tons used, included structural fills/embankments, road base/subbase/pavement, concrete/concrete products, raw feed for clinker, aggregate production, and snow and ice control.[1]

In general, bottom ash is a low-value, high-volume commodity, and the delivered price is highly dependent on transportation distance. Profitable beneficial use of bottom ash typically occurs when a local market (within 30 miles) is available or can be developed.

FGD Material

FGD materials are derived from a variety of processes to control sulfur emissions. These systems include wet, dry, and semidry systems, which produce vastly different by-products comprised of primarily either calcium sulfate ($CaSO_4$) or calcium sulfite ($CaSO_3$). The physical nature of FGD materials varies from a wet thixotropic sludge-like material to a dry powdered material depending on the process. Wet systems can produce either oxidized or unoxidized material. Forced-oxidized systems produce gypsum (calcium sulfate dihydrate [$CaSO_4 \cdot 2H_2O$]), whereas unoxidized systems, typically referred to as inhibited oxidation or natural oxidation systems, will produce a wet material that is comprised primarily of calcium sulfite with varying levels of calcium sulfate. Dry FGD systems include duct sorbent injection, lime injection multistage burner, and FBC systems. Dry FGD materials can vary widely in their properties. SDA systems are semidry but produce a dry powdered by-product that is either collected separately or, more commonly in the United States, collected with the fly ash to optimize sorbent use. SDA material and fly ash may also be commingled after collection for management purposes.

ACAA reported FGD material in three categories in 2005: 1) FGD gypsum, 2) FGD material wet scrubbers, and 3) FGD material dry scrubbers. Over 77% of the nearly 12 million tons of FGD gypsum was beneficially used. The primary use for FGD gypsum are in the manufacture of gypsum wallboard. The production and use of FGD gypsum is expected to continue to increase as more coal-based power plants convert their desulfurization processes to produce marketable gypsum. ACAA reported that, in 2005, 17.7 million short tons of wet FGD material was produced, of which 689,184 short tons (0.039%) was beneficially used primarily in mining applications. For dry FGD material, 1.4 million short tons was used, and 159,198 short tons (11%) was beneficially used in 2005. Major uses for dry FGD material, listed in order of most tons used, included mining applications, agriculture, concrete/concrete products, and flowable fill.[1]

Wet FGD material from unoxidized systems and dry FGD material are typically low-value materials. FGD gypsum, on the other hand, can be a very profitable material, typically when sold to manufacture gypsum products. Prices for FGD gypsum in merchant markets are negotiated among buyers and sellers, and published figures are not always relevant. According to the U.S.

Geological Survey, in 2005, the average values (free on board from mine or plant) were $7.48 per metric ton for crude gypsum and $20.26 per ton for calcined gypsum.[15] The average value of uncalcined gypsum used in agriculture and in cement production was about $17.89 per ton.

Boiler Slag

Boiler slag is the molten inorganic material from coal that drains to the bottom of cyclone-type or other wet-bottom furnaces and discharges into a water-filled pit where it is cooled and removed as glassy, angular particles. However, if gases are trapped in the molten slag as it is tapped from the furnace, the slag can be somewhat porous. The particle size of boiler slag ranges from 0.5 to 5.0 mm.

Nearly 97% of the 1,957,392 short tons of boiler slag produced was beneficially used in 2005, primarily as blasting grit and roofing granules.[1]

The market value of boiler slag is highly dependent on transportation distance and application.

FBC Material

FBC material is a mixture of unburned coal, unreacted sorbent, ash, and spent bed material. FBC fly ash is collected in the flue of an FBC boiler using a particulate collection device. Bottom ash is removed from the bottom of the FBC boiler. Some FBC material is self-cementing and has a tendency to swell.

Over 69% of the 1,366,438 short tons of FBC material produced was beneficially used in 2005. Major beneficial use applications, listed in order of short tons used, included soil modification/stabilization, road base/subbase/pavement, flowable fill, waste stabilization/ solidification, and structural fills/embankments.[1]

Gasification By-Products

By-products from gasification systems vary widely. IGCC systems produce elemental sulfur or sulfuric acid and slag as their primary by-products. IGCC slag is generally a black, angular, vitreous material having the appearance of coarse black sand. Char that is formed in the IGCC system is associated with the slag as it exits in the gasifier system, but in some systems, the char is separated from the slag and may be recycled as fuel.

ACAA does not report production or use statistics for gasification by-products; however, the management of gasification by-products from U.S. IGCC plants is known and described below:

- TECO Energy's IGCC Polk Station produces a sulfuric acid and slag stream. The plant produces 92% H_2SO_4 and is currently selling the entire supply to municipal water treatment facilities and is making a profit of nearly $2 million/year with that by-product stream.[16] TECO's IGCC slag is marketed as "black diamond," and all of it is used to produce cement. TECO provides the slag to a cement manufacture at no cost and subsidizes that market by providing shipping costs.[17]

- SG Solutions, LLC's IGCC plant produces 99.99% pure elemental sulfur that is sold to the fertilizer industry. Slag quality from this plant varies because of the char, but the slag by-product is moved from the Wabash River site daily, and only a small amount is stored on-site for short periods of time.[18]

Regulatory Status of CCP Use in the United States

The Resource Conservation and Recovery Act (RCRA), 42 U.S.C. 6901 et seq, and its state counterparts regulate the generation, storage, treatment, and disposal of hazardous wastes. Section 3001(b)(3)(A)(i) of RCRA, the Bevill Exemption, excluded certain large-volume wastes, including CCPs, from regulation under Subtitle C as hazardous wastes. EPA is currently drafting regulations under Subtitle D of RCRA (nonhazardous solid wastes) for CCPs disposed of in landfills or surface impoundments.

Subtitle D of RCRA delegates regulation of nonhazardous solid wastes to individual states, and all states have regulations on the disposal of CCPs. Several states have adopted laws governing CCP utilization, but requirements vary widely among states. Requests for permission to beneficially use CCPs are frequently handled on a case-by-case basis or under generic state recycling regulations. States that do specify acceptable beneficial use applications for CCPs are generally the states where the most progress has been made regarding CCP utilization in a manner that is technically feasible while being protective of the environment.

The EERC 1999 Barriers Report reported that an important barrier originating in RCRA legislation is the indiscriminate designation of CCPs as solid wastes, whether they are recovered for use or disposed of in a regulated facility.[3] The "waste" designation can trigger case-by-case approval and permitting procedures that discourage CCP use. This concept will be discussed further throughout this report.

The need for and scope of RCRA regulation of CCPs used as fill in surface and underground mines is still being evaluated. In an attempt to review the adequacy of coal ash beneficial use programs nationwide to determine if federal regulation, guidelines, or other requirements are needed to help ensure that the beneficial use of coal ash on mine sites does not cause groundwater contamination, the EPA commissioned the National Academy of Sciences (NAS) to perform an evaluation. The result was a report entitled *Managing Coal Combustion Residues in Mines* and will be further discussed later in this report (see section entitled *Impact of NAS Study*).[19]

STATE REVIEW PROCESS

Each state review followed the same methodology which was very effective for conducting a multiday site visit in a central location within the state reviewed. Panels of key stakeholders were assembled and interviewed during the course of each site visit. Information provided during the interviews was compiled and summarized in individual reports. The following sections describe each step of the review process in more detail. Tasks are listed in order; however, many tasks were implemented concurrently.

Task 1: Establish an Administrative Team

A project administrative team was established to perform the majority of the administrative work, including organizing the review, compiling findings, and writing reports. Ms. Tera Buckley, EERC Marketing Research Specialist, acted as team leader, with input from Ms. Debra Pflughoeft-Hassett, EERC Senior Research Advisor.

Task 2: Select a State

The project's administrative team, with assistance from project sponsors, conducted an in-depth evaluation to select each state. Each state selection process used different selection criteria; however, there were three common criteria that each state met:

1. The state should serve as a role model for other states. The EERC believed selecting a model state would be most beneficial to other states and that the information gained from a model state would be most beneficial in preparing this national synthesis report.

2. States from different geographic areas and climatic conditions should be considered. Selecting different locations would likely mean each state would have access to a different coal source and thus produce CCPs with varying composition and performance. In addition, the market conditions were expected to vary among geographic areas.

3. To facilitate a smooth state review, the state's environmental and transportation departments must be willing to participate in the review. State government agency participation was critical to the success of the state review process.

In addition to these common criteria, special considerations were made during the state selection process. For example, the first two state reviews were not to address mining because the NAS was in the process of issuing its position on using CCPs in mining applications, and the state reviews were not to interfere with the NAS study. The NAS study was completed before the third state was selected, therefore, for the third state review, preference was given to a state with prominent mining beneficial use applications. Another special consideration was what the administrative team considered a "model" state. The first state reviewed was to have what could be considered model beneficial use regulations in place, meaning that it had regulations in place that encourage CCP use while still being protective of the environment. However, for the second state review, it was decided to go to a state that was in the process of developing new regulations regarding CCP use. This would allow the administrative team to better understand the thought process behind the regulation development process. Then, for the third review, it was ultimately decided to return to a state where beneficial use rules were in place and had been tested over time.

Texas, Florida, and Pennsylvania were ultimately selected for review because each of these states has a CCP utilization rate significantly higher (60%–70%) than the national average, are in different geographic locations, and have addressed an array of CCP management issues.

A fourth state, North Dakota, was reviewed in 2007; however, the results from that state review are not included in this report. A separate final report from the North Dakota state review will be available in early 2008.

Task 3: Form an Advisory Board

A second team, the project advisory board, was formed to provide input to interviewee selection, assist in the development of a standard questionnaire, and review findings. Advisory board members serving on one or more state reviews and their associated contact information are listed in the project participant list in Appendix A.

Task 4: Assemble a Review Team

A select group of individuals comprised the review team. The primary role of the review team was to administer the meetings at the review. Review team members serving on one or more state reviews and associated contact information is listed in Appendix A.

Task 5: Select Interviewees and Develop the Review Guide

To conduct the series of state reviews, discussion group sessions were held during a multiday site visit in a central location within the state. The discussion groups comprised key CCP stakeholders representing the following groups[*]:

- Government agencies – directors and other key personnel of state or regional transportation and environmental agencies
- CCP generators – environmental and ash managers at electric generating companies
- CCP suppliers – CCP marketers and suppliers of ash beneficiation systems
- Cement and concrete – ready-mix concrete suppliers and cement producers
- Engineering/consulting firms – firms specializing in CCP use in various applications
- Wallboard – users of FGD gypsum for wallboard production
- Mining – mining officials from state government agencies
- Special interest – environmental and citizen groups and research institutions

[*] Each review had different discussion groups representing key stakeholders in that state. The groups listed represent all of the discussion groups held during the series of state reviews and were not included in each individual state review.

A series of open-ended questions and background information on the purpose of the review were provided to each discussion group prior to the site visit. During the discussion group sessions, the list of questions guided discussion; however, an open forum was used and allowed for flexible interaction. Those not able to attend a session in person were given the opportunity to provide written comments or participate in a telephone interview. Everyone who participated in the state reviews was provided a copy of the draft final report for review.

Task 6: Prepare Final Report and Disseminate Information

The primary objective of this task was to prepare a final report that can be used to encourage CCP use in the state reviewed and in other states. Target audiences for the individual state review final reports included CCP industry representatives and users, members of American Association of State Highway and Transportation Officials (AASHTO), Association of State and Territorial Solid Waste Management Officials, and other state and federal agency groups and individuals.

The results of the state reviews were organized as follows:

- Keys – highlight strengths or positive aspects
- Barriers – issues that detract from a CCP stockholder’s ability to increase CCP utilization
- Threats – upcoming issues that could hinder future CCP utilization
- Actions – methods for overcoming barriers and threats

These sections were modeled after a SWOT (strengths, weaknesses, opportunities, threats) analysis commonly used by marketing professionals to audit an organization and the environment in which it operates. It is the first stage of planning and helps identify key issues. The SWOT terms were modified to reflect terms that the authors felt were more applicable to the CCP industry.

SUMMARY OF RESULTS

Each state had a different regulatory framework, political climate, infrastructure, economy, coal source, and geographic location. These characteristics contributed to differences in CCP production and use among the states reviewed. Despite these unique characteristics, several commonalities were identified and used to translate individual state review observations to a national perspective on the status of CCP regulations, standards, and practices.

Industry Group Involvement in Developing Beneficial Use Regulations

Each state had an industry group whose membership consisted primarily of the state’s electric generating companies — Texas was represented by the Texas Coal Ash Utilization

Group (TCAUG); Florida by the Florida Electric Power Coordinating Group, Inc. (FCG); and Pennsylvania by the Electric Power Generation Association (EPGA). These groups worked to promote the use of CCPs and remove barriers prohibiting utilization, such as the lack of regulations allowing the beneficial use of CCPs. Organized industry-led groups can be effective in working with government agencies and state legislators because each one represents a unified voice on behalf of its members and allows industry to pool its collective knowledge base and monetary resources to address key issues. The following is a summary of how these industry-led groups aided in developing beneficial use regulations in each of the states reviewed and describes the resulting specifications.

An overview of state solid waste laws and regulations governing the beneficial use of CCP in all fifty states can be found in Volume 2 of *Engineering and Environmental Specifications of State Agencies for Utilization and Disposal of Coal Combustion Products*.[4]

Regulatory Development and Status in Texas

TCAUG was instrumental in getting state legislation passed in 1991 (Senate Bill [SB] 1340) that encouraged recycling and required state and local governments to amend their specifications for road and bridge construction to include CCPs. In 1993, TCAUG was again influential in getting language added to SB 1051 which established the Recycling Market Development Board (RMDB) and charged this body with developing a study to identify economic and regulatory incentives and disincentives for recycling and identifying existing and potential markets for, among other materials, CCPs. As part of SB 1051, the Texas General Land Office (GLO) prepared two market studies, entitled “Texas Recycles: Marketing Our Neglected Resources” and “Texas Recycles II: Marketing Our Neglected Resources,” to lay the groundwork for strategies to develop and expand recycling industries and markets in Texas.[20]

The GLO report issued in 1994 identified regulatory barriers at the Texas Natural Resources Conservation Commission (TNRCC, predecessor agency to the Texas Commission on Environmental Quality [TCEQ]) as one of the major impediments to increased CCP utilization. As a result, the TNRCC, GLO, TCAUG, and the Texas Department of Transportation (TxDOT) formed a task force to study the issue. TCAUG hired EPRI to present technical information to the task force, and Texas university professors provided case studies where CCPs were used successfully. The result of this cumulative effort was an issuance of a coproduct regulatory guidance letter in 1995 by the TNRCC that recognized that CCPs utilized in many construction applications could be best accomplished if the materials were not considered a solid waste. With this letter, recycling of CCPs in Texas began to increase substantially.[20]

In an effort to develop a single beneficial use rule for solid wastes, TCAUG and a similar association from the steel industry approached TCEQ to revise its solid waste rules. It was decided that taking a statewide approach would be the most effective way to get a solid waste rule approved that applied to a number of industries. In 2001, TCEQ formed a working group to meet with TCAUG to draft an agency rule that would convert the 1995 guidance effort into an agency rule. This effort took several months of negotiation and drafting and ultimately produced the “eight-waste criteria rule,” as further described below.

Proposed on October 27, 2000, and adopted on April 20, 2001, the amendment to the Texas Administrative Code (TAC) Title 30 Chapter 335, commonly referred to in Texas as the eight-waste criteria rule but through rulemaking became a seven-waste criteria rule, was perhaps the most influential rule that opened the doors for coal ash use in Texas by omitting utilized CCPs from the state's definition of solid waste so long as the material continues to meet all of the following criteria:

1. A legitimate market exists for the recycling material as well as its products.

2. The recycling material is managed and protected from loss, as would be raw materials or ingredients or products.

3. The quality of the product is not degraded by substitution of a raw material or product with the recycling material.

4. The use of the recycling material is an ordinary use, and it meets or exceeds the specifications of the product it is replacing without treatment or reclamation. Or if the recycling material is not replacing a product, the recycling material is a legitimate ingredient in a production process and meets or exceeds raw material specifications without treatment or reclamation. (Note: treatment may impact future FGD utilization; this is in another section of the report.)

5. The recycling material is not burned for energy recovery, used to produce a fuel, or contained in a fuel.

6. The recycling material is a legitimate ingredient in a production process and meets or exceeds raw material specifications without treatment or reclamation.

7. The recycling material must not present an increased risk to human health, the environment, or waters of the state when applied to the land or used in products which are applied to the land.[21]

The rule (30 TAC 335.1 Subchapter R) classifies industrial solid wastes into the following three categories:

- Class I – Any industrial waste that is toxic; corrosive; flammable; a strong sensitizer or irritant; a generator of sudden pressure by decomposition, heat, or other means; or may pose a substantial present or potential danger to human health or the environment. Besides nominal exceptions, CCPs produced in Texas are not categorized as Class I wastes.

- Class II – Any industrial waste which cannot be described as hazardous under Class I or does not meet the criteria for Class III. The majority of CCPs produced in Texas are categorized as Class II wastes.

- Class III – Inert and essentially insoluble industrial waste. Some bottom ashes produced in Texas are categorized as Class III and are, therefore, not subject to the TCEQ's eight-waste criteria rule.

TCEQ's classification is a self-classification system, meaning utilities classify their own materials. Data generated by the utility to classify its materials are subject to TCEQ audit. The vast majority of CCPs produced in Texas are exempt from solid waste classification. As a result, CCPs are able to compete in the marketplace like any other raw or manufactured material. No permits or prior approvals are required as long as the CCPs meet the eight-waste criteria rule.

If CCPs are stored or disposed as wastes, the General Prohibitions in 30 TAC 335.4 apply along with other solid waste regulations in Chapter 335. All wastes must be properly tested and classified (30 TAC 335.503). All wastes disposed of must be deed-recorded (30 TAC 335.5), and related waste management units must be listed on the facility Notice of Registration. Technical guidelines (30 TAC 335.3) provide the basis for proper siting and design of landfills. The TCEQ requires groundwater monitoring for landfills and surface impoundments.

In Texas, the collaborative effort between TCAUG, TCEQ, TxDOT, and the GLO resulted in proactive regulations that cleared the way for coal ash recycling in Texas. TCAUG used a push–pull strategy in its approach by consulting many levels at each of the state agencies because it believed it needed all levels of state agencies to work together. In addition, TCAUG presented one universal voice from industry to state agencies. TCAUG attributes its success to these strategies and its tenacity over a 10-year period.

Regulatory Development and Status in Florida

Unlike the other two states, Florida did not have beneficial use rules for CCPs in place at the time of the state review. Florida evaluated proposed beneficial use projects on a case-by-case basis. Electric utilities and ash marketers interviewed expressed extreme frustration in working with the Florida Department of Environmental Protection (FDEP) and indicated that they had made numerous proposals to FDEP to beneficially use CCPs over a period of decades and had been repeatedly rejected. Despite their frustrations, everyone who participated in the review appeared to be open to each others' ideas and willing to work with each other to develop a beneficial use rule that would benefit industry, consumers, and the environment. FDEP realized that adopting beneficial use rules for CCPs would be cumbersome and complicated and stated it would look to the Florida Electric Power Coordinating Group, Inc. (FCG), for guidance.

Two previous formal attempts were made to develop a beneficial use rule in Florida. In 2003, the FCG developed draft legislative bills SB 2338 and House Bill (HB) 1607. These bills were later abandoned after FDEP and FCG mutually agreed the vision was too broad and because they could not agree on interim storage requirements. Although this effort did not result in new CCP regulations, this exercise was still valuable in that working relationships were developed and a preliminary understanding of issues and viewpoints resulted. This legislative process was a separate undertaking from the rulemaking effort on the Industrial Waste Disposal and Reuse (IWDR) rule that was initiated by FDEP. A workshop to kick off this rulemaking was held in July 2003 but was delayed primarily because of workload issues brought on by two devastating hurricane seasons and other rulemaking efforts. FDEP plans to continue work on developing the IWDR rule that will address CCPs along with other industrial by-products.

At the state review session, electric utilities, ash marketers, and FDEP agreed to get together in 2006 to develop new regulations concerning industrial by-products, including CCPs. All parties agree that the new rule will likely include a list of preapproved uses and a list of uses that will need to be evaluated by FDEP on a case-by-case basis.

Regulatory Development and Status in Pennsylvania

A significant development in the history of beneficial use of coal ash in Pennsylvania occurred in 1986 with the introduction and passage of HB 2274, commonly referred to then as "the coal ash bill."

Mr. Douglas Biden, EPGA, in written comments to the Pennsylvania Department of Environmental Protection (PA DEP), summarized the history of the bill. He indicated that HB 2274 originated in 1985 with the House Mines and Energy Management Committee (hereinafter referred to as the Committee) requesting testimony from the electric power industry on House Resolution No. 19, which directed the Committee to explore ways to promote the use of Pennsylvania coal and its by-products.[22] At this time, electric generating companies were planning to install air pollution control devices that would significantly increase the amount of CCPs produced and quickly take up precious landfill space. The industry made considerable research and development investments in developing beneficial uses for CCPs. So much progress was made that questions arose among policymakers as to why CCPs were considered a "waste," rather than the "resource" they had become. However, industry efforts to beneficially use the material were frequently frustrated by the PA DEP (then Pennsylvania Department of Environmental Resources) solid waste regulations, which governed the disposition of coal ash. Using CCPs required a permit from PA DEP, a process that could take a year or more to obtain. PA DEP staff appeared sympathetic; however, they said their hands were tied by the Solid Waste Management Act which defined coal ash as a solid waste, so that all materials thus defined had to be handled and disposed according to the regulations.[22]

Proposed legislation excluded coal ash from the definition of solid waste and established provisions for the beneficial use of coal ash. The proposed legislation defined "coal ash" as fly ash, bottom ash, or boiler slag resulting from the combustion of coal that is or has been beneficially used, reused, or reclaimed for a commercial, industrial, or governmental purpose. The term includes such materials that are stored, processed, transported, or sold for beneficial use, reuse, or reclamation. After thorough legal and environmental research, HB 2274 was signed into law as Act 168 of 1986 as an amendment to the Pennsylvania Solid Waste Management Act of 1980. In 1992, provisions describing standards for the beneficial use of coal ash were placed in the residual waste management regulations and were revised in 1997.

Today, Pennsylvania regulates the beneficial use of coal ash under Pennsylvania's Residual Waste Management Regulations (Title 25 PA Code, Chapter 287, Sections 661–666).[23] The PA DEP allowed EPGA to provide input into this regulatory process. Because EPGA was allowed input into the regulation process, industry is generally accepting of the resulting regulations. These regulations define the following eleven beneficial uses for coal ash and do not require a permit:

1. As a structural fill material (287.661)

2. As a soil substitute or additive (287.662)

3. For defined uses at active coal-mining sites (287.663)

4. For use at abandoned coal or noncoal surface mine sites (287.664)

5. In the manufacture of concrete (287.665.1)

6. To extract or recover minerals and compounds contained within the coal ash (287.665.2)

7. As a fly ash-stabilized product (287.665.3)

8. Use of bottom ash or boiler slag as an antiskid material (287.665.4)

9. As a raw material for a product with commercial value, including the use of bottom ash in construction aggregate (287.665.5)

10. For mine subsidence control, mine fire control, and mine sealing (287.665.6)

11. As a drainage material or pipe bedding (287.665.7)

The beneficial uses defined above are generally accepted by industry and have cleared the way for increased CCP utilization in the state. The exception to this is FGD material,* which was not included in the regulations because it was not readily available as a product when the regulations were put in place.

Effectiveness of Industry-Led Group Involvement in Developing Beneficial Use Regulations

Based on the cumulative experience of the industry groups participating in the state reviews, it is clear that using industry groups to facilitate the development of new regulations, revise existing regulations, or to encourage legislation is a very effective way of getting industry's voice heard and understood. An education process is typically required to help state agencies and/or legislators understand the complicated issues associated with CCP utilization. This effort can require a considerable commitment of time and money by industry. Experience assembled from the state reviews indicated that the education process and relationship building

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* FGD material is defined as material generated from various wet forced-oxidized systems or unoxidized systems producing an either sulfate-rich (calcium sulfate [$CaSO_4$], commonly referred to as FGD gypsum) or sulfite-rich (calcium sulfite [$CaSO_3$], also know as scrubber sludge). Dry FGD systems are not presently used in Pennsylvania.

with state agencies and/or legislators should be ongoing because it is important to retain institutional knowledge of CCPs as staff is turned over. It is particularly important if the regulations are subjective and open to interpretation.

State Department of Transportation (DOT) Specifications

State DOTs have the responsibility to write specifications for road construction and other transportation applications that define acceptable CCP use in DOT projects. State DOTs often look to the AASHTO and ASTM for guidance on developing their own specifications. State DOT specifications typically set the bar for other CCP users in the state because the road-building industry generally views state DOT specifications as cautious and stringent, thus lessening the potential for failure and subsequent liability. Contractors are also familiar with DOT specifications, enhancing their acceptance and use in the construction industry. For these reasons, DOT specifications are of particular importance because they impact not only DOT projects, but a much broader spectrum of construction practices.

Many state DOTs have specifications that prescribe a minimum and maximum amount of fly ash that can be used in concrete. However, industry would like state DOTs to consider performance-based standards, rather than prescriptive standards (i.e., same mix design for each application), because they provide flexibility for the concrete supplier, can produce a better quality concrete, may be more economical, and allow higher quantities of fly ash to be used. Initiatives on the federal, state, and local levels will be required to adopt performance-based concrete specifications. National organizations such as AASHTO and ASTM, as well as private and government entities, must first demonstrate the long-term sustainability of concrete developed according to performance specifications. Following the demonstrations, an education process from industry to DOTs will be needed.

In the states reviewed, each DOT office has different specifications for how CCPs could be used in DOT projects. The following is a summary of DOT specifications in each state reviewed. Summaries of DOT specifications for all fifty states can be found in Volume 1 of *Engineering and Environmental Specifications of State Agencies for Utilization and Disposal of Coal Combustion Products*.[4]

DOT Status in Texas

TxDOT was one of the last state agencies to adopt coal ash specifications, adopting its rules in August 2004. Until that time, TxDOT granted special specifications and provisions on a district and statewide basis. From 1982 to 1996, TxDOT only incorporated CCPs into 41 roadway applications.[24] However, a dramatic increase in fly ash utilization was observed once TxDOT made CCP use a priority by adopting the following specifications.

DMS-4610 – Fly Ash

This product qualification specification was revised in August 2004 (formally DMS-8900) and establishes the requirements, test methods, and the Fly Ash Quality Monitoring Program (FAQMP) for Class C, Class F, and ultrafine fly ash used in concrete products.

TxDOT has a prequalified list of suppliers of Class C and Class F fly ashes. TxDOT accepts the product suppliers' certifications of fly ash quality; however, it does reserve the right to conduct random sampling of prequalified materials for testing and to perform random audits of test reports.

DMS-4615 – Fly Ash for Soil Treatment

This product qualification specification was adopted in August 2004 and establishes the requirements and test methods for Class C and Class F fly ash used in subgrade or base treatment. It also describes the FAQMP.

DMS-11,000 – Evaluating and Using Nonhazardous Recyclable Materials

This specification was adopted in August 2004 and covers the process for evaluating the environmental factors associated with nonhazardous recyclable materials (NRM) not addressed in other department specifications. Fly and bottom ash are considered NRMs because they have established histories of use by TxDOT.

Product Application Specifications and Special Provisions

TxDOT adopted several product application specifications in June 2004 allowing CCP use. Some of those applications include the following:

- Item 247 – Flexible Base
- Item 265 – Fly Ash or Lime–Fly Ash Treatment (Road-Mixed)
- Item 334 – Hot-Mix Coal-Laid Asphalt Concrete Pavement
- Item 341 – Dense-Graded Hot-Mix Asphalt
- Item 344 – Performance-Designed Mixtures
- Item 346 – Stone-Matrix Asphalt
- Item 401 – Flowable Backfill
- Item 421 – Hydraulic Cement Concrete

In addition, TxDOT issued special specifications and provisions for CCP use including the following:

- Special Specification 3157 – Cold Processed – Recycled Paving Material for Use as Aggregate Base Course (1993)

- Special Provision to Item 421 Portland Cement Concrete (1993)

DOT Status in Florida

Florida Department of Transportation (FLDOT) has a source list of supplementary cementitious materials (slag, silica fume, metakaolin, Class C or Class F fly ash, ultrafine fly ash) that are routinely used in state projects. The list also includes a Class F biomass fly ash generated from burning tree bark and a Class F fly ash generated from burning coal and petroleum coke. To get on the source list, a cementitious supplier must use a quality control plan accepted by the State Materials Office (Section 929, Pozzolans and Slag, Revised March 14, 2007).

FLDOT specifies how portland cement concrete is to be produced in Section 346. Section 346.2.3 pertains to the supplementary cementitious materials listed above and reads as follows:

“Use as desired, on an equal weight replacement basis, fly ash, silica fume, metakaolin, other pozzolans, and slag materials as a cement replacement in all classes of concrete, with the following limitations:

1) Mass Concrete:

a. Fly Ash – ensure that the quantity of cement replaced with fly ash is 18% to 50% by weight.

b. Slag – ensure that the quantity of cement replaced with slag is 50% to 70% by weight. Ensure that slag is 50% to 55% of total cementitious content by weight of total cementitious materials when used in combination with silica fume and/or metakaolin.

2) Drilled Shaft:

a. Fly Ash – ensure that the quantity of cement replaced with fly ash is 33% to 37% by weight.

b. Slag – ensure that the quantity of cement replaced with slag is 58% to 62% by weight.

3) For all other concrete uses not covered in Nos. 1 and 2 above:

a. Fly Ash – ensure that the quantity of cement replaced with fly ash is 18% to 22% by weight.

b. Slag – ensure that the quantity of cement replaced with slag is 25% to 70% for slightly and moderately aggressive environments and 50% to 70% by weight when used in extremely aggressive environments. Ensure that slag is 50% to 55% of total cementitious content by weight of total cementitious materials when used in combination with silica fume and/or metakaolin.

4) Type IP (MS) Portland-Pozzolan Cements: Ensure that the quantity of pozzolan in Type IP (MS) is in the range of 15% to 40% by weight.

5) Silica Fume and Metakaolin:

a. Cure in accordance with the manufacturer's recommendation and approved by the Engineer.

b. Silica Fume – ensure that the quantity of cement replaced with silica fume is 7% to 9% by weight.

c. Metakaolin – ensure that the quantity of cement replaced with metakaolin is 8% to 12% by weight."

In bridge superstructures, blended cements are allowed in slabs, barriers, and precast and prestressed applications exposed to moderately aggressive environments but not slightly aggressive environments. In extremely aggressive environments, the recommended cementitious mixtures are Type II cement with fly ash or slag. For bridge substructures, drainage structures, and other structures, the recommendations are similar (Table 1 of Section 346).

For reinforced concrete that does not require Type II cement plus slag or pozzolan(s), all applications that require Type II cement plus pozzolan(s), and prestressed concrete, FL DOT specifies the maximum chloride content limits for each of the concrete applications (Section 346.4.2).

A flowable fill mixture, which is designed to be excavatable, is not allowed to contain fly ash but must contain 75–100 pounds of cement per cubic yard and have a maximum 28-day strength of 100 psi. A flowable fill mixture designed to be nonexcavatable is to contain 75–100 pounds of cement and 150–600 pounds of fly ash per cubic yard and have a maximum 28-day strength of 125 psi (Section 121).

DOT Status in Pennsylvania

In order for CCPs to be used in Pennsylvania Department of Transportation (PennDOT) projects, they must be preapproved. Bulletin 14 lists all approved bottom ash sources, and Bulletin 15 lists all approved fly ash sources that can be used on PennDOT projects. To get on an approved list, one must fill out an application and provide a quality control plan. Usually an ash marketer approaches PennDOT to get a material approved, but sometimes a specific unit or plant manager will make a request. PennDOT has Class F and Class C fly ashes on its list from many states, including Illinois, Indiana, Maryland, Massachusetts, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, and West Virginia. Fly ash is often imported because most fly ash sources in Pennsylvania do not meet specifications for use in concrete because of high unburned carbon content.

Most Class F fly ashes are approved by PennDOT for alkali silica reactivity (ASR) mitigation. Class F fly ash plays an important role in PennDOT projects because about 70% of its aggregate sources are reactive. ASR occurs when reactive aggregates chemically react with alkaline components of portland cement, forming ASR gel. The gel adsorbs water and expands, damaging the concrete. Class F fly ash is effective in controlling expansion due to ASR, but Class C fly ash and other materials can also be used in certain applications. PennDOT specifications allow the portland cement portion of concrete to be reduced by 15% of fly ash and by 25% of ground granulated blast furnace slag for ASR mitigation.

PennDOT has material specifications for fly ash utilization which include:

1. Fly ash used with lime for soil stabilization. Fly ash must be tested in accordance with AASHTO T 135 (Wetting-and-Drying Test of Compacted Soil-Cement). Physical requirements for fly ash are also established in ASTM C 593 (Standard Specification for Fly Ash and Other Pozzolans for Use with Lime for Soil Stabilization) (Publication 408, Section 724.2).

2. Fly ash used as a pozzolan in portland cement concrete mixtures. Fly ash must be tested in accordance with ASTM C 311 (Standards and Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete). According to Publication 408, Section 724.2, fly ash must meet specifications set forth in AASHTO M 295 (Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete). LOI is limited to 6%.

3. Fly ash used to mitigate the effects of reactive aggregate associated with ASR in concrete. Fly ash must conform to the optional chemical requirements of AASHTO M 295 (Publication 408, Section 704.1[g]3.c).

Fly ash, slag, and bottom ash meeting material specifications set by PennDOT can be used for the following types of flowable backfill applications as long as they come from approved sources (Publication 408, Section 220):

- Where future excavation of the backfill may be necessary, such as at utility trenches, pipe trenches, bridge abutments, and around box or arch culverts.

- Where excavation of backfills is not anticipated, including replacing unsuitable soils below structure foundations; filling abandoned conduits, tunnels, and mines; and backfilling around pipe culverts where extra strength is required.

- In construction areas requiring low-density backfill material as in abutments over highly deformable soils, backfilling retaining walls, filling vaults, and backfilling on top of buried structures.

PennDOT allows the use of ground granulated blast furnace slag as a pozzolan (Publication 408, Section 724.3). Ground granulated blast furnace slag must be tested in accordance with AASHTO M 302/ASTM C 989 (Ground Granulated Blast Furnace Slag for Use in Concrete and Mortars). In addition, bottom ash and ground granulated blast furnace slag are allowed for use as an antiskid material and are often mixed with salt.

Materials not meeting the specifications or standards covered in Publication 408 will require testing in accordance with PennDOT's Product Evaluation process. This process can take years because it is a case-by-case review.

Air Emission Regulations Impact on CCP Use

The Clean Air Act Amendments of 1990 required large reductions in emissions of nitrogen oxide (NO_x) and sulfur dioxide (SO_2) from coal-based power plants. In March 2005, EPA announced the following new clean air regulations that will further reduce emissions of NO_x and SO_2 and require limits on mercury emissions from coal-based power plants:

- The Clean Air Interstate Rule (CAIR) applies to SO_2 and NO_x emissions in 28 eastern states and Washington, D.C. CAIR calls for selected states to have a 70% reduction of SO_2 emissions and a 60% reduction of NO_x emissions compared to 2003 levels by the year 2015.

- The Clean Air Mercury Rule (CAMR) is the first federal rule to limit mercury emissions from coal-based power plants. This rule calls for a 70% reduction of mercury emissions by 2018.

These regulations seek to lower levels using cap-and-trade mechanisms by which power plants are assigned emission limits but can exceed those limits by purchasing credits from companies whose emissions are below their assigned limits.

In addition to federal regulations, several states are proposing their own regulations that would require further reductions in SO_2, NO_x, and mercury emissions over a shorter time frame than required under the federal rules.

To comply with these new federal and state air emission regulations, it is anticipated that the nation's coal-based power plants will employ a variety of technologies. Significant changes in the chemical composition, physical properties, and morphology of CCPs may occur as a result of the application of new emission control technologies. Universal concerns brought forth during the state reviews, either directly or indirectly related to the impact these air emission regulations will have on CCP management, are described below.

Impacts of SO_2 Control

Coal-based power plants generally employ one of two strategies to control SO_2 emissions: 1) burn compliance fuels or 2) install FGD systems. Compliance fuels can be obtained by burning low-sulfur coal (coals with sulfur content below 2% by weight), blending low- and high-sulfur coals, and washing coal. Most modern power plants, and all plants built after 1978, are required to have a FGD system.[25] To further reduce SO_2, eastern coal-based power plants are expected to install primarily wet FGD systems, resulting in a significant increase in the amount of FGD gypsum produced; whereas in the western United States where coal based-power plants burn low- to medium-sulfur coals, dry FGD systems (primarily SDAs) are expected to be installed resulting in an increase in the amount of dry FGD material produced.

In Pennsylvania alone, there is an expected surplus of more than 4 million short tons of FGD gypsum a year as a direct result of the installation of wet FGD systems. Nationally, Bruce predicts that over the next 20 years, the North American supply of FGD gypsum is going to exceed the demand by a wide margin, with a surplus of 10–15 million tons a year by 2015.[26] Electric generating companies do not want to be dependent on wallboard and cement plants to use all of their FGD gypsum because plants may shut down temporarily or close, and the markets for wallboard and cement fluctuate based on building trends. Also, the wallboard and cement markets may soon be oversupplied with synthetic gypsum.

The potential increase in production volume of dry FGD material also raises concern because of its current low utilization rate (11.15%) in the United States. Most states have regulations, policies, and rules that apply to fly ash, bottom ash, and boiler slag beneficial use; however, products from FGD systems are relatively new in comparison to other products, and several states do not have regulations in place that deal specifically with dry FGD material. Currently, the potential to produce revenue from the sale of dry FGD material is limited; therefore, most electric generating companies find it more economically feasible to dispose the material rather than dedicate resources (i.e., employees and infrastructure) to utilize it.[25]

Impacts of NO_x Control

Many coal-based power plants have had to reduce NO_x emissions, and a variety of NO_x control technologies (low-NO_x burners, SCR, and SNCR units) have been implemented across the United States. This has resulted in the production of fly ash with a noticeable decline in quality, namely, the presence of unburned carbon at varying levels. Some fly ash contaminated by unburned carbon are no longer suitable for use in concrete. Fly ash with a high unburned carbon content (generally at levels above 6% LOI) or with variable LOI's are unsuitable for use in concrete because the unburned carbon affects air entrainment in the concrete. The entrained air is required for freeze-thaw resistance. When it is economically viable, fly ash with high burned carbon content is sold as a raw material for cement manufacture. However, some cement plants cannot use fly ash with unburned carbon contents greater than 30% because of operational problems and the need to meet carbon dioxide (CO_2) emission requirements and total hydrocarbon limits. Separation and high-temperature treatment technologies have been developed and installed at some power plants to allow production of a fly ash product that meets required specifications for LOI.

SCR and SNCR technologies can also result in treating fly ash and bottom ash with ammonia. These contaminants will likely disrupt the cement and concrete markets.

Impacts of Mercury Control

Many coal-based power plants are expected to rely on the cobenefits of SO_2 and NO_x controls for mercury control. Other than wet FGD systems, the leading technology to comply with mercury emission regulations is activated carbon injection (ACI). Other system configurations such as EPRI's TOXECON™ system may be used for mercury control.

The stability of mercury and other air toxic elements associated with CCPs as the result of mercury control has become a prominent question and has raised concern by state regulatory agencies and citizen groups about the potential environmental stability of these elements under disposal and utilization conditions.[27] The EERC recently concluded an in-depth 4-year investigation on the potential for mercury and other air toxic element releases from CCPs under a variety of management scenarios and made the following conclusions[28]:

- ACI increased the total mercury content in the test samples.

- Direct leaching tests indicated that mercury was not readily leached from fly ash or FGD materials. Leachate mercury concentrations were below the 0.01-µg/L analytical reporting limit for most samples evaluated.

- Mercury leachate concentrations did not correlate to total mercury concentrations.

- When exposed to ambient-temperature air in laboratory experiments, fly ash samples either released or sorbed small amounts of mercury. Samples containing unburned carbon or AC tended to sorb mercury in ambient-temperature vapor-phase experiments.

- Laboratory data indicated that the potential for ambient-temperature vapor-phase mercury releases from CCPs are unlikely to impact atmospheric mercury loading.

- Mercury was not released to the vapor phase at temperatures below 250°C in elevated-temperature experiments, but for most samples, 100% of the mercury in the CCP was released by 750°C.

- Under microbiologically mediated conditions, only very low levels of elemental and organomercury were released in the vapor-phase and leachate, although more elemental mercury was released.

- Field experiments at a lignite CCP disposal site indicated low-level vapor-phase releases of mercury, as was generally noted in laboratory experiments for lignite fly ash samples. Releases from FGD materials were noted both in laboratory and field measurements.

Investigations by the research community continue on the potential for mercury to be released under a variety of management situations; however, the current state of the science indicates that mercury associated with CCPs is stable and has low potential to be released under most management conditions, including disposal. The exception to this is exposure to elevated temperatures such as those achieved in wallboard and cement manufacture, as further described here:

- *Wallboard Manufacture* – The ultimate fate of mercury in FGD gypsum used to manufacture wallboard is uncertain and can vary from facility to facility. Questions still remain regarding how much mercury is released into the atmosphere during the rest of the life cycle of wallboard (e.g., via dust when wallboard is cut or crushed) and the ultimate fate of mercury once the FGD gypsum and/or wallboard is disposed of in a landfill. There is also some concern that mercury contained in FGD gypsum wallboard may leach into the groundwater at municipal landfills once the wallboard reaches the end of its life cycle and is disposed. In addition, the potential for mercury captured in

FGD gypsum to be released during wallboard production is still under investigation. A study conducted by URS investigated this question and determined that the wallboard industry would emit less than one ton of mercury compared to the current coal-based electric generating company emissions of 48 tons per year.[29]

- *Cement Manufacture* – Fly ash from units using sorbent injection for mercury control may no longer be able to be used in cement manufacture unless the manufacturer demonstrates that the use of such ash will not lead to increased mercury emissions from the cement kiln.[30] EPA has voluntarily taken reconsideration on the ban on fly ash where sorbent injection for mercury control is practiced and has been petitioned to reconsider its decision not to place restrictions on the current use of fly ash.[31] EPA plans to complete these reconsiderations by the end of 2007.

In addition to mercury, ACI presents a challenge for fly ash sold to the concrete market. Fly ash containing activated carbon (AC) will likely no longer be able to be used in concrete because AC impacts air entraining admixtures. Beneficiation technologies and treatments have been developed to address this concern; however, the applicability of these technologies is very site-specific to each power plant, and there is limited information available on the potential rerelease of AC-captured mercury from these operations.

According to DOE, significant economic impacts are expected to result as a result of CAMR. DOE estimates a loss of $908 million/year for fly ash and a loss of $213 million/year for FGD materials reuse applications.[32] If RCRA were to reconsider its RCRA Subtitle C disposal determination and consider CCPs to be hazardous, it could cost more than $11 billion/year.

Impact of the NAS Study

In recent years, the beneficial use of coal ash on mine sites has become a controversial topic on local, state, and national levels. As a result, EPA was tasked to review the adequacy of coal ash beneficial use programs nationwide to determine if federal regulation, guidelines, or other requirements are needed to help ensure that the beneficial use of coal ash on mine sites does not cause groundwater contamination. NAS was commissioned to perform this evaluation and published a report entitled *Managing Coal Combustion Residues in Mines*.[19]

As an attempt to not interfere with the ongoing NAS study, mining was not addressed in the Texas or Florida state reviews. However, the NAS report was completed in time for the third review, and thus state mining regulations and the NAS study were discussed during the Pennsylvania review.

The PA DEP has a comprehensive regulatory program for the beneficial use of CCPs for mine reclamation. The beneficial use of CCPs at active coal mine operations is accomplished through the coal mine permitting process outlined in the following:

- *Residual Waste Management Regulations* (287.663-287.664) – Defines the beneficial uses for coal ash at active coal mining sites and abandoned coal or noncoal surface mine sites.

- *Beneficial Use of Coal Ash at Active Coal Mine Sites* (563-2112-206) – This document describes the procedure for the district mining offices to review requests for the beneficial use of coal ash at active mine sites.

- *Certification Guidelines for Beneficial Use of Coal Ash* (563-2112-224) – This document provides the guidelines for certifying coal ash for beneficial uses and the forms with instructions that are necessary for the department to certify coal ash for beneficial use.

- *Technical Guidance Document for Beneficial Use of Coal Ash* (563-2112-225) – This document describes the four beneficial uses – 1) placement, 2) soil substitute or additive, 3) alkaline addition, and 4) low-permeability material of coal ash – that can be approved in active coal mine permits or that can be approved as part of the department's mine reclamation contracts or other department-approved mine reclamation projects.

Two additional permit application modules were developed for use with the coal mine permit application for evaluating proposals for beneficial use of coal ash. Module 25 was developed for placement of coal ash as fill material, and Module 27 was developed for use of coal ash as a soil substitute or additive. These documents and permit application modules, in conjunction with Pennsylvania's residual waste management regulations, very clearly outline how coal ash is to be used in mine settings in Pennsylvania.

The NAS report lists 40 findings or recommendations under 12 categories and concluded that using CCPs for mine reclamation is a viable option, as long as precautions are taken to protect the environment and public health. Those interviewed during the Pennsylvania state review generally agreed with this conclusion; however, they felt that the report was "middle of the road" and was a missed opportunity to showcase the benefits of using CCPs in mines. Furthermore, the report did not recognize the vast differences between the highly alkaline CCPs produced by CFB plants and the less alkaline fly ash produced by pc-based plants.

Mr. Kim Vories, Office of Surface Mining, issued his technical review of the NAS report and concluded he was in agreement with the following findings that support[33]:

- The use of CCPs in mine reclamation.

- The need for specific Federal regulations under the Surface Mining Control and Reclamation (SMCRA) Act of 1977 that describes the minimum permitting, bonding, and environmental performance standard requirements when they are placed on active coal mines.

- The research priorities to specifically address the hydrogeologic fate of CCPs and any leachate generated by those CCPs in relation to public heath and environmental quality.

- Developing mine-appropriate leachate tests.

Mr. Vories further concluded that the limitations of the NAS study were in its inability to:

- Acknowledge the profound differences between regulatory environments that control placement of CCPs at mines.
- Evaluate available groundwater monitoring data and scientific research within the context of the applicable regulatory environments.
- Acknowledge the volumes of scientific studies and state regulatory data that show no degradation of water quality because of the placement of CCPs at SMCRA mines for the last 29 years.

PA DEP is considering making the following minor modifications to its monitoring requirements based on recommendations in the NAS report:

- Broaden the parameters it monitors in groundwater and leachate.
- Require the recording of landowner consent forms. These were only recommended to be recorded in the past.
- Increase monitoring of heavy metals quarterly instead of annually in order to provide information on seasonal information and to allow for more rigorous analysis and interpretation of the data.
- Require more conditions in permits.
- Investigate specific compaction techniques and fugitive dust issues.
- Require risk assessments.

The U.S. Department of the Interior Office of Surface Mining (OSM) sets standards for the operation of surface coal mines and reclamation of the land following mining. Currently, OSM is developing national rules for active SMCRA coal mines and abandoned mines that receive federal funding for reclamation. The new rules will utilize existing SMCRA authorities. The current schedule is to have a proposed rule during 2007, with a final rule during 2008, although OSM stated this is an optimistic time line. OSM published an advance notice of proposed rulemaking in the Federal Register formalizing its intentions. Once these rules become final, OSM will write Part 732 notification letters to each of the mining states (including Pennsylvania) telling them that if they want to continue permitting CCP placement under SMCRA, they must adopt rules that are equivalent to the federal rules. The OSM rules will not be modeled after Pennsylvania's residual waste beneficial use coal ash rules but will designate all of the existing SMCRA rules which must be complied with in order to conduct CCP placement at a SMCRA mine. Some new rules may be necessary such as the addition of a definition of terms. These rules will not apply to abandoned mine land (AML) sites where no federal funding is involved.[33] In Pennsylvania, the ARIPPA program to reclaim AMLs does not receive funding from the federal SMCRA AML program and, therefore, does not fall under SMCRA regulatory authority.

Communication, Education, and Perception Barriers

Several communication and perception barriers were discussed during the state reviews. These types of nontechnical barriers were found among the general public, end users, and within government agencies and electric generating companies. The following sections describe specific barriers pertaining to communication and perception.

Communication During Demonstration Projects

Government agencies, legislators, and industry generally agree that making modifications to current regulations or writing new regulations is a lengthy process. This process often requires the completion of one or more field-scale demonstration projects to provide government agencies with the data they need to feel comfortable with the environmental and engineering appropriateness of using specific CCPs in beneficial use applications. Based on the states reviewed, government agencies do not appear to make regulatory decisions based on research performed outside of their own state because they do not believe external studies use CCPs that are identical to those produced by their electric generating companies or take into account their state's unique geographic, geologic, or climatic conditions. Also, laboratory experiments were not viewed as capable of replicating what will happen in the field.

Industry often takes on the responsibility and cost of conducting field-scale demonstration projects with the intention of generating the data government agencies need to make decisions. However, the demonstration process gets complicated when a government agency requests a new set of data midway through the project or after its completion. Government agencies indicated the demonstration process could be expedited if industry would provide them with the information/data they need up front; whereas, industry indicated that the government agencies should say what information/data they need and then industry would conduct the demonstration in a way to provide it. Turnover of government agency personnel during the course of a demonstration can also be a challenge, especially when a new government decision maker wants to see additional or different data that wasn't planned for at the onset of the demonstration. In some cases, it is difficult or impossible to provide these data without repeating the entire demonstration. Industry further indicated that, in some instances, government agency staff do not have the technical knowledge base or time needed to completely understand the issues. These roadblocks can delay the regulation process for years.

Another hurdle when conducting demonstration projects is the inconsistency of testing procedures used. For example, some environmental departments prefer that the toxicity characteristic leaching procedure be used for all leaching tests, whereas other departments prefer to select a leaching procedure depending on how the CCP is to be used. The inconsistency of testing procedures makes it difficult to compare data.

To help facilitate communications between industry and governmental agencies, it is recommended for industry to partner with a university or consulting firm with experience and expertise in the specific area to be addressed when conducting a demonstration project. Oftentimes, a third party can provide an unbiased technical perspective on what the field demonstration project can accomplish and aid in the interpretation of data. Industry support groups such as TCAUG, FCG, or EPGA also offer an excellent forum for industry to pool its intellectual and monetary resources and collectively approach state agencies for the mutual benefit of all parties involved, providing the project benefits the majority of members. In addition, state-derived research and development (R&D) funds may be available in some states to partially fund large-scale demonstrations and other projects. For example, coal-mining states often have R&D funds set aside specifically for CCP issues. Examples of these programs include the North Dakota Lignite Research Council, Ohio Coal Development Office, and Illinois Clean Coal Institute.

Another way to help bridge the communication gap is for industry to present data to government agency staff in an easy to read format that provides concise interpretations of the data. Government agencies should not be expected to analyze volumes of data.

Waste vs. Product Perception

As previously mentioned, there are various terms used to refer to coal ash. The industry debates that since electric generating companies are not in business to produce coal ash, then coal ash must be considered a by-product. Others proclaim that if a material is used or recycled, then it must be a product. Conversely, others believe that the material should be termed a waste, no matter whether it is disposed of or beneficially used. Nevertheless, the names by-product and waste have powerful effects on consumers and regulators/legislators. To illustrate this point, TCEQ was able to develop a rule that puts CCPs in the same category as other recycled materials such as plastic, aluminum, and paper by defining any reused CCP as a product. However, there are situations in Texas where the material, whether it is reused or disposed of, is still perceived of as a waste. If the industry as a whole could change how legislative bodies perceive coal ash and market coal ash as a product, it could put coal ash on the same platform as other recycled materials.

Plant Operator Education

Today, CCP quality is becoming increasingly important as new air emission control technologies are installed on coal-based power plants, thus further impacting the quality of CCPs produced. However, the quality of CCPs can be improved depending on how the plant is operated.

Power plant ash managers mentioned that one of their biggest hurdles is to educate their own plant operators about how to produce good-quality CCPs on a consistent basis. Some electric generating companies have internal education programs for plant operators that specifically address ash quality, whereas CCP quality is not a factor during the combustion process at other companies.

External educational programs could be developed by universities, with funding from electric generating companies and government, to teach plant operators about how to produce electricity efficiently while meeting emission control requirements and still maintaining a consistent by-product. Colleges educating future plant operators could also integrate ash production and management into their course curriculum.

Advocacy Groups

Some advocacy groups[34–41] have criticized the beneficial use and disposal requirements of CCPs. Those interviewed during the individual state review sessions stated that some advocacy groups believe that government agencies fail to protect humans by caving to political pressure and that the people are left to defend themselves against what they see as dirty coal-burning power plants. CCP industry stakeholders interviewed believe these advocacy groups attack the beneficial use and disposal of CCPs in an indirect way to stop the burning of coal to produce electricity. These groups have been effective in delaying or terminating some beneficial use applications, simply because potential project proponents may wish to avoid the hassle of dealing with these groups.

It is important that CCP stakeholders continue to present factual information to advocacy groups and the audiences of advocacy groups. Facilitating discussions among the CCP industry and advocacy groups may be more successful if a third party was used to moderate the discussions.

Awareness of Federal CCP Programs

Most participants in the discussion groups were not aware of the Green Highways Partnership, the Industrial Resources Council, or C^2P^2. Some had heard of the programs but did know what they could do to become involved or support these programs. For example, many did not think they could become a C^2P^2 member if they were not doing something significant with CCP utilization and did not understand what was expected of members. In addition, they did not know who at their company/organization had the authority to sign the C^2P^2 registration form.

These nation-wide programs offer a method of promoting beneficial use success stories and earn national recognition for those successes. Those interviewed indicated that these programs could offer a means of educating the general public about these success stories so that they hear about the positive aspects of CCP utilization. These programs would likely be perceived by the general public as more credible than information from industry alone. Also, more outreach needs to be done by these programs to get industry involved.

Education of Specifiers/Engineers

Lack of knowledge or negative perceptions toward CCPs was cited among district and local highway personnel, architects, engineers, and contactors. The lack of knowledge could be attributed to the fact that engineers coming out of college receive, on average, less than 18 hours of concrete training in their materials class. In those 18 hours, CCPs are briefly mentioned, and professors often reference old data. It was suggested that negative perceptions could often be attributed to one bad experience that could have happened several decades ago using the material. In most instances, if CCPs were used in a project that failed, the CCPs were typically blamed for the failure even if CCPs were not the cause. This reaction typically occurs when users are not educated about the material. Negative perceptions and lack of knowledge are interconnected and can have detrimental impacts on coal ash use. For example, at one time, the Austin concrete market almost turned to an all-cement market because of one misuse resulting from a lack of education about the material. However, TxDOT did cite instances where CCPs were initially blamed for a failure, and TxDOT's laboratory subsequently confirmed the correct cause for the failure. These types of corrections are imperative to overcoming education and attitude barriers.

Some DOT offices have large variations of CCP use between district offices. This could be due in part because different areas of states may require different road building techniques based on geographic conditions. This could also be because some district engineers have more negative or positive opinions of CCP use in road building applications.

Local educational efforts, such as technical presentations or short courses targeted specifically toward specifiers and engineers, are an effective method for educating this audience. State specifiers and engineers typically do not have funding available to travel long distances. It is imperative that the educational effort be held at a convenient location. The Federal Highway Administration and EPA have several effective educational materials that are available free-of-charge and include its "Fly Ash Facts for Highway Engineers," "User Guidelines for Waste and Byproduct Materials in Pavement Construction," and "Using Coal Ash in Highway Construction: A Guide to Benefits and Impacts."

Encouragement and Incentives to Utilize CCPs

Different methods that could be taken to increase CCP utilization were discussed at the individual state reviews. The following is a summary of direct and indirect methods that can be taken to encourage CCP use.

States Need Beneficial Use Policies for CCPs

Based on the information obtained during the individual state reviews, it is clear that not having state CCP beneficial use policies in place is a major barrier for increased CCP use. It also became apparent that state agencies that currently do not have CCP beneficial use policies in place, such as the FDEP, will likely continue on the same path if they are not approached to change policies. FDEP indicated that it did not have a push from the state or federal government or the general public to use CCPs and, therefore, had not dedicated the resources required to get those policies in place.

Mandates from state legislators can be an effective way of getting environmental departments to develop and adopt beneficial use policies; however, input from industry typically leads to policies that both parties (government and industry) agree will increase CCP utilization while still being protective of the environment.

State-Led Recycling Initiatives

Each state reviewed had state-led recycling initiatives that were intended to increase the use of industrial by-products; however, only Texas had a program that focused specifically on CCPs. Based solely on the information obtained during the review process, statewide recycling initiatives that specifically encourage the use of CCPs are effective in gaining acceptance of

CCPs as a recycled material among government agency staff, end users, and the general public. Recycling program's that do not specify CCP use are not effective in directly encouraging CCP utilization.

The following is a summary of state-led recycling incentives in each of the state's reviewed.

Texas-Led Recycling Incentives

TxDOT's Road to Recycling Initiative was successful in encouraging and promoting CCP use. In 1999, TxDOT highlighted CCPs in its "Year of the Road to Recycling" campaign. The campaign included the development of a 46-page CCP summary document that includes a material overview, research summaries, case studies, a list of TxDOT specifications currently allowing use of CCPs, material sources, and a summary of TxDOT's experience with the material. TxDOT used this tool to educate its staff and contractors about the benefits of using CCPs in TxDOT projects.

The Texas transportation and environmental departments had programs that promoted the use of recycled materials including CCPs. These programs were a result of the state senate passing a bill to establish the RMDB. The RMDB was charged with coordinating the recycling activities of all state agencies and pursuing an economic development strategy that focuses on the state's waste management priorities and the development of recycling industries and markets.

Florida-Led Recycling Incentives

The only push to recycle industrial by-products in Florida was in 1974 when the Florida Resource Recovery and Management Act (Chapter 403.701) required each county to prepare a Solid Waste Management Plan. In 1988, this Act was amended by the Solid Waste Management Act to establish state goals, regulations, and programs for a host of solid waste activities. The Act sets recycling goals and requires counties to develop recycling programs to meet these goals. It also creates programs to encourage the recycling of specific materials such as waste tires, compost, and batteries. However, the Act does not address or encourage the beneficial use of CCPs.

Pennsylvania-Led Recycling Incentives

Since 1998, PennDOT and PA DEP have operated under a Memorandum of Understanding to promote and support recycled materials in state highway construction and maintenance projects. PennDOT's Strategic Environmental Management Program focuses on recycled material use in maintenance projects, and the Strategic Recycling Program evaluates and helps implement recycling opportunities for new projects. These programs are spearheaded by PennDOT, with support from PA DEP. Both of these programs consider CCPs to be recycled materials; however, they are not actively encouraging the use of CCPs. In order for these programs to look more closely at CCPs, they would likely need to be approached by industry.

Federal Encouragement of State-Led Recycling Initiatives

Programs such as EPA's C^2P^2 could encourage CCP use at the state level by showing state legislators how initiatives such as the Texas RMDB encouraged recycling in other states. The promotion of Comprehensive Procurements Guidelines may also be helpful in encouraging states to recycle.

LEED and Other Green Building Programs Encourage the Use of CCPs

The U.S. Green Building Council's LEED Green Building Rating System was created to transform the built environment to sustainability by providing the building industry with consistent, credible standards for what constitutes a green building. Various LEED initiatives including legislation, executive orders, resolutions, ordinances, policies, and incentives are found in 53 cities, 10 counties, 17 states, 33 schools, and 11 federal agencies across the United States and Canada.[42] In addition, there has been a steady progression of non-LEED-related green building initiatives from various municipalities, federal government, and states around the country.

The LEED program indirectly encourages CCP recycling by offering points for products containing recycled materials, locally available products, and energy-efficient products (i.e., concrete blocks, autoclaved cellular concrete). It is estimated that 18 of LEED's possible 69 assessment points are related to CCP-containing products, namely concrete. However, the current LEED system does not favor the use of fly ash in concrete from a percent content standpoint. For example, standard concrete containing 15% fly ash replacement versus a high-volume fly ash replacement rate of 50% would receive the same amount of credits. Even in Texas, where the LEED program is popular, there have been several LEED-certified buildings that did not incorporate fly ash into their concrete. Furthermore, a major green building conference in Austin did not address CCPs, indicating to the authors and those who participated in the Texas state review that the CCP industry is not doing enough to promote CCP recycling in the green building industry.

The environmental and engineering benefits of using CCP-containing products should be a factor when the decision is made to use products that may or may not contain CCPs. Often, if CCPs are used in construction projects, it is likely because of the economic savings associated when using the material and not because of the fact that CCPs are a recycled material offering environmental and engineering benefits over virgin resources (i.e., decreased need for landfill space, conservation of natural resources, reduced CO_2 emissions, reduced overall cost of generating electricity, and production of better products).

Because the LEED program is growing and becoming the most highly recognized and credible national green building program, the authors suggest that the CCP industry do more to become involved in LEED. LEED offers a forum for the CCP industry to promote its successes to new audiences who may not have heard about the benefits of using CCPs or considered CCPs to be a valuable recycled material. These new audiences tend to be more receptive to appeals to use recycled products than the traditional clients of the CCP industry and may be able to publicize and promote the merits of CCP use to new end users. ACAA recently joined LEED, and it is anticipated that many industry leaders will follow. More work also needs to be done on state and local levels to encourage governments to adopt LEED initiatives that will either directly or indirectly encourage CCP use.

CO_2 Credits

With air emission regulations in place for SO_2, NO_x, and mercury, the coal ash industry is anticipating the implementation of more stringent federal CO_2 controls. Some states are also considering or have adopted their own CO_2 emission restrictions in the absence of federal mandates. These controls will place increased importance on carbon trading. As an example, it is estimated that 0.8–1 ton of CO_2 is saved for every 1 ton of fly ash used to replace cement in concrete because by using fly ash, the user is preventing CO_2 emissions from cement production. With nearly 15 million tons of fly ash used in concrete and concrete products alone, there is a significant amount of potential CO_2 emission credits available for concrete applications. The question still remains on who will receive these carbon credits. Everyone from the CCP generator, CCP marketer, ready-mix supplier, and ultimate end user will be vying for these credits.

TRI Reporting

During the reviews, the question was raised, "Why do you have to report beneficial uses of CCPs as 'releases to land' under federal TRI?" It was suggested that TRI should exempt beneficially reused material and only require reporting of material that is sent to a disposal site. EPA offers site-specific exemptions but said that in order to get an exemption for all electric generating companies, there would have to be a large test case from a large electric generating company with support from industry groups such as ACAA. Some industry representatives interviewed believe this change is necessary because some definitions of release contradict the goals of C^2P^2. In addition, TRI reporting takes considerable effort, and this change would be an incentive for the power plant manager to reuse more material.

Economics

Economics are a key factor in the beneficial use of CCPs. In most cases of beneficial use observed during the state review process, economics were the primary reason why CCPs were selected over virgin materials. Engineering performance was also considered but the environmental benefits for using the material were rarely considered a reason to use CCPs. Oftentimes, end users are not even aware that their product contains CCPs. Economics may become less of a factor in the future as CO_2 credits become more valuable and the green building movement gains more wide-spread acceptance.

The economic viability of CCP use is expected to become even more important as more requirements are placed on CCP disposal and the permitting process for new landfills or surface impoundments becomes more difficult. For example, EPA issued a Notice of Data Availability (NODA) to inform the public on the disposal of CCPs in landfills and surface impoundments. This NODA is in review.

Economics are also a critical factor within the electric generating company management structure. The electric generating company representatives interviewed were middle-level managers and said that convincing upper management to make ash utilization a priority was possible once they saw the economic advantages. These economic advantages are best realized when they are shown in the operations and planning side of the company rather than the fuel side because the revenue stream from selling by-products gets lost in the fuel cost. However, ash managers at electric generating companies that have inexpensive and plentiful disposal options often find it difficult to make the case that resources (i.e., employees and infrastructure) should be dedicated to ash utilization when it is cheaper to dispose of the material.

CONCLUSIONS

With the information gained from conducting the series of state reviews, it is reasonable to perform an analysis on how the successes in the states reviewed can be translated to other states. This paper presented a brief summary of commonalities that appeared when the three state reviews were analyzed. The following is a list of recommendations that can be applied to industry and state agencies that would encourage the use of CCPs.

Recommendations to Industry

- Use existing or institute new industry groups to facilitate communication with state agencies on the development of rules, regulations, guidelines, or policies that support the beneficial use of CCPs.

- Be proactive and support state agencies in developing new rules, guidelines, regulations, and policies that encourage the beneficial use of CCPs. State agencies that currently do not have CCP beneficial use policies in place will likely continue on the same path if they are not approached to change. Industry involvement typically leads to policies that both parties agree on while still being protective of the environment.

- Support educational activities for government agency staff and specifiers/engineers that focus on the environmental, engineering, and economic benefits of using CCPs. This can be accomplished by sponsoring or hosting workshops and educational activities. Case studies highlighting economic savings and enhanced product performance using CCPs can also be documented and disseminated.

- Take advantage of state and federal programs to facilitate and fund demonstration projects. Local, long-term demonstration projects are perceived as being extremely valuable to state agencies.

- Use existing resources (DOE, EPA, ACAA, Western Region Ash Group, other state groups, university groups) to promote CCP use in states. These agencies have numerous outreach tools, research reports, and data available that support the beneficial use of CCPs.

- Continue to ensure quality CCP-containing products because one misuse can be detrimental to future CCP use.

- Foster new relations, particularly between electric generating companies and cement and concrete producers, to work collaboratively to increase CCP utilization. For example, joint investments could be made to develop infrastructure at the plant site.

- Launch your own public relations campaign to promote your company as being a good steward of the environment by using CCPs in an environmentally appropriate manner.

Recommendations to State Agencies

- Look to available resources, including those in other states, for guidance on use applications. Beneficial use applications that work in one state can generally work in another; however, state agencies should still remain cautious of special considerations (i.e., high water table) in their individual states.

- Participate in educational events at local, state, regional, and national levels as able.

- Review existing resources from industry groups, federal agencies, and universities to better understand use options. Oftentimes, new data does not need to be generated to support new uses.

- Communicate concerns to industry and participate in research and demonstration projects.

- Develop straightforward guidelines to qualify CCPs for specific use applications using guidelines in other states or federal guideline recommendations.

- Implement recycling initiatives that encourages state agencies to use CCPs, and educate them on the benefits of using CCPs.

Recommendation to Federal Agencies

- Provide state agencies with technical guidance on developing cautious guidelines for use. Successful case studies could be used to highlight potential applications.

- Provide economic incentives for using CCPs. These incentives could come in the form of tax credits or subsidies to any entity or consumer along the utilization chain, including electric generating companies, ash marketers, ready-mix suppliers, and end users.

- Continue to provide grants and other funding opportunities for research and development to address new technical challenges (i.e., CCP quality after new air emissions regulations are adopted).

- Track and promote the quantity of CCPs used in federal projects.

- Continue to offer educational opportunities and learning materials to state agencies and end users. Federal agencies tend to be perceived as offering unbiased information, so educational efforts supported by federal agencies can be seen as more credible.

- Cooperate with federal green-building initiatives (i.e., USGBC LEED, EPA Comprehensive Procurement Guidelines) to promote CCPs as a green material and develop standards that encourage greater use.

- Work toward consistent messages regarding CCP utilization within and between federal agencies, including definitions of beneficial use, releases, and use of terms (i.e., coal combustion products vs. fossil fuel waste).

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