COAL COMBUSTION PRODUCTS

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Electricity accounts for 35% of the energy consumed in the United States, and more than one-half the Nation's electricity is generated by burning coal. Coal burning, combined with pollution control technologies, generates large quantities of byproducts. During 2001, about 900 million metric tons (Mt) of coal was burned, and about 107 Mt of coal combustion products (CCPs) was generated by electric utilities and nonutilities.

Fly ash represents a major component (more than 58%) of CCPs produced, followed by flue gas desulfurization (FGD) material (24%), bottom ash (16%), and boiler slag (2%). Among the major CCP components, FGD material has shown the highest gains in the use rate in 2001 at about 28% of the amount produced (figs. 2-3). This is an increase of 50% compared with 2000 (table 1).

In 2000, the last year for which comprehensive site information is available, 293 electric powerplants used coal as the primary energy source in a total 2,776 electric power generating plants in 41 States (U.S. Department of Energy, December 2000§[1]). The American Coal Ash Association (ACAA) sent out production and consumption survey forms to 85 companies in the United States that owned 858 generating units.

Description and Terminology

The working definition for solid materials resulting from the combustion of coal has been evolving. Environmental regulators first used the term coal combustion wastes. Later, the term coal combustion byproducts gained popularity. Lately, CCPs has become a common term for those in the power industry, the ash marketers, and most users of these materials. The solids included in CCPs are fly ash, bottom ash, boiler slag, and FGD material (synthetic gypsum).

An American Society for Testing and Materials (ASTM) subcommittee under Committee E-50 on Environmental Assessment, on which the U.S. Geological Survey (USGS) is represented, was recently formed to address the question of standards and definitions of coal and CCP terms. The proposed definitions for some of the pertinent terms are as follows:

1. Fly ash is coal ash that exits in a combustion chamber in the flue gas and is captured by air pollution control equipment, such as electrostatic precipitators, baghouses, or wet scrubbers.
2. Class C fly ash is fly ash that meets criteria for that class as defined in ASTM C618 for use in concrete.
3. Class F fly ash is fly ash that meets criteria for that class as defined in ASTM C618 for use in concrete.
4. Bottom ash consists of agglomerated ash particles—which are formed in pulverized-coal boilers—that are too large to be carried in the flue gases and adhere to the boiler walls or fall through open grates to an ash hopper at the bottom of the boiler.
5. Boiler slag is molten ash collected at the base of the slag tap and cyclone boilers that is quenched with water and shatters into black, angular particles that have a smooth, glassy appearance.
6. FGD is the process of removing gaseous sulfur dioxide (SO_2) from boiler exhaust gas. Primary types of FGD processors are wet scrubbers and dry scrubbers; sorbent injection is another primary process. SO_2 sorbents include lime, limestone, sodium-based compounds, and high-calcium fly ash.
7. FGD material is the product of an FGD process that typically uses a high-calcium sorbent, such as lime or limestone. Sodium-based sorbent and high-calcium fly ash are also used in some systems. The physical nature of these materials varies from a wet, thixotropic sludge to a dry, powdered material, depending on the process.

FGD units remove SO_2 from flue gas but, in doing so, generate large quantities of synthetic gypsum (FGD material), which is a mixture of gypsum ($CaSO_4{\bullet}2H_2O$), calcium sulfite ($CaSO_3$), fly ash, and unreacted lime or limestone. A number of powerplants convert the $CaSO_3$ to calcium sulfate ($CaSO_4$) by forced oxidation and take appropriate measures to reduce other impurities in the synthetic material and, thus, produce synthetic gypsum that meets or exceeds the specifications for wallboard manufacture. Wallboard plants that have been recently constructed adjacent to such electric utilities use the FGD gypsum from those electric utilities. About 26 Mt of FGD material was produced in 2001, and about 7.3 Mt (28%) was used, mostly for wallboard manufacture.

FGD issues affect, directly or indirectly, coal, gypsum, lime, limestone, and soda ash industries. Increased commercial use of FGD products represents an economic opportunity for high-sulfur coal producers and the sorbent industry. Synthetic gypsum competes directly with natural gypsum as raw material for wallboard and cement manufacture. The value of CCPs is well-established by research and commercial practice in the United States and abroad. As engineering materials, these products can add value while helping conserve the Nation's natural resources.

Legislation and Government Programs

The Resource Conservation and Recovery Act (RCRA), enacted in 1976, has been the primary statute governing the management and use of CCPs. These have been the subject of investigation by the U.S. Environmental Protection Agency (EPA), which published its regulatory determination on wastes from the combustion of fossil fuels in May 2000 (U.S.

[1]A reference that includes a section twist (§) is found in the Internet Reference Cited section.

Environmental Protection Agency, 2000). The agency concluded that CCPs do not pose sufficient danger to the environment to warrant regulation as hazardous under section 3001(b)(3)(C) of subtitle C of the RCRA. However, the EPA also determined that national regulations under subtitle D of the RCRA are warranted for CCPs when they are disposed of in landfills or surface impoundments. Furthermore, possible modifications to existing regulations established under the authority of the Surface Mining Control and Reclamation Act are warranted when they are used to fill surface or underground mines.

The EPA remains critical of State programs and emphasizes the need for Federal Government oversight to ensure that minefilling is done appropriately to protect human health and the environment, particularly since minefilling is a recent but rapidly expanding use of CCPs (U.S. Environmental Protection Agency, 2000, p. 32231).

The majority of electric power utilities, especially in the Eastern and Midwestern States, burn high-sulfur bituminous coal. Increased consumption of high-sulfur coal has contributed to an acid rain problem in North America. To address this problem, the U.S. Congress passed the Clean Air Act Amendments of 1990 (CAAA) (Public Law 101-549) with stringent restrictions on sulfur oxide emissions. The SO_2 reduction provisions of the CAAA, which would be implemented in a two-phase plan to be completed by 2010, forced electric utilities to find ways to reduce SO_2 emissions. A number of utilities have switched to alternative fuels, such as low-sulfur coal or fuel oil, as partial or temporary solutions to the problem. A significant number of electric utilities still using high-sulfur coal have installed FGD units.

The CAAA takes a new nationwide approach to the acid rain problem. The law sets up a market-based system designed to lower SO_2 emissions. Beginning in the year 2000, annual releases of SO_2 would be about 40% lower than the 1980s levels. With the start of the implementation of phase II of the CAAA, all powerplants will have to install continuous emission monitoring systems (CEMS), which are instruments that monitor SO_2 and nitrogen oxide (NOx) emissions. A powerplant's program for meeting these requirements will appear on the plant's permit, which will be filed with the State and the EPA.

Since the passage of the CAAA, a number of important studies published show that breathing particulate matter at the concentration allowed by the current standard can have significant health effects—including premature death and an increase in respiratory illness. Also, the EPA argues that the current standard does not adequately protect visibility—defined as the ability of the human eye to perceive distance, color, contrast, and detail.

The current standards apply to particulates up to 10 micrometers (μm) in diameter. Studies, however, indicate that it is the smaller particles—less than 2.5 μm in diameter—that are largely responsible for the health effects of greatest concern and for visibility impairment. Based on this information, the EPA has issued final regulations to rectify the particulate matter standards by adding new statements that provide more stringent goals for fine particles in air (U.S. Environmental Protection Agency, 2000). The EPA estimates that the new standards will reduce premature deaths by about 15,000 per year and serious respiratory problems in children by about 250,000 cases per year.

The Surface Mine Conservation and Recovery Act (SMCRA) did not directly contemplate the disposal of solid wastes in a coal mine other than wastes generated by coal mining operations (i.e., coal processing waste, noncoal mine waste, underground development waste, and spoil). CCPs are directly referenced in the regulations of the U.S. Department of the Interior's Office of Surface Mining (OSM) only at 30 CFR §§817.41(h)(2)(iii) and (v), which include fly ash and FGD material in the seven allowable types of discharges into an underground coal mine. In the same vein, the lack of direct regulations for the placement of CCPs in coal mines does not counteract the application of the SMCRA to regulating CCP placement in coal mines. All permitting and performance regulatory standards apply to CCPs and any other materials that may be placed in coal mines.

A State regulatory authority has primary regulatory responsibility for coal exploration and surface coal mining and reclamation operations during the permanent regulatory program. Once the State program is in effect, the OSM has the oversight function of evaluating the administration of those programs. The OSM must institute a Federal regulatory program for Federal and Indian lands in a State that does not have a program.

Production

Production data are compiled from a survey sent to electric utilities by the ACAA. In 2001, out of 85 survey forms mailed, 42 responses were received compared with 25 and 35 in 2000 and 1999, respectively. The 42 responses received in 2001 represent 511 of 858 power generating units owned by the 85 utilities that received the survey forms. This translates into a 60% response rate for 2001. Response rates for 2000 and 1999 are 36% and 50% respectively. Significantly lower response rates for 1999 and 2000 may have led to underestimation of the CCP quantities generated in these years.

The majority of the utilities surveyed are in the Northwest and the Midwest. The respondents report production and consumption numbers for each category as well as the quantity of coal burned. Production and use rates of CCPs for the years 1997 through 2001 have been rather steady, with the exception of 2001, which registered an increase from that of the previous year (table 1). CCP production totaled more than 107 Mt in 2001, a 9% increase compared with that of 2000. The increase in the production of FGD material to 25.9 Mt in 2001 from 23.3 Mt in 2000 accounts for 2.5% of the 9% increase. The quantity of coal consumed by the electricity producers (utility and nonutility) was 981 Mt and 992 Mt for 2001 and 2000, respectively. The observed increase in CCP production, therefore, cannot be explained on the basis of coal burned. The use of higher ash-content coal at the start of the implementation of phase II of the CAAA is highly improbable. The rest of the reported increase in 2001 can partly be explained by more accurate data gathering in 2001, resulting from a higher rate of response to the 2001 ACAA survey.

CCP production estimates are based on transportation to a use, a storage, or a disposal site. For CCPs that are kept in ponds, production numbers may be based on the ash content of the coal burned or on the actual tonnages when the ash is removed from the pond. Many of the consumption numbers reported are based on how much CCP leaves the storage site based on trucks passing over a scale. Tonnages for some bulk uses are based on the capacity of trucks doing the hauling. Most unused CCPs are placed in landfills or impoundments. For many utilities, landfilling and impounding the unmarketed or unmarketable CCPs is economically the most viable method. However, landfills are not always cheaper when capital costs and land acquisition are included in the costs. As a result, many utilities are increasing their marketing efforts to avoid the cost of developing new landfills necessary to store increasing quantities of CCPs.

Electric utilities faced with the requirement of meeting the new sulfur oxide emission levels imposed by the CAAA started to switch to alternative fuels, especially natural gas. During the past 5 years, this has resulted in the share of coal used in the Nation's electric powerplants decreasing to less than 45% from almost 65%. In 2000 (the most recent year for which data are available), 1,024 coal-burning units were in operation in 41 States, with the number of units ranging from 1 (in Alaska) to 105 (in Ohio) and only 1 coal-burning unit reported as being in the planning stage. Several States (Alaska, Montana, New Jersey, Oregon, and South Dakota) had fewer than four units that produced only a small fraction of their electricity from burning coal, and nine States (California, Connecticut, Hawaii, Idaho, Maine, Rhode Island, Vermont, and Washington) did not operate any coal-burning units. Indiana met the largest fraction (92%) of its electricity needs from coal-burning units, followed by Ohio (82%). Ohio produced the largest quantity of electricity from coal [23,051 megawatts (MW) of 28,057 MW total]. Indiana (20,530 MW of 22,661 MW total) and Texas (20,477 MW of 67,916 MW total) followed Ohio in quantity of electricity produced from coal.

In an effort to improve data collection procedures, the ACAA is considering asking for additional information in the survey forms, including the quantity of coal burned for power generation, coal quality (ash and sulfur content), the British thermal unit value of coal burned, the number of boilers retired, the number of new units commissioned, any new FGD units installed, and the sources and quantities of sorbents consumed. Ash content of coal burned, if reported, can be used to estimate approximate fly ash and bottom ash generated, which can be compared with the reported ash quantities to form an opinion on the accuracy and completeness of the data collected. The lack of data on coal quality in 2001 does not allow a check of the accuracy of the reported data.

The commencement in January 2000 of phase II of the CAAA offers an additional explanation for the reported increase in FGD material generation. To meet the more stringent emission standards under phase II, many utilities are planning ahead by overcomplying in phase I. As a long-term solution, some utilities are installing scrubbers instead of less expensive options. A survey of 116 utilities conducted by Industrial Information Services Company found that 41% of respondents will switch to cleaner fuels for phase II, and 28% will acquire additional emission allowances (Melvin Johnson, U.S. Department of Energy, Energy Information Administration, oral commun., 2002).

The energy policy of the current [2001] administration that calls for increased use of fossil fuels, especially coal, in electric power generation may lead to further increases in the generation of CCPs. The administration, however, has budgeted significant funds to be used in research directed towards development of clean coal technology that may ultimately lead to reduction in the generation of CCPs by coal-burning utilities.

Retirement of a number of old, inefficient wet bottom boilers mainly accounts for the decrease in the production of boiler slag. Wet bottom units are inefficient, and therefore, many utilities retire the old units and use the rest only for peak power generation. The U.S. Department of Energy's Energy Information Administration (EIA) does not survey boiler slag, and therefore, no adjustments could be made using EIA data.

Consumption

Total CCP use in 2001 increased to 36.87 Mt from 28.59 Mt in 2000, a 29% increase. Fly ash and bottom ash uses increased by 14% and 20%, respectively, whereas boiler slag decreased by 18%. FGD material use increased by 50% from 2000 (table 1). The analysis of the increases in production rates also applies to the observed increase in use rates.

Owing to their chemical and physical properties, different CCPs are suitable for different uses. CCPs are used in agriculture, blasting grit, cement, concrete, mine backfill, and roofing applications. Other current [2001] uses include road base and subbase, wallboard production (FGD gypsum), and waste stabilization. Potential FGD material uses also include applications in subsidence and acid mine drainage control and as fillers and extenders (tables 2-4).

Among CCPs, fly ash was used in the largest quantities and found the widest range of applications, with construction applications accounting for about 60% of consumption, followed by structural fills and waste stabilization (fig. 4). Structural fill, ice control, and road base and subbase applications are major bottom ash uses. About 66% of bottom ash is used in road base and subbase, structural fill, and snow and ice control (fig. 5). Other uses include concrete, mining applications, and cement clinker raw feed. Bottom ash can also be used as fine aggregate in asphalt paving mixtures. Some bottom ash is sufficiently well-graded that pavements containing bottom ash alone can meet gradation requirements. It is used more commonly in cold-mix emulsified asphalt mixtures where gradation requirements and durability are not as critical as in hot-mix surface mixtures.

Owing to its abrasive properties, boiler slag is used almost exclusively in the manufacture of blasting grit. Use as roofing granules is also a significant market. Blasting grit and roofing granules make up almost all (97%) boiler slag applications (fig. 6). Boiler slag can also be used as fine aggregate, especially in hot-mix asphalt owing to its superior hardness, affinity for asphalt, and dust-free surface, which aid in asphalt adhesion and resistance to stripping. Since boiler slag exhibits a uniform particle size, it is commonly blended with other aggregates for use in asphalt mixtures.

Wallboard manufacture accounts for the bulk (83%) of FGD material uses (fig. 7). Cement and concrete account for a majority of other uses of FGD material. Agricultural uses account for only 1.5% of total FGD material use. However, the potential for FGD material use in agriculture exceeds even its use in wallboard manufacture. This potential has yet to be substantiated through demonstration projects.

World Review

Data were obtained from major European and Asian countries, including China, India, the Republic of Korea, and Russia (table 5). Data from European Union countries are combined under the European Coal Combustion Products Association (ECOBA), comprising Belgium, France, Germany, Greece, Ireland, the Netherlands, Poland, Portugal, Spain, and the United Kingdom. ECOBA members, as reported, account for more than 90% of CCP production in Europe.

In 2000, the ECOBA used more than 53% (32 Mt) of the 59.3 Mt of CCPs its member countries generated compared with about 34% used in the United States. More than 18 Mt of the 39 Mt of fly ash produced was used (47% use rate). A somewhat smaller fraction (40%) of bottom ash, 100% of boiler slag, and 67% of synthetic gypsum produced found beneficial uses (table 5). Raw material shortages and favorable state regulations account for the higher use rates of CCPs in Europe. As in the United States, ECOBA members used CCPs in a number of applications, with concrete leading the way at 27%, followed by portland cement manufacture with 20%. Various other uses made up the remainder.

Canada, India, Israel, Japan, the Republic of Korea, South Africa, and Turkey reported partial data. Canada used about 1.8 Mt (23%) of 7.8 Mt of CCPs produced. Coal-burning electric utilities in India generated 94 Mt of CCPs in 2000, of which about 13% (12.5 Mt) was used. The remainder was disposed of in wet ponds. Japan produced 10.1 Mt and used 8.5 Mt. These figures translate into an 84% use rate for Japan. The high disposal cost of CCPs in Japan ($100.00 per metric ton) make alternative uses economically viable (Mark Early, Barlow Junker Pty Ltd., oral commun., 2001).

Large-volume CCP use in India, China, and the Republic of Korea is an environmental and economic necessity owing to the planned increase in coal-fired powerplants to meet future electricity needs and the high ash content of coal burned. In 2001, burning of coal in China and India that contains 40% to 45% mineral matter generates more than 90 million metric tons per year (Mt/yr) of CCPs. The situation in the Republic of Korea is even more serious owing to the fact that the country burns more coal for electricity production than any other country in the world. Coal in the Republic of Korea also contains high fractions of mineral matter, which result in the generation of CCP quantities four times (per metric ton of coal burned) that of the United States (Ji-Young Ryu, Korea Electric Power Corp., written commun., 2002).

Current Research and Technology

Research and development efforts in FGD have been directed, for the most part, toward either decreasing the quantities of the reaction products or increasing their economic value to upgrade them from waste products to resources.

Consol Energy Corporation is successfully manufacturing aggregates from CCPs using a pelletization process it developed (Aggregates Manager, 2000). Fly ash and synthetic gypsum are combined by disk pelletization with moderate-temperature curing to form aggregates. If commercialized, such manufactured aggregates may eventually play an important role in the 2.7-billion-metric-ton-per-year aggregates market.

In order to reduce NOx emissions to meet the requirements of the CAAA restrictions, many electric utilities installed no-NOx burners. No-NOx burners, however, lead to a significant increase in the unburned carbon content in fly ash, in certain cases exceeding 10%. High carbon content renders fly ash unsuitable for cement and concrete applications, which account for the bulk of fly ash consumption. Excess unburned carbon in concrete-containing fly ash cement reduces the freeze-thaw resistance of concrete by capturing the air-entraining agents that are used to modify the microstructure by introducing controlled porosity.

Researchers at The Pennsylvania State University have developed a method to economically separate unburned coal from fly ash (Skillings Mining Review, 1999). It appears that the unburned carbon separated from the fly ash is suitable for manufacturing activated carbon, which is used in water treatment and gas purification processes. These carbon products have a significant market with 350,000 metric tons per year sold. The unburned carbon, separated from fly ash, does not need cleaning or grinding, nor does it need heating to remove volatiles, and it can be separated for $10 to $15 per ton of fly ash. This would present several benefits, including the use of waste material that would otherwise require disposal and the elimination of the cost incurred by the disposal, cleaning fly ash so that it is usable by concrete or cement producers, and creating more activated carbon for consumption. Anthracite, which is currently (2001) used as the precursor in the manufacture of activated carbon, sells for about $50.00 per metric ton.

Maxam Gold Corp. developed a laboratory technique for winning metal values from fly ash. Preliminary laboratory tests indicated that 79% to 98% of several metals in commercial quantities are extractable using the Maxam process technology (Dale L. Runyon, Maxam Resource Recovery, LCC, oral commun., 2002). Analysis of the processed fly ash samples revealed that all environmentally detrimental elements were reduced to acceptable levels, allowing the fly ash to meet the EPA ground water quality standards.

Reports of research and development results during the past two decades indicate that an increase in the development of uses for CCPs will happen in small steps. At the 14th International Symposium on Management and Use of Coal Combustion Products held in San Antonio, TX, in January 2001, researchers from industry, academia, and Federal and State governments made presentations that covered a range of topics from characterization to applications of CCPs in acid mine abatement, agriculture, landfills, manufacture of building blocks, mine backfilling, and recovery of high value rare-earth metals (American Coal Ash Association, 2001).

The perception of potential harm to the environment leads to government policies that translate into rigid barriers to the use of CCPs. The recent decision by the EPA to list CCPs under subsection D of the RCRA, which classifies CCPs as potentially hazardous in mine reclamation and mine backfill applications, is a serious barrier to the use of CCPs in mine applications. Researchers and marketing professionals have been making efforts to remove such barriers to the use of these materials.

Outlook

Two principal factors that will affect the size of the coal market and, therefore, quantities of CCPs generated are market deregulation and emissions regulations. The administration's energy policies and market deregulation will encourage electric utilities to search for the lowest cost fuel, and that may well be coal. Increased use of coal will lead to generation of increased quantities of ash. Moreover, there is the need to comply with phase II of the CAAA, which went into implementation in January 2000 and is causing increases in the generation of FGD material. Phase II of the CAAA capped powerplant SO_2 emissions nationally at 7.72 Mt/yr. As of January 2000, there were about 10 Mt of SO_2 allowances available for sale to noncompliant plants. The allowances were accrued during phase I of the CAAA. Quick disappearance of emission allowances will force utilities to switch to cleaner fuels or to retrofit powerplants with emission control systems.

In 2001, power generation systems with more than 10,000-MW capacity supported FGD units, limestone units with more than 6,000-MW capacity, and lime units with nearly 4,000-MW capacity are under construction. Moreover, the construction of limestone systems with 7,000-MW capacity and lime systems with 6,000-MW capacity are in the planning stage. When operational, these systems are expected to almost triple the quantity of FGD material to 75 to 80 Mt/yr from the current level of 26 Mt/yr. With continued installation of FGD units, FGD material production could double the amount of CCPs currently being generated. This, combined with the potential effect of future EPA rulemaking, presents a formidable challenge to electric utilities and CCP-user industries—to find more uses and increase consumption.

Technical, economic, institutional, and regulatory barriers to use of large quantities of CCPs will have to be overcome in the long term. Technical and economic barriers are not mutually exclusive in that technologic advancements usually result in economic efficiency. Principal technical barriers include issues related to CCP production, specifications and standards, materials characterization, product demonstration and commercialization, and user-related factors.

Economic barriers to increased CCP use can be key among all factors affecting byproduct use. With proper economic incentives, other barriers to increased use of CCPs can be overcome. For coal-burning electric utilities, revenue from the sale of CCPs is often insignificant. The high cost of transporting the low unit-value CCPs and competition from locally available natural materials are two of the most important economic barriers.

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Skillings Mining Review, 1999, Penn State researchers study use of coal byproducts: Skillings Mining Review, v. 88, no. 13, March 27, p. 9.
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GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Gypsum. Ch. in Mineral Commodity Summaries, annual.
Gypsum. Ch. in Minerals Yearbook, annual.
Gypsum. Mineral Industry Surveys, monthly.

TABLE 1

HISTORIC COAL COMBUSTION PRODUCT PRODUCTION AND CONSUMPTION 1/

(Thousand metric tons)

	1997	1998	1999	2000	2001
Fly ash:					
Production	54,700	57,200	56,900	57,100	61,800
Consumption	17,500	19,200	18,900	17,600	20,000
Percentage use	32.10	33.60	33.20	30.90	32.30
Bottom ash:					
Production	15,400	15,200	15,300	15,400	17,100
Consumption	4,600	4,760	4,930	4,460	5,750
Percentage use	30.20	31.30	32.10	29.00	33.70
Boiler slag:					
Production	2,490	2,710	2,620	2,430	2,300
Consumption	2,340	2,170	2,150	2,120	1,650
Percentage use	94.10	80.10	81.80	87.00	71.70
Flue gas desulfurization material:					
Production	22,800	22,700	22,300	23,300	25,900
Consumption	1,980	2,260	4,030	4,380	7,300
Percentage use	8.67	10.00	18.10	18.80	28.20
Total coal combustion products:					
Production	95,400	97,800	97,100	98,200	107,000
Consumption	26,500	28,400	30,000	28,600	34,700
Percentage use	27.80	29.00	30.80	29.10	32.40

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Coal Ash Association.

TABLE 2

TOTAL COAL COMBUSTION PRODUCT PRODUCTION AND CONSUMPTION IN 2001 1/

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	Flue gas desulfurization material	Total coal combustion products 2/
Production	61,800	17,100	2,300	25,900	107,000
Consumption:					
Agriculture	20	20	--	100	140
Blasting grit and roofing granules	--	40	1,350	--	1,390
Cement clinker raw feed	940	710	--	440	2,090
Concrete-grout	11,200	710	--	440	12,400
Flowable fill	730	10	--	--	740
Mineral filler	100	10	10	--	120
Mining applications	740	110	--	130	980
Road base and subbase	930	550	--	40	1,520
Snow and ice control	--	770	20	--	790
Soil modification	670	100	--	--	770
Structural fills	2,910	1,050	10	170	4,140
Wallboard	--	--	--	5,650	5,650
Waste stabilization and solidification	1,310	60	--	40	1,410
Other	410	1,610	260	280	2,550
Total	20,000	5,750	1,650	7,300	34,700
Individual use percentage	32.30	33.70	71.70	28.20	XX
Cumulative use percentage	32.30	32.60	33.70	32.40	32.40

XX Not applicable. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes categories I and II, dry and ponded, respectively.

Source: American Coal Ash Association.

TABLE 3
DRY COAL COMBUSTION PRODUCT PRODUCTION AND CONSUMPTION IN 2001 1/

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	Flue gas desulfurization material	Total coal combustion products
Production	46,600	12,000	790	17,000	72,300
Consumption:					
Agriculture	20	20	--	90	130
Blasting grit and roofing granules	--	30	370	--	400
Cement clinker raw feed	620	120	--	30	770
Concrete-grout	11,000	650	--	440	12,100
Flowable fill	110	10	10	--	130
Mineral filler	90	10	10	--	110
Mining applications	570	90	--	100	760
Road base and subbase	930	360	--	40	1,330
Snow and ice control	--	600	--	--	600
Soil modification	670	100	--	--	770
Structural fills	2,840	470	10	170	3,490
Wallboard	--	--	--	4,030	4,030
Waste stabilization and solidification	870	60	--	40	970
Other	20	910	190	220	1,340
Total	17,800	3,430	580	5,160	26,900
Individual use percentage	38.10	28.80	73.40	30.40	XX
Cumulative use percentage	38.10	36.20	36.70	35.30	35.30

XX Not applicable. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Coal Ash Association.

TABLE 4
PONDED COAL COMBUSTION PRODUCT PRODUCTION AND CONSUMPTION IN 2001 1/

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	Flue gas desulfurization material	Total coal combustion products
Production	15,300	5,130	1,510	8,840	30,800
Consumption:					
Agriculture	--	--	--	10	10
Blasting grit and roofing granules	--	10	980	--	990
Cement clinker raw feed	320	20	--	--	350
Concrete-grout	210	50	--	--	260
Flowable fill	620	--	--	--	620
Mineral filler	10	--	--	--	10
Mining applications	170	20	--	30	220
Road base and subbase	--	190	--	--	190
Snow and ice control	--	180	20	--	200
Soil modification	--	--	--	--	--
Structural fills	70	580	--	--	650
Wallboard	--	--	--	1,620	1,620
Waste stabilization and solidification	440	10	--	--	440
Other	390	690	60	60	1,200
Total	2,230	1,760	1,060	1,710	6,760
Individual use percentage	14.60	34.30	70.20	19.30	XX
Cumulative use percentage	14.60	19.50	23.00	22.00	22.00

XX Not applicable. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Coal Ash Association.

TABLE 5
WORLD PRODUCTION AND CONSUMPTION OF COAL COMBUSTION PRODUCTS IN 2001 1/

(Thousand metric tons, unless otherwise noted)

Country or association	Fly ash	Bottom ash	Boiler slag	Fluidized bed combustion ashes	Other	Spray dryer absorbent product	Flue gas desulfurization gypsum	Total	Percentage of use
European Coal Combustion Products Association:									
Production	39,000	5,580	2,350	1,020	277	460	10,700	59,300	XX
Consumption:									
Cement raw material	4,420	165	--	29	--	--	--	4,620	7.8
Blended cement	2,000	--	--	1	--	--	--	2,000	3.4
Concrete addition	5,980	--	156	--	--	--	--	6,140	10.3
Aerated concrete blocks	745	62	--	--	--	--	--	807	1.4
Nonaerated concrete blocks	343	970	--	--	--	--	--	1,310	2.2
Lightweight aggregate	14	52	--	--	--	2	--	68	0.1
Bricks and ceramics	68	5	--	--	10	--	--	83	0.1
Grouting	389	--	--	--	--	--	--	389	0.7
Asphalt filler	202	--	168	--	--	--	--	370	0.6
Subgrade stabilization	251	68	--	--	--	--	--	319	0.5
Pavement base course	414	218	1,220	38	--	--	--	1,890	3.2
General engineering fill	1,290	542	--	182	37	25	--	2,080	3.5
Structural fill	1,240	141	--	--	--	--	--	1,380	2.3
Soil amendment	175	--	--	58	--	78	--	311	0.5
Infill	577	--	--	357	--	244	--	1,180	2.0
Blasting grit	--	22	720	--	--	--	--	742	1.3
Plant nutrition	30	--	--	--	--	28	--	58	0.1
Set retarder for cement	--	--	--	--	--	--	793	793	1.3
Projection plaster	--	--	--	--	--	--	778	778	1.3
Plaster boards	--	--	--	--	--	--	5,500	4,500	7.6
Gypsum blocks	--	--	--	--	--	--	245	245	0.4
Self-leveling floor screeds	--	--	--	--	--	--	1,330	1,330	2.2
Other	84	5	90	15	230	26	10	460	0.8
Total	18,200	2,250	2,354	680	277	403	7,650	31,800	53.7
Landfill, reclamation, restoration	17,000	2,620	NA	182	NA	33	733	20,600	34.7
Temporary stockpile	2,340	95	NA	NA	NA	NA	1,310	3,740	6.3
Disposal	2,070	614	NA	153	NA	24	948	3,810	6.4
Utilization rate percent	89.00	87.00	100.00	85.00	100.00	95.00	79.00	XX	XX
Canada:									
Production	5,500	1,800	NA	NA	NA	NA	500	7,800	XX
Consumption	1,100	200	NA	NA	NA	NA	500	1,800	23.0
India:									
Production	NA	NA	NA	NA	NA	NA	NA	94,000	XX
Consumption	NA	NA	NA	NA	NA	NA	NA	12,500	13.0
Israel:									
Production	NA	NA	NA	NA	NA	NA	NA	1,320	XX
Consumption	NA	NA	NA	NA	NA	NA	NA	1,290	98.0
Japan:									
Production	7,000	1,400	NA	NA	NA	NA	1,700	10,100	XX
Consumption	6,000	1,000	NA	NA	NA	NA	1,500	8,500	84.0
Korea, Republic of:									
Production	NA	NA	NA	NA	NA	NA	NA	300,000	XX
Consumption	NA	NA	NA	NA	NA	NA	NA	15,000	5.0
South Africa:									
Production	2,000	NA	NA	NA	NA	NA	NA	2,000	XX
Consumption	NA	NA	NA	NA	NA	NA	NA	NA	NA
Turkey:									
Production	NA	NA	NA	NA	NA	NA	NA	20,000	XX
Consumption	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA Not available. XX Not applicable. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

FIGURE 1
HISTORIC COAL COMBUSTION PRODUCTS PRODUCTION DATA FROM 1997 TO 2001

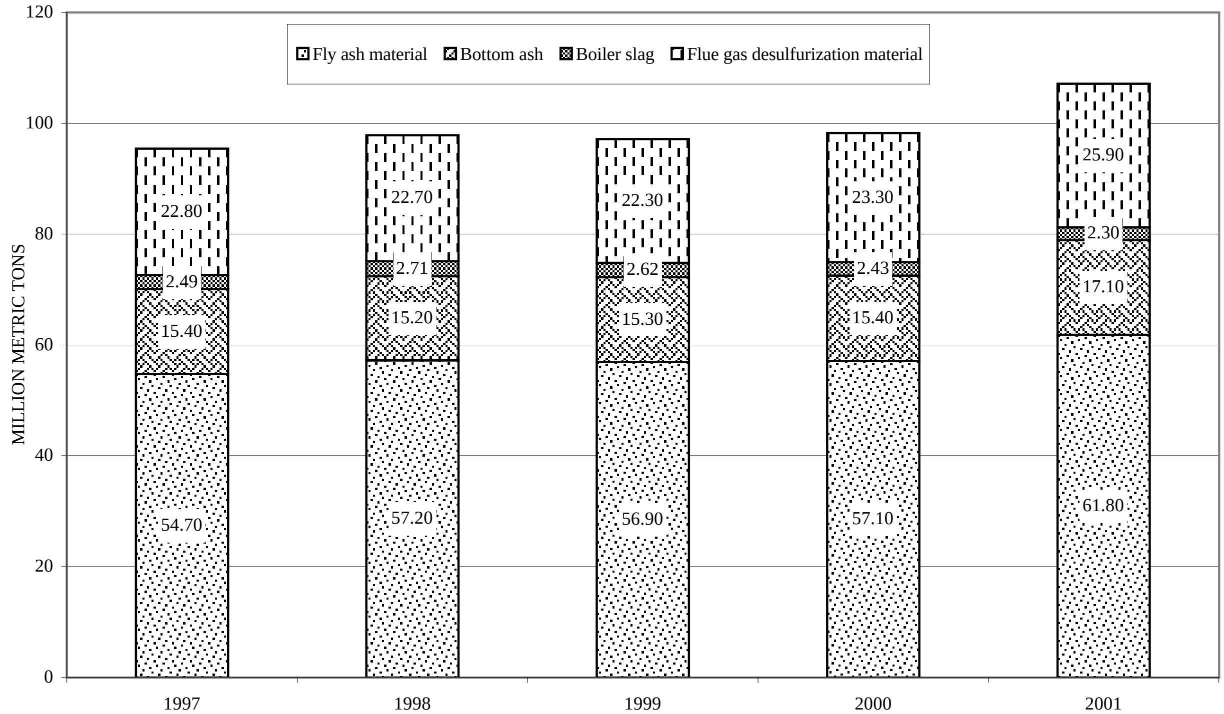

FIGURE 2
HISTORIC COAL COMBUSTION PRODUCTS CONSUMPTION DATA FROM 1997 TO 2001

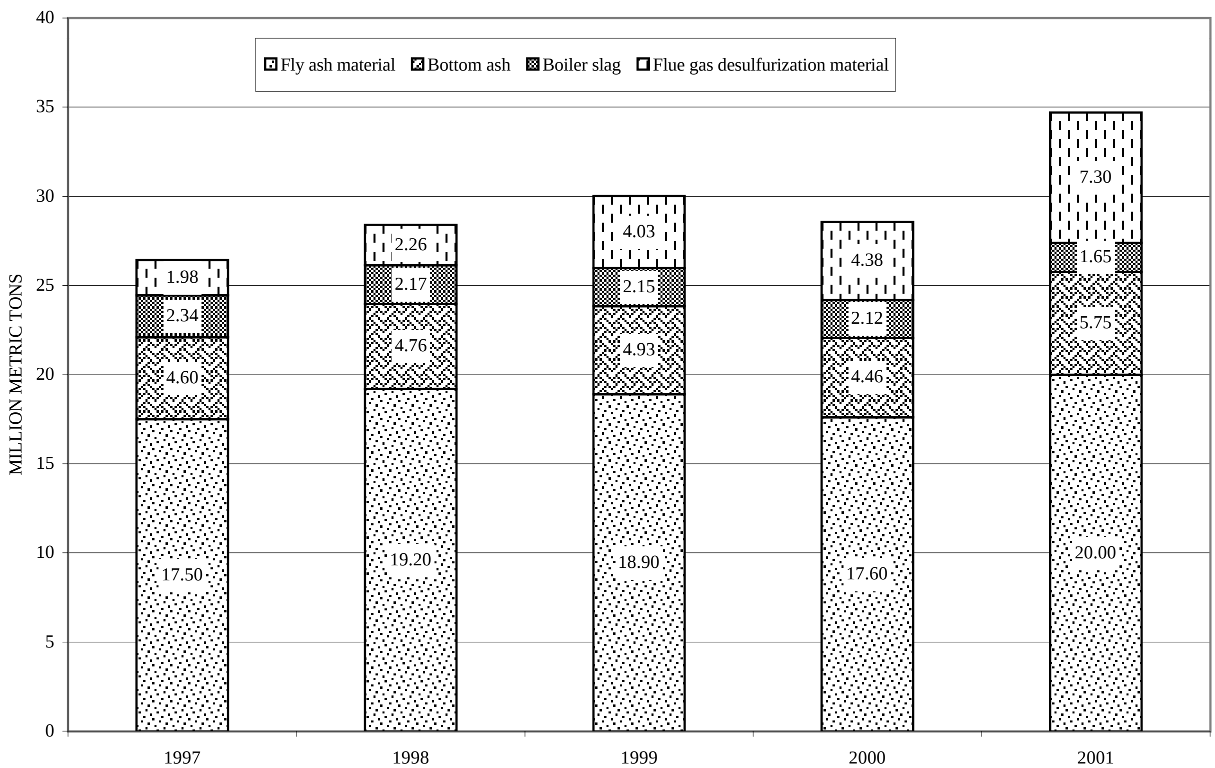

FIGURE 3
PRODUCTION AND CONSUMPTION OF COAL COMBUSTION PRODUCTS IN THE UNITED STATES IN 2001

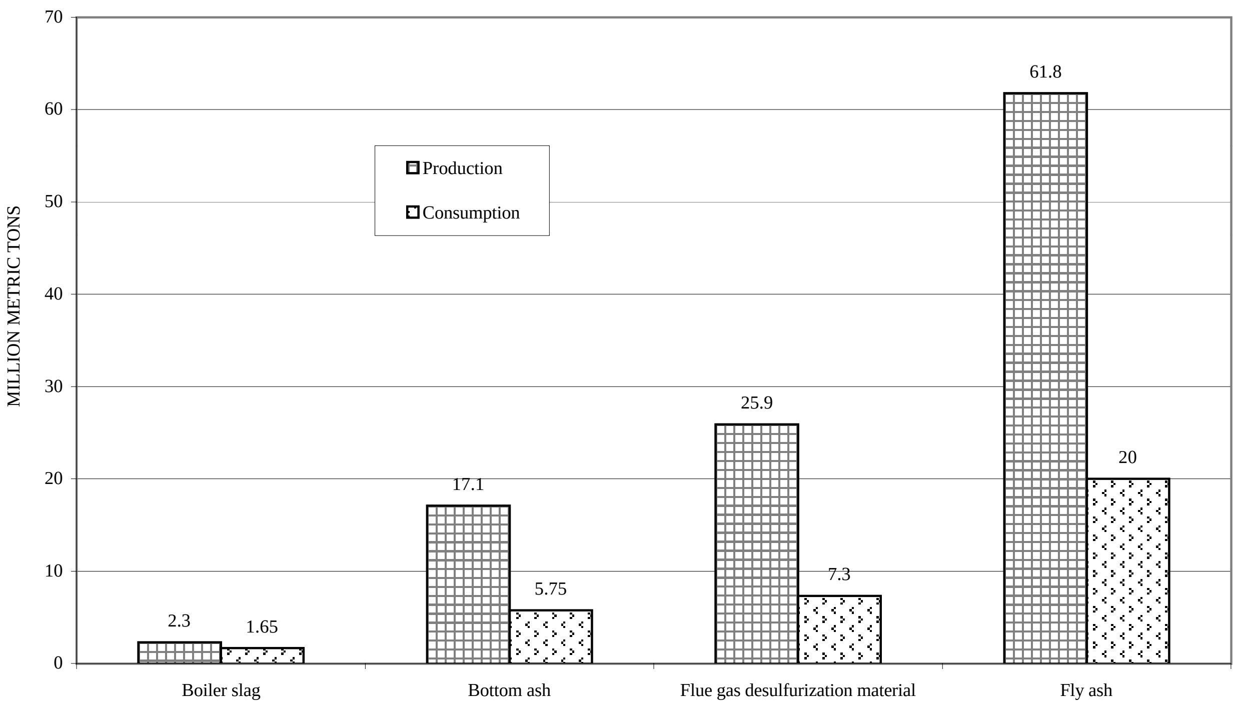

FIGURE 4
LEADING FLY ASH USES IN 2001

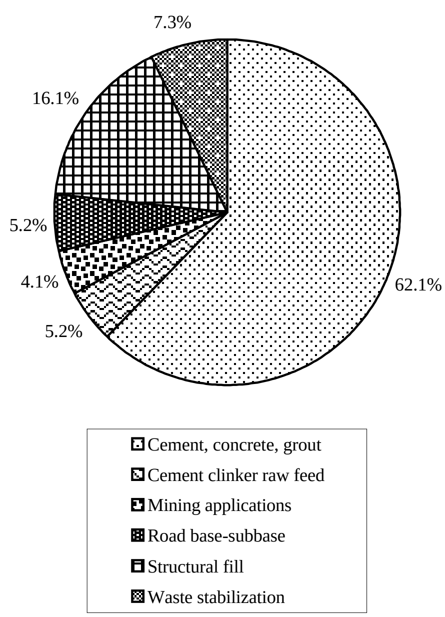

FIGURE 5
LEADING BOTTOM ASH USES IN 2001

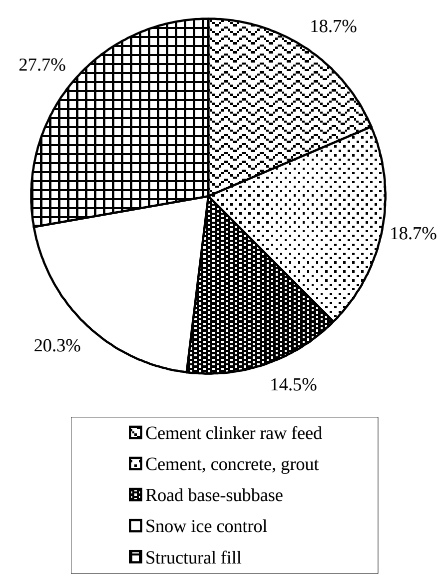

FIGURE 6
LEADING BOILER SLAG USES IN 2001

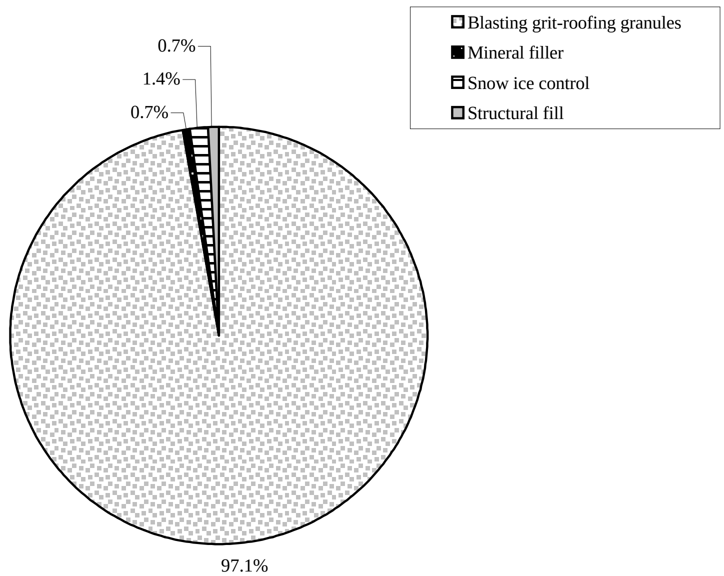

FIGURE 7
LEADING FLUE GAS DESULFURIZATION MATERIAL USES IN 2001