

# PRODUCTION AND USE OF COAL COMBUSTION PRODUCTS IN THE U.S.

*Historical Market Analysis*

**PREPARED BY: AMERICAN ROAD & TRANSPORTATION BUILDERS ASSOCIATION**

**PREPARED FOR: AMERICAN COAL ASH ASSOCIATION**

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## **ABOUT ARTBA**

Established in 1902, the American Road & Transportation Builders Association's (ARTBA) membership includes over 6,000 private and public sector representatives that are involved in the planning, designing, construction and maintenance of the nation's roadways, waterways, bridges, ports, airports, rail and transit systems.

## **ABOUT THE AUTHOR**

This research was conducted by Dr. Alison Premo Black, senior vice president and chief economist for the American Road & Transportation Builders Association in Washington, D.C.

Dr. Black, who earned her PhD in Economics at The George Washington University in the Nation's Capital, also holds an M.A. in International Economics and Latin American Studies from the Johns Hopkins School of Advanced International Studies. She graduated magna cum laude from Syracuse University, where she was a member of Phi Beta Kappa and the Golden Key Honors Society, with majors in International Relations, Latin American Studies and Spanish. Since joining ARTBA in 2000, Dr. Black has led teams and authored over 75 studies examining state transportation funding and investment patterns and was responsible for the 2011 report "The Economic Impacts of Prohibiting Coal Fly Ash Use in Transportation Infrastructure Construction."

## **ACKNOWLEDGMENTS**

This study relied on historical data on coal combustion products (CCPs) compiled by the American Coal Ash Association (ACAA), considered the authoritative source for CCP production and use statistics in the U.S. ACAA conducts a voluntary annual survey of the coal-fueled electric utility industry to track quantities of CCPs produced and beneficially used. The annual CCP Production & Use Survey Report has been used by industry and government agencies including the Environmental Protection Agency and the Department of Energy.

This study relied on energy data related to electric generation, projected coal unit retirements, fuel costs, and CCP disposition from the U.S. Energy Information Administration (EIA). The EIA collects, analyzes and disseminates independent and impartial energy information for policymakers and public understanding. The EIA publishes the Annual Energy Outlook and data collected directly from generators on numerous annual survey forms.



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# EXECUTIVE SUMMARY

Coal combustion products (CCPs) are valuable materials that have numerous applications, including the construction of dams, bridges and highways; building products; manufacturing; mining and agricultural uses. Products containing CCPs can be found in nearly every U.S. home, including gypsum wallboard, foundations, roofing shingles and concrete driveways. CCPs are the solid byproducts from burning coal to produce electricity. Although collectively known as “coal ash,” CCPs are a class of materials that have varied chemical and physical characteristics and include fly ash, bottom ash, flue gas desulfurization (FGD) material, boiler slag and fluidized bed combustor (FBC) ash.

The use of coal ash in concrete (specifically fly ash) dates back to the construction of the Hoover Dam. By the 1970s, the use of fly ash was encouraged for roadway and interstate highway construction by the Federal Highway Administration (FHWA). The utilization of CCPs as replacement for mined or manufactured materials has been increasing over the last four decades. Since 1974, the American Coal Ash Association (ACAA) has collected data on the production and utilization of CCPs in the U.S. This study is the first to examine historical trends in annual production and utilization from 1974 to 2013.

This study was undertaken to examine the impacts of economic and regulatory factors on past CCP production and utilization. Relationships between the CCP data and other economic factors, including electricity demand and generation, U.S. recessions and changes in markets for CCPs, were analyzed using a variety of data sources and economic models. Details on this econometric analysis, which is the basis of a 20-year forecast for CCP production and use, can be found in a companion document.

Regulatory and policy factors include major environmental regulations affecting coal-fueled electricity generation, technologies for emissions reductions, regulatory uncertainty and standards and specifications pertaining to CCPs.

## CCP PRODUCTION 1974 – 2013

Once accounting for over 50 percent of total electric generation, coal-fueled power generation has fallen to just over 40 percent in 2013 due to a number of factors. Environmental regulations, competition from natural gas power and relatively flat electricity demand has resulted in the retirement of coal-fueled capacity, reducing coal-fueled electricity generation, and thus, CCP production.

The overall production of CCPs grew at an average annual rate of 1.7 percent, from 59.5 million short tons in 1974 to 114.7 million short tons in 2013, as shown in Figure E-1. Production of fly ash and FGD material, which combined represent 77 percent of total CCP production by weight, have been positively impacted by capital investments from coal-fueled generating utilities to meet the requirements of the 1970 Clean Air Act and its amendments in 1977 and 1990. Production of fly ash has grown at an average annual rate of just under one percent, while production of FGD material has grown at an average annual rate of 3.5 percent, driven in large part by the development of technologies for reducing sulfur dioxide emissions in response to federal regulation.

### CCP UTILIZATION 1974 – 2013

The growth in CCP utilization has been enabled by the development of standards for CCP use in construction and new techniques for using higher quantities of ash. CCP utilization has grown during three of the last five U.S. recessions since 1974, as shown in Figure E-2, as concrete producers and other end users have utilized CCPs as less expensive material substitutes to save on overall material costs. This includes the most recent recession that began in December 2007.

During periods following two regulatory determinations (1993 and 2000) by the U.S. Environmental Protection Agency (EPA) that CCPs did not warrant regulation as a hazardous waste, CCP utilization increased significantly, as can be seen in Figure E-2. Fly ash utilization doubled from 10.5 million short tons in 1993 to 20.1 million short tons in 2000, growing at an average annual rate of 10 percent. Between 2000 and 2007, fly ash utilization increased 6.6 percent annually. Similarly, FGD material utilization grew by 23 percent annually from 1993 through 2000, and by 12 percent annually between 2000 and 2008.

EPA's decision to reconsider the classification of CCPs as a hazardous waste after the December 2008 coal ash spill in Kingston, Tennessee resulted in regulatory uncertainty for CCP markets. CCP utilization had been at its highest in 2008 at 60.6 million short tons following the 2007 recession. After EPA's reconsideration, CCP utilization declined by 15 percent from 2008 to 2013. Despite increased CCP utilization during previous recessions, regulatory uncertainty affected markets for CCPs, reducing overall utilization after 2008.

### NEW MARKETS AND STANDARDS

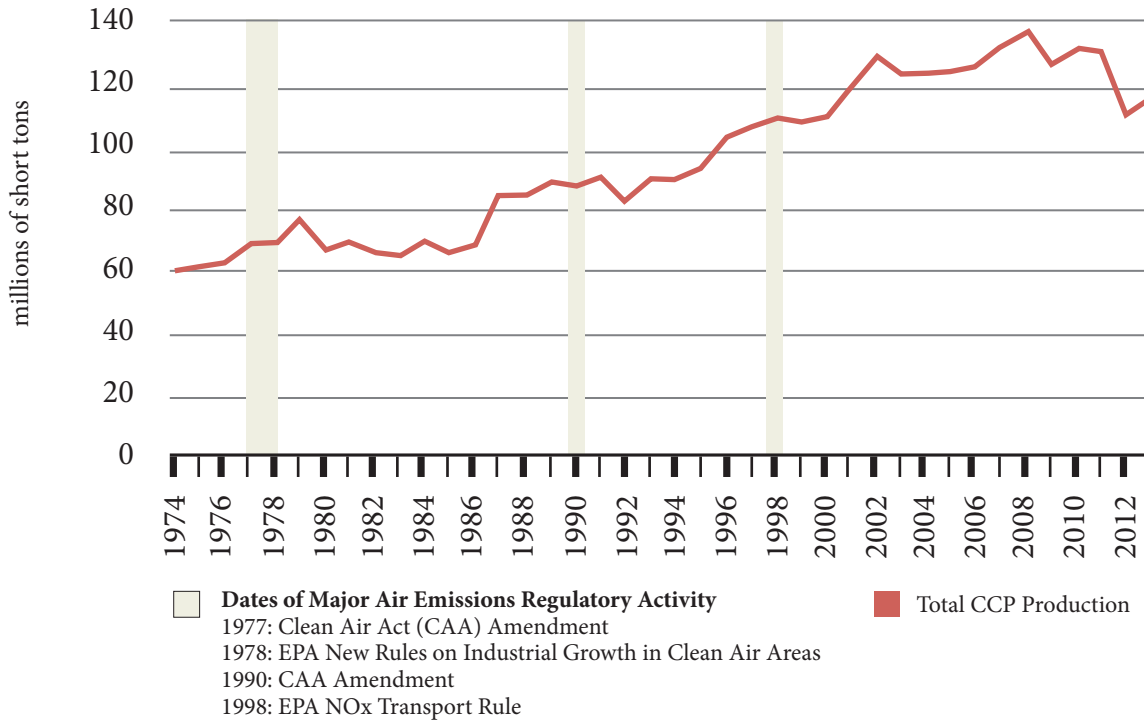
Since 1974, markets and applications for CCPs have increased dramatically. Total CCP utilization has increased from 8.7 million short tons in 1974 to 51.6 million short tons in 2013, as shown in Figure E-3. This represents an increase of nearly 500 percent over that period, or an average increase of 5.1 percent annually, as shown in Figure E-4.

The development of industry standards and specifications for CCP utilization in various engineering applications has encouraged wider use of these materials. More than a dozen federal agencies have published articles, guidelines and standards on the beneficial use of CCPs. EPA has released a study supporting the use of fly ash in concrete and FGD gypsum in wallboard. Further, EPA's final rule for CCP disposal specifically exempts beneficial uses, which will impart regulatory certainty for markets in the years to come.<sup>1</sup>

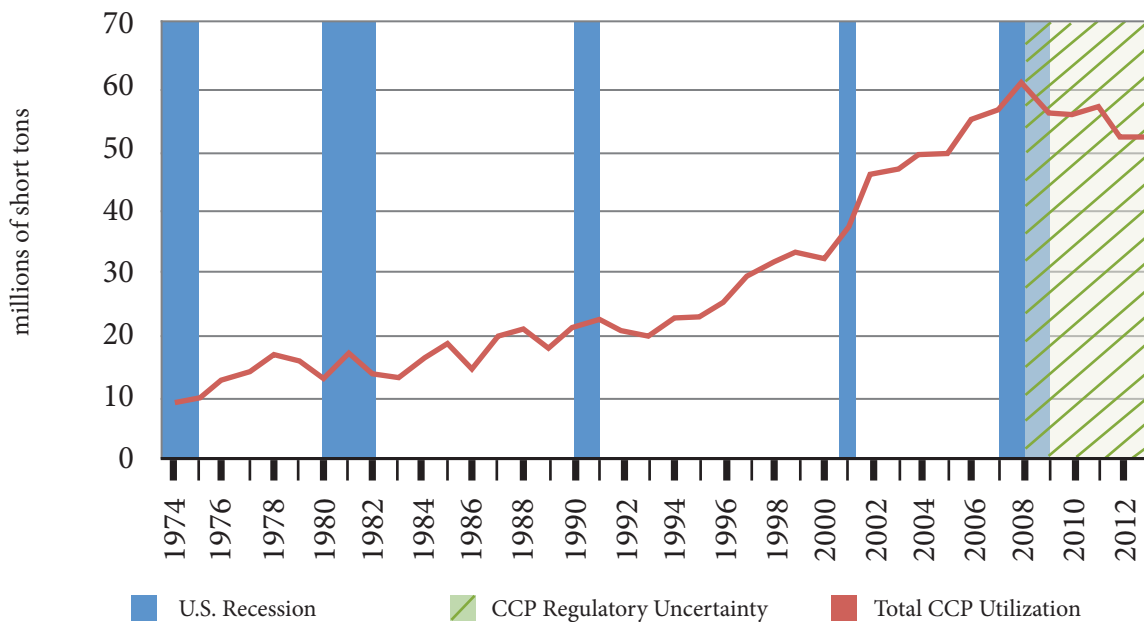
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<sup>1</sup> The final rule, Disposal of Coal Combustion Residuals from Electric Utilities was published in the Federal Register on April 17, 2015 and uses the terminology coal combustion residuals (CCRs) rather than coal combustion products. The rule does not regulate practices that meet the definition of a beneficial use of CCR. 80 Fed. Reg. 21301.

**FIGURE E-1: PRODUCTION OF CCPs HAS GROWN AT AN AVERAGE ANNUAL RATE OF 1.7 PERCENT**



**FIGURE E-2: UTILIZATION OF CCPs HAS INCREASED DURING RECESSIONS, BUT DROPPED DURING A PERIOD OF REGULATORY UNCERTAINTY**



**Major U.S. Recessions**

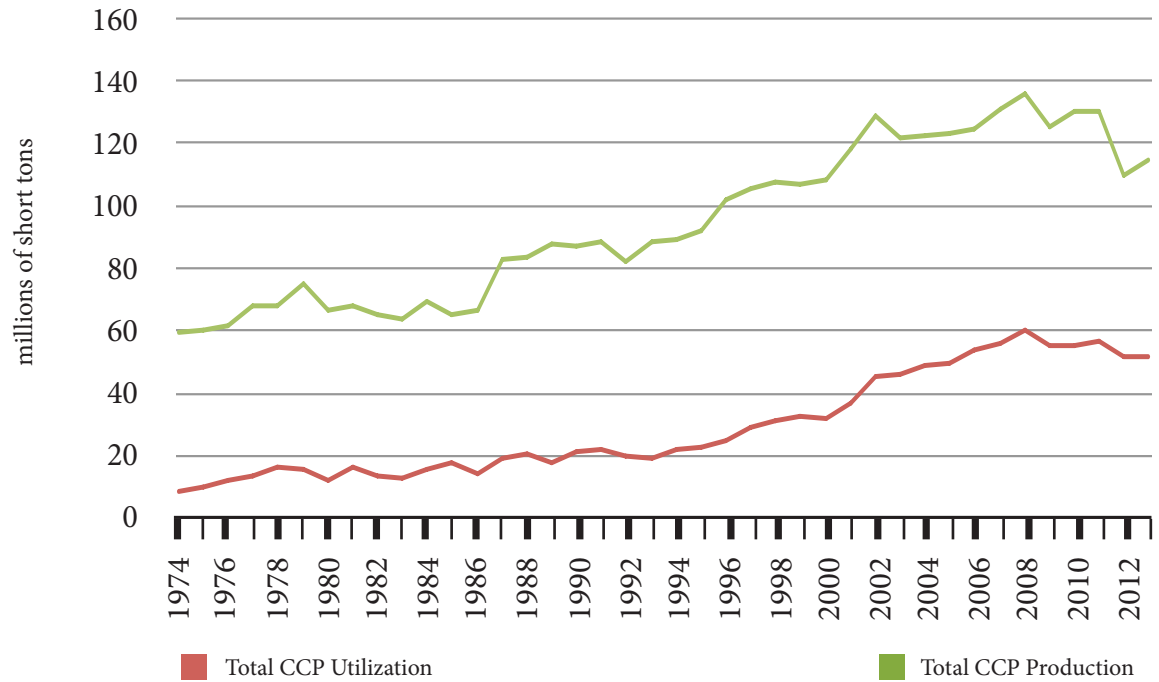
November 1973 to March 1975  
 January to July 1980  
 July 1981 to November 1982

July 1990 to March 1991  
 March to November 2001  
 December 2007 to June 2009

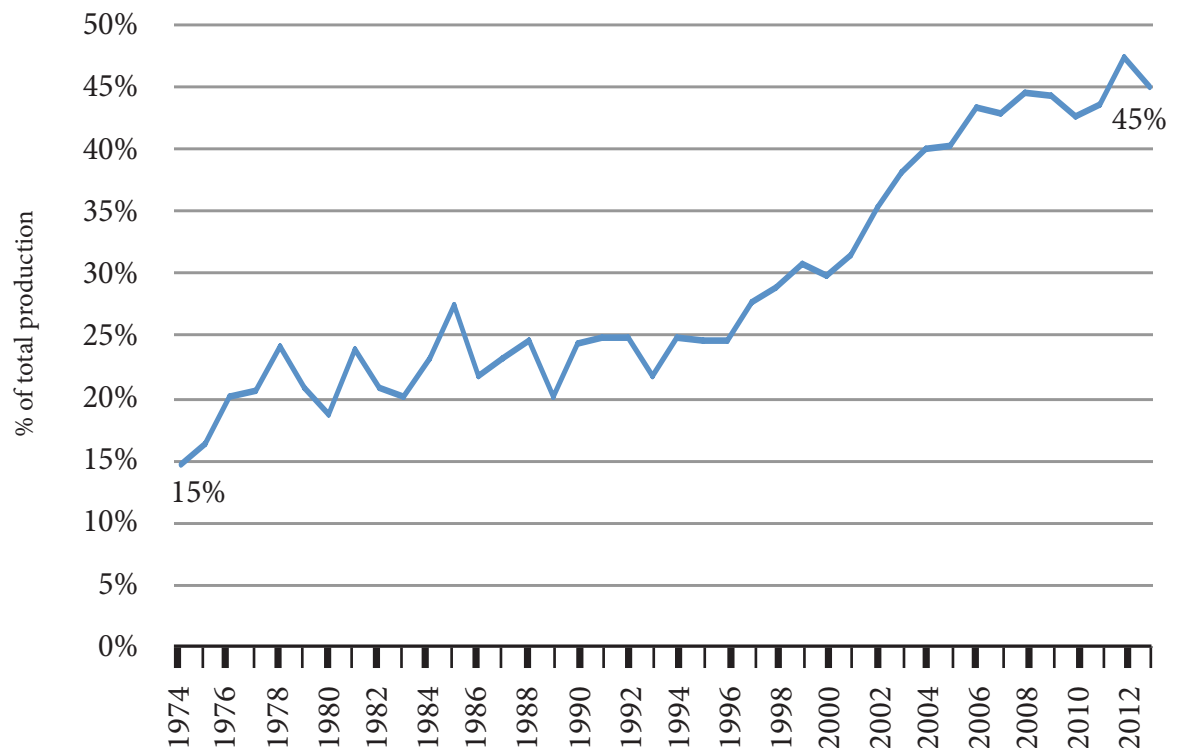
**CCP Regulatory Uncertainty:**

December 2008 to April 2015  
 EPA decision to reconsider the classification of CCPs as a hazardous waste

**FIGURE E-3: PRODUCTION OF CCPs HAS INCREASED WITH INSTALLATION OF POLLUTION CONTROL EQUIPMENT, AND USE OF CCPs HAS INCREASED AS NEW MARKETS EMERGE**



**FIGURE E-4: THE PERCENTAGE OF CCPs UTILIZED HAS INCREASED SIGNIFICANTLY SINCE 1993**





# THE GENERATION OF COAL-FUELED ELECTRICITY

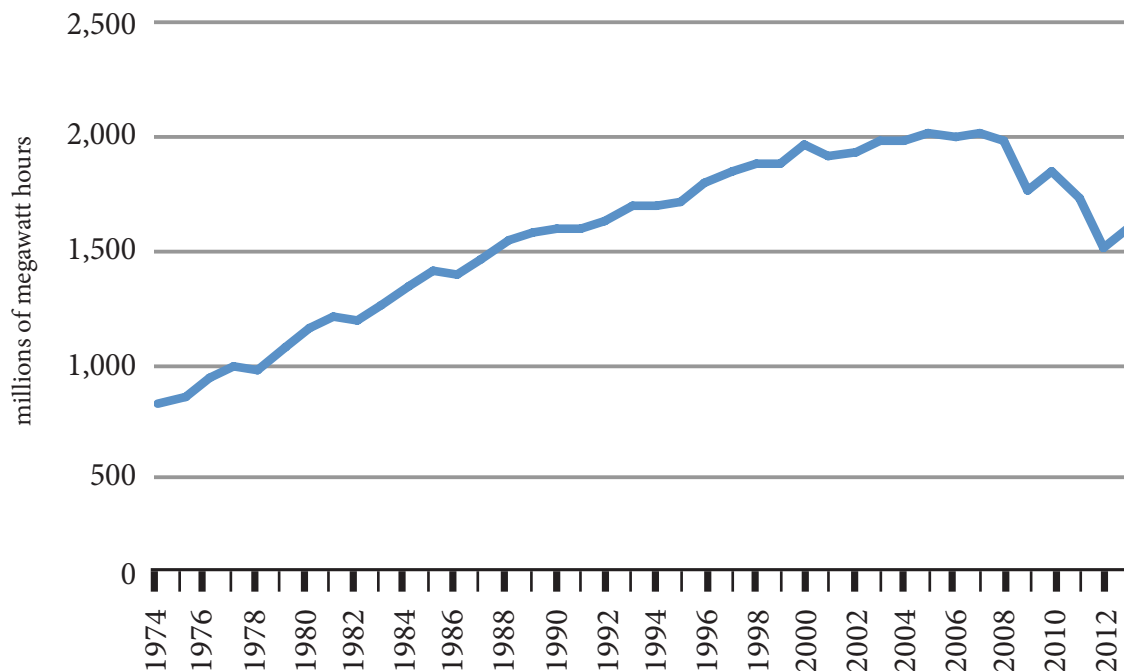
Coal is the largest energy source for generation of electricity in the United States, accounting for over 40 percent of electricity generation in 2013.<sup>2</sup> The share of coal generated electricity was 44 percent of total electricity in 1974, increasing to as high as 57 percent in 1988.

Although the share of coal generated electricity has declined since 1988, the overall consumption of coal by the power sector and the megawatt hours of coal generated electricity have remained high, resulting in the continued production of large volumes of CCPs.

The total consumption of coal for electricity grew from 391.8 million short tons in 1974 to a peak of just over 1 billion short tons in 2008. Since that time, consumption has declined to 858.4 million short tons.

There are a number of factors that have contributed to the recent decline in coal consumption for electricity. Environmental regulations have led to the closure of some coal-fueled generating capacity. Other contributing factors include competition from lower priced natural gas and a slower growth in electricity demand.<sup>3</sup>

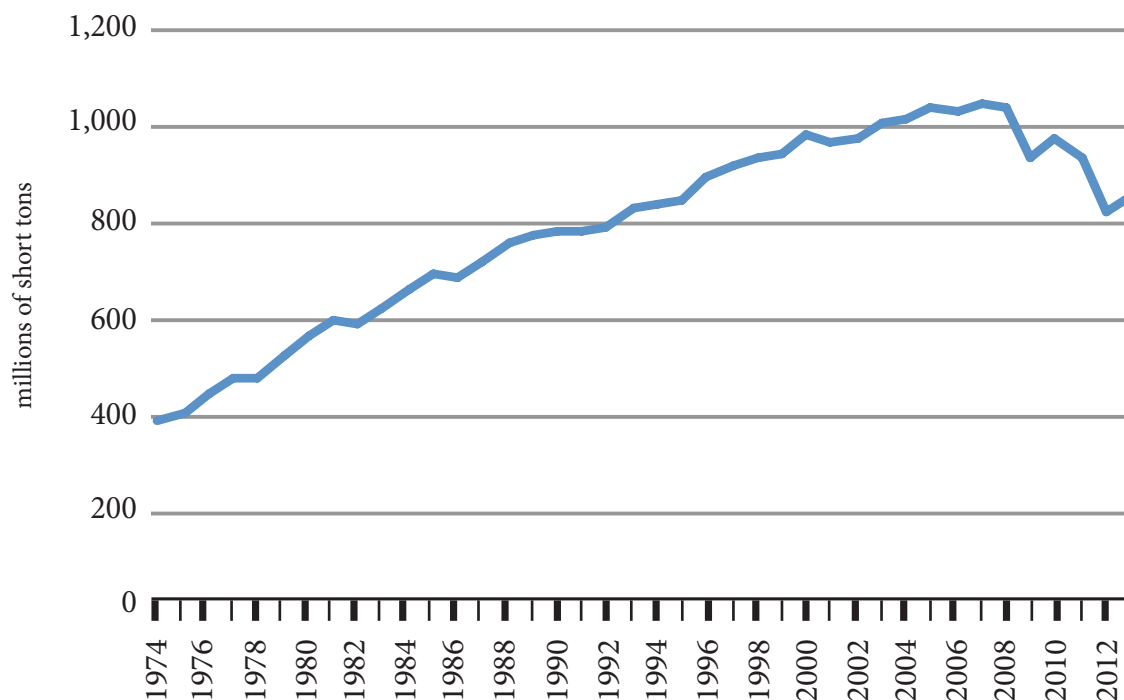
**FIGURE 1-1: ELECTRICITY GENERATED FROM COAL IN THE U.S.**



<sup>2</sup>Outlook, Annual Energy. "Annual Energy Outlook, 2014." US Energy Information Administration, Early Release Overview (2014). ([http://www.eia.gov/forecasts/aeo/er/early\\_elecgen.cfm](http://www.eia.gov/forecasts/aeo/er/early_elecgen.cfm))

<sup>3</sup>U.S. EIA. "AEO2014 projects more coal-fired power plant retirements by 2016 than have been scheduled." February 14, 2014. (<http://www.eia.gov/todayinenergy/detail.cfm?id=15031>)

FIGURE 1-2: COAL CONSUMPTION FOR ELECTRICITY IN THE U.S.



### INCREASED COMPETITION

Economic drivers have impacted coal consumption by electric utilities since 2008, including increased competition from natural gas.

The more widespread use of high-volume, horizontal hydraulic fracturing techniques, commonly known as “fracking,” have provided greater access to U.S. shale and natural gas reserves since the early 2000s and lowered the costs of withdrawing and producing natural gas. Shale gas reserves are located in a number of states, including Texas (49 billion cubic feet in 2013), Pennsylvania (44.3 billion cubic feet), West Virginia (18.1 billion cubic feet) and Arkansas (12.2 billion cubic feet).<sup>4</sup>

Fracking has led to a “revolution” in natural gas drilling.<sup>5</sup> As the price of natural gas has fallen relative to coal, utilities have used this energy source to generate a greater share of total electricity. In 1974, natural gas accounted for 17 percent of total U.S. net electricity generation. That grew to 27 percent in 2013.

The price of natural gas fell from \$9.26 per thousand cubic feet in 2008 to \$4.93 in 2009, according to data from the U.S. Energy Information Administration (EIA), a one-year decline of nearly 47 percent. The price continued to drop, reaching \$3.54 in 2012.

<sup>4</sup>U.S. EIA data on Shale Gas Proved Reserves as of December 31, 2013 ([http://www.eia.gov/dnav/ng/ng\\_enr\\_shale-gas\\_dcu\\_nus\\_a.htm](http://www.eia.gov/dnav/ng/ng_enr_shale-gas_dcu_nus_a.htm))

<sup>5</sup>Kris Maher & Tom McGinty, “Coal’s Decline Hits Hardest in the Mines of Kentucky,” Wall Street Journal November 26, 2013. (<http://www.wsj.com/articles/SB10001424052702304337404579212262280342336>)

FIGURE 1-3: PRICE OF NATURAL GAS

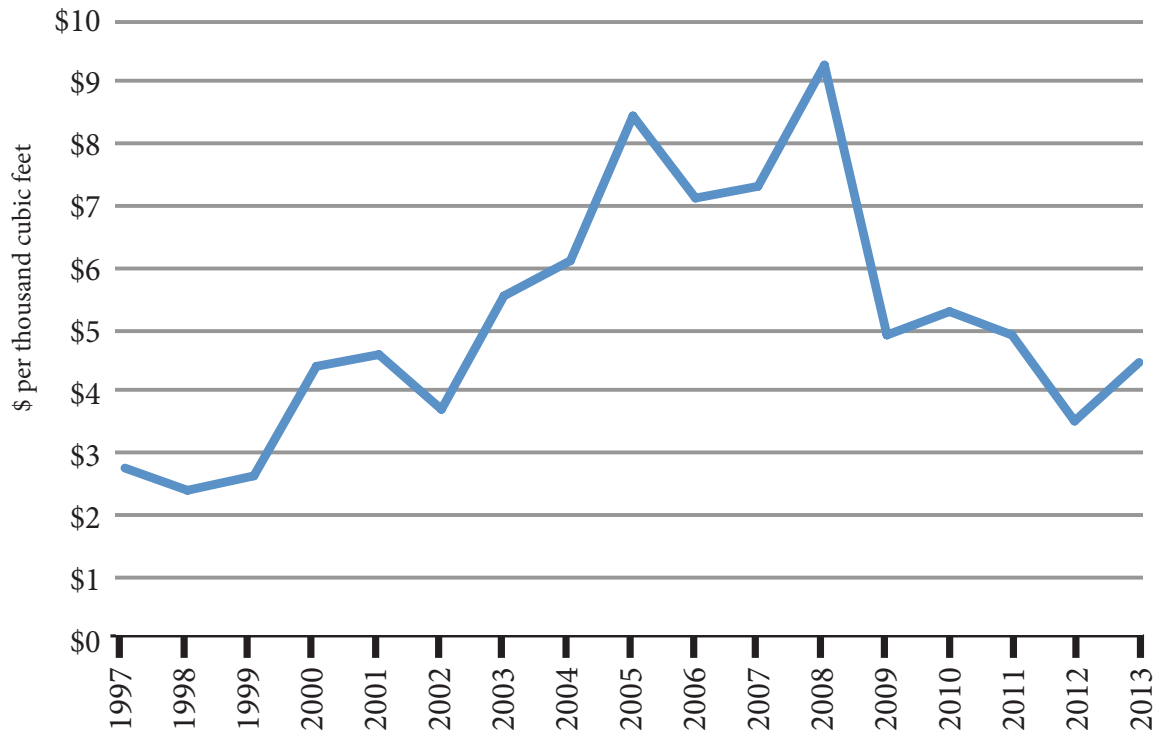
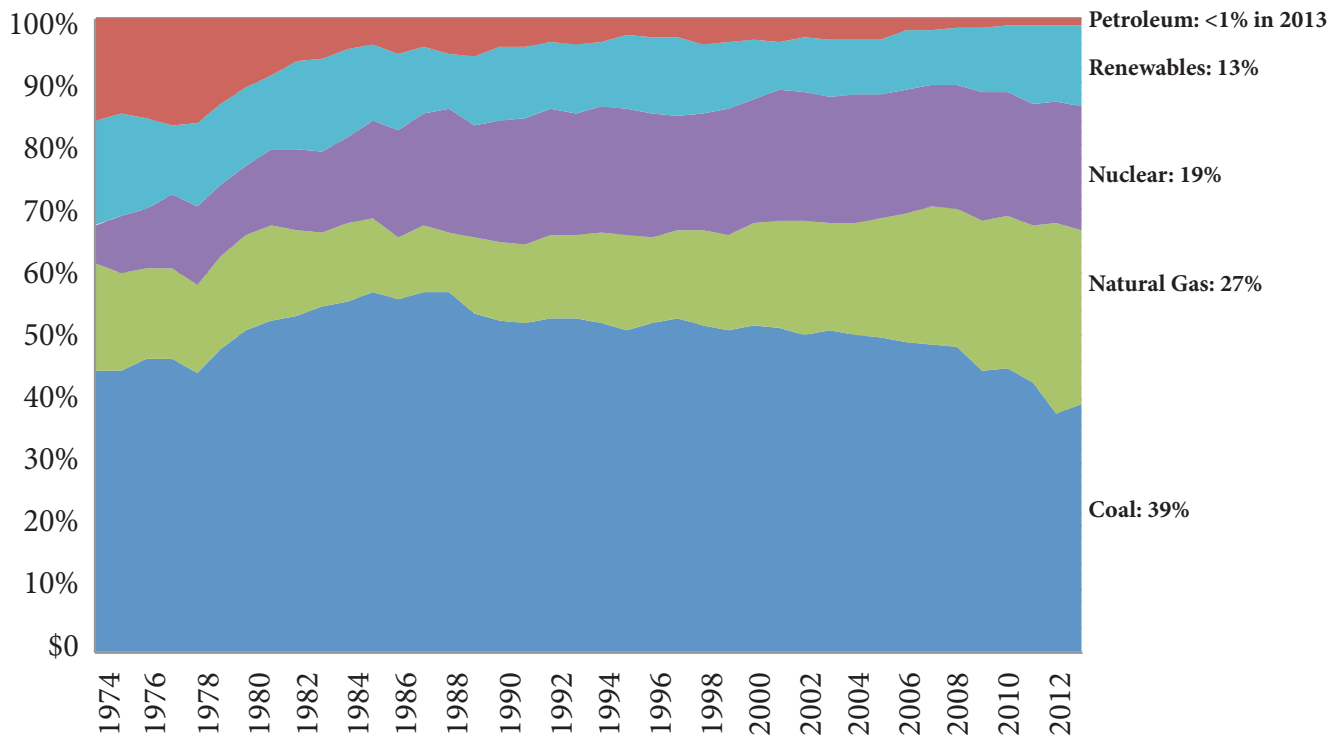


FIGURE 1-4: U.S. ELECTRICITY NET GENERATION BY SOURCE, 1974 TO 2013





### DEMAND FOR ELECTRICITY

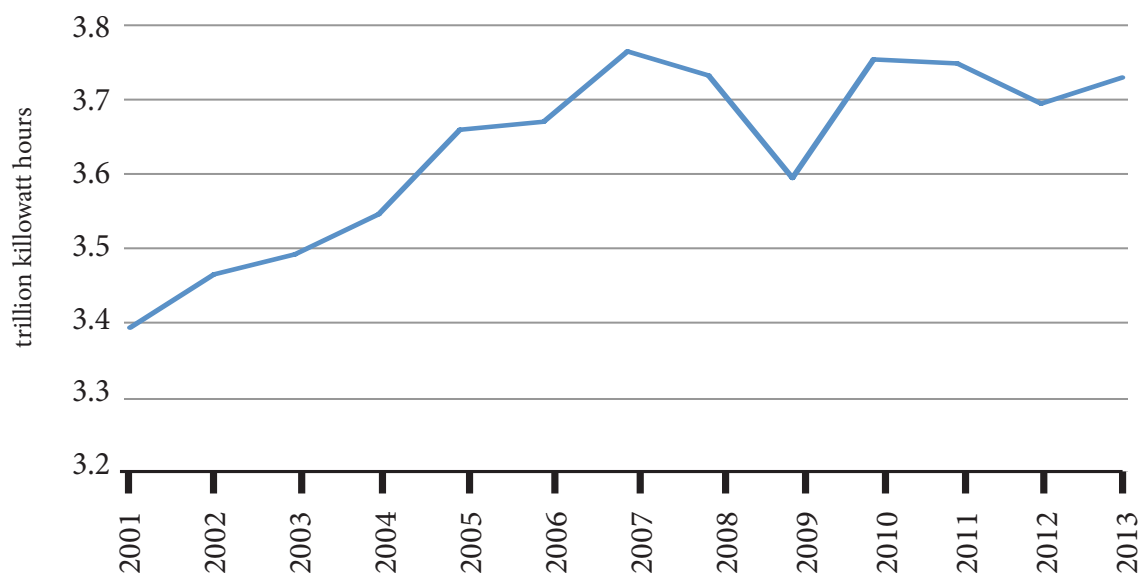
The overall demand for electricity has also impacted total coal consumption by utilities. Such factors as economic growth, income, tax changes, energy prices and weather drive residential and commercial demand.<sup>6</sup>

Americans consumed 3.73 trillion kilowatt hours of electricity in 2008, according to data from EIA. That fell 3.7 percent in 2009, during the recession, to 3.6 trillion kilowatt hours. A nine percent decline in industrial electricity consumption accounted for over two-thirds of the overall downturn.

Weather has the most significant impact on residential electricity demand, especially cold weather.<sup>7</sup>

If the average temperature is higher, people don't use as much electricity to heat their homes. The average temperature for 2012 was the warmest on record since 1974, according to data from U.S. the National Climatic Data Center, followed by 2006, 1998 and 1999. In 2012, residential electricity demand was down 3.4 percent from 2011 levels, compared to a decline of less than one percent for the commercial and industrial sectors combined.

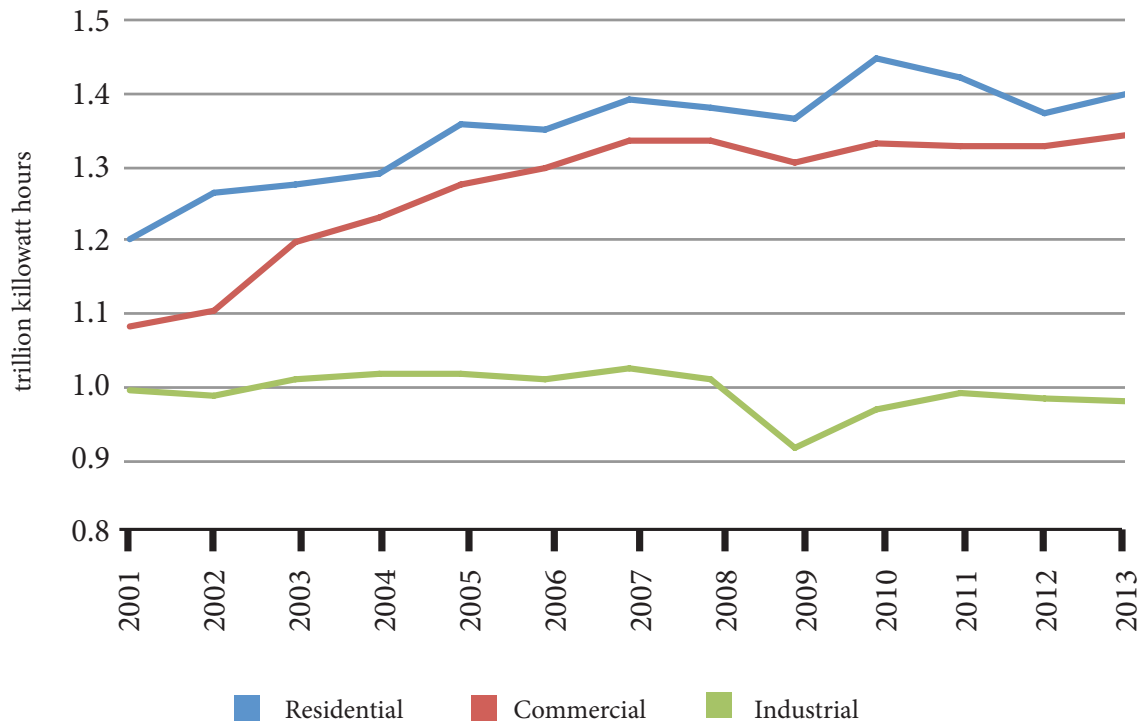
**FIGURE 1-5: TOTAL U.S. RETAIL SALES OF ELECTRICITY**



<sup>6</sup>Jay Zarnikau, "Functional form in energy demand modeling." *Energy Economics*, Volume 25 (2003). (<http://www.sciencedirect.com/science/article/pii/S0140988303000434>)

<sup>7</sup>David Kamerschen & David V. Porter. "The demand for residential, industrial and total electricity, 1973-1998." *Energy Economics*, Volume 26, Issue 1, (2004). (<http://www.sciencedirect.com/science/article/pii/S0140988303000331>)

FIGURE 1-6: TOTAL U.S. RETAIL SALES OF ELECTRICITY BY MAJOR SECTOR









## PLANT CLOSURES AND ENVIRONMENTAL REGULATIONS

Electric utilities shut down coal-fueled units representing 8.1 gigawatts of generating capacity in 2013 and 2014, according to data from EIA.<sup>8</sup>

Although more closures are expected in the next few years, this is not expected to have a significant impact on CCP production. This is because most of the units that are being closed are older, smaller, and not as frequently utilized, and are therefore not producing a significant share of the total production of CCPs. EIA describes the units closed between 2010 and 2012 as “small, with an average size of 97 megawatts (MW), and inefficient, with an average tested heat rate of about 10,695 British thermal units per kilowatt-hour (Btu/kWh).”<sup>9</sup>

Historically, federal and state regulations have had a role in overall CCP production by requiring utilities to install equipment that capture the ash produced during the generation of electricity from coal. The major piece of legislation affecting the industry was the Clean Air Act, first introduced in 1963, with amendments in 1970, 1977 and 1990. The 1963 Clean Air Act was the first federal legislation involving air pollution, and provided funds for federal research, ambient monitoring studies and stationary source inspections.<sup>10</sup>

According to the U.S. Environmental Protection Agency (EPA), the 1970 amendment to the Clean Air Act “resulted in a major shift in the federal government’s role in air pollution control.” The legislation gave both federal and state governments the ability to limit emissions from stationary and mobile sources. The 1970 act required the following:<sup>11</sup>

- EPA was directed to establish national ambient air quality standards for the major criteria air pollutants.
- States were required to develop implementation plans on how they would establish limits for individual sources to meet and maintain the national standards.
- The legislation contained deadlines and strengthened enforcement of emission limitations.
- New sources were forced to meet standards based on the best available technology.

National Ambient Air Quality Standards (NAAQS) were established under the 1970 amendment to the Clean Air Act for the priority pollutants ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide and lead. The emission standards most affecting the utility industry were for particulate matter, nitrogen oxides and sulfur dioxide.

The implementation of technologies to meet the new emissions standards for particulate matter meant that power plants began to capture fly ash in emissions control equipment.

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<sup>8</sup>Outlook, Annual Energy. “Annual Energy Outlook, 2014.” US Energy Information Administration, Early Release Overview (2014), ([http://www.eia.gov/forecasts/aeo/er/early\\_elecgen.cfm](http://www.eia.gov/forecasts/aeo/er/early_elecgen.cfm)), Table A9.

<sup>9</sup>U.S. EIA. “AEO2014 projects more coal-fired power plant retirements by 2016 than have been scheduled.” February 14, 2014 (<http://www.eia.gov/todayinenergy/detail.cfm?id=15031>)

<sup>10</sup>U.S. EPA. “History of the Clean Air Act.” (<http://www.epa.gov/air/caa/amendments.html>)

<sup>11</sup>U.S. EPA. “The Benefits and Costs of the Clean Air Act, 1970 to 1990.” prepared for the U.S. Congress October 1997 (<http://www.epa.gov/cleanairactbenefits/retro.html>)

Emissions standards for new power plants were established by the EPA and required the latest technology that corresponded to a roughly 75 percent reduction from the average emissions rates at the time. Power plants could meet this standard by installing a Flue Gas Desulphurization (“FGD”) system or burning low-sulfur coal.

U.S. manufacturing companies, privately and cooperatively owned electric utilities, publicly owned electric utilities and other non-manufacturing companies spent \$2.24 billion on plants and equipment for air pollution abatement in 1972.<sup>12</sup>

EPA estimates that as a result of Clean Air Act compliance, particulate matter emissions from coal-fueled electricity generating plants decreased from 1.68 million short tons in 1970 to 941,000 short tons in 1979, and to 188,000 short tons in 2005.<sup>13</sup>

The 1977 amendment to the Clean Air Act established the New Source Review permitting program, requiring legal documents for facility owners and operators that want to construct new or modify existing factories, industrial boilers and power plants.<sup>14</sup>

In 1978, EPA followed up with new rules on industrial growth in clean air areas, requiring “large new pollution sources such as factories and power plants which build in these areas to install the best available pollution control technology.”<sup>15</sup>

The Clean Air Act amendments of 1990 “substantially increased the authority and responsibility of the federal government” and implemented new regulatory programs and standards.<sup>16</sup> Prior to the amendment, EPA regulated air toxics “one chemical at a time.” The new approach identified major industrial sources for 187 listed toxic air pollutants and steps to “reduce pollution by requiring sources to install controls or change production processes.”

As part of the update, EPA issued a two-phase strategy to reduce nitrogen oxide emission from utilities that used coal boilers. Phase I took effect in January 1996 and required emissions levels from a group of dry-bottom wall-fired boilers and tangentially-fired boilers to reduce their emission by over 400,000 tons per year between 1996 and 1999.<sup>17</sup> The goal of the second phase, which began in 2000, was to reduce nitrogen oxide emissions by an additional 2 million tons per year.

EPA issued the NOx Transport Rule in 1998 that required 21 states and Washington, D.C. to use new and cleaner control strategies to further reduce nitrogen oxide emissions by one million tons by 2007. The rule allowed each state to determine how it planned to reduce its emissions.<sup>18</sup>

<sup>12</sup>Cogan, Christine, “Pollution Abatement and Control Expenditures, 1972-94,” Survey of Current Business (<http://www.bea.gov/scb/pdf/national/niparel/1996/0996eed.pdf>)

<sup>13</sup>EPA, “National Emissions Inventory, Trends for Electric Generating Utilities for 1970 to 2005”, (2008).

<sup>14</sup>U.S. EPA, New Source Review (<http://www.epa.gov/ttnchie1/trends/>)

<sup>15</sup>EPA Press Release, June 13, 1978. (<http://www2.epa.gov/aboutepa/epa-announces-new-rules-industrial-growth-clean-air-areas>)

<sup>16</sup>EPA, History of the Clean Air Act, August 15, 2013. (<http://www.epa.gov/air/caa/amendments.html>)

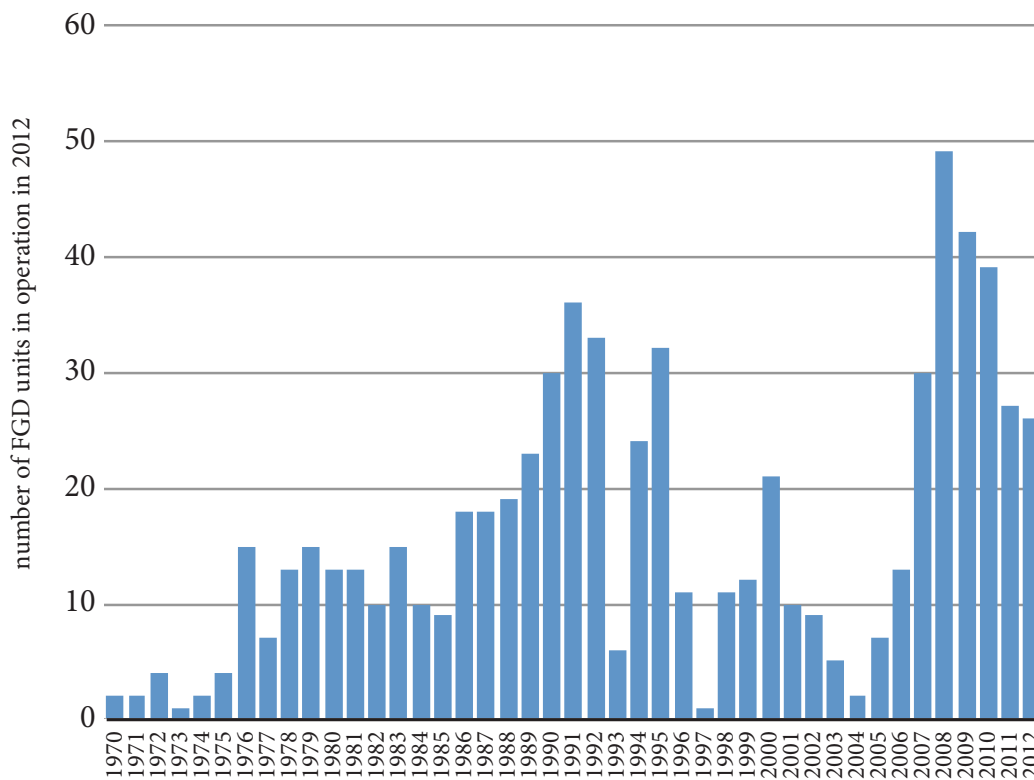
<sup>17</sup>Maroto-Valer, M. Mercedes, D. N. Taulbee, and J. C. Hower. “Characterization of Fly Ash Carbons Derived Due to the Implementation of NOx Clean Air Act Amendments.” Prepr. Pap. Am. Chem. Soc., Div. Fuel Chem 45 (2000): 401-405. ([https://web.anl.gov/PCS/acsfuel/preprint%20archive/Files/45\\_3\\_WASHINGTON%20DC\\_08-00\\_0401.pdf](https://web.anl.gov/PCS/acsfuel/preprint%20archive/Files/45_3_WASHINGTON%20DC_08-00_0401.pdf))

<sup>18</sup>EPA, “The Regional Transport of Ozone: New EPA Rulemaking on Nitrogen Oxide Emissions” (<http://www.epa.gov/air/noxfacts.pdf>)

The 1990 amendment to the Clean Air Act introduced a permanent cap on sulfur dioxide emissions from electric power plants across the country and implemented a cap and trade system. In order to comply with the new standards, utilities could either switch to low sulfur coal, add FGD scrubbers or other equipment to remove emissions, purchase permits from other utilities, or use some combination of those strategies.<sup>19</sup>

Of the operational FGD units in 2012, 219 began service between 1956 and 1990, 217 units began service between 1990 and 2000, and 259 units after 2001. A total of 183 operation units just began service in the last five years, between 2008 and 2012.

**FIGURE 1-7: CURRENT OPERATIONAL FGD UNITS BY YEAR SERVICE BEGAN**



<sup>19</sup>Institute for Energy Research. "The Facts About Air Quality and Coal-Fired Power Plants." (<http://instituteforenergyresearch.org/studies/the-facts-about-air-quality-and-coal-fired-power-plants/>)



### CHANGES IN TYPE OF COAL

In addition to the volume of coal burned by electric utilities, changes in the types of coal consumed have had an impact on the historical production of CCPs.

There are four main classifications for coal, known as coal rank: anthracite, bituminous, subbituminous and lignite. Each type varies based on heating value, moisture, fixed carbon content, ash content, sulfur and chlorine.<sup>20</sup>

Utilities may burn one or more types of coal at a power plant to generate electricity, and may even blend different types of coal. Most coal-fueled electricity generating plants burn bituminous or subbituminous coals. The use of lignite coal is generally limited to utilities that are located near those coal supplies.<sup>21</sup> Anthracite coal is rarely used for electricity generation.

In 1974, over 84 percent of the coal deliveries to utilities was bituminous coal, with an average ash content of 14.6 percent. Subbituminous coal, with an average ash content of 8.3 percent, accounted for just over 12 percent of all deliveries.<sup>22</sup>

With the implementation of the Clean Air Act provisions, utilities began using more of the subbituminous coal, which has both a lower sulfur and ash content.

By 1990, subbituminous coal accounted for nearly 30 percent of deliveries. The average ash content of the coal that year was 6.2 percent. Bituminous coal, with an average ash content of 10.5 percent, accounted for 61 percent of deliveries, with lignite coal at just below 10 percent, with an ash content of 12.4 percent.

In 2005, subbituminous coal was 49 percent of deliveries and bituminous coal was 47 percent. That trend continued, with subbituminous coal accounting for 53.2 percent of deliveries in 2012, while bituminous coal was 38 percent.<sup>23</sup>

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<sup>20</sup>Purdue University, Indiana Center for Coal Technology Research. "CCTR Basic Facts File #8." (<http://www.purdue.edu/discoverypark/energy/assets/pdfs/cctr/outreach/Basics8-CoalCharacteristics-Oct08.pdf>)

<sup>21</sup>EPA. "Available and Emerging Technologies For Reducing Greenhouse Gas Emissions From Coal-Fired Electric Generating Units." October 2010. (<http://www.epa.gov/nsr/ghgdocs/electricgeneration.pdf>)

<sup>22</sup>ARTBA analysis of historic EIA form 423 and FERC-423 data. (<http://www.eia.gov/electricity/data/eia423/>)

<sup>23</sup>ARTBA analysis of EIA form 923 data. (<http://www.eia.gov/electricity/data/eia923/>)

# TOTAL CCP PRODUCTION

The total production of CCPs has grown from 59.5 million short tons in 1974 to 114.7 million short tons in 2013, an increase of 93 percent. There were 413 plants that reported collecting CCPs in 2012.<sup>24</sup>

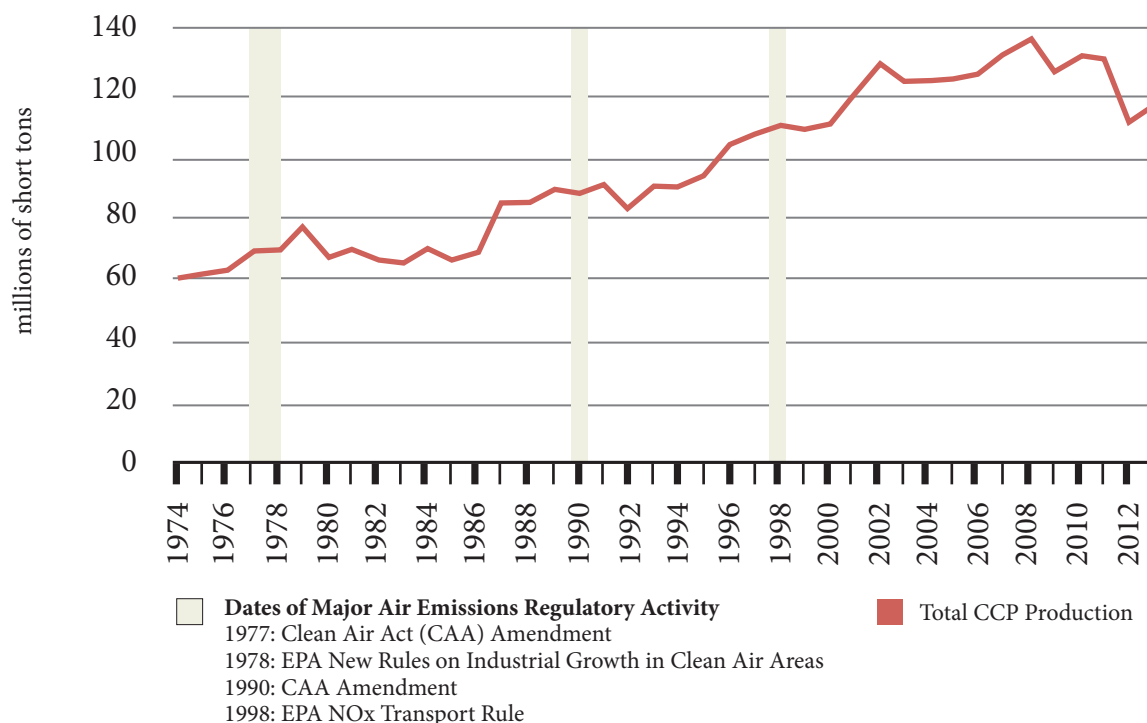
As a byproduct of the coal combustion process, CCP production is primarily driven by the consumption of coal for electricity generation. Although the overall impact can vary from year to year, this link is particularly evident during the sharp swings in the coal generated electricity market over the last few years. The most recent example of this was in 2012. CCP production fell in all the major product types when the total volume of coal generated electricity declined in response to lower natural gas prices and a very mild winter.<sup>25</sup>

Additional growth over the last 40 years, especially for fly ash and FGD material, is attributable to environmental regulations that required electric utilities to begin collecting CCPs.

In particular, the 1968 Clean Air Act, with amendments in 1970, 1977 and 1990 set regulations for nitrogen oxides, particulate matter and sulfur dioxide that required utility owners to install equipment and processes to capture CCPs. The legislation also allowed states to set additional emissions standards and required reduced output levels for key emissions with the construction of new utility generators and plants.

New developments in technology to meet these standards, such as the evolution of scrubber and boiler technology and the use of low sulfur coal, have had implications for individual CCP markets.

**FIGURE 2-1: PRODUCTION OF CCPs HAS GROWN AT AN AVERAGE ANNUAL RATE OF 1.7 PERCENT**



<sup>24</sup>ARTBA analysis of EIA form 923 data. (<http://www.eia.gov/electricity/data/eia923/>)

<sup>25</sup>U.S. EIA. "Monthly coal and natural gas-fired generation equal for first time in April 2012." July 6, 2012. (<http://www.eia.gov/todayinenergy/detail.cfm?id=6990>)







## FLY ASH PRODUCTION

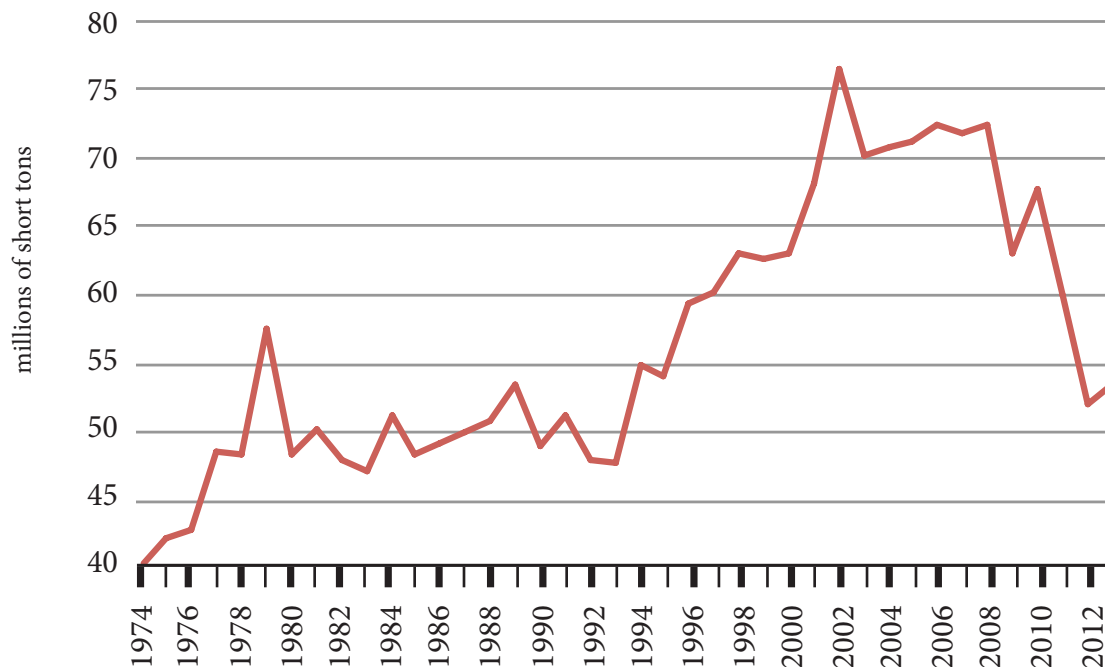
Since 1974, the production of fly ash has increased 29 percent from 40.4 million short tons to 53.4 million short tons in 2013, growing at an average annual rate of just under one percent.

As the non-combustible mineral portion of coal, the production of fly ash is wholly related to the volume of coal generated electricity. The capture of fly ash has also been impacted by the implementation of emission control regulations by coal-fueled electricity producing utility plants.

During the early years of the Clean Air Act, fly ash production grew from 40.4 million short tons in 1974 to 57.5 million short tons in 1979. Total fly ash production averaged 50 million short tons over the next decade, between 1980 and 1990.

Fly ash production grew at an average annual rate of 2.2 percent between 1990 and 2008, increasing from 48.9 to 72.5 million short tons. This rate of growth was higher than the average annual increase in coal consumption for electricity, which was 1.6 percent, and megawatt hours of coal generated electricity, which grew at a rate of 1.2 percent.

FIGURE 2-2: FLY ASH PRODUCTION





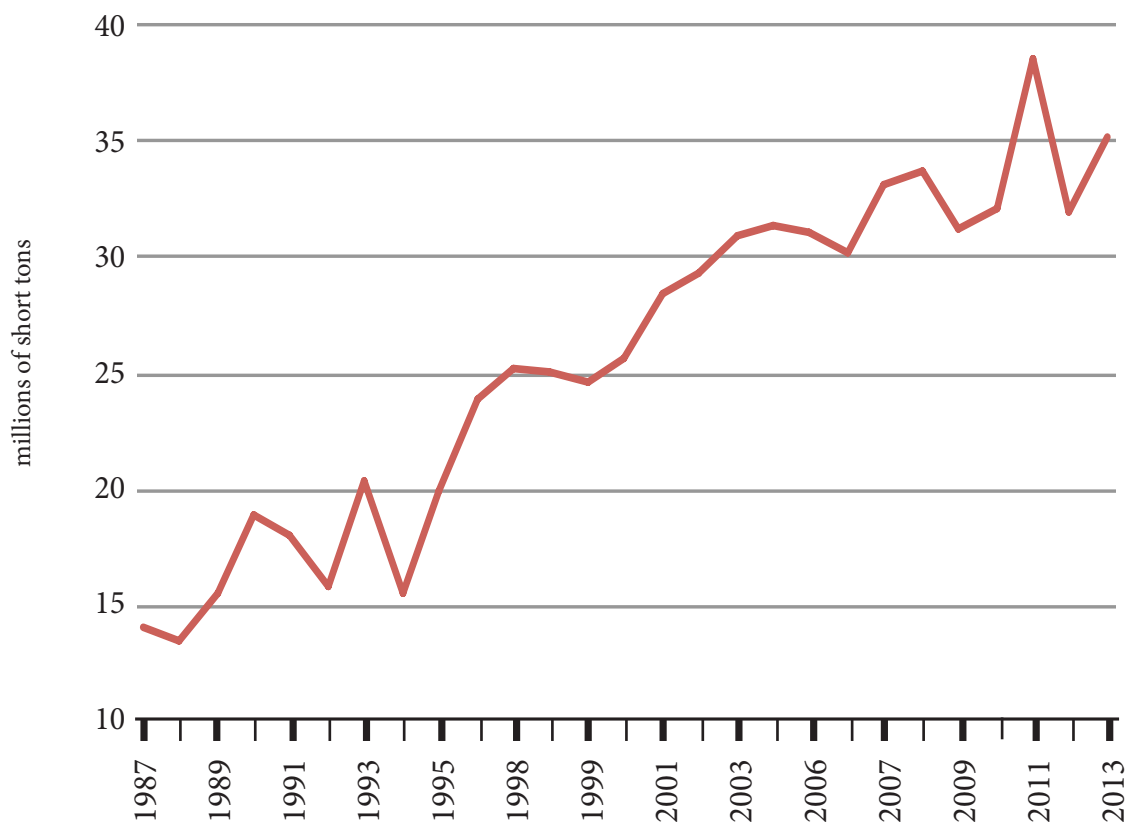
### FGD MATERIAL PRODUCTION

The production of FGD material, including FGD gypsum, wet scrubber and dry scrubber material, has grown from 14.2 million short tons in 1987 to 35.2 million short tons in 2013, an increase of 148 percent. The average annual growth rate for FGD production was 3.5 percent over that time period, greater than the average annual growth rate in megawatt hours of coal generated electricity (0.3 percent), the consumption of coal for electricity generation (0.7 percent) and U.S. real GDP (2.6 percent).

A growing number of coal-fueled electricity generators use a FGD process to remove gaseous sulfur dioxide from the boiler exhaust gas. The primary types of FGD processes used are wet scrubbers, dry scrubbers and sorbent injections with lime, limestone, sodium-based compounds or high-calcium coal fly ash. Depending on the process used, the resulting FGD material can be a wet sludge or a dry powder.<sup>26</sup>

Historically, the production of FGD material has been dependent on changes in the technology and processes for capturing FGD material, environmental regulations for sulfur dioxide emissions and the overall volume of coal used by coal-fueled electricity generating plants.

**FIGURE 2-3: FGD MATERIAL PRODUCTION**



<sup>26</sup>American Coal Ash Association. "Glossary of terms concerning the management and use of coal combustion products (CCPs)." American Coal Ash Association, Inc., Aurora, CO (2003).

### CHANGES IN FGD TECHNOLOGY & SCRUBBERS

There were 808 FGD units with 1,326 unit scrubber trains or modules installed at U.S. steam-electric power plants that had a capacity of 10 megawatt hours or more in 2012.<sup>27</sup> A total of 695 of these units are operational, 35 are under construction and 16 are expected to go into service within the next ten years. There are 30 units that have been retired and 15 that are out of service.

Over 69 percent of these units are classified as a spray type wet scrubber, a spray dryer type FGD or semi-dry FGD scrubber. In all, utilities have either spent or plan to invest approximately \$57.4 billion for the purchase, installation, and planned upgrades on these units.

There has been a clear shift in the type of scrubbers being put into service by power plants over the last two decades that has coincided with increases in FGD production.

Dry scrubber technology for commercial utilities began appearing in the U.S. in the late 1970s and early 1980s. This type of scrubber has been primarily used to retrofit applications on units that burn low-sulfur coals.<sup>28</sup>

The growing popularity of wet scrubbers over the last forty years is in part due to the equipment's high removal efficiencies and the simplicity of the overall system. Wet scrubbers have become "state of the art methods for achieving removal efficiencies in the 90% to 98% range."<sup>29</sup>

Of the operational scrubbers that began service between 1990 and 2000, 122 were classified as spray dryer type, dry FGD or semi-dry FGD equipment. A total of 54 were classified as spray type wet scrubbers. In the last five years of available data, between 2008 and 2012, there were 29 dry scrubbers that were put into service and 84 wet scrubbers.

During this time, there has also been an increase in the number of utilities that have reported the recovery of a "salable byproduct" from their FGD equipment.<sup>30</sup> Of all the FGD units in operation today, utilities report that 194 units produce a byproduct material that is sold. Of that total, 130 units are wet scrubbers, of which 84 began service between 2008 and 2012.

These equipment changes have occurred as total FGD production, as measured in the ACAA survey has shown significant growth. Total annual FGD production averaged 21.2 million short tons between 1990 and 2000, and rose to an average of 33.5 million short tons between 2008 and 2012. In 2013, FGD production reached 35.2 million short tons.

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<sup>27</sup>ARTBA analysis of EIA-860 form data, Schedule 6 Part F.

<sup>28</sup>Paul S. Nolan. "Flue gas desulfurization technologies for coal-fired power plants." Coal Tech 2000 International Conference, Jakarta, Indonesia. 2000. (<http://www.babcock.com/library/Documents/br-1709.pdf>)

<sup>29</sup>Ibid.

<sup>30</sup>Ibid.



## BOTTOM ASH PRODUCTION

The production of bottom ash grew one percent between 1974 and 2013, increasing from 14.3 to 14.5 million short tons. Production has increased and contracted over the years, reaching a high of 19.8 million short tons in 2002. The production of bottom ash is driven by the volume of coal generated electricity, total coal consumption by electric utilities and the type of coal being burned.

Bottom ash is comprised of the “ash particles formed in pulverized coal furnaces that are too large to be carried in the flue gases and impinge on the furnace walls or fall through open grates to an ash hopper at the bottom of the furnace.”<sup>31</sup> Whereas fly ash is light enough to fly up the stack, bottom ash falls to the bottom of the furnace. If the boiler is a dry bottom boiler, the material is dry bottom ash. If the utility is using a wet-bottom boiler, the material is boiler slag.

When pulverized coal is burned in a dry bottom boiler, about 80 percent of the ash flies up the flue gas and is recovered as fly ash, and the remaining 20 percent of the unburned material is bottom ash. Since 1974, bottom ash has averaged 21.5 percent of the total amount of fly and bottom ash produced.

Of the 413 plants that reported collecting ash in 2012, 84 percent collected both fly ash and bottom ash. Just 34 utilities reported collecting fly ash with no bottom ash, and nine said they produced bottom ash without any fly ash.<sup>32</sup>

As is the case with fly ash, the production of bottom ash is related to coal consumption by electric utilities for the generation of electricity. Although changes in the production of bottom ash have mirrored the ups and downs of fly ash production, the bottom ash market has not seen the same level of overall growth since 1974. Further research in this area is needed to explore the reasons for the difference between fly ash and bottom ash production, given the traditional relationship between their production levels.

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<sup>31</sup>American Coal Ash Association. “Glossary of terms concerning the management and use of coal combustion products (CCPs).” American Coal Ash Association, Inc., Aurora, CO (2003). ([http://www.acaa-usa.org/Portals/9/Files/PDFs/ACAA\\_Glossary\\_of\\_Terms-April\\_2003.pdf](http://www.acaa-usa.org/Portals/9/Files/PDFs/ACAA_Glossary_of_Terms-April_2003.pdf))

<sup>32</sup>ARTBA analysis of EIA form 923 data.

FIGURE 2-4: BOTTOM ASH PRODUCTION

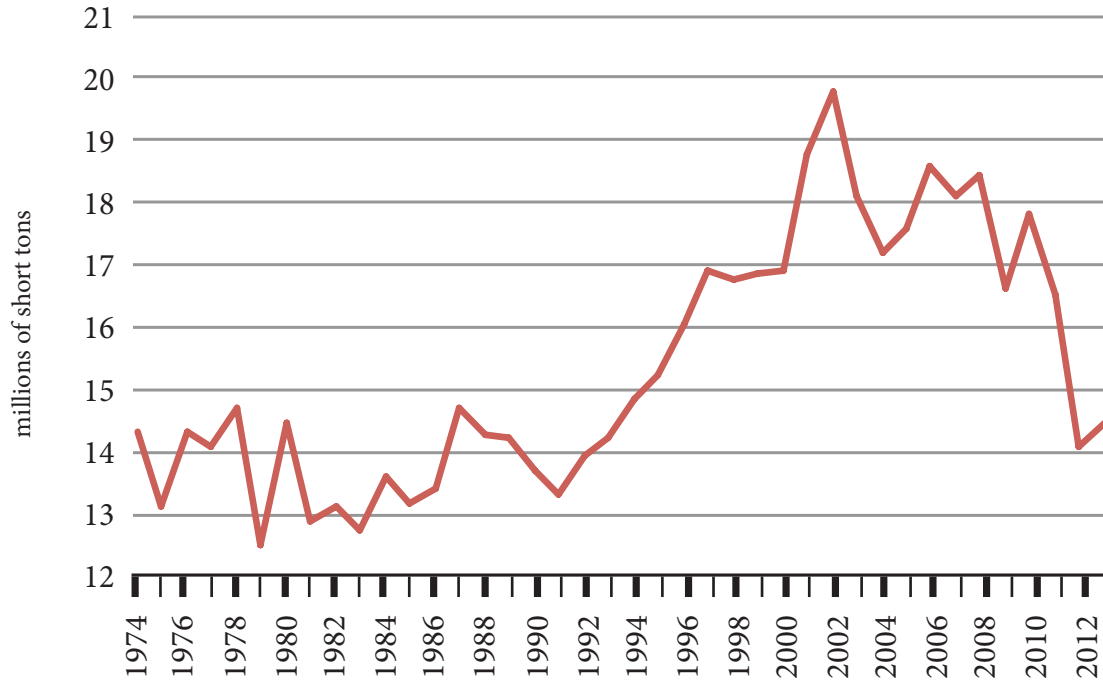
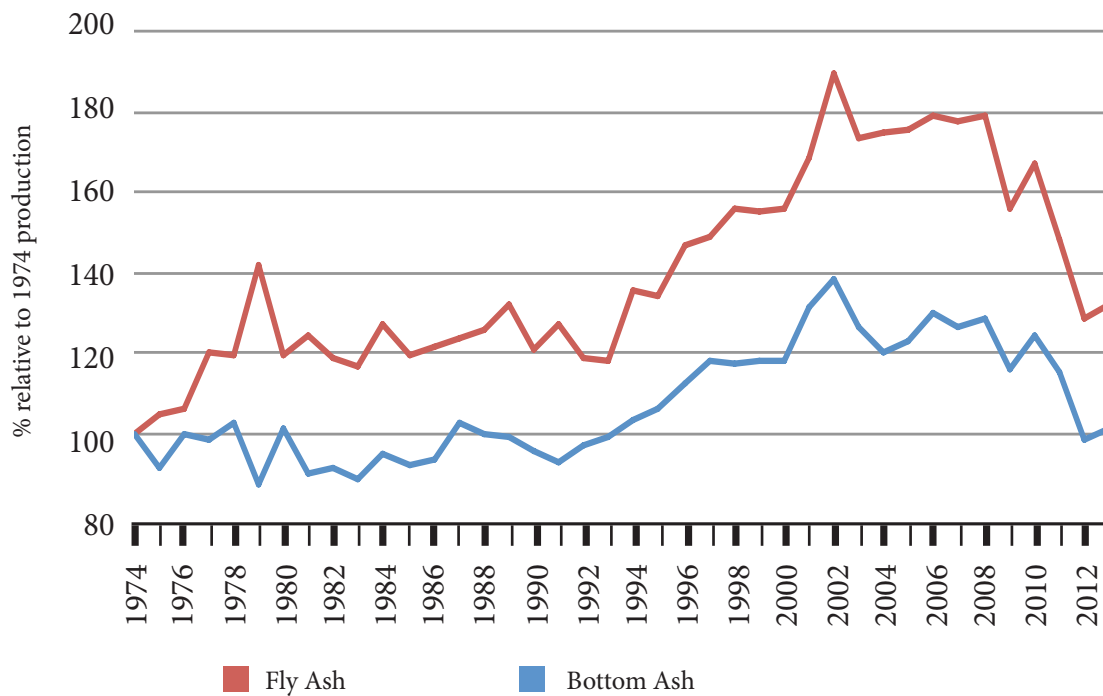


FIGURE 2-5: INDEX OF FLY ASH AND BOTTOM ASH PRODUCTION, 1974 TO 2013





## BOILER SLAG PRODUCTION

Boiler slag production has dropped 72 percent from 4.8 million short tons in 1974 to 1.4 million short tons in 2013. The decrease in supply is largely due to the retirement of the wet-bottom boilers that produce this type of CCP.<sup>33</sup>

The slag tap boiler and the cyclone boiler are the two types of wet-bottom boilers used in the U.S. When pulverized coal is burned, the ash that falls to the bottom is kept in a liquid state. Both of the types of wet-bottom boilers contain quenching liquid that mixes with the molten ash to form a hard, black, angular, glassy material sometimes referred to as “Black Beauty.”<sup>34</sup>

In a slag-tap furnace, as much as 50 percent of the ash becomes boiler slag. In a cyclone furnace, that total can be as high as 70 to 80 percent. The remaining ash in both cases leaves the furnace in the form of fly ash.<sup>35</sup>

Wet-bottom boilers are more compact than pulverized coal boilers that are found at the larger utility generating plants. Thus they are used more often by industrial manufacturing plants and smaller utilities.<sup>36</sup>

Most of the existing cyclone boilers in the U.S. were constructed before 1981. These boilers have high nitrogen oxide emission rates, and “no new cyclone boilers are expected to be built.”<sup>37</sup> With fewer wet-bottom boilers being used, this has impacted the production of boiler slag.

Utilities are turning more to the fluidized-bed combustion boiler, which includes many of the benefits of wet bottom boilers, such as burning lower rank coals with higher moisture and ash contents. This alternative technology has less nitrogen oxide emissions.<sup>38</sup>

There were 147 wet-bottom boilers in operation in 1985 where coal was the primary fuel for the boiler, representing over 14 percent of the boilers mainly burning coal. By 1996, there were 128 such operational boilers. This downturn coincided with a sharp decline in boiler slag production, which fell from a high of 6.2 million short tons in 1993 to 2.7 million short tons in 1997.<sup>39</sup>

Since that time, the average annual production of boiler slag has been 2.2 million short tons, and the total for 2013 was a new low of 1.4 million short tons. Of the primarily coal burning boilers in operation in 2012, there were 137 wet-bottom boilers, the same number as in 2005. Utilities plan to retire 13 of the wet-bottom boilers between 2013 and 2020.<sup>40</sup>

<sup>33</sup>Rusta S. Kayoncu and Donald W. Olson. Coal combustion products. US Department of the Interior, US Geological Survey, 2001. (<http://pubs.usgs.gov/fs/fs076-01/fs076-01.pdf>)

<sup>34</sup>Warren Chesner, Robert J. Collins, and M. H. MacKay. User guidelines for waste and by-product materials in pavement construction. No. FHWA-RD-97-148. 1998. (<http://www.fhwa.dot.gov/publications/research/infrastructure/structures/97148/intro.cfm>)

<sup>35</sup>Ibid.

<sup>36</sup>University of Kentucky, Center of Applied Energy Research. (<http://www.caer.uky.edu/kyasheducation/boilerslag.shtml>)

<sup>37</sup>U.S. EPA. “Available and Emerging Technologies for Reducing Greenhouse Gas Emissions From Coal-Fired Electric Generating Units.” October 2010. (<http://www.epa.gov/nsr/ghgdocs/electricgeneration.pdf>)

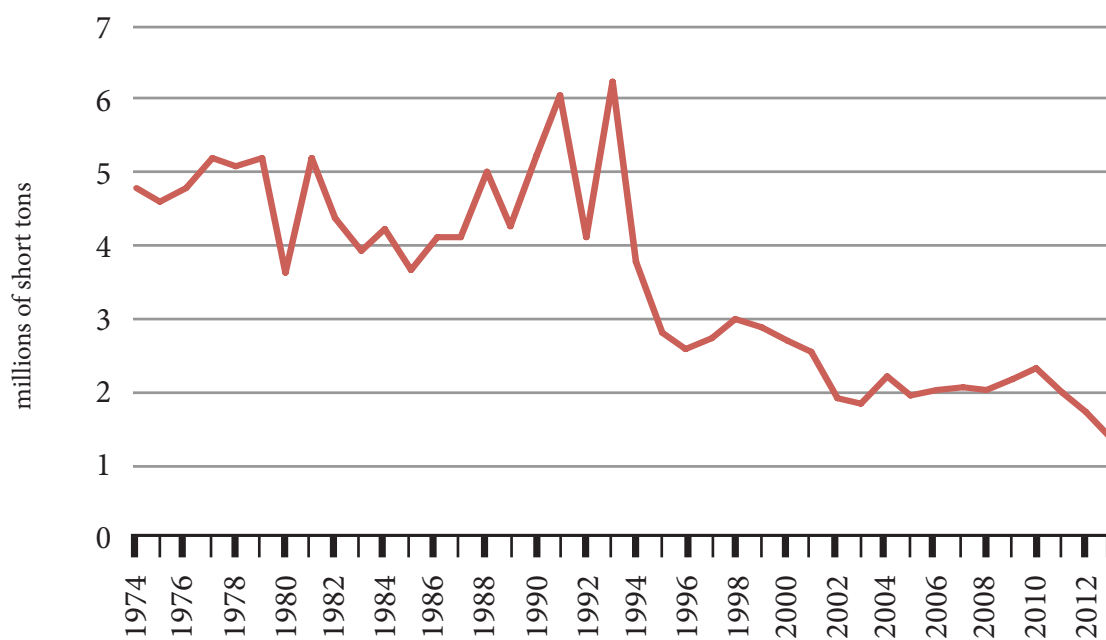
<sup>38</sup>Ibid.

<sup>39</sup>ARTBA analysis of EIA report 767 data for operational boilers where the primary source of fuel is coal.

<sup>40</sup>ARTBA analysis of EIA Reports 923 and 860 data for operational boilers where the primary source of fuel is coal.



**FIGURE 2-6: BOILER SLAG PRODUCTION**



### FBC ASH PRODUCTION

Total production of ash from fluidized bed combustion (FBC) has increased from 1.2 million short tons in 2002 to 10.3 million short tons in 2013. Part of this increase was the expansion of the ACAA production and use survey in 2007 to include data from the Anthracite Region Independent Power Producers Association (ARIPPA), comprised of non-utility alternative energy electric power generation stations that burn waste coal using FBC technology.

Since that time, the total production has grown from 6.1 million short tons in 2007, increasing at an average annual rate of nine percent.

The production of FBC ash is highly dependent on the volume of coal generated electricity, total coal consumption by electric utilities and the burning of waste coal. In addition, this market is impacted by technology and equipment upgrades to comply with environmental regulations.

FBC ash is the fly ash and the bed ash produced by an FBC boiler. The FBC fly ash is collected in the flue of the boiler with a baghouse filter or electrostatic precipitator. The bed ash is the residue that is removed from the bottom of the boiler.<sup>41</sup>

In an effort to meet emissions requirements, more utilities are building FBC boilers, which allows operators to burn lower rank coals with a higher moisture and ash content while reducing nitrogen oxide emissions.<sup>42</sup> FBC boilers operate at a lower temperature than conventional boilers, and this reduced temperature results in the reduction in nitrogen oxide emissions.

FBC technology is also used to convert coal refuse from current and past mining activities into energy. Many of these plants, captured in the ARIPPA data, are located in Pennsylvania. ARIPPA members have removed more than 212 million tons of coal refuse and restored more than 8,200 acres of damaged mine lands since 1988.<sup>43</sup>

There were 46 plants that produced FBC ash in 2012, with the largest volumes in Texas, Pennsylvania and Kentucky.<sup>44</sup>

FBC ash production fell sharply in 2012 from 13.2 to 9.8 million short tons, a decline of 26 percent. This was the same year that coal consumption for electricity fell 12 percent and the total megawatt hours of coal generated electricity was down 13 percent, once again highlighting how such dramatic shifts in these markets will impact CCP production.

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<sup>41</sup>American Coal Ash Association. "Glossary of terms concerning the management and use of coal combustion products (CCPs)." American Coal Ash Association, Inc., Aurora, CO (2003). ([http://www.acaa-usa.org/Portals/9/Files/PDFs/ACAA\\_Glossary\\_of\\_Terms-April\\_2003.pdf](http://www.acaa-usa.org/Portals/9/Files/PDFs/ACAA_Glossary_of_Terms-April_2003.pdf))

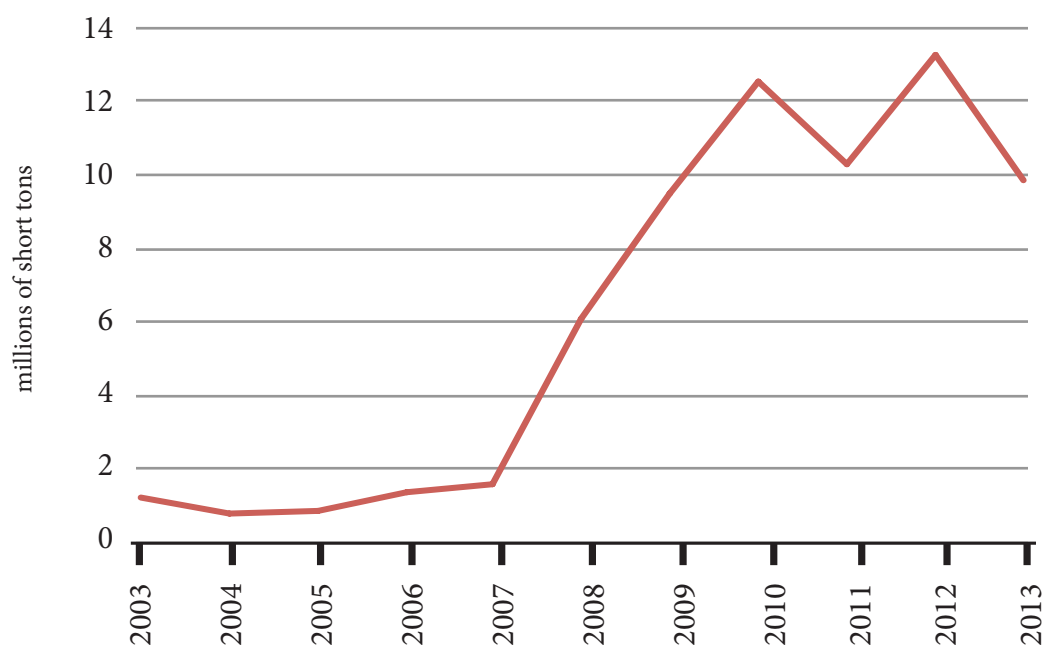
<sup>42</sup>Ibid.

<sup>43</sup>"Environmental Win-Win, ARIPPA's Role: Cleaning Up Historic Coal Waste Sites, Restoring the Land Using Ash." Ash at Work 1 (2014). (<http://arippa.org/documents/ACAA%20ARIPPA%20Environmental%20Win-Win%20Article.pdf>)

<sup>44</sup>ARTBA analysis of EIA 923 form data.



**FIGURE 2-7: FBC ASH PRODUCTION**





# TOTAL CCP UTILIZATION

Total CCP utilization increased from 8.7 million short tons in 1974 to 51.6 million short tons in 2013, an increase of nearly 500 percent. Utilization was as high as 60.6 million short tons in 2008.

Two of the largest beneficial uses of CCPs in the U.S. are fly ash as a replacement for portland cement in concrete and FGD gypsum as a replacement for mined gypsum in wallboard.<sup>45</sup>

Research and analysis has shown that the beneficial use of CCPs can “contribute significant environmental and economic benefits.”<sup>46</sup> This can include reduced greenhouse gas emissions, reduced need for disposing of CCPs in landfills and the reduced use of virgin resources. The economic benefits include job creation in the end industries, reduced costs associated with CCP disposal, increased revenue from the sale of CCPs, and savings from using CCPs in place of other costly materials.

A number of factors have impacted CCP utilization over the last 39 years:<sup>47</sup>

- Regulatory certainty or uncertainty
- Demand from end markets, including production changes to incorporate a growing supply of CCPs
- Role of specifications and standards
- Logistics and infrastructure to support beneficial use as an alternative to disposal
- Role of technologies to improve ash quality
- Emerging utilization technologies
- Wider use and recognition that CCP material makes a superior product

As CCPs have become more widely used in construction materials, mining applications and agriculture, among other markets, and standards have been established, the focus has shifted to techniques for using increasingly higher quantities of ash. New industries have also emerged to help CCP producers improve, maintain and manage their supply.<sup>48</sup>

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<sup>45</sup>U.S. EPA Office of Solid Waste and Emergency Response, Office of Resource Conservation and Recovery. “Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard.” (February 2014) ([http://www.epa.gov/waste/conserve/imr/ccps/pdfs/ccr\\_bu\\_eval.pdf](http://www.epa.gov/waste/conserve/imr/ccps/pdfs/ccr_bu_eval.pdf))

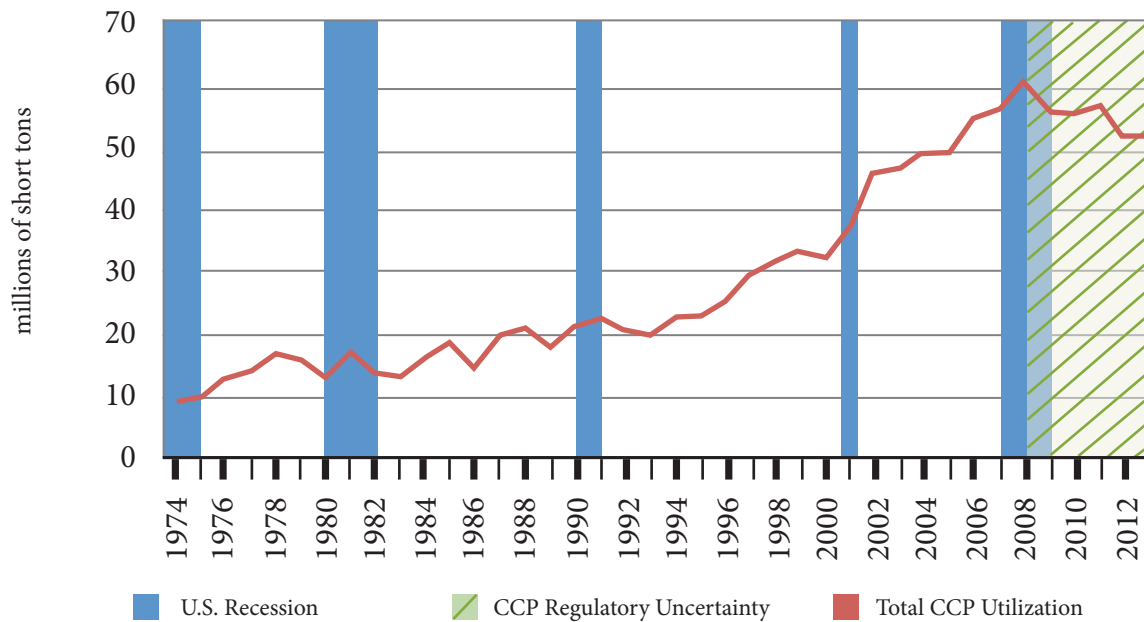
<sup>46</sup>Ibid.

<sup>47</sup>John Ward & A. Steward. The value of coal combustion products: an economic assessment of CCP unitization for the US economy. American Coal Council, Phoenix, AZ (United States), (2010). ([https://c.ymcdn.com/sites/www.americancoalcouncil.org/resource/resmgr/Docs/ACC\\_2010\\_CCP\\_ECON\\_ASSESSMENT.pdf](https://c.ymcdn.com/sites/www.americancoalcouncil.org/resource/resmgr/Docs/ACC_2010_CCP_ECON_ASSESSMENT.pdf))

<sup>48</sup>Ibid.



**FIGURE 3-1: UTILIZATION OF CCPs HAS INCREASED DURING RECESSIONS, BUT DROPPED DURING A PERIOD OF REGULATORY UNCERTAINTY**



**Major U.S. Recessions**  
 November 1973 to March 1975  
 January to July 1980  
 July 1981 to November 1982

July 1990 to March 1991  
 March to November 2001  
 December 2007 to June 2009

**CCP Regulatory Uncertainty:**  
 December 2008 to April 2015  
 EPA decision to reconsider the  
 classification of CCPs as a  
 hazardous waste

### FLY ASH UTILIZATION

Fly ash utilization has grown from 3.4 million short tons in 1974 to 23.3 million short tons in 2013, an increase of 586 percent. The utilization rate of fly ash has grown from 8.4 percent of production in 1974 to 43.7 percent in 2013.

Although the overall demand for construction materials and ready-mixed concrete are main drivers of fly ash utilization, there are a number of regulatory incentives and disincentives that have historically impacted the market.

Between 1975 and 2013, fly ash utilization grew at an average annual rate of 4.4 percent, well above the average annual growth rate for ready-mixed concrete production at 1.5 percent and U.S. GDP, which increased at an annual rate of three percent.

The majority of fly ash is used as an additive to enhance the durability and strength of construction materials, including concrete. The physical and chemical properties of fly ash improve both the plastic and hardened properties of concrete. “Adding fly ash to concrete reduces the water required, improves pumpability, reduces segregation, yields higher ultimate strength, and is very effective at mitigating durability problems like alkali-silica reactivity and reinforcing steel corrosion.”<sup>49</sup>

Fly ash has been used in many U.S. large-scale construction projects, beginning with the Hungry Horse Dam in Montana in 1948. Engineers with the U.S. Bureau of Reclamation were looking for a way to mitigate the heat of hydrating cement during the placement of concrete on the structure. That project alone used 120,000 metric tons (132,277 short tons of fly ash).<sup>50</sup> Between 1950 and 1970, concrete with fly ash content as high as 50 percent was used on over 100 major dam construction projects across the country.<sup>51</sup>

Other key uses of fly ash include structural fills and embankments, mining applications and waste stabilization and solidification.

Over time, the focus on fly ash utilization has shifted from education, demonstrating the usefulness of the material and establishing standards, to emerging technologies helping fly ash producers improve and maintain the quality of the product being utilized.<sup>52</sup>

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<sup>49</sup>Hank Keiper, P.E., “Addressing Coal’s Negative Impact – Beneficial Use of Fly Ash,” *The Virginia Engineer*, (April 2011). (<http://vaeng.com/guestarticle/addressing-coal-s-negative-impact-beneficial-use-of-fly-ash>)

<sup>50</sup>Ruta S. Kalyoncu and Donald W. Olson, “Coal Combustion Products,” U.S. Geological Survey Fact Sheet 076-01. (<http://pubs.usgs.gov/fs/fs076-01/fs076-01.html>)

<sup>51</sup>*Ibid.*

<sup>52</sup>John Ward & A. Steward. *The value of coal combustion products: an economic assessment of CCP unitization for the US economy*. American Coal Council, Phoenix, AZ (United States), (2010). ([https://c.ymcdn.com/sites/www.americancoalcouncil.org/resource/resmgr/Docs/ACC\\_2010\\_CCP\\_ECON\\_ASSESSMENT.pdf](https://c.ymcdn.com/sites/www.americancoalcouncil.org/resource/resmgr/Docs/ACC_2010_CCP_ECON_ASSESSMENT.pdf))

FIGURE 3-2: FLY ASH UTILIZATION

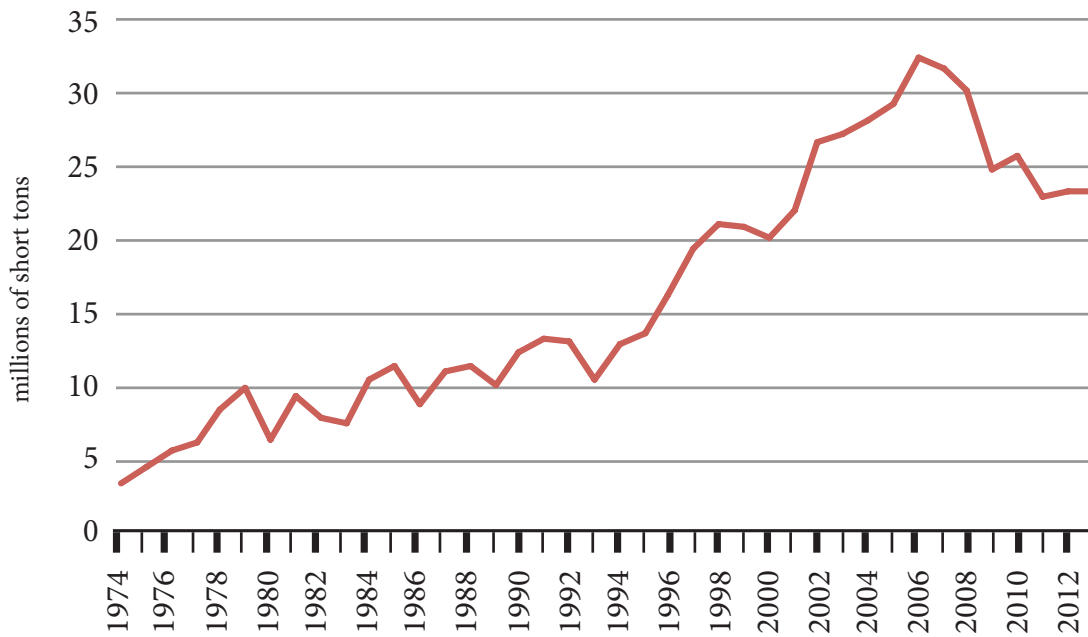
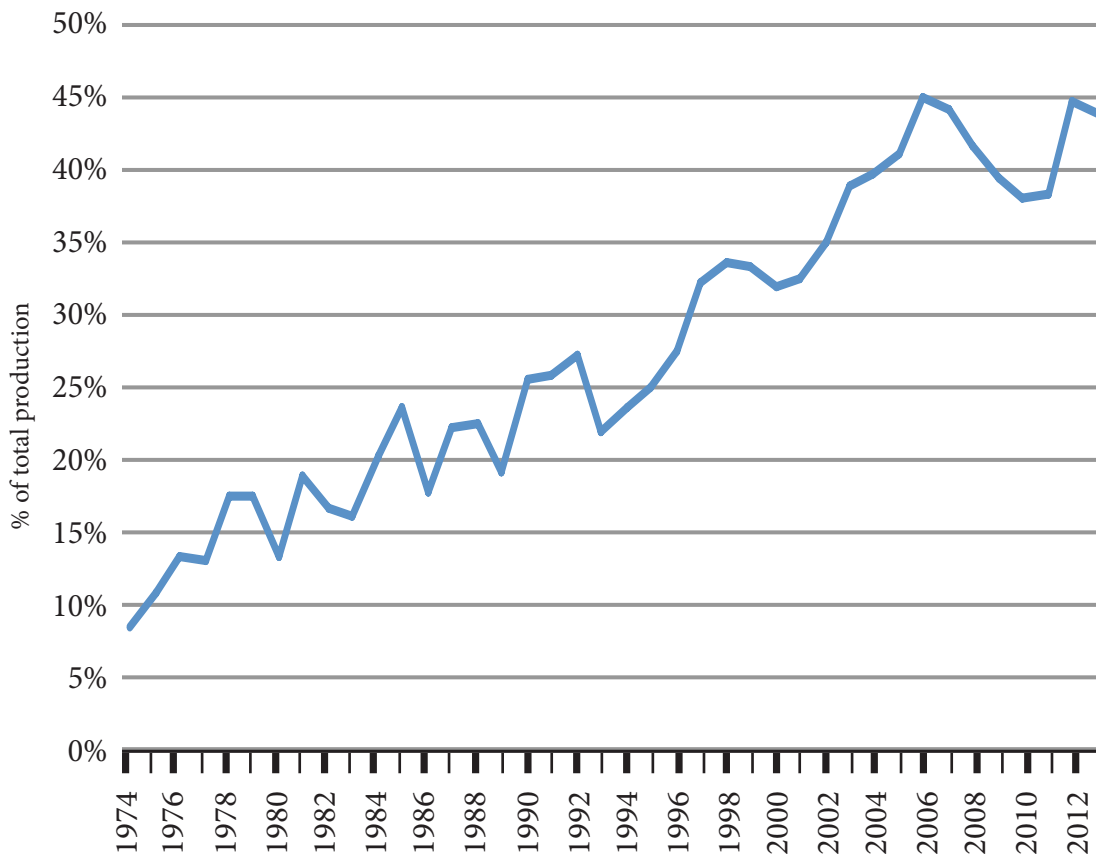


FIGURE 3-3: FLY ASH UTILIZATION RATE





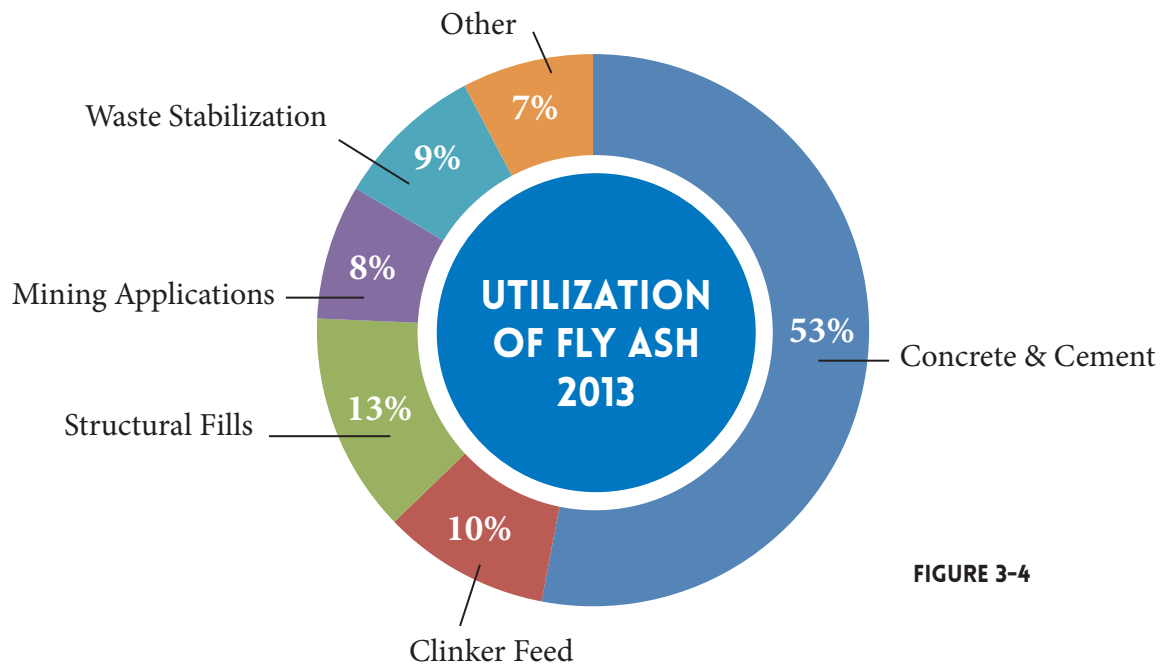
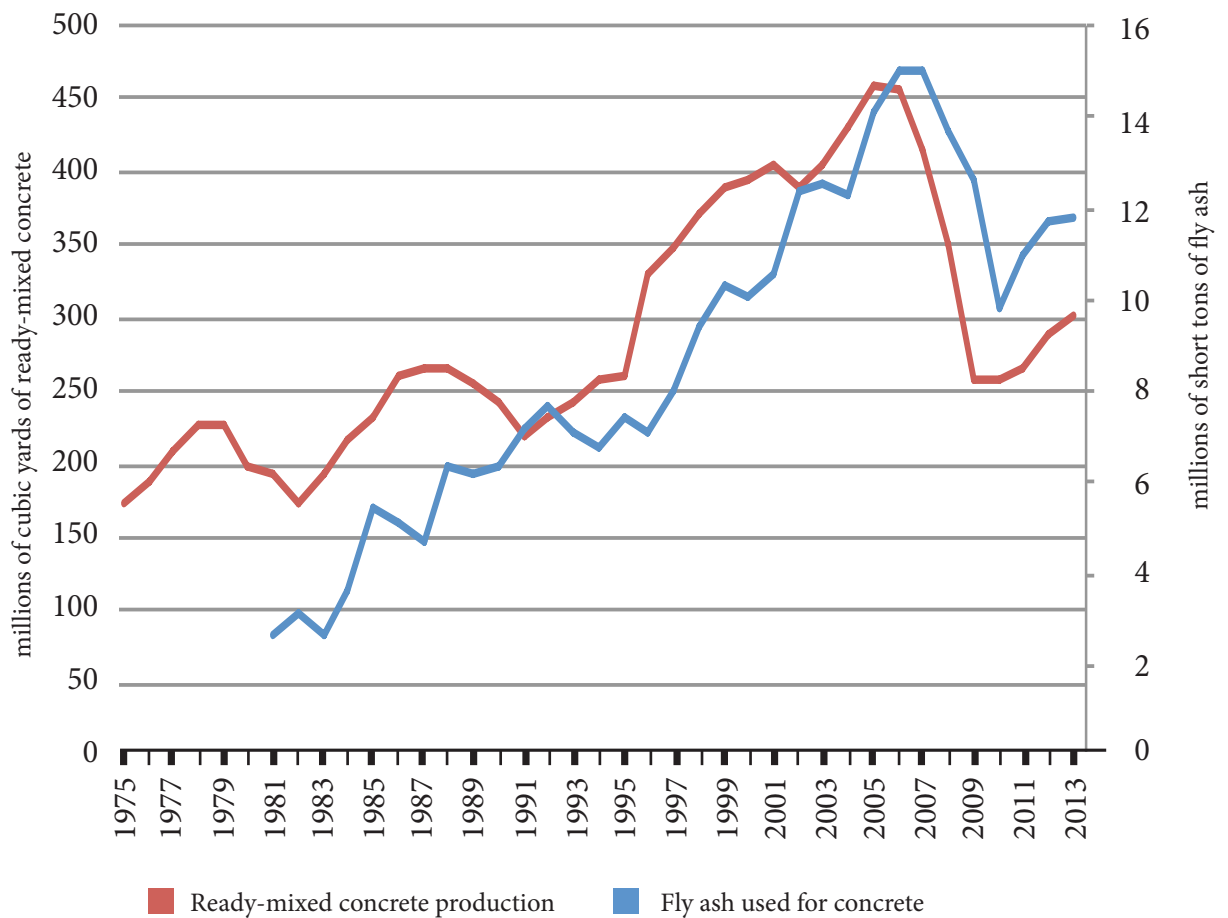


FIGURE 3-4

FIGURE 3-5: READY-MIXED CONCRETE PRODUCTION &amp; FLY ASH USED FOR CONCRETE



## REGULATORY CERTAINTY & GROWTH OF FLY ASH UTILIZATION

Historically, regulations regarding the classification of fly ash as either a solid waste or a hazardous material have had an impact on utilization.

The Resource Conservation and Recovery Act (RCRA), which amended the Solid Waste Disposal Act of 1965, is the primary law that governs the disposal of hazardous and solid waste in the United States.

RCRA Subtitle C establishes a “cradle to grave” system for controlling materials classified as hazardous waste. If a material is a solid waste but not considered hazardous, it is regulated under RCRA Subtitle D, which requires states to develop a comprehensive plan for managing nonhazardous solid waste.<sup>53</sup> In the original legislation, it was not clear if fly ash was considered a hazardous waste under Subtitle C or a solid waste under Subtitle D.

On October 12, 1980, Congress passed a law which amended RCRA. Fly ash and other CCPs were temporarily excluded from regulation under Subtitle C as a hazardous waste until further study and assessment. This regulatory exemption, known as the Bevill exemption, meant that CCPs were temporarily considered a solid waste under Subtitle D, thus subject to state regulations, until a formal report was conducted by EPA.

On August 9, 1993, EPA issued a regulatory determination that concluded that CCPs should continue to be exempt from Subtitle C of the RCRA because of the “limited risks posed by them and the existence of generally adequate State and Federal regulatory programs.”<sup>54</sup>

Under this environment of regulatory certainty, fly ash utilization doubled from 10.5 million short tons in 1993 to 20.1 million short tons in 2000, growing at an average annual rate of 10 percent. During the same time period the production of ready-mixed concrete grew at an average annual rate of seven percent.

The EPA issued a Final Regulatory Determination on May 22, 2000 that retained the Bevill exemption for fly ash and other “fossil fuel combustion wastes,” reaffirming the 1993 notice. EPA also determined that there would be no additional regulation for fly ash and the agency did “not wish to place any unnecessary barriers on beneficial use.” EPA announced it would develop national standards for the disposal of fly ash and other CCPs in landfills, surface impoundments and mines.

This utilization of fly ash grew at an average annual rate of 6.6 percent between 2000 and 2007, compared to an average annual rate of growth of 0.7 percent for ready-mixed concrete production. Fly ash utilization grew from 20.1 million short tons in 2000 to 31.6 million short tons in 2007.

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<sup>53</sup>U.S. EPA, “History of RCRA” (<http://www.epa.gov/osw/laws-regs/rcrahistory.htm>)

<sup>54</sup>U.S. Federal Register Vol. 58, No. 151, 40 CFR Part 261, “Final Regulatory Determination on Four Large-Volume Wastes From the Combustion of Coal by Electric Utility Power Plants.” (<http://www.epa.gov/epawaste/nonhaz/industrial/special/mineral/pdfs/080993.pdf>)

In the most recent recession, which began in December 2007 and ended June 2009, fly ash utilization declined slightly in 2007 and 2008, falling from 32.4 million short tons in 2006 to 31.6 million short tons in 2007 (a decline of 2.5 percent) and 30.1 million short tons in 2008 (a further decline of 4.7 percent).

GROWTH IN FLY ASH UTILIZATION AND READY-MIXED CONCRETE		
	AVERAGE ANNUAL GROWTH RATE	
TIME PERIOD	FLY ASH UTILIZATION	READY-MIXED CONCRETE PRODUCTION
1974 to 1980	11.2%	3.5%
1981 to 1990	3.1%	2.5%
1991 to 2000	4.8%	6.8%
2000 to 2008	5.2%	-1.5%
2009 to 2013	-5.0%	-3.1%
<b>Total for 1974 to 2013</b>	<b>5.1%</b>	<b>1.6%</b>

Meanwhile, the U.S. production of ready-mixed concrete had started to fall even before the official start of the recession, declining from 458.3 million cubic yards in 2005 to 456.8 million cubic yards in 2006 and 414.6 million cubic yards in 2007.

It was not until 2009 that fly ash utilization fell to 24.7 million short tons, a decline of 18 percent from 2008 levels—one full year after the recession began in December 2007. Although total volumes of ready-mixed concrete in 2013 are still below their pre-recession levels, the market bottomed out in 2010 and production has increased annually since that time. Meanwhile, fly ash utilization continues to remain depressed.

## INDUSTRY SPECIFICATIONS AND MATERIALS STANDARDS

Over the years, the development of guidelines, specifications and industry standards have encouraged wider use of fly ash in U.S. construction markets.

Guidelines for the use of fly as a concrete additive are part of standards ASTM C 618 and AASHTO M 295, ensuring that the final product conform to consistent, high quality physical and chemical properties.<sup>55</sup>

Additional standards address the particle size of fly ash (ASTM D 422 and AASHTO T88), the specific gravity (ASTM D 554 and AASHTO T 100) and the compaction (ASTM D 698 and AASHTO T 999 and T 180).

Other specifications for the use of CCPs for various manufacturing and engineering purposes have been developed separately. This includes standards for using fly ash with lime (ASTM C 593), blended hydraulic cements (ASTM C 595 and ASTM C 1157), for soil stabilization (ASTM D 5239), structural fills (ASTM E 2277-14), surface mine reclamation (ASTM E 2278 and ASTM E 2243-02) and other uses (ASTM D 5759).

More than a dozen federal agencies have published articles, guidelines and standards on the beneficial use of fly ash for construction and agricultural purposes. Many of these publications have been instrumental in educating a larger audience about the benefits of fly ash to improve material performance and reduce costs.

Some examples of U.S. federal support of fly ash utilization include:<sup>56</sup>

- **ENVIRONMENTAL PROTECTION AGENCY:** Over the years EPA has published a number of case studies and procurement guidelines that include information on using fly ash.<sup>57</sup>

In 1993, President Clinton established a federal environmental executive at EPA to develop a federal plan “to encourage the acquisition of recycled and environmentally preferable products by the Federal Government.” This included issuing guidance for federal agencies, which should consider the “elimination of virgin material requirements,” life cycle costs, recyclability, waste prevention and the use of environmentally preferable products in the acquisition planning for all procurements and contract awards.<sup>58</sup>

In 1997, EPA adopted the “Comprehensive Guideline for the Procurement of Products Containing Recovered Waste” and the “Recovered Materials Advisory Notice.” The guidelines recommended that all federal agencies, state and local government agencies and contractors using federal funds revise their cement and concrete procurement to allow the use of fly ash and ensure that guide specifications “do not inappropriately or unfairly discriminate against

<sup>55</sup>John Ward & A. Steward. The value of coal combustion products: an economic assessment of CCP unitization for the US economy. American Coal Council, Phoenix, AZ (United States), (2010). ([https://c.ymcdn.com/sites/www.americancoalcouncil.org/resource/resmgr/Docs/ACC\\_2010\\_CCP\\_ECON\\_ASSESSMENT.pdf](https://c.ymcdn.com/sites/www.americancoalcouncil.org/resource/resmgr/Docs/ACC_2010_CCP_ECON_ASSESSMENT.pdf))

<sup>56</sup>Ibid.

<sup>57</sup>A full list of detailed historical documents is available from ACAA in the Compilation of Regulations, Standards, Guidelines, Websites and other References Pertinent to Coal Combustion Products, revised February 12, 2007. (<http://www.epa.gov/epawaste/conserve/imr/pdfs/acaadoc.pdf>)

<sup>58</sup>Executive Order 12873—Federal Acquisition, Recycling and Waste Prevention, October 20, 1993. (<http://www.epa.gov/oppt/epp/pubs/eo12873.pdf>)



the use of coal fly ash ...”<sup>59</sup> Similar recommendations were made for the use of fly ash in flowable fills.

EPA recently conducted an evaluation of the beneficial use of fly ash as a direct substitute for portland cement in concrete. In the 2014 report *Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard*, the Agency concludes “the beneficial use of CCRs, when conducted in an environmentally sound manner, can contribute significant environmental and economic benefits” and “the agency supports the beneficial use of coal fly ash in concrete and FGD gypsum in wallboard.”<sup>60</sup> The evaluation was based on the methodology developed by the Agency and published in 2013.<sup>61</sup>

- **FEDERAL HIGHWAY ADMINISTRATION (FHWA) GUIDELINES:** FHWA has published several documents and guidelines for using CCPs and fly ash in highway construction: *Fly Ash Facts for Highway Engineers*, *Using Coal Ash in Highway Construction: A Guide to Benefits and Impacts* and *User Guidelines for Waste and Byproduct Materials in Pavement Construction*.<sup>62</sup>

FHWA has also published research information on high-volume fly ash mixtures and the associated benefits of this technology.<sup>63</sup>

- **ARMY CORPS OF ENGINEERS:** There are a number of Army Corps specifications and reports that discuss the use of fly ash in concrete for transportation and construction projects.<sup>64</sup> The Army Corps also allows fly ash to be used for sub-grade stabilization, embankments, flowable fill, soil amendment and asphalt filler.
- **ADDITIONAL FEDERAL AGENCIES:** Additional material has been published by the Federal Aviation Administration, the U.S. Department of Agriculture, the U.S. Geological Survey and the U.S. Department of Energy.<sup>65</sup>

State Departments of Transportation (DOTs) also maintain specifications for fly ash used in concrete. Although specifics may vary regionally, nearly all of the standards are based on ASTM C618 or AASHTO M295.<sup>66</sup> An average of 75 percent of all the concrete poured on U.S. highways,

<sup>59</sup>U.S. EPA. “Consolidated Recovered Materials Advisory Notice (RMAN) For the Comprehensive Procurement Guideline (CPG),” Compiled December 1997, revised as recently as September 2007. (<http://www.epa.gov/epawaste/conserve/tools/cpg/pdf/consolrman.pdf>)

<sup>60</sup>U.S. EPA Office of Solid Waste and Emergency Response, Office of Resource Conservation and Recovery. “Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard.” (February 2014) ([http://www.epa.gov/waste/conserve/imr/ccps/pdfs/ccr\\_bu\\_eval.pdf](http://www.epa.gov/waste/conserve/imr/ccps/pdfs/ccr_bu_eval.pdf))

<sup>61</sup>U.S. EPA Office of Solid Waste and Emergency Response, Office of Resource Conservation and Recovery. “Methodology for Evaluating Encapsulated beneficial Uses of Coal Combustion Residuals.” (September 2013) [http://www2.epa.gov/sites/production/files/2014-12/documents/ccr\\_bu\\_method.pdf](http://www2.epa.gov/sites/production/files/2014-12/documents/ccr_bu_method.pdf)

<sup>62</sup>FHWA Reports # FHWA-IF-03-019, # EPA-530-K-05-002 and # FHWA-RD-97-148. (<http://www.fhwa.dot.gov/pavement/recycling/fafacts.pdf>)

<sup>63</sup>FHWA-HRT-12-062. “Benefits of High Volume Fly Ash: New Concrete Mixtures Provide Financial, Environmental and Performance Gains.” FHWA-HRT-10-051 (<http://www.fhwa.dot.gov/advancedresearch/pubs/10051/>)

<sup>64</sup>Toy S. Poole. *Use of Large Quantities of Fly Ash in Concrete*. No. WES/TR/SL-95-9. ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS STRUCTURES LAB, 1995. ([http://acwc.sdp.sirsi.net/client/en\\_US/default/search/detailnonmodal/ent:\\$002f\\$002fSD\\_ILS\\$002f0\\$002fSD\\_ILS:282653/ada/?rt=CKEY%7C%7C%7CCKEY%7C%7C%7Cfalse](http://acwc.sdp.sirsi.net/client/en_US/default/search/detailnonmodal/ent:$002f$002fSD_ILS$002f0$002fSD_ILS:282653/ada/?rt=CKEY%7C%7C%7CCKEY%7C%7C%7Cfalse))

<sup>65</sup>ACAA, “Compilation of Regulations, Standards, Guidelines, Websites and other References Pertinent to Coal Combustion Products,” (2007). (<http://www.epa.gov/epawaste/conserve/imr/pdfs/acaadoc.pdf>)

<sup>66</sup>Bruce A. Dockter and Diana M. Jagiella. “Engineering and Environmental Specifications of State Agencies for Utilization and Disposal of Coal Combustion Products.” *World of Coal Ash Conference*, Lexington Kentucky. 2005. (<http://www.worldofcoalah.org/2005/ashpdf/136doc.pdf>)

valued at nearly \$10 billion, utilizes fly ash as a partial cement replacement blend.<sup>67</sup>

A recent report by the Transportation Research Board, which included a survey of state DOTs and a literature review, suggested a need for “refining the existing classification method to include properties known to affect performance.”<sup>68</sup> As one example the authors noted that the classification of fly ash does not include reporting calcium content, which is important for alkali-silica reaction mitigation practices.

### FGD MATERIAL UTILIZATION

The utilization of FGD material has grown from 1.02 million short tons in 1987 to 12.9 million short tons in 2013, increasing at an average annual rate of 10.3 percent.

Most of the FGD material, 7.4 million short tons, was used in gypsum panel products in 2013. Known as FGD gypsum or synthetic gypsum, this material can be used as a full substitute for mined gypsum in wallboard and drywall because the primary chemical constituent is identical.<sup>69</sup> FGD gypsum may even have higher gypsum purity than mined gypsum because of the “greater control over the chemical composition of the final product.”<sup>70</sup>

FGD material is also used as an input for blended cement and feed for clinker and in both mining and agricultural applications.

The total utilization of FGD material has grown from 7.2 percent of total material produced in 1987 to 37 percent in 2013.

As a substitute for natural gypsum, demand for FGD material has historically been related to demand for gypsum wallboard and total U.S. construction activity. But as wallboard manufacturers have recognized the superior properties of FGD material—they have shifted their production process to further reduce the costs of using the synthetic material.

As overall demand for gypsum has increased with U.S. construction activity, the use of FGD synthetic gypsum has coincided with a decline in gypsum imports.

The growth in the utilization of FGD over the last 27 years is supported by increased production, the commercialization of the product and the ease of substitution with the virgin material. FGD material has become the “preferred feedstock” for wallboard manufactures because its “uniform properties simplify manufacturing operations for existing users.”<sup>71</sup> In addition, many wallboard manufacturers have located new facilities near coal-fueled power plants to have access to FGD gypsum.

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<sup>67</sup>Alison Premo Black, et al. “The Economic Impacts of Prohibiting Coal Fly Ash Use in Transportation Infrastructure Construction.” (2011). (<http://trid.trb.org/view.aspx?id=1123544>)

<sup>68</sup>Lawrence L. Sutter, R. Douglas Hooton, and Scott Schlorholtz. Methods for Evaluating Fly Ash for Use in Highway Concrete. Vol. 749. Transportation Research Board, 2013. ([http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp\\_rpt\\_749.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_749.pdf))

<sup>69</sup>EPA. “Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard.” (February 2014). ([http://www.epa.gov/waste/conservation/ccps/pdfs/ccr\\_bu\\_eval.pdf](http://www.epa.gov/waste/conservation/ccps/pdfs/ccr_bu_eval.pdf))

<sup>70</sup>Ibid.

<sup>71</sup>U.S. Department of Energy National Energy Technology Laboratory, DOE/NETL-2001/1158. “Advanced Flue Gas Desulfurization Demonstration Project, A DOE Assessment.” (August 2001). (<http://www.netl.doe.gov/research/coal/major-demonstrations/clean-coal-technology-demonstration-program/bectso-adflug>)

FIGURE 3-6: FGD MATERIAL UTILIZATION

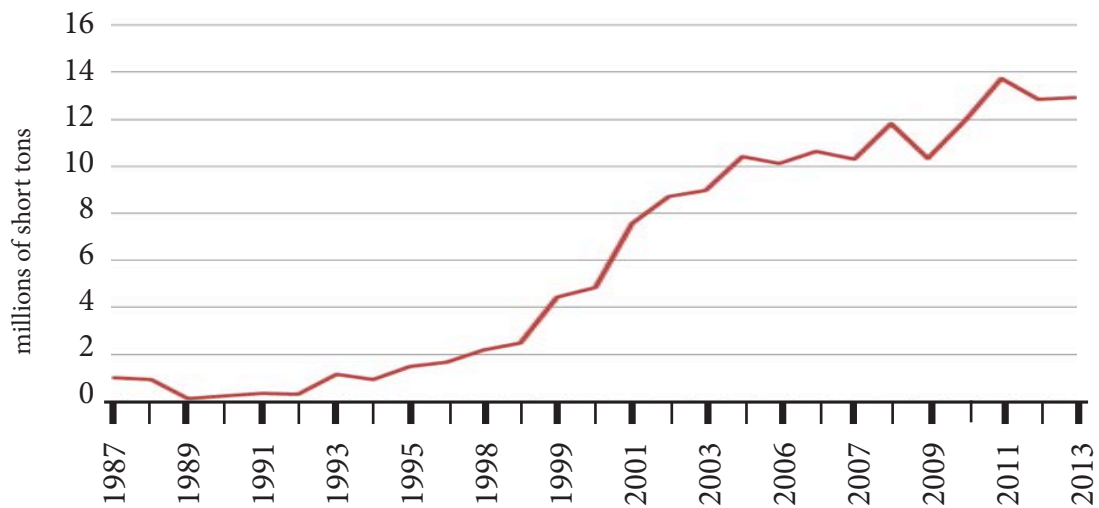


FIGURE 3-7: FGD MATERIAL UTILIZATION RATE

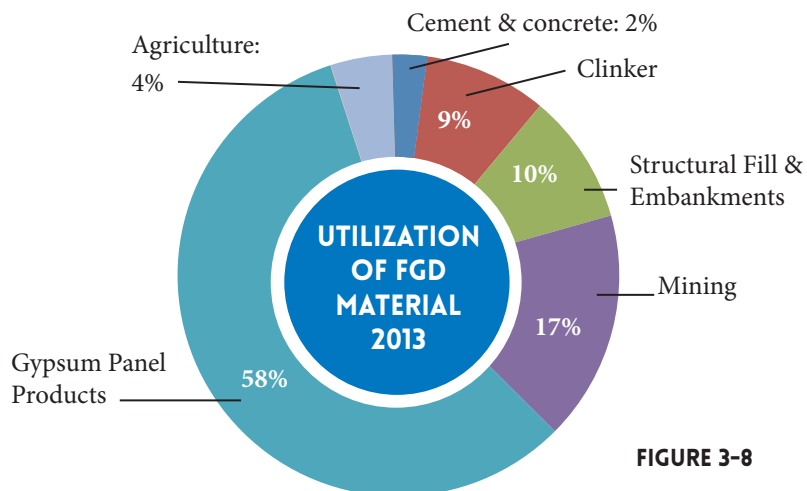
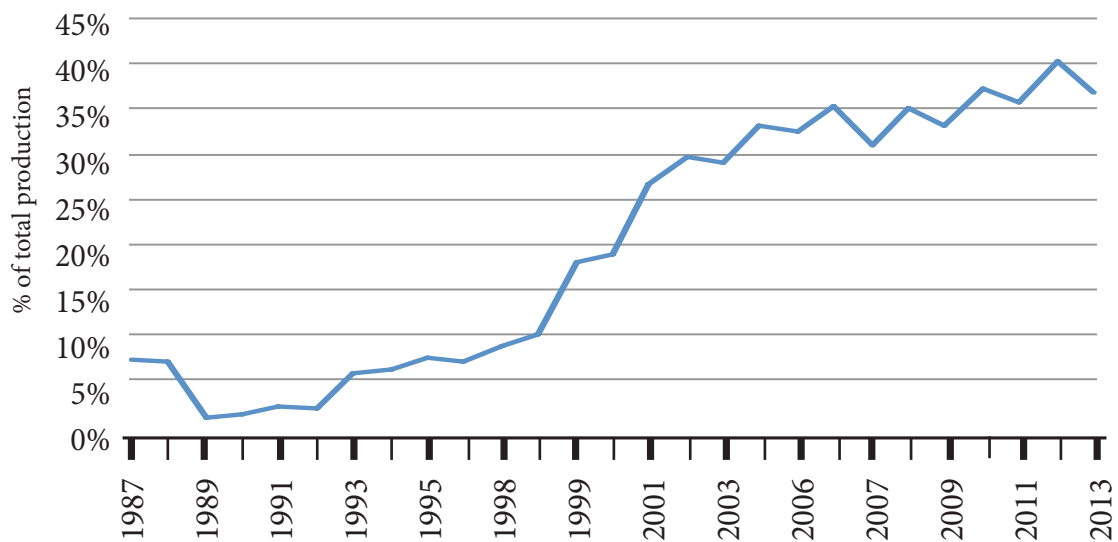


FIGURE 3-8

### GROWTH IN FGD MATERIAL UTILIZATION—1987 TO 2008

Between 1987 and 1992 the utilization of FGD material averaged 486,500 short tons per year. In the U.S. gypsum market, “byproduct gypsum” accounted for 4.2 percent of total domestic production in 1987 and 2.6 percent of U.S. consumption. The U.S. Geological Survey noted that there were seven companies that sold byproduct gypsum “principally for agricultural use, but some for gypsum wallboard manufacturing.”<sup>72</sup>

The utilization of FGD material began increasing significantly after 1993, growth that coincided with the regulatory certainty provided by the EPA. FGD material was one of the CCPs being reviewed by EPA for regulation under RCRA Subtitle C or Subtitle D and was included in the Bevill exemption in 1980.

The EPA final regulatory determination that concluded CCPs and FGD gypsum should continue to be exempt from Subtitle C of the RCRA and regulated as a solid waste, issued on August 9, 1993, provided regulatory certainty for utilization.

Between 1993 and 2000, utilization grew at an average annual rate of 23 percent, increasing from 1.2 million short tons in 1993 to 4.8 million short tons in 2000.

During this same time, total domestic gypsum production grew at an average annual rate of 5.7 percent, crude gypsum mining grew at a rate of 3.1 percent and total U.S. domestic gypsum consumption grew at a rate of 5.0 percent. The total million square feet of wallboard products sold increased at an average annual rate of 1.7 percent.

Synthetic gypsum grew from 4.8 percent of total domestic gypsum production to 20.2 percent. As a percentage of total consumption, synthetic gypsum increased from 2.9 percent of the market to 14.7 percent.

Although the U.S. continued to import more gypsum to meet growing demand, as a percentage of total production, imports declined from 31 percent of the market in 1993 to 27 percent in 2000. The use of imports continued to decline over the next decade, both in terms of volume and market share, with additional regulatory certainty and the increased use of FGD material.

The EPA issued another Final Regulatory Determination on May 22, 2000 that retained the Bevill exemption for FGD material, reaffirming the 1993 notice and determined that there would be no additional regulation. At this point, FGD material was “becoming very important as a substitute for mined gypsum in wall board manufacturing, cement production and agricultural applications.”<sup>73</sup>

Between 2000 and 2008, FGD material utilization grew at an average annual rate of 12 percent, more than doubling from 4.8 million short tons to 11.8 million short tons as the overall U.S. gypsum market was in decline.

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<sup>72</sup>U.S. Geological Survey. “Gypsum.” Minerals Yearbook (1987) (<http://minerals.usgs.gov/minerals/pubs/commodity/gypsum/>)

<sup>73</sup>U.S. Geological Survey. “Mineral Commodity Summaries.” (2002) (<http://minerals.usgs.gov/minerals/pubs/mcs/2002/mcs2002.pdf>)

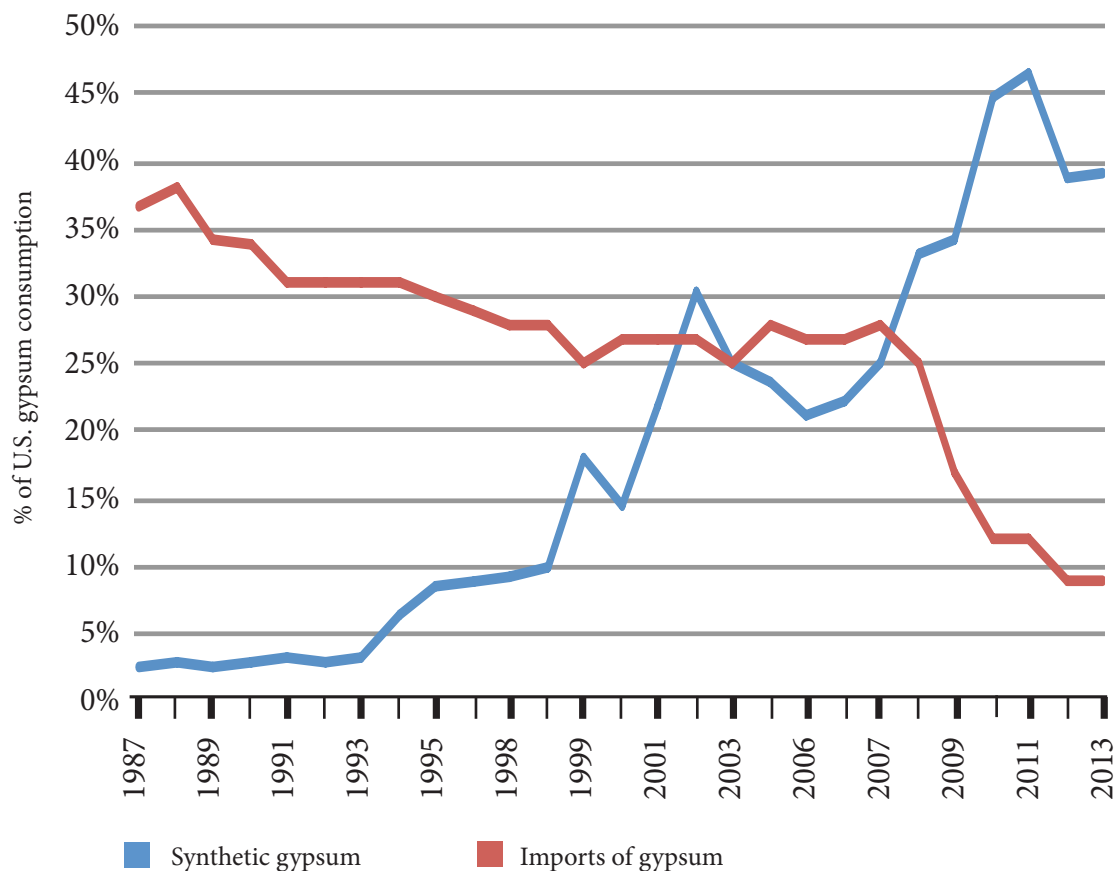


FGD material was increasingly used as a substitute for U.S. mined crude gypsum and gypsum imports. U.S. production of crude gypsum declined at an average annual rate of 5.2 percent between 2000 and 2008, falling from 19.5 million metric tons to 12.7 million metric tons. Total domestic gypsum production declined at a rate of 1.1 percent and total gypsum consumption fell at a rate of 1.8 percent. This decline was driven by lower demand for gypsum products: total volume of wallboard products sold in the United States declined at an average annual rate of 2.9 percent.

Synthetic gypsum from FGD plants grew at an average annual rate of 8.7 percent between 2000 and 2008 as imports of gypsum declined at a rate of 2.8 percent.

The availability of FGD material as a substitute for mined gypsum continued to change the fundamentals of the domestic industry. To take advantage of the FGD material, “much of the production at new and expanded facilities will consume synthetic gypsum produced by scrubbing emission from coal-fired electric power plants.”<sup>74</sup>

**FIGURE 3-9: SYNTHETIC (FGD) GYPSUM HAS BEEN REPLACING GYPSUM IMPORTS**



<sup>74</sup>U.S. Geological Survey. “Gypsum.” Minerals Yearbook (2007)

FIGURE 3-10: TOTAL U.S. GYPSUM PRODUCTION &amp; UTILIZATION

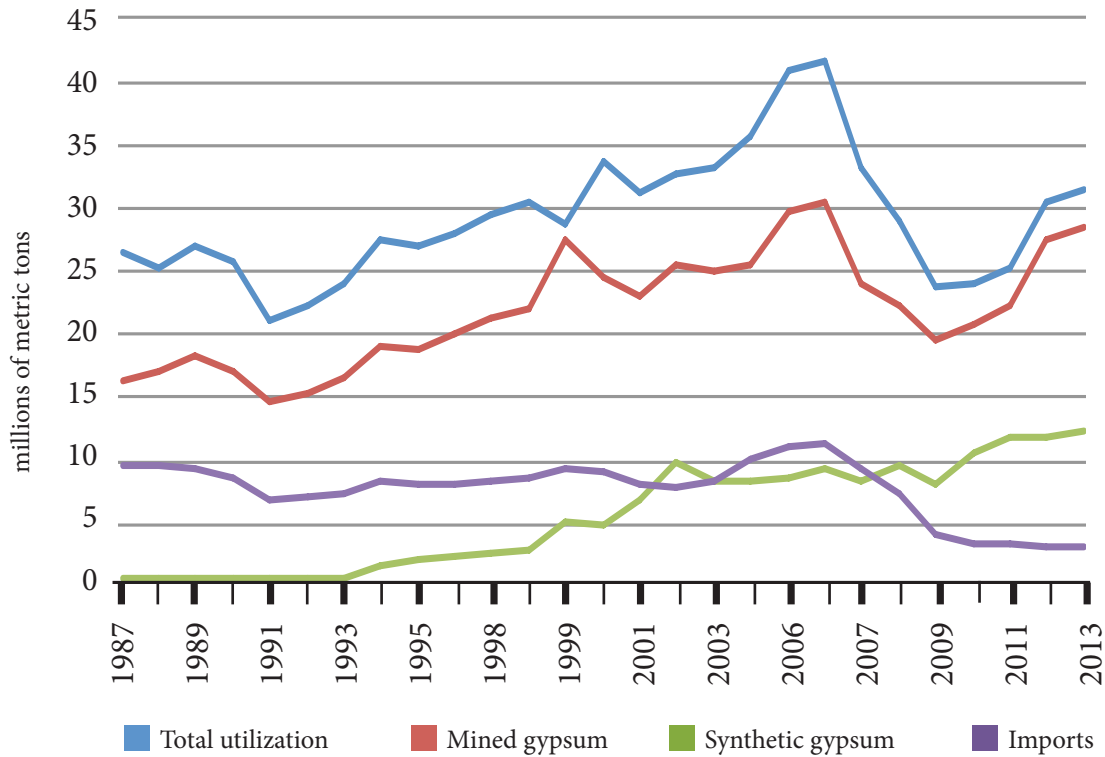
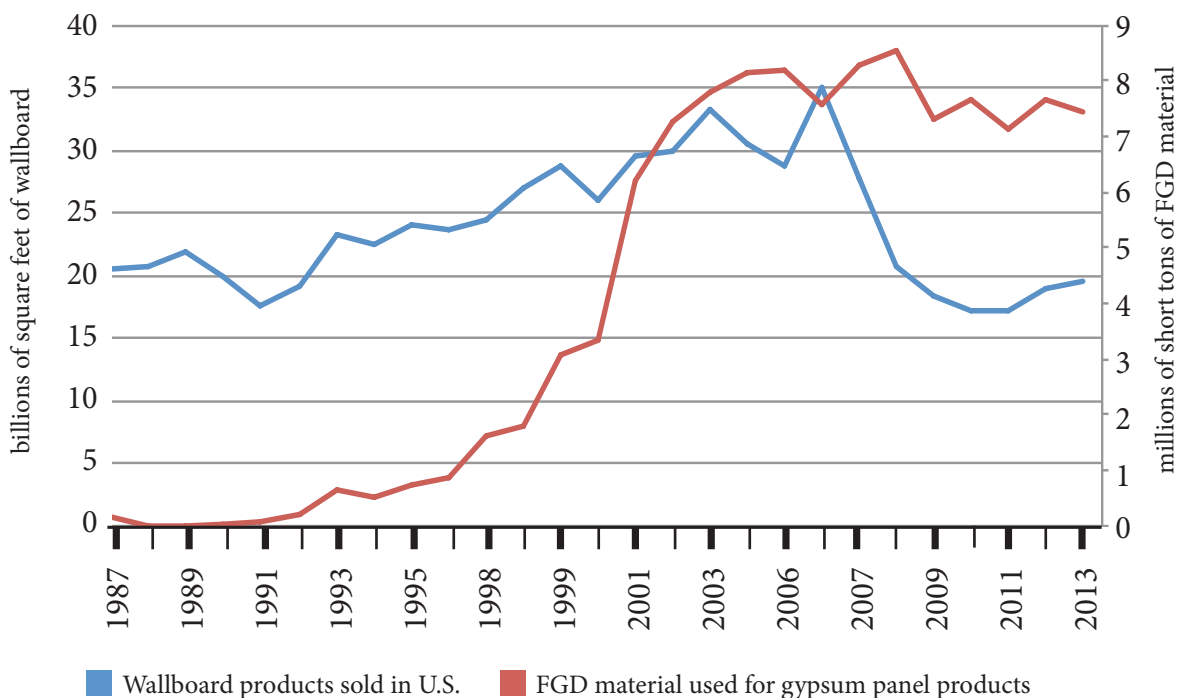


FIGURE 3-11: SALES OF WALLBOARD PRODUCTS &amp; FGD MATERIAL UTILIZATION



### RECENT DEVELOPMENTS IN FGD MATERIAL UTILIZATION—2008 TO 2013

Recent development in the utilization of FGD material have been largely driven by overall demand for gypsum wallboard and the supply of FGD material.

FGD material utilization continued to grow between 2008 and 2013, increasing from 11.8 million short tons to 12.9 million short tons. But the rate of average annual growth has slowed to two percent.

Total U.S. gypsum production and consumption declined in 2008 and 2009 as “the housing and construction markets continued to falter.”<sup>75</sup> The utilization of FGD material also declined from 11.8 million short tons in 2008 to 10.3 million short tons in 2009, following the U.S. recession.

FGD material utilization began to grow in 2010, even as sales of wallboard products and total U.S. gypsum production declined further. The increase in FGD material helped to meet a slight increase in overall domestic gypsum consumption in 2010.

The utilization of FGD material for agriculture and mining applications has grown significantly since 2008. Total utilization for mining nearly doubled from 794,745 short tons in 2008 to 1.5 million short tons in 2013.

The use of FGD material for agriculture applications was 281,752 short tons in 2008. That has grown to 655.6 thousand short tons in 2013. Although gypsum was used for agriculture purposes as early as the 18<sup>th</sup> century, high extraction and transportation costs meant it was used only for a few crops.<sup>76</sup> Much like the wallboard industry, agriculture producers are finding that the availability of FGD gypsum, as well as the smaller and uniform particle size mean that the synthetic material is providing “greater soil improvements” than commercially mined gypsum.<sup>77</sup>

### INDUSTRY SPECIFICATIONS AND MATERIALS STANDARDS

There are several standards and specifications that have helped support the growing utilization of FGD materials.

FGD gypsum used for wallboard and related materials are produced in compliance with ASTM C1396, ASTM C 1395, ASTM C 1278 and ASTM C1179, among others.<sup>78</sup>

FHWA published guidelines for using FGD material in pavement construction as a subbase material in 1997.<sup>79</sup>

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<sup>75</sup>U.S. Geological Survey, “Gypsum.” Minerals Yearbook (2008)

<sup>76</sup>Dexter B. Watts and Warren A. Dick. “Sustainable uses of FGD gypsum in agricultural systems: Introduction.” Journal of environmental quality 43.1 (2014): 246-252.

<sup>77</sup>Ibid.

<sup>78</sup>Gypsum Association. “Gypsum Panel Products Types, Uses, Sizes and Standards (GA-223-04).” (<https://www.gypsum.org/wp/wp-content/uploads/2011/11/223-04.pdf>)

<sup>79</sup>Warren H. Chesner, Robert J. Collins, and M. H. MacKay. User guidelines for waste and by-product materials in pavement construction. No. FHWA-RD-97-148. 1998. (<http://www.fhwa.dot.gov/publications/research/infrastructure/structures/97148/intro.cfm>)

## BOTTOM ASH UTILIZATION

Bottom ash utilization has grown from 2.9 million short tons in 1974 to 5.6 million short tons in 2013, an increase of 95 percent. The utilization rate of bottom ash has grown from 20.3 percent of production in 1974 to 39 percent in 2013.

Bottom ash is mainly used as an input for blended cement, clinker and concrete products, structural fills and embankments, soil modification and snow and ice control.

Although bottom ash has a chemical composition that is similar to fly ash, the size of the material can range from “fine sand to large gravel,” and thus it does not have any cementitious properties.<sup>80</sup> Since bottom ash is not pozzolanic it has more limited applications in the cement and concrete industry than fly ash.<sup>81</sup> Bottom ash is typically used as a lightweight aggregate in precast concrete products, including concrete blocks and masonry units.<sup>82</sup> The final product is much lighter than when using conventional aggregates, such as sand and gravel, and is just as strong.<sup>83</sup>

Two-thirds of the bottom ash utilized in 2013 was for concrete, blended cement/feed for clinker and structural fills and embankments.

In terms of highway embankments, subgrades and sub-bases, bottom ash has properties that “compare favorably with conventional highway materials” and meet the same specification requirements in testing.<sup>84</sup> Research also shows that there is “no difference in performance” when bottom ash is incorporated into asphalt mixtures.<sup>85</sup> Some mixes with bottom ash are improved by showing “high-temperature rutting and low-temperature cracking characteristics” and require less compactive effort to achieve “desired optimum densities.”<sup>86</sup>

The same regulatory incentives and disincentives that have impacted fly ash utilization have also had an effect on the utilization of bottom ash.

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<sup>80</sup>Texas Coal Ash Utilization Group, FAQ. “What are coal combustion products?” (<http://www.tcaug.org/faq/>)

<sup>81</sup>R.C. Joshi and R. P. Lohita. Fly ash in concrete: production, properties and uses. No. 2. CRC Press, 1997. ([https://books.google.com/books/about/Fly\\_Ash\\_in\\_Concrete.html?id=8ITxm7zHul4C](https://books.google.com/books/about/Fly_Ash_in_Concrete.html?id=8ITxm7zHul4C))

<sup>82</sup>G.J. Dienhart, B. R. Stewart, and S. S. Tyson. “Coal ash: innovative applications of coal combustion products.” American Coal Ash Association, Alexandria, VA (1998).

<sup>83</sup>University of Kentucky, Center for Applied Energy Research (<http://www.caer.uky.edu/kyasheducation/bottomash.shtml>)

<sup>84</sup>Wsei-Hsing Huang, “The use of bottom ash in highway embankments, subgrades, and subbases.” (1990). (<http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1782&context=jtrp>)

<sup>85</sup>Khaled Ksaibati and Jason Stephen. Utilization of bottom ash in asphalt mixes. No. MCP Report No. 99-104A. Department of Civil and Architectural Engineering, University of Wyoming, 1999. (<http://trid.trb.org/view.aspx?id=502631>)

<sup>86</sup>Ibid.



FIGURE 3-12: BOTTOM ASH UTILIZATION

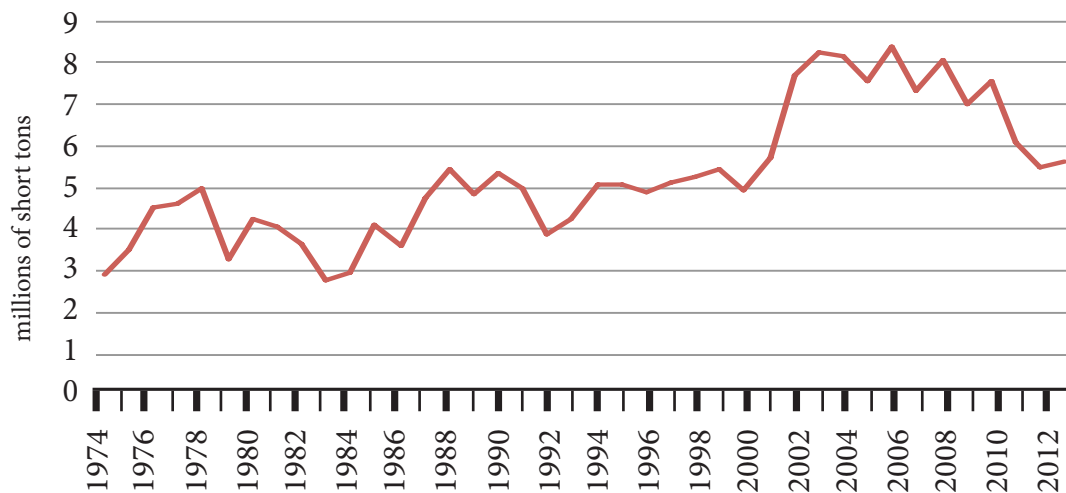


FIGURE 3-13: BOTTOM ASH UTILIZATION RATE

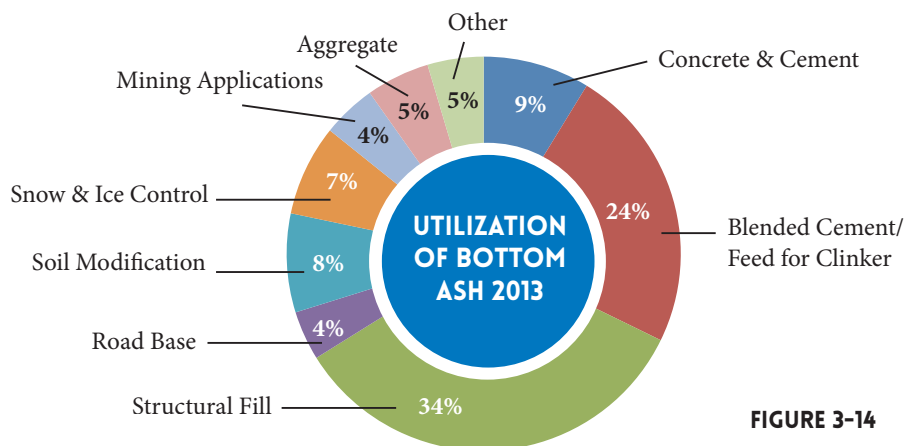
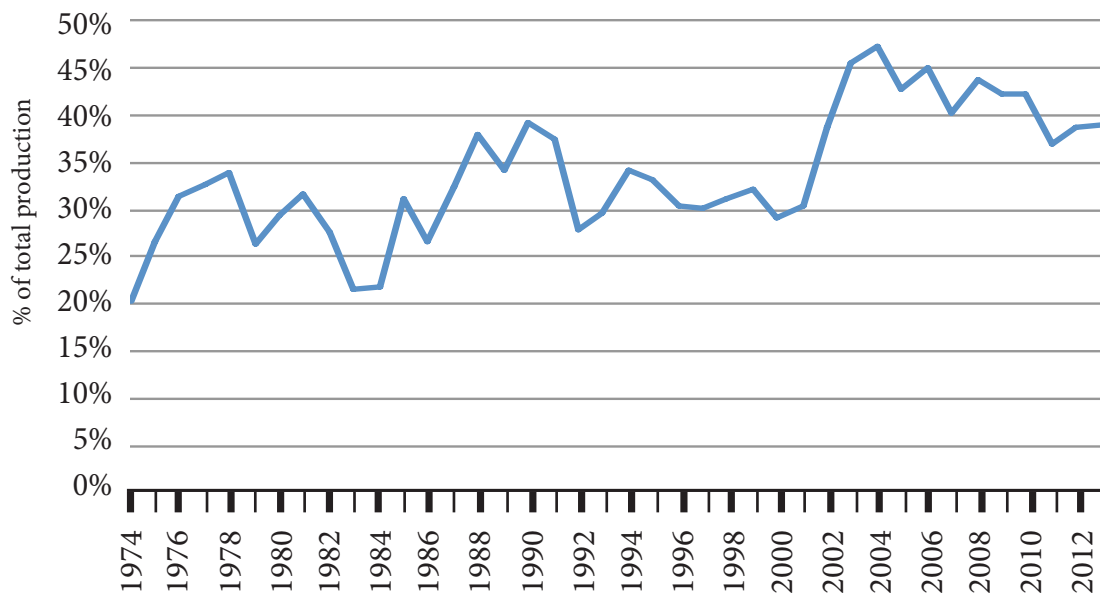


FIGURE 3-14

### REGULATORY CERTAINTY & BOTTOM ASH UTILIZATION—1974 TO 2007

Bottom ash was one of the “four Bevill CCR wastes” along with fly ash, boiler slag and FGD materials, that was being considered a coal combustion residual under the RCRA and the Bevill Amendment exemption.<sup>87</sup>

The utilization of bottom ash grew at an average annual rate of two percent between 1974 and 1993, outpacing bottom ash production, which was fairly flat over the same time period, declining slightly from 14.3 million short tons in 1974 to 14.2 million short tons in 1993.

The utilization of bottom ash continued to grow at an average annual rate of two percent between 1993 and 2000, after the August 9, 1993 EPA Regulatory Determination that concluded bottom ash and CCPs should continue to be exempt from Subtitle C of the RCRA and not be classified as a hazardous waste.

Total bottom ash utilization grew from 4.2 million short tons in 1993 to 4.9 million short tons in 2000.

The Final Regulatory Determination issued by EPA on May 22, 2000 that retained the Bevill exemption for bottom ash ushered in a new era of regulatory certainty.

Between 2000 and 2008, the utilization of bottom ash grew at an average annual rate of six percent, growing from 4.9 million short tons to 8.0 million short tons. This increase in volume reflects higher demand for bottom ash as an input for blended cement and concrete and structural fills/embankments.

This growth occurred at a time when the real value of pavement work, which is a major end market for bottom ash in structural fills, actually declined slightly from \$57.2 billion in work to \$56.9 billion. U.S. production of ready-mixed concrete fell at an average annual rate of one percent between 2000 and 2008, and housing starts declined at an average annual rate of four percent. This points to the increased value of bottom ash as a less expensive substitute for traditional building materials, especially during a time when the construction markets are beginning to weaken.

Bottom ash utilization has declined at an average annual rate of seven percent between 2008 and 2013, falling from 8 million short tons to 5.6 million short tons in the environment of regulatory uncertainty.

GROWTH IN BOTTOM ASH UTILIZATION	
TIME PERIOD	AVERAGE ANNUAL GROWTH RATE
1974 to 1980	6.6%
1981 to 1990	3.1%
1991 to 2000	-0.1%
2000 to 2008	6.3%
2009 to 2013	-6.9%
<b>Total for 1974 to 2013</b>	<b>1.7%</b>

<sup>87</sup>EPA, June 21, 2010, Proposed Rule, “Hazardous and Solid Waste Management System; Identification and Listing of Special Wastes; Disposal of Coal Combustion Residuals From Electric Utilities.” ([http://www.epa.gov/epawaste/non-haz/industrial/special/fossil/ccr-rule/ccr\\_propd\\_rul.htm](http://www.epa.gov/epawaste/non-haz/industrial/special/fossil/ccr-rule/ccr_propd_rul.htm))

### BOILER SLAG UTILIZATION

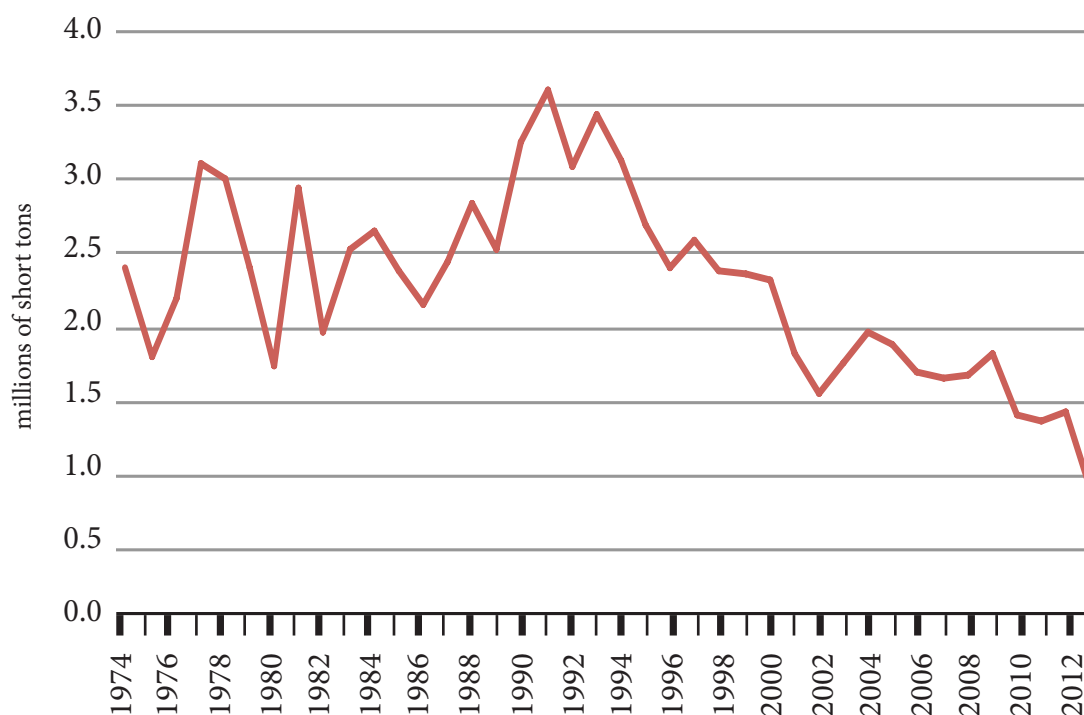
The utilization of boiler slag has declined at an average annual rate of 2.5 percent, falling from 2.4 million short tons in 1974 to 909,066 short tons in 2013. Despite this decline, the utilization rate of boiler slag remained high compared to other CCPs, averaging 70 percent over the same time period.

In 2013, 98 percent of the boiler slag utilized was for roofing granules or blasting grit. The use of boiler slag in the cement and concrete industry, as well as embankments, road base or subbase, is limited.<sup>88</sup>

The decline in boiler slag utilization is due in large part to a decline in production and availability. Boiler slag production peaked at 6.2 million short tons in 1993 and fell sharply to 3.8 million short tons in 1994 as more wet-bottom boilers began to be retired.

So although boiler slag continues to be utilized at a high rate after that time, the overall utilization has fallen in line with production. Overall, boiler slag is a unique product that is used in a niche market. The future availability and utilization of boiler slag is questionable given the continued replacement of older, wet bottom boilers that produce the material.

FIGURE 3-15: BOILER SLAG UTILIZATION



<sup>88</sup>R.C. Joshi and R. P. Lohita. Fly ash in concrete: production, properties and uses. No. 2. CRC Press, 1997. ([https://books.google.com/books/about/Fly\\_Ash\\_in\\_Concrete.html?id=8ITxm7zHul4C](https://books.google.com/books/about/Fly_Ash_in_Concrete.html?id=8ITxm7zHul4C))

FIGURE 3-16: BOILER SLAG UTILIZATION RATE

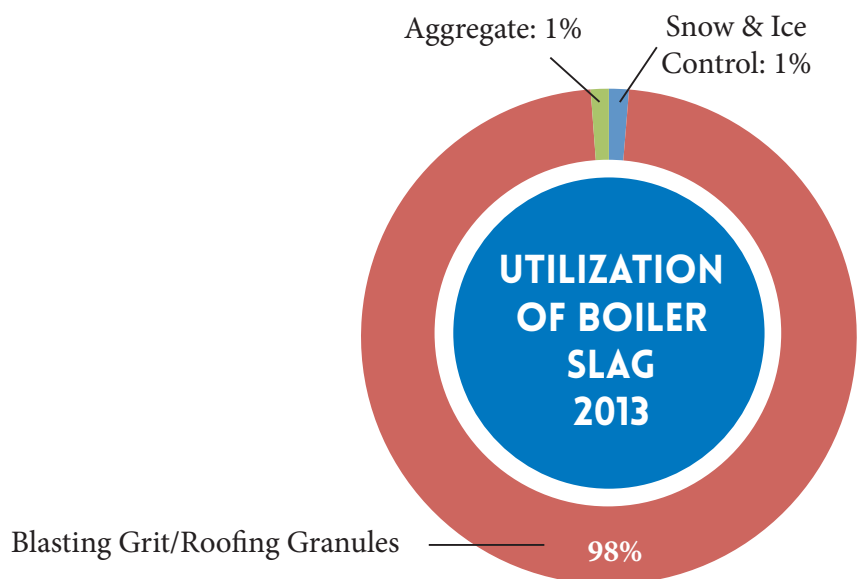
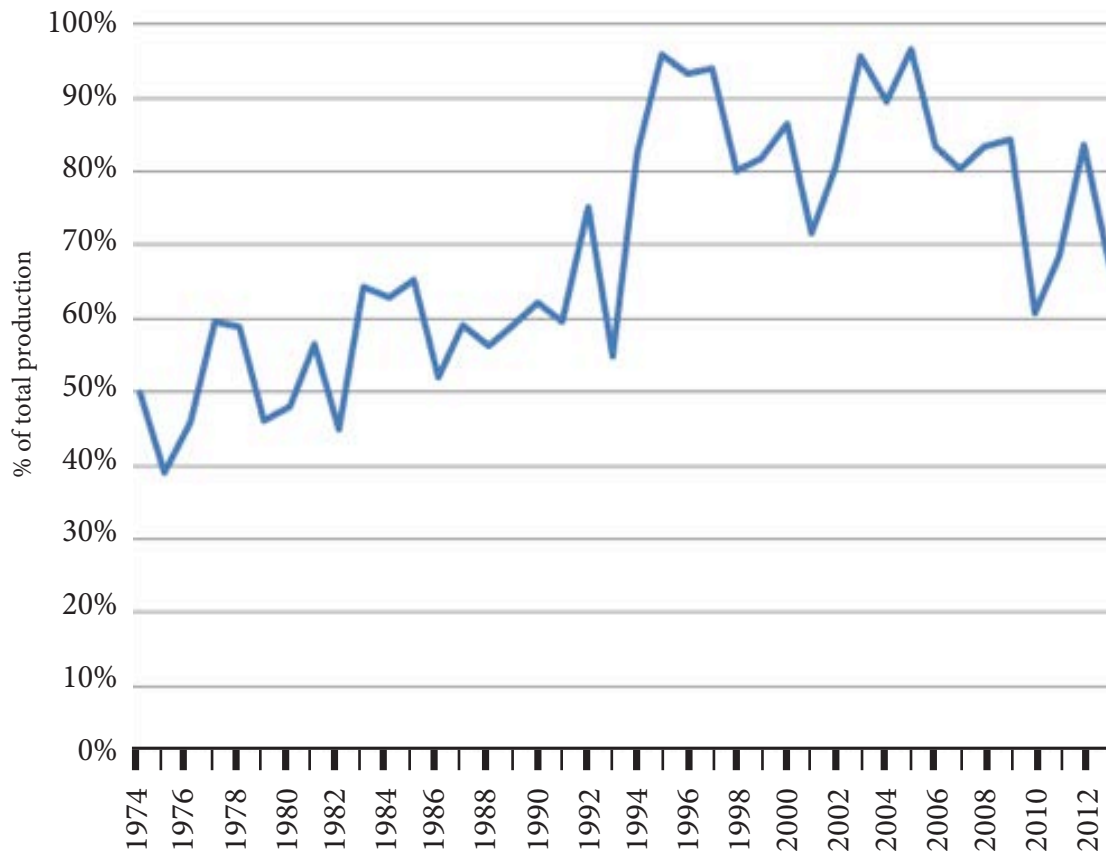


FIGURE 3-17



### FBC ASH UTILIZATION

The utilization of FBC ash has increased from 953,410 short tons in 2002 to 8.8 million short tons in 2013. In 2013, over 95 percent of the FBC ash utilized was for mining applications. The remaining FBC ash was used in soil modification and stabilization, waste stabilization and aggregates.

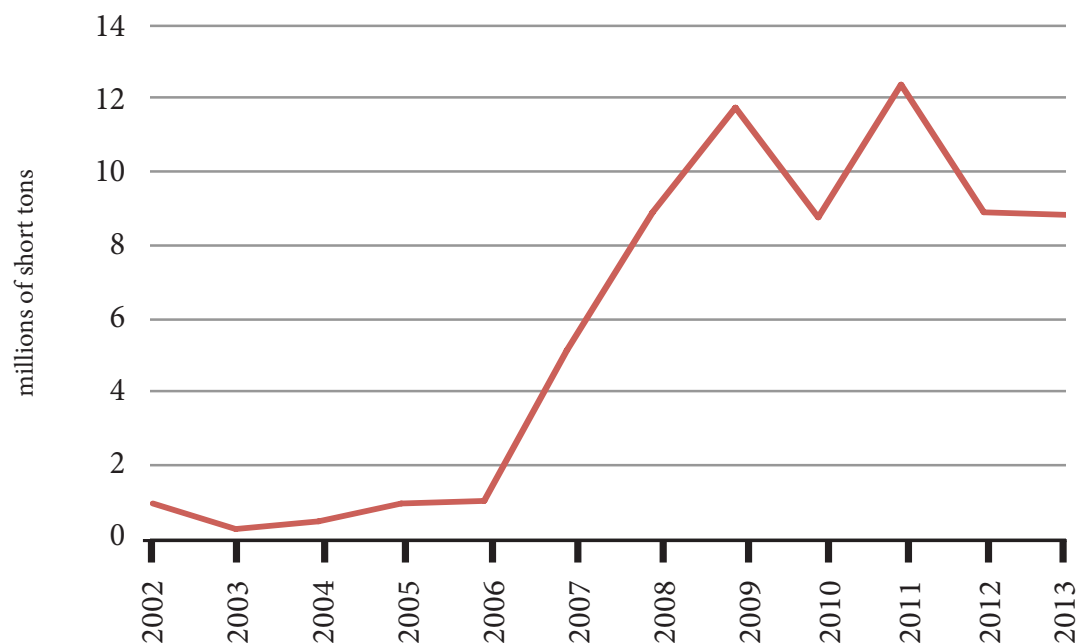
In 2007, ACAA expanded the production and use survey to include data from the ARIPPA, a group of non-utility alternative energy electric power generation stations that burn waste coal using FBC technology.

FBC ash provides a number of environmental and economic benefits when used in mines, and has been placed in at least 20 sites across the country.<sup>89</sup>

Most FBC ash has been used in surface mines to help restore the land to beneficial use. In several states FBC ash has also been used to fill underground mines, providing structural support.<sup>90</sup>

In the case of Clinton County, Pennsylvania, the use of FBC ash had a positive impact on the water quality. The alkaline FBC ash neutralized the acidic waters, resulting in “precipitous decreases in arsenic, cadmium, and aluminum concentrations...”<sup>91</sup>

**FIGURE 3-18: FBC ASH UTILIZATION**



<sup>89</sup>Ishwar P. Murarka and Jim Erickson. “Use of coal combustion products in mine-filling applications: a review of available literature and case studies.” (2006). (<http://www.wri.org/wp-content/uploads/2012/05/99-EC-W05.pdf>)

<sup>90</sup>Ibid.

<sup>91</sup>Ibid.

FIGURE 3-19: FBC ASH UTILIZATION RATE

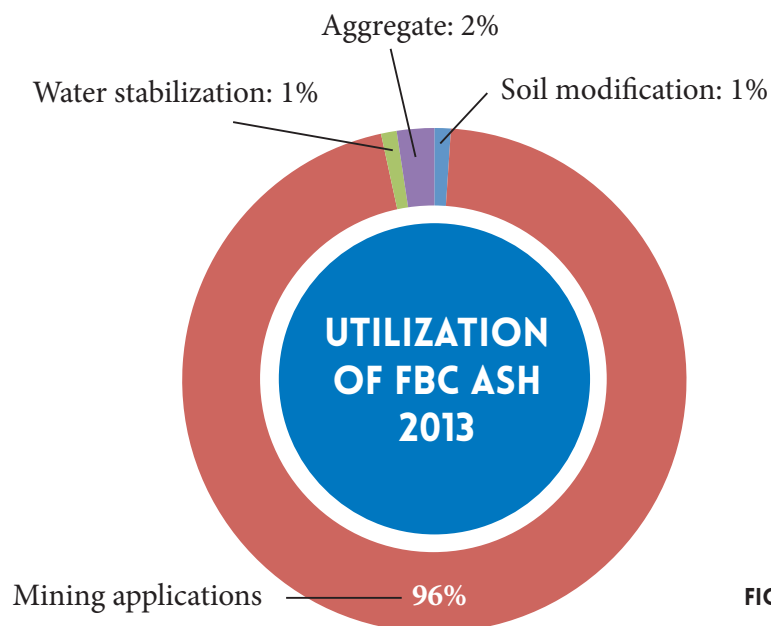
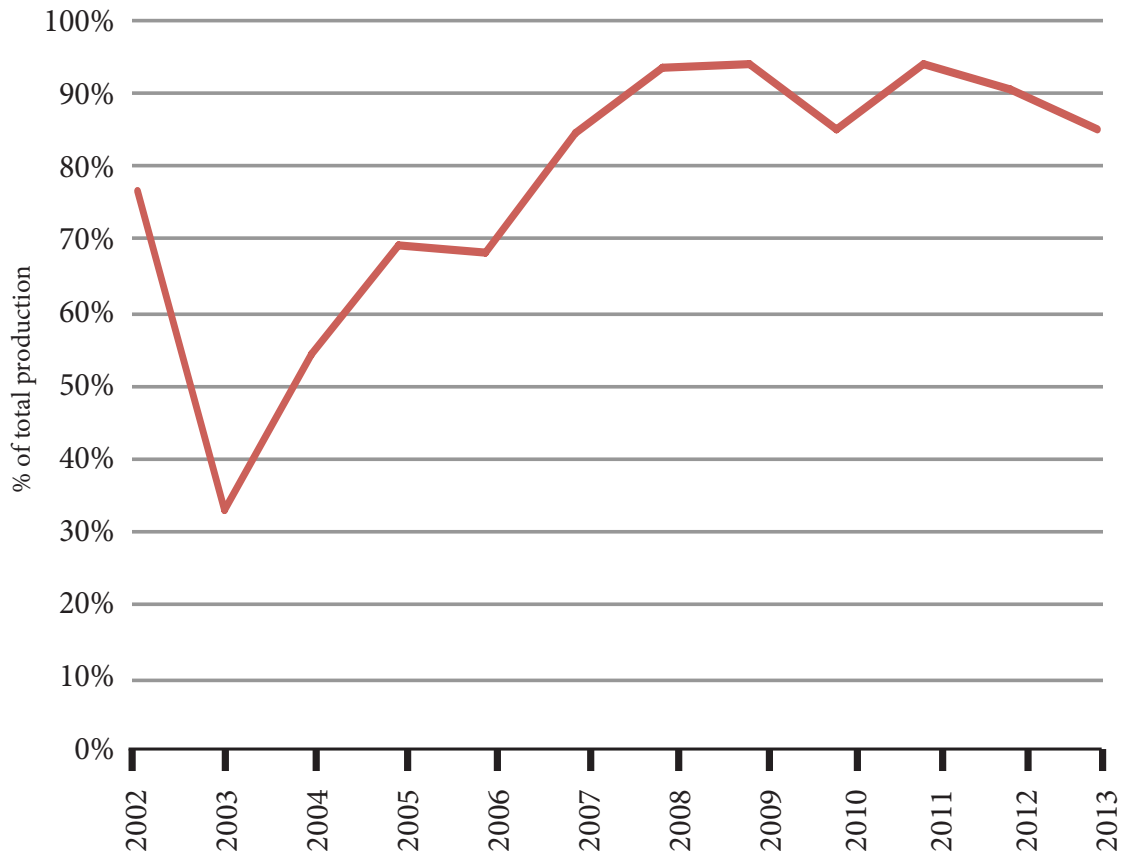


FIGURE 3-20

# REGULATORY UNCERTAINTY AND CCP UTILIZATION

On December 22, 2008, a containment dike at a Kingston, Tennessee power plant's coal ash disposal facility failed, flooding more than a billion gallons of ash slurry into an area of 300 acres. Following the incident, coal ash disposal received renewed interest from Congress, which held several hearings on the issue.

The EPA looked for ways to obtain federal RCRA jurisdiction over coal ash disposal and discussed reversing the 2000 Final Regulatory Determination, possibly classifying coal ash as a hazardous waste under Subtitle C. On June 21, 2010, EPA published a proposed rule to regulate fly ash and other CCPs for the first time under either Subtitle C or Subtitle D of RCRA. The rule would not be finalized until December 19, 2014, resulting in six years of uncertainty about the status of fly ash, bottom ash, FGD material and other CCPs as a nonhazardous waste under RCRA Subtitle D, as clarified in the exemptions of the Bevill Amendment.

In October 2010, the EPA Office of Inspector General published a review of the agency's Coal Combustion Products Partnership (C2P2) website, concluding that it conflicted with agency policies and positions as proposed in the proposed rule. The C2P2 program was created in 2001 by the EPA's Resource Conservation Challenge voluntary program to actively promote the beneficial use of CCPs. The removal of the website was another indicator over the questionable status of coal ash's classification as a hazardous material, further contributing to market uncertainty.

EPA noted that the website "presented an incomplete picture regarding actual damage and potential risks that can result for large-scale placement" and the site "gave the appearance that EPA endorses commercial products."<sup>92</sup> The report also noted the December 2008 incident in Kingston, Tennessee as part of the background on the issue.

Revisiting the classification of fly ash under RCRA Subtitle C or Subtitle D created a new level of uncertainty, putting a damper on the utilization of fly ash and other CCPs.

The downturn in CCP utilization during this uncertainty coincided with the U.S. recession from December 2007 to June 2009. The contraction in U.S. construction market activity impacted overall demand for construction materials, including ready-mixed concrete, but this was not solely responsible for the sharp decline in CCP utilization.

Historically, the use of CCPs has grown during economic downturns as concrete and other construction material producers turn to less expensive products to save on overall costs. Typically, CCPs are less expensive than the materials they replace.

Bottom ash utilization increased following the beginning of every U.S. recession since 1973, including the most recent economic downturn.

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<sup>92</sup>EPA Office of Inspector General. "Early Warning Report: Website for Coal Combustion Products Partnership Conflicts with Agency Policies." Report No. 11-P-0002, October 13, 2010 (<http://www.epa.gov/oig/reports/2011/20101013-11-P-0002.pdf>)

Fly ash utilization increased in three of the last five U.S. recessions:

- **NOVEMBER 1973–MARCH 1975.** Total tons of utilized fly ash increased steadily from 3.4 million tons in 1974, during the height of the recession, to 4.5 million short tons in 1975 and 5.7 million short tons in 1976.
- **JULY 1990–MARCH 1991.** Fly ash utilization, which was 10.2 million short tons in 1989, increased in both 1990 and 1991, even as the total U.S. production of ready-mix concrete declined. Total volumes of ready-mixed concrete production would not return to the 1989 pre-recession levels until 1994.
- **MARCH 2001–NOVEMBER 2001.** Fly ash utilization grew from 20 million short tons in 2000 to 22 million short tons in 2001, and continued to grow steadily over the next seven years. U.S. production of ready-mixed concrete grew in 2001, but dropped in 2002 and 2003, gradually returning to pre-recession levels in 2004.

Fly ash utilization declined during the double-dip recession that occurred from January to July of 1980 and July 1981 to November 1982 (counted as one recession for this analysis), but began to recover before the U.S. ready-mixed concrete market. Total fly ash utilized dropped from 10 million short tons in 1979 to 6.4 million short tons in 1980. The market began to recover, increasing to 9.4 million short tons in 1981 before falling back to 8 million short tons in 1982. In 1984, the total volumes of fly ash utilized recovered to pre-recession 1979 levels, after nearly five years. During the recession total cubic meters of U.S. ready-mixed concrete produced declined, climbing back to pre-recession levels in 1985, one year after the fly ash market.

In the most recent recession, which began in December 2007 and ended June 2009, fly ash utilization declined slightly in 2007 and 2008, falling from 32.4 million short tons in 2006 to 31.6 million short tons in 2007 (a decline of 2.5 percent) and 30.1 million short tons in 2008 (a further decline of 4.7 percent).

Meanwhile, the U.S. production of ready-mixed concrete had started to fall even before the official start of the recession, declining from 458.36 million cubic yards in 2005 to 456.8 million cubic yards in 2006 and 414.6 million cubic yards in 2007.

It was not until 2009 that fly ash utilization fell to 24.7 million short tons, a decline of 18 percent from 2008 levels—one full year after the recession began in December 2007. Although total volumes of ready-mixed concrete in 2013 are still below their pre-recession levels, the market bottomed out in 2010 and production has increased annually since that time. Meanwhile, fly ash utilization continues to remain depressed.

Given historical patterns, we would expect fly ash utilization to show signs of recovery before the turnaround in the ready-mixed concrete market. The sharp drop in fly ash utilization in 2009 and the continued low levels of activity despite the uptick in ready-mixed concrete production point to another factor impacting the market—the uncertainty over the regulatory environment.

Bottom ash utilization in the most recent recession, which began in December 2007 and ended June 2009, actually grew in 2008 to eight million short tons from 7.3 million short tons in 2007.

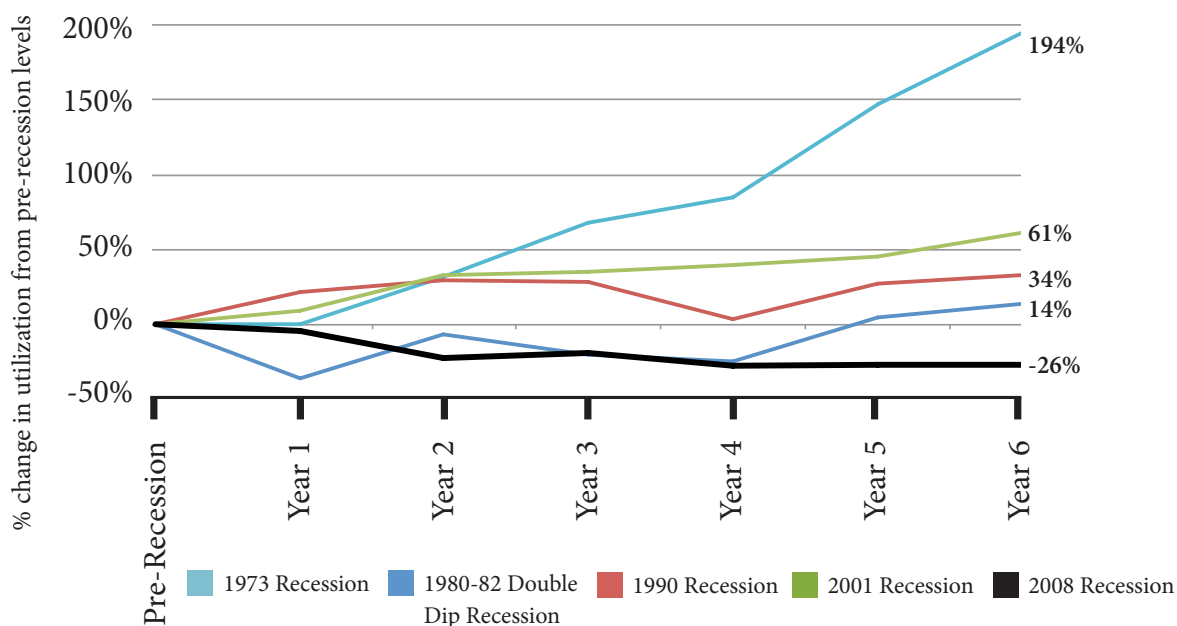
Total utilization dropped sharply to seven million short tons in 2009, after the Kingston, Tennessee accident and declined further to 5.6 million short tons in 2013.

Given the historical relationship between bottom ash utilization and the overall U.S. economy, we would have expected the utilization in 2013 to be higher than pre-recession levels.

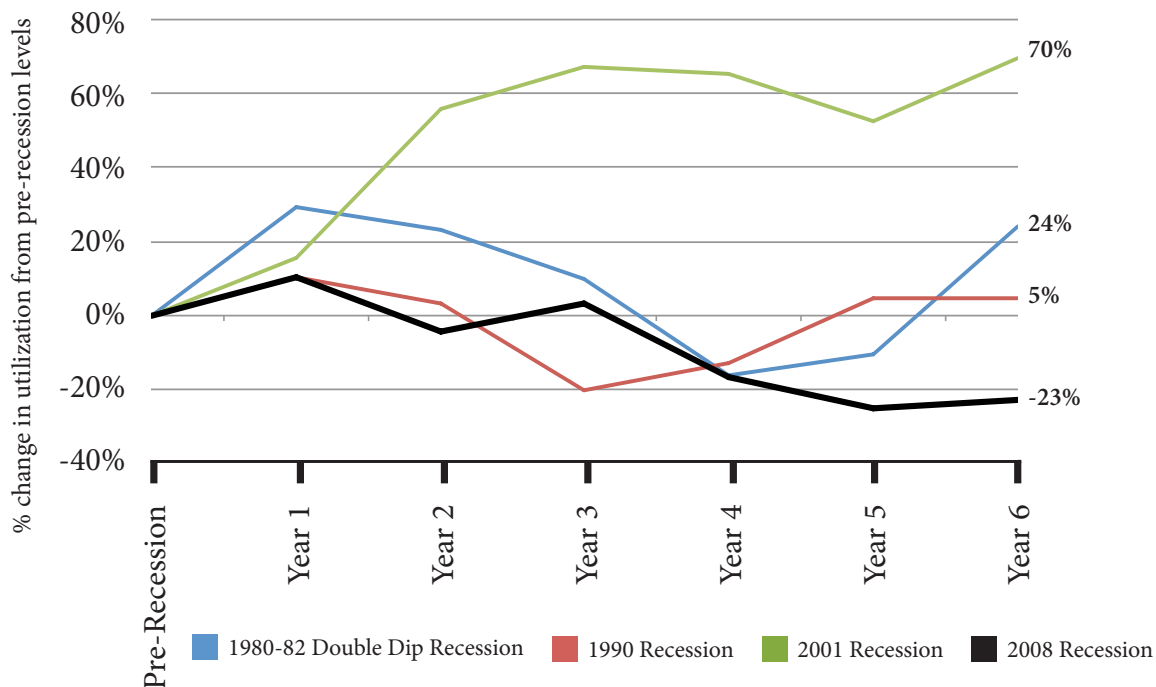
Regulatory uncertainty has not had a significant impact on the utilization of FGD material because of the close distribution ties between suppliers and wallboard manufacturers.

There are currently a few large, vertically integrated companies that mine gypsum and manufacture wallboard and related products, with seven companies producing 62 percent of U.S. crude gypsum.<sup>93</sup>

**FIGURE 4-1: ANNUAL PERCENT CHANGE IN U.S. FLY ASH UTILIZATION VERSUS PRE-RECESSION LEVELS**



**FIGURE 4-2: ANNUAL PERCENT CHANGE IN U.S. BOTTOM ASH UTILIZATION VERSUS PRE-RECESSION LEVELS**



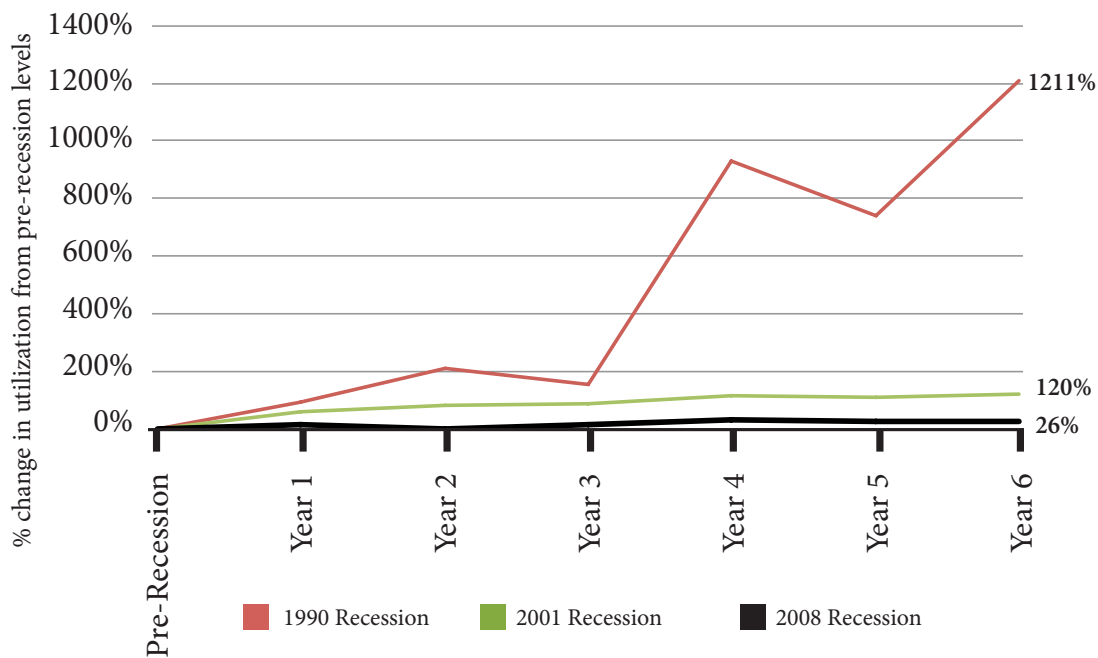
<sup>93</sup>U.S. Geological Survey. "Gypsum." Minerals Yearbook (2012) (<http://minerals.usgs.gov/minerals/pubs/commodity/gypsum/>)



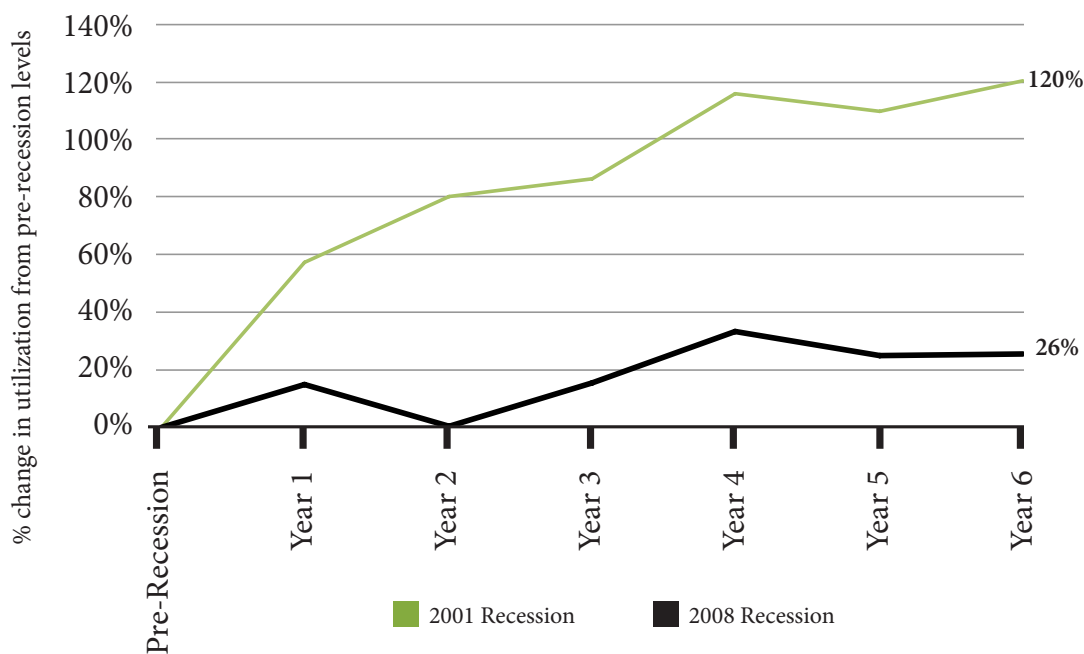
With close commercial ties and manufacturing facilities located near plants that supply FGD material, these firms are less impacted by the regulatory uncertainty surrounding the CCP market compared to fly ash.

This means that the utilization of FGD material has been impacted by larger market supply and demand and new areas for beneficial use.

**FIGURE 4-3: ANNUAL PERCENT CHANGE IN U.S. FGD MATERIAL UTILIZATION VERSUS PRE-RECESSION LEVELS**



**FIGURE 4-4: ANNUAL PERCENT CHANGE IN U.S. FGD MATERIAL UTILIZATION VERSUS PRE-RECESSION LEVELS FOR 2001 AND 2008**









# MAJOR MARKETS FOR THE BENEFICIAL USE OF CCPs

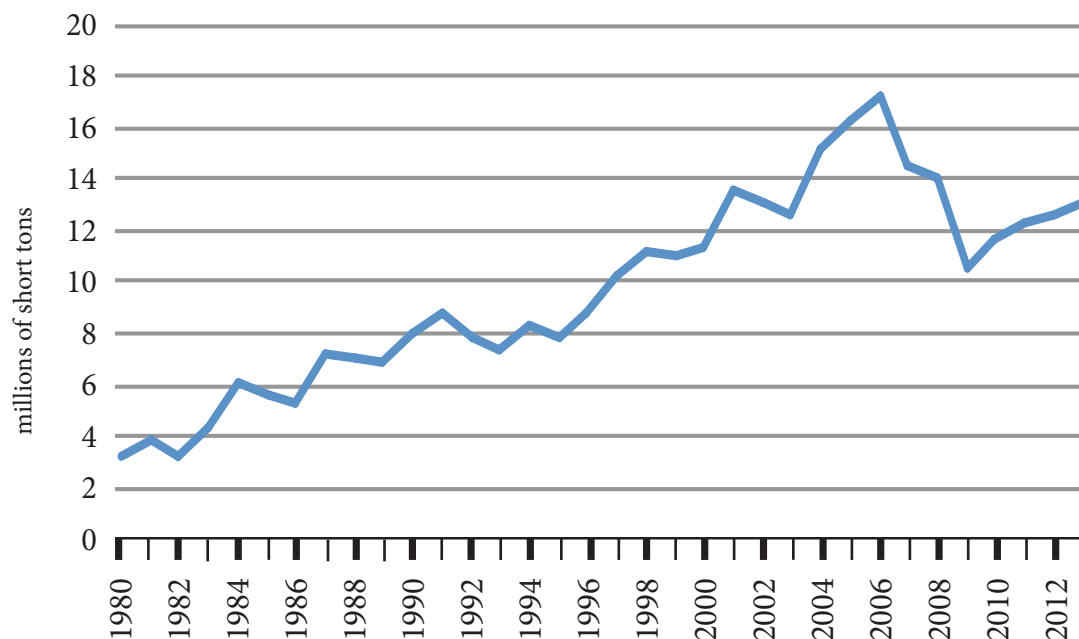
## CEMENT AND CONCRETE PRODUCTS

The beneficial use of CCPs as an input for cement and concrete products has historically been one of the primary uses of CCPs. Fly ash, the largest volume CCP, is a “pozzolan” that when mixed with calcium hydroxide produced during cement hydration, takes on many of the same properties as cement. Thus utilizing fly ash with cement in concrete mixtures produces concrete that is stronger, more durable, easier to work with, and is more economical.

Some of the key insights into this end use market:

- A total of 3.2 million short tons CCPs were utilized for cement and concrete products in 1980. This grew to 13.1 million short tons in 2013, an increase of 306 percent.
- The use of CCPs in this industry grew at an average annual rate of 4.3 percent between 1980 and 2013.
- Fly ash is the main type of CCP used, accounting for 94 percent of the total amount of CCPs utilized for concrete and cement products in 2013.
- The overall use of CCPs in the cement and concrete market is closely correlated with total U.S. ready-mixed concrete production and consumption, which is tied to the U.S. economy and construction markets.

**FIGURE 5-1: CCPs UTILIZED FOR CONCRETE AND CEMENT PRODUCTS**



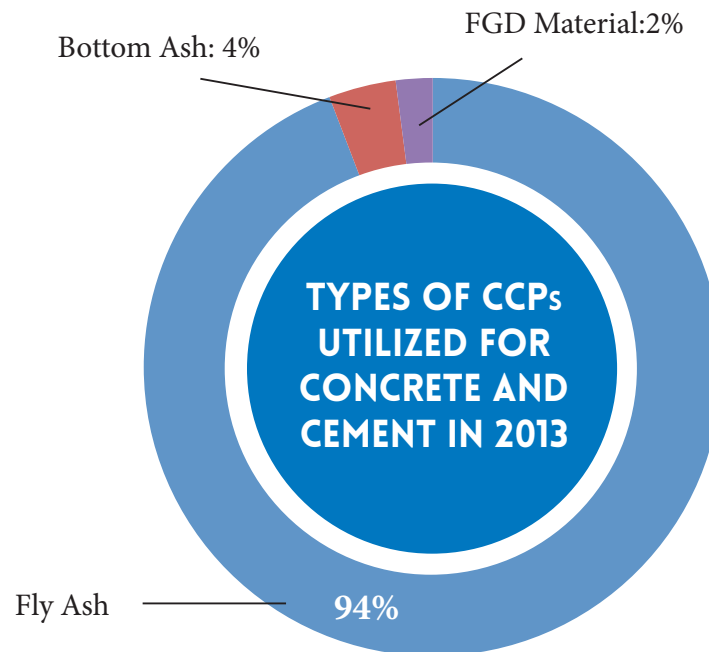


FIGURE 5-2

**FIGURE 5-3: OVERALL DEMAND FOR READY-MIX CONCRETE IS A MAJOR DRIVER OF CCPs UTILIZED FOR CONCRETE/CEMENT**



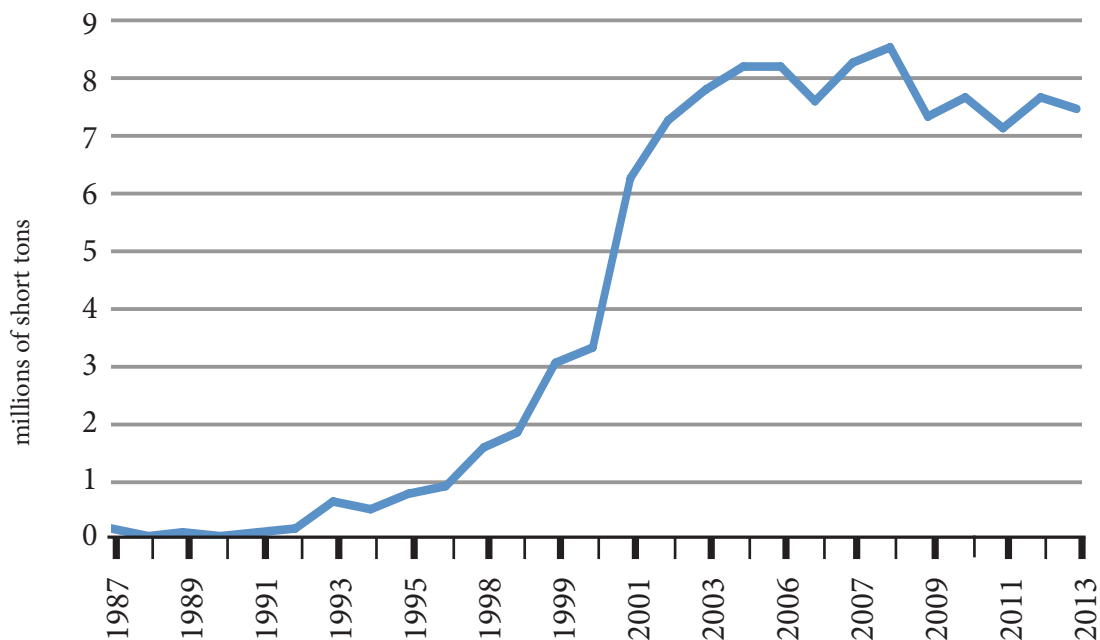
## GYPSUM PANEL PRODUCTS

Over forty percent of the gypsum panel products manufactured in the United States, including wallboard, ceiling board and backing board, contain CCPs.<sup>94</sup> The primary type of coal ash used for this market is dry FGD material, either in the form of dry scrubber material or FGD gypsum, a fine particulate matter. Wet FGD material can also be used in making wallboard after it has dried out.

ACAA began collecting data on the beneficial use of CCPs for gypsum panel products in 1987. Some of the key insights into this end use market:

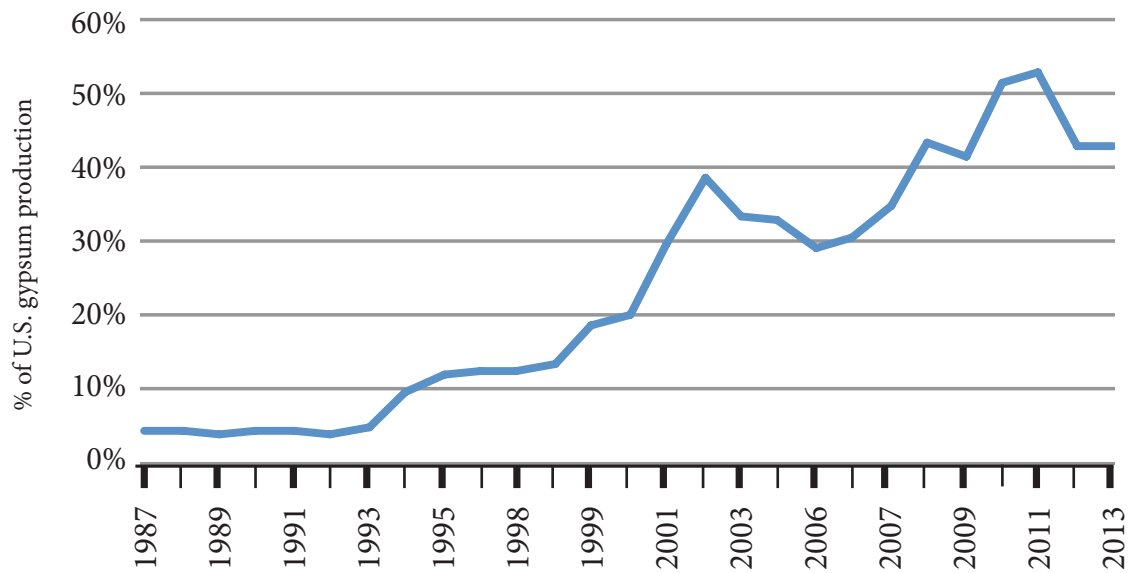
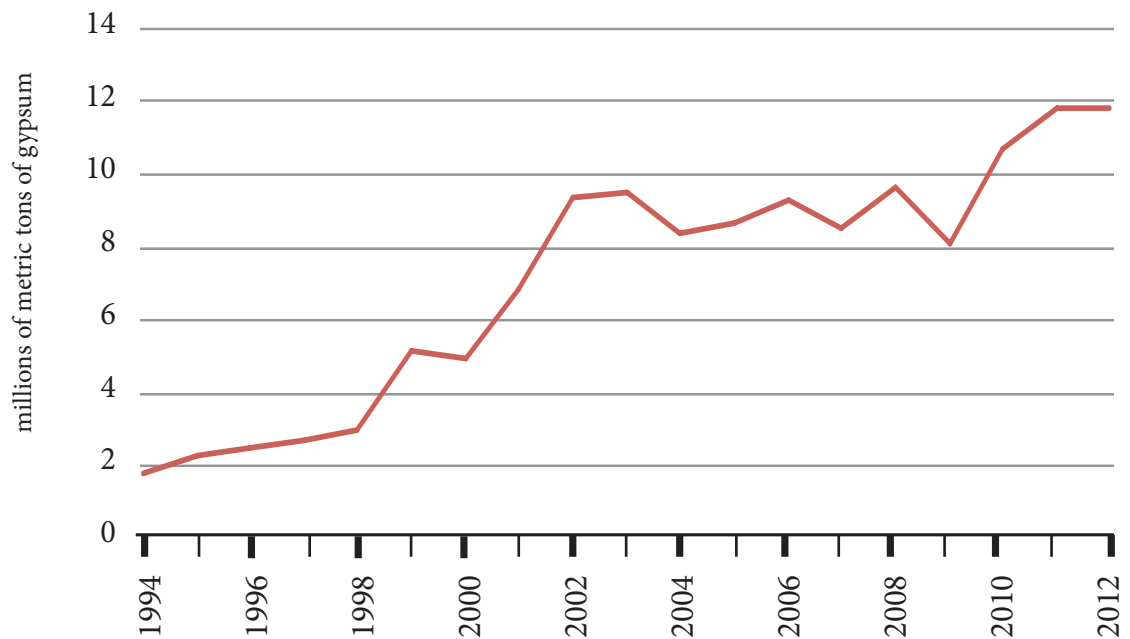
- Just over 157,000 tons of CCPs were used for gypsum panel products in 1987. This grew to 7.4 million short tons in 2013.
- The use of CCPs in this industry grew at an average annual rate of 16 percent between 1987 and 2013.
- FGD gypsum material and FGD material from wet and dry scrubbers were the only CCPs utilized for gypsum panel products in 2013. Historically, small amounts of fly ash, bottom ash and even boiler slag have been recorded in the ACAA data.
- An estimated 90 percent of domestic gypsum consumption is accounted for by manufacturers of wallboard and plaster products, according to the U.S. Geological Service. The demand for gypsum is correlated with the strength of the construction industry.

**FIGURE 5-4: CCPs UTILIZED FOR GYPSUM WALLBOARD AND OTHER MATERIALS**



<sup>94</sup>“Beneficial Use of Coal Combustion products An American Recycling Success Story.” Ash at Work 1 (2013). (<http://www.acaa-usa.org/Portals/9/Files/PDFs/ASH01-2013.pdf>)



**FIGURE 5-5: SYNTHETIC GYPSUM AS PERCENT OF TOTAL GYPSUM PRODUCTION****FIGURE 5-6: OVERALL U.S. SALES OF SYNTHETIC GYPSUM**







## MINING APPLICATIONS

The mining industry uses CCPs in a variety of ways, including as a fill material for mine sites to restore original land contours. In Pennsylvania, CCPs are used as a low permeability material to pave pit floors, cap materials, encapsulate rejected material and even cap entire sites.<sup>95</sup> A study by the National Academy of Sciences recommended that placing CCPs in mines as part of the reclamation process was a “viable option” for utilizing coal ash material.<sup>96</sup>

Some highlights of the use of CCPs in mining applications:

- A total of 160,000 short tons of CCPs were utilized for mining applications in 1980. This increased to over 1.1 million short tons in 2006. The average annual growth in the utilization of CCPs by the mining industry was 9.3 percent over that 26 year period.
- In 2007, ACAA began including data on the beneficial use of FBC ash for mining purposes collected by ARIPPA, a Pennsylvania association of 14 power plants that utilize waste coal for fuel.
- With the new data, the total beneficial use of CCPs for mining applications was 6.7 million short tons in 2007.
- Average annual growth in the use of CCPs in this area grew at an average annual rate of 11.2 percent since 2007, reaching 12.7 million short tons in 2013.
- Historically, fly ash was the main type of CCP utilized for mining applications, accounting for 75 percent of the market in 1980.
- With the inclusion of the ARIPPA data, FBC Ash now accounts for over 66 percent of the CCPs utilized for mining applications.
- Regardless of the change in methodology, the beneficial use of CCPs for mining applications has been growing since 1980.

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<sup>95</sup>Dalberto, et al. “Overview: Coal Ash Beneficial Use and Mine Land Reclamation.” Pennsylvania Department of Environmental Protection ( [http://www.depweb.state.pa.us/portal/server.pt/document/1239456/chapter\\_1\\_final\\_pdf](http://www.depweb.state.pa.us/portal/server.pt/document/1239456/chapter_1_final_pdf).)

<sup>96</sup>National Research Council. Managing Coal Combustion Residues in Mines. The National Academies Press. Washington, DC. 228 p. (2006). (<http://www.nap.edu/catalog/11592/managing-coal-combustion-residues-in-mines>)

FIGURE 5-7: CCPs RECYCLED FOR MINING APPLICATIONS

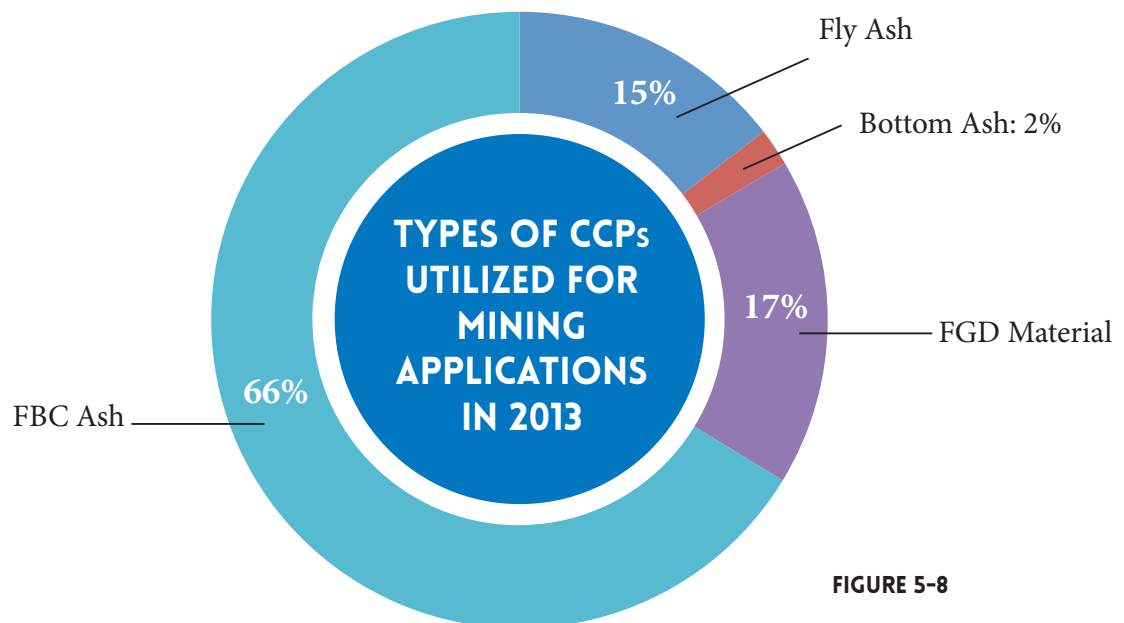
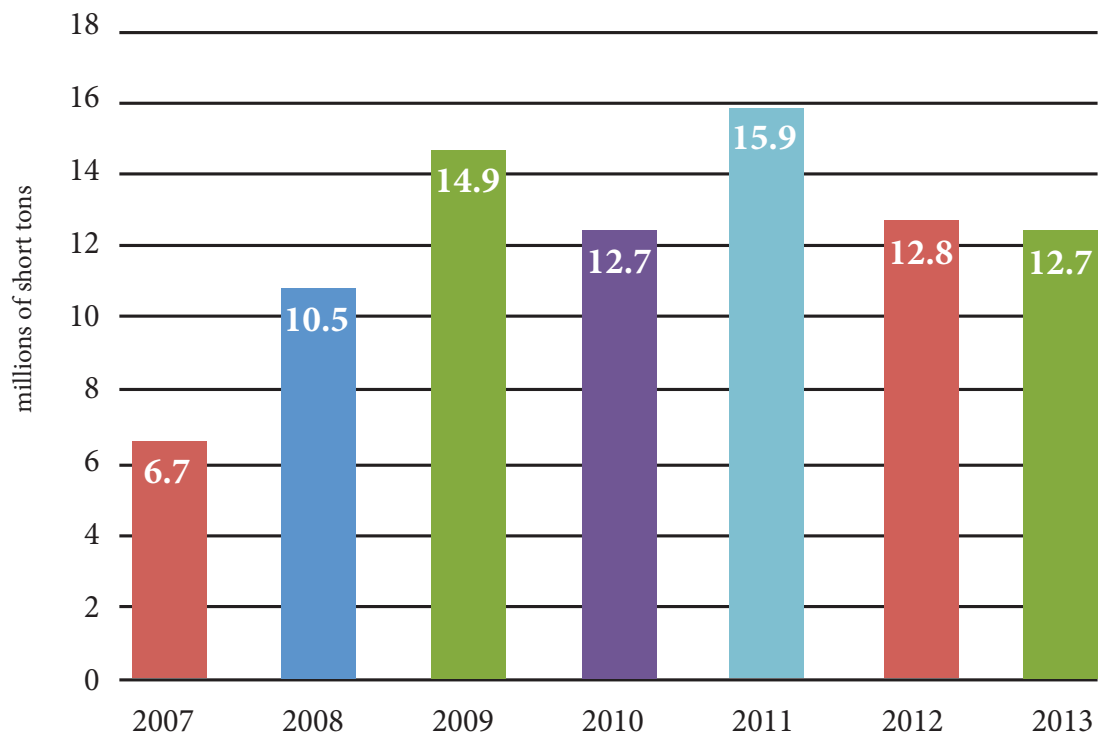


FIGURE 5-8

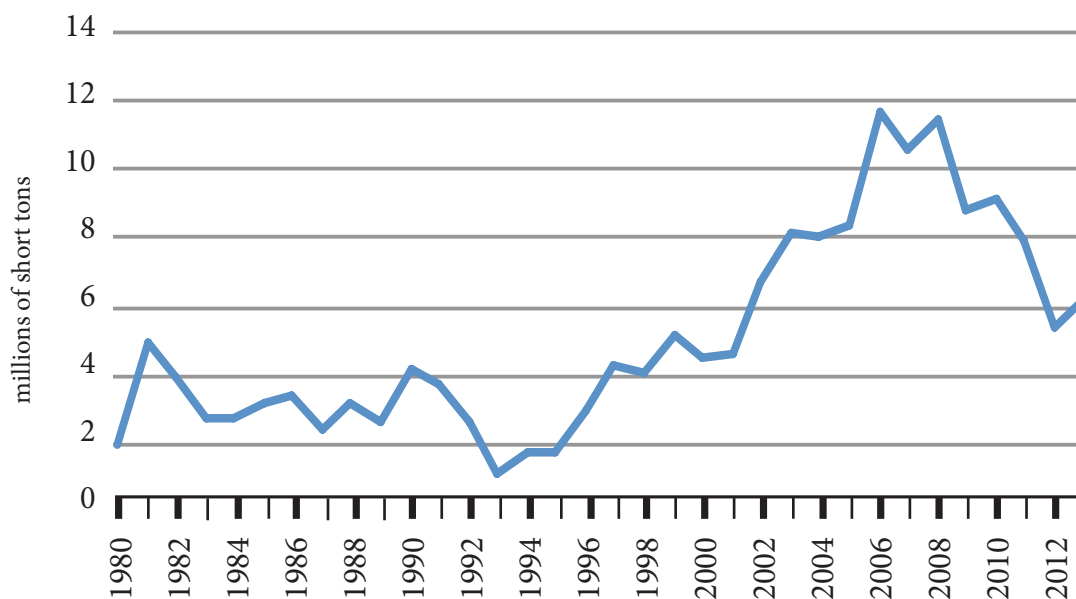


## STRUCTURAL FILLS AND EMBANKMENTS

CCPs improve the strength and durability of structural fills and embankments, creating a stable base for construction projects, trench filling and other excavations, especially for road construction. Some of the beneficial engineering properties include its moisture-density relationships, the particle size distribution, shear strength, bearing strength, permeability and consolidation characteristics.<sup>97</sup>

- Just under 2.0 million short tons of CCPs were utilized for structural fills and embankments in 1980. This grew to 6.2 million short tons in 2013, an increase of 209 percent.
- The use of CCPs in this industry grew at an average annual rate of 3.5 percent between 1980 and 2013.
- Fly ash is the main type of CCP used, accounting for 49 percent of the total amount of CCPs utilized for structural fills and embankments in 2013. This is compared to 50 percent in 1980. Bottom ash accounted for 31 percent of the utilized material in 2013, down from 41 percent in 1980.
- The highway and bridge construction industry is one of the main sectors using CCPs for structural fills and embankments. The downturn in this beneficial use since 2008 mirrors the decline in the real value of U.S. pavement work over the same time period.

**FIGURE 5-9: CCPs UTILIZED FOR STRUCTURAL FILLS AND EMBANKMENTS**



<sup>97</sup>Warren H. Chesner, Robert J. Collins, and M. H. MacKay. User guidelines for waste and by-product materials in pavement construction. No. FHWA-RD-97-148. 1998. (<http://www.fhwa.dot.gov/publications/research/infrastructure/structures/97148/intro.cfm>)

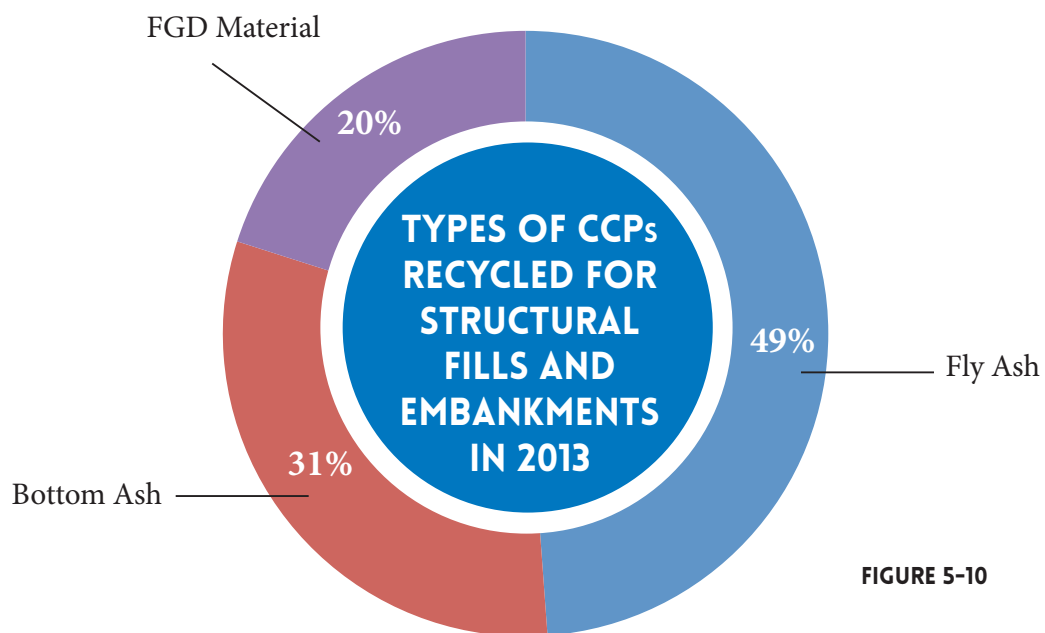
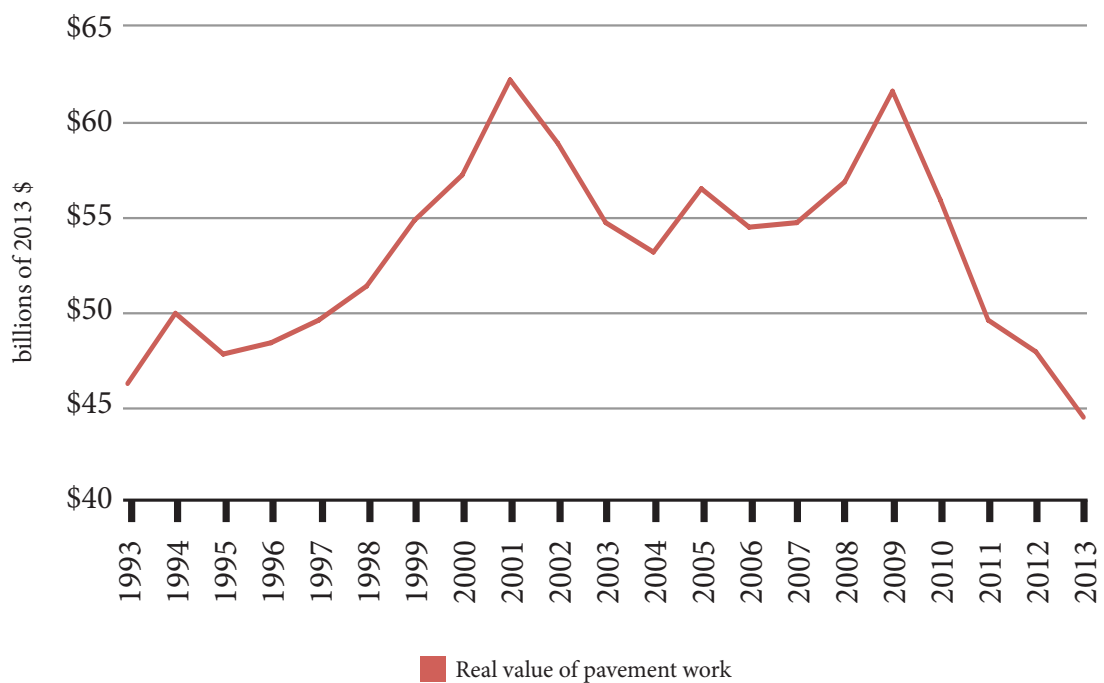


FIGURE 5-10

**FIGURE 5-11: HIGHWAY CONSTRUCTION IS A MAJOR END MARKET FOR THE BENEFICIAL USE OF CCPs IN STRUCTURAL FILLS AND EMBANKMENTS**



### ADDITIONAL BENEFICIAL USE MARKETS

Other beneficial use markets, including agriculture, aggregates, oil field services, blended cement/clinker feed and waste stabilization, utilize significant volumes of CCPs.

**AGRICULTURE:** ACAA began collecting data on the beneficial use of CCPs for agriculture in 1995. This market had grown from 14,681 short tons in 1995 to 598,105 short tons in 2013. Although it is just one percent of the total utilization of CCPs, the increase in use has been significant. The major CCP types utilized for agriculture are FGD, fly ash and bottom ash.

**BLENDED CEMENT/FEED FOR CLINKER:** Since 1999, the use of CCPs for this industry has grown from 1.4 million short tons to 4.8 million short tons, an increase of 235 percent. The amount of CCPs utilized for blended cement and feed for clinker were nine percent of total utilization reported by ACAA in 2013.

**WASTE STABILIZATION/SOLIDIFICATION:** This end use market has grown from utilizing 400,000 short tons of CCPs in 1991 to over 2.2 million short tons in 2013, an increase of 447 percent. This beneficial use represented four percent of total CCP utilization in 2013.

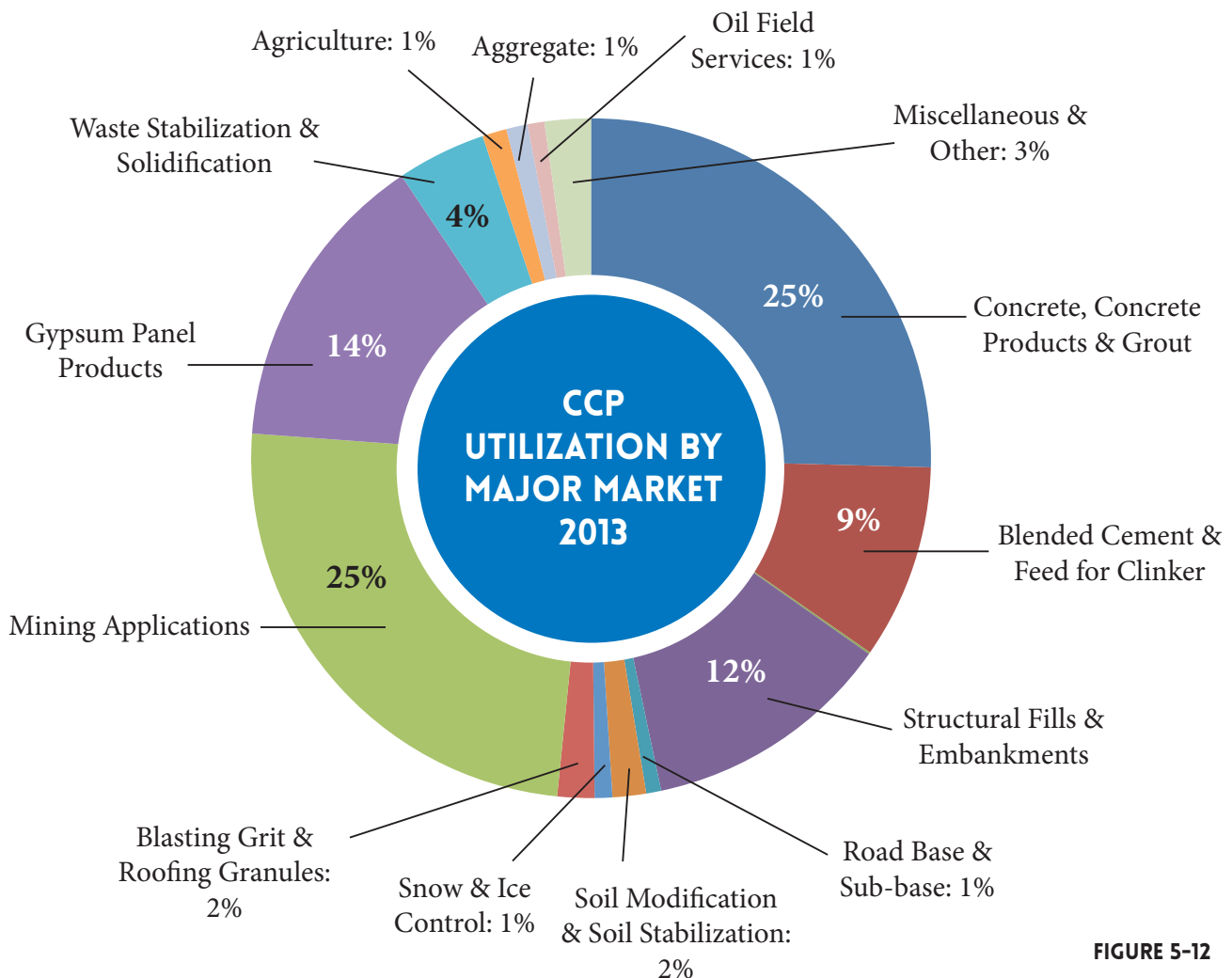


FIGURE 5-12

## APPENDIX: HISTORICAL DATA TABLES

CCP TOTAL PRODUCTION (IN SHORT TONS)						
YEAR	FLY ASH	BOTTOM ASH	BOILER SLAG	ALL FGD MATERIALS	FBC ASH	TOTAL CCPs
1974	40,400,000	14,300,000	4,800,000			59,500,000
1975	42,300,000	13,100,000	4,600,000			60,000,000
1976	42,800,000	14,300,000	4,800,000			61,900,000
1977	48,500,000	14,100,000	5,200,000			67,800,000
1978	48,300,000	14,700,000	5,100,000			68,100,000
1979	57,500,000	12,500,000	5,200,000			75,200,000
1980	48,310,000	14,450,000	3,640,000			66,400,000
1981	50,260,000	12,870,000	5,180,000			68,310,000
1982	47,910,000	13,130,000	4,370,000			65,410,000
1983	47,150,000	12,730,000	3,940,000			63,820,000
1984	51,320,000	13,620,000	4,210,000			69,150,000
1985	48,310,000	13,150,000	3,650,000			65,110,000
1986	49,260,000	13,410,000	4,130,000			66,800,000
1987	50,113,178	14,715,570	4,115,899	14,204,638		83,149,285
1988	50,905,161	14,272,459	5,025,540	13,526,701		83,729,861
1989	53,383,591	14,205,221	4,267,563	15,603,436		87,459,811
1990	48,931,722	13,705,653	5,234,316	18,932,688		86,804,379
1991	51,300,000	13,300,000	6,050,000	18,100,000		88,750,000
1992	48,061,898	13,917,623	4,112,796	15,883,538		81,975,855
1993	47,756,492	14,215,711	6,228,523	20,340,130		88,540,856
1994	54,835,570	14,827,165	3,785,852	15,545,068		88,993,655
1995	54,166,769	15,224,269	2,806,557	19,974,829		92,172,424
1996	59,355,009	16,060,762	2,568,349	23,854,328		101,838,448
1997	60,264,791	16,904,663	2,741,614	25,163,394		105,074,462
1998	62,995,872	16,760,091	2,980,627	25,002,877		107,739,467
1999	62,699,947	16,875,991	2,890,843	24,608,099		107,074,880
2000	62,943,732	16,915,826	2,684,889	25,652,994		108,197,441
2001	68,123,551	18,788,004	2,536,195	28,482,792		117,930,542
2002	76,500,000	19,800,000	1,919,579	29,235,394	1,248,599	128,703,572
2003	70,150,000	18,100,000	1,836,235	30,861,618	796,718	121,744,571
2004	70,800,000	17,200,000	2,202,296	31,395,426	867,397	122,465,119
2005	71,100,000	17,600,000	1,957,392	31,102,263	1,366,438	123,126,093
2006	72,400,000	18,600,000	2,026,066	30,188,146	1,580,912	124,795,124
2007	71,700,000	18,100,000	2,072,695	33,162,242	6,092,756	131,127,693
2008	72,454,230	18,431,297	2,028,455	33,672,068	9,487,057	136,073,107
2009	63,000,000	16,600,000	2,176,054	31,181,736	12,524,796	125,482,586
2010	67,700,000	17,800,000	2,332,944	32,080,506	10,267,914	130,181,364
2011	59,900,000	16,500,000	2,002,764	38,428,388	13,246,123	130,077,275
2012	52,100,000	14,100,000	1,720,945	31,985,517	9,843,922	109,750,384
2013	53,400,000	14,450,000	1,355,939	35,159,926	10,326,745	114,692,610

## APPENDIX: HISTORICAL DATA TABLES

CCP TOTAL UTILIZATION (IN SHORT TONS)							
YEAR	FLY ASH	BOTTOM ASH	BOILER SLAG	ALL FGD MATERIALS	FBC ASH	TOTAL CCPs	UTILIZATION RATE - TOTAL CCPs
1974	3,400,000	2,900,000	2,400,000			8,700,000	14.6%
1975	4,500,000	3,500,000	1,800,000			9,800,000	16.3%
1976	5,700,000	4,500,000	2,200,000			12,400,000	20.0%
1977	6,300,000	4,600,000	3,100,000			14,000,000	20.6%
1978	8,400,000	5,000,000	3,000,000			16,400,000	24.1%
1979	10,000,000	3,300,000	2,400,000			15,700,000	20.9%
1980	6,420,000	4,260,000	1,750,000			12,430,000	18.7%
1981	9,410,000	4,070,000	2,930,000			16,410,000	24.0%
1982	7,950,000	3,630,000	1,970,000			13,550,000	20.7%
1983	7,520,000	2,760,000	2,530,000			12,810,000	20.1%
1984	10,430,000	2,960,000	2,650,000			16,040,000	23.2%
1985	11,390,000	4,100,000	2,380,000			17,870,000	27.4%
1986	8,776,000	3,585,000	2,145,000			14,506,000	21.7%
1987	11,049,576	4,769,054	2,436,178	1,021,032		19,275,840	23.2%
1988	11,364,244	5,433,161	2,833,348	930,210		20,560,963	24.6%
1989	10,153,399	4,848,288	2,518,306	112,635		17,632,628	20.2%
1990	12,420,163	5,360,104	3,252,220	215,852		21,248,339	24.5%
1991	13,200,000	5,000,000	3,600,000	350,000		22,150,000	25.0%
1992	13,071,114	3,870,241	3,089,714	289,774		20,320,843	24.8%
1993	10,507,824	4,231,249	3,424,017	1,163,076		19,326,166	21.8%
1994	12,930,690	5,082,966	3,117,838	944,182		22,075,676	24.8%
1995	13,562,813	5,068,493	2,689,309	1,476,662		22,797,277	24.7%
1996	16,234,488	4,868,253	2,396,070	1,656,132		25,154,943	24.7%
1997	19,317,362	5,096,905	2,578,851	2,183,363		29,176,481	27.8%
1998	21,105,468	5,239,184	2,387,737	2,494,262		31,226,651	29.0%
1999	20,793,473	5,420,676	2,363,464	4,452,405		33,030,018	30.8%
2000	20,076,909	4,937,908	2,321,568	4,824,727		32,161,112	29.7%
2001	22,004,955	5,712,398	1,818,473	7,583,495		37,119,321	31.5%
2002	26,628,881	7,689,589	1,549,972	8,701,404	953,410	45,523,256	35.4%
2003	27,136,524	8,247,273	1,756,004	8,980,981	263,623	46,384,405	38.1%
2004	28,068,970	8,152,469	1,973,385	10,421,603	473,391	49,089,818	40.1%
2005	29,118,454	7,541,972	1,890,809	10,116,747	944,559	49,612,541	40.3%
2006	32,423,569	8,378,494	1,690,999	10,631,817	1,078,291	54,203,170	43.4%
2007	31,626,037	7,303,538	1,663,980	10,302,014	5,143,436	56,039,005	42.7%
2008	30,142,274	8,076,255	1,689,892	11,820,549	8,864,690	60,593,660	44.5%
2009	24,716,665	7,000,665	1,834,257	10,342,050	11,748,374	55,642,011	44.3%
2010	25,723,217	7,541,732	1,418,996	11,921,473	8,732,008	55,337,426	42.5%
2011	22,975,450	6,082,407	1,374,716	13,733,186	12,406,559	56,572,318	43.5%
2012	23,205,204	5,474,167	1,437,556	12,855,313	8,914,774	51,887,014	47.3%
2013	23,321,230	5,640,693	909,066	12,934,146	8,794,240	51,599,375	45.0%

Includes both internal and external utilization, which was captured separately through 1994.



## APPENDIX: HISTORICAL DATA TABLES

UTILIZATION OF CCPs BY MAJOR MARKET (IN SHORT TONS)								
YEAR	CONCRETE, CONCRETE PRODUCTS & GROUT	BLENDED CEMENT, FEED FOR CLINKER	FLOWABLE FILL	STRUCTURAL FILLS & EMBANKMENTS	ROAD BASE & SUB-BASE	SOIL MODIFICATION & STABILIZATION	SNOW AND ICE CONTROL	BLASTING GRIT & ROOFING GRANULES
1980	3,230,000			1,990,000	860,000			1,810,000
1981	3,920,000			4,950,000	930,000		1,110,000	1,180,000
1982	3,190,000			3,930,000	1,075,000		1,350,000	750,000
1983	4,372,000			2,780,000	932,000		651,000	1,560,000
1984	6,130,000			2,740,000	847,090		1,114,000	1,240,000
1985	5,665,000			3,230,000	1,228,000		984,000	1,412,000
1986	5,340,000			3,411,000	1,099,000		734,000	1,591,000
1987	7,255,559			2,377,390	772,385		883,915	1,604,985
1988	7,101,759			3,190,085	663,268		1,151,338	1,934,023
1989	6,884,289			2,651,372	1,391,804		719,769	1,807,418
1990	7,987,651			4,176,336	2,064,815		1,717,304	1,836,845
1991	8,725,000			3,700,000	1,875,000		1,900,000	1,966,666
1992	7,896,343			2,688,955	2,385,363		793,823	2,062,656
1993	7,431,940		383,003	1,142,350	2,756,085		1,203,600	2,720,718
1994	8,334,138		741,860	1,776,549	1,710,108		1,019,875	2,719,558
1995	7,813,821		357,263	1,760,889	1,204,122		719,875	2,185,990
1996	8,860,150		367,579	2,940,755	1,590,527		780,245	2,342,450
1997	10,239,786		401,418	4,346,622	2,722,774		779,672	2,448,330
1998	11,215,311		399,031	4,042,372	3,134,635		767,320	2,359,872
1999	11,086,908	1,425,027	860,456	5,219,512	2,342,026	110,634	1,162,262	2,289,131
2000	11,357,204	1,307,724	759,085	4,545,144	2,137,850	139,803	892,990	2,245,560
2001	13,628,275	1,226,678	811,142	4,574,749	1,675,785	850,548	871,707	1,530,028
2002	13,090,433	2,806,977	455,018	6,686,630	2,247,131	1,003,254	778,712	1,640,125
2003	12,679,134	3,954,504	156,945	8,187,469	1,661,388	773,076	788,184	1,497,744
2004	15,239,721	3,482,892	179,735	8,085,768	1,587,290	712,173	923,603	1,817,550
2005	16,353,334	4,215,234	250,234	8,349,999	1,461,992	1,139,640	547,541	1,633,407
2006	17,194,884	5,358,457	109,357	11,702,561	1,648,451	1,018,943	372,656	1,759,940
2007	14,515,690	4,989,988	114,979	10,598,118	1,179,509	1,371,228	781,346	1,449,561
2008	14,015,616	4,198,198	74,794	11,501,247	1,802,025	1,251,968	700,913	1,637,867
2009	10,610,410	3,577,726	398,198	8,856,396	968,291	957,116	302,827	1,743,621
2010	11,669,321	4,133,191	201,733	9,116,218	964,455	966,806	590,714	1,363,969
2011	12,282,718	4,209,009	210,288	7,883,521	1,153,675	1,112,438	464,444	1,390,457
2012	12,580,260	5,324,445	150,544	5,403,116	547,511	510,254	256,128	1,183,854
2013	13,120,252	4,774,924	44,142	6,152,569	366,861	823,017	432,884	906,683

Note: Data for 1980 does not include 2.67 million short tons for “other uses” that is included in the total utilization number. This was the only year that included this additional category.

## APPENDIX: HISTORICAL DATA TABLES

UTILIZATION OF CCPs BY MAJOR MARKET (IN SHORT TONS)										
YEAR	MINING APPLICATIONS	GYPSUM PANEL PRODUCTS	WASTE STABILIZATION & SOLIDIFICATION	AGRICULTURE	AGGREGATE	OIL FIELD SERVICES	MISC.	GROUT	ASPHALT	TOTAL UTILIZATION
1980	160,000						1,190,000	360,000	160,000	12,430,000
1981	70,000						3,730,000	390,000	130,000	16,410,000
1982	110,000						2,700,000	290,000	160,000	13,555,000
1983	170,000						2,070,000	170,000	104,000	12,809,000
1984	120,000						3,050,000	670,000	134,000	16,045,090
1985	1,020,000						3,980,000	290,000	80,000	17,889,000
1986	27,000						1,905,000	190,000	209,000	14,506,000
1987	444,579	157,147					5,509,420	129,124	141,339	19,275,844
1988	613,025	16,951					5,327,323	175,813	387,397	20,560,982
1989	22,190	72,277					3,632,956	242,341	208,211	17,632,628
1990	61,798	43,947					2,871,062	338,864	149,705	21,248,328
1991	216,663	100,000	400,000				2,850,000	200,000	216,666	22,149,996
1992	83,395	202,858	545,362				3,168,148	35,718	458,222	20,320,844
1993	29,692	633,526	736,938				1,984,847	146,299	157,168	19,326,166
1994	257,724	533,941	254,359				4,476,325	17,044	234,195	22,075,676
1995	726,753	741,616	980,683	14,681			6,155,832		135,752	22,797,276
1996	843,506	887,064	2,241,686	27,089			4,026,240		247,651	25,154,942
1997	1,680,895	1,603,762	3,339,743	98,412			989,800		525,264	29,176,478
1998	2,163,365	1,814,944	3,641,421	102,812			1,158,302		427,266	31,226,652
1999	1,923,216	3,053,268	2,013,749	137,052			1,172,852		233,925	33,030,018
2000	1,700,949	3,328,651	2,043,095	94,649			1,373,926		234,482	32,161,112
2001	1,078,264	6,224,872	1,555,595	157,199			2,806,031		128,448	37,119,320
2002	3,841,080	7,247,856	3,467,327	86,021	687,525		1,240,415		240,739	45,519,244
2003	2,330,032	7,780,906	3,999,623	50,487	687,839		1,741,411		84,010	46,372,752
2004	1,692,313	8,148,078	2,774,563	216,012	458,856		3,630,015		129,975	49,078,544
2005	1,132,945	8,178,079	2,839,954	415,741	872,776		2,071,154		140,838	49,602,868
2006	1,338,391	7,579,187	2,796,015	251,775	918,788		2,052,953		90,970	54,193,328
2007	6,701,910	8,254,849	2,800,031	180,100	1,013,373		1,973,173		102,723	56,039,005
2008	10,466,272	8,533,732	3,784,546	320,863	901,462		1,120,232		265,587	60,575,320
2009	14,897,415	7,288,755	3,738,799	388,990	574,083		1,323,172			55,625,800
2010	12,723,659	7,661,636	3,410,941	508,721	588,912		1,437,150			55,337,424
2011	15,897,089	7,110,921	2,751,974	612,365	624,806		868,613			56,572,320
2012	12,812,131	7,641,625	3,053,301	683,610	393,692	602,339	744,204			51,887,016
2013	12,676,264	7,446,839	2,186,926	598,105	524,088	413,210	1,132,611			51,599,375

Note: Data for 1980 does not include 2.67 million short tons for “other uses” that is included in the total utilization number. This was the only year that included this additional category.

# METHODOLOGY AND SOURCES

The primary source of data on CCP production and utilization is the American Coal Ash Association (ACAA), which began collecting data in 1966. ARTBA used the published reports from 1977 through 2013 to analyze the overall market. Relationships between the CCP data and other economic factors, including electricity demand and generation, U.S. recessions and changes in markets for CCPs, were analyzed using economic models. Although this study does not include the results of this econometric analysis, they were used as the basis for a 20-year forecast for CCP production and use in a companion document.

In the original 1977 report, data was reported on fly ash, bottom ash and boiler slag. Through the 1994 report, utilization was reported for internal and external (or commercial) use. In this analysis we have combined these two categories, since the goal is to capture the total beneficial use.

In the 1980 report, ACAA captured two additional utilization categories, entitled “Ash Removed From Plant Sites At No Cost to Utility” and “Ash Utilized After Disposal Costs.” Both of these totals are included with the commercial and internal utilization for the grand total of CCPs utilized in that year. This was the only year those two additional categories were included. Thus the total utilization categories in the appendix in 1980 do not add up to the final utilization number that year.

Although ACAA captures the beneficial use of CCPs by detailed end markets prior to 1980, the categories differ from future reports. Thus most of the end market analysis in the report, for the beneficial use, is for 1980 to 2013.

In the 1984 report ACAA listed comparative results at the bottom of the report and included total CCPs produced and utilized in previous years. On this report, the 1983 totals are different from the published 1983 report. There is no note of a revision, so we have included data from the original 1983 report for this analysis.

In 1987 ACAA began capturing data on FGD sludge. This category was renamed FGD by-product in 1988, FGD sludge in 1989 and FGD material in 1990. In 2002, ACAA classified FGD materials as FGD Gypsum, FGD Material Wet Scrubbers, FGD Material Dry Scrubbers and FGD Other. For the purposes of this report, we have combined all FGD related categories into one total.

There are a few minor discrepancies in the 1988 published ACAA report, where individual totals for fly ash, bottom ash, boiler slag and FGD gypsum utilization in the external markets are slightly different from the published subtotals. In most cases, the subtotals are off by less than ten tons of material. We have used the sum of the utilization reported, so the total we include in the year 1988 for utilization is slightly different (20,560,982 short tons versus the original 20,560,963 short tons) that was in the original report.

Several external and internal utilization totals were estimated by ARTBA for the 1991 analysis. For several end use markets, the ACAA published report includes “<50,000” or “<100,000” instead of specific totals. We estimated these numbers based on the total utilization reported, so all final totals add up to the total production and utilization reported for the year.

The 1994 ACAA report (as well as the 1999 and 2001 report) split CCPs into dry and ponded categories. The data reported for that year in this analysis is for the combined total in the ACAA published report.

In 2007, ACAA included data on FBC ash collected by a Pennsylvania association of 14 power producers, ARIPPA. The published report included total utilization and production both with and without the additional FBC Ash totals. We included the ARIPPA data in the 2007 numbers. From 2008 onward, the ARIPPA totals were not reported separately, and folded into the total ACAA report.

In 2013, the total utilization numbers used in this report for boiler slag, FGD material and FBC ash are slightly different from the published totals in the ACAA annual survey. The total utilization numbers reported by ACAA are different from the individual sum of utilization by major category. This report uses the sum of all the individual utilizations listed on the ACAA report as the total utilization for boiler slag, FGD material and FBC ash. For example, the boiler slag total utilization reported by ACAA in 2013 is 897,185 short tons, but adding up the individual ACAA published numbers for boiler slag utilization in the soil stabilization (1,000), snow and ice (11,797), blasting grit (884,861), waste (727) and aggregate (10,681) categories, the total utilization would be 909,066 short tons.

Additional market data is from the U.S. Energy Information Association, the U.S. Geological Survey and the U.S. Census Bureau.

For additional information please contact:

**Dr. Alison Premo Black**

ARTBA Senior Vice President &  
Chief Economist  
202.289.4434  
ablack@artba.org



