



Key Findings 2015

Coal Combustion Products Utilization

U.S. Historical Perspective and Forecast

Produced by the American Coal Ash Association (ACAA)

Building a Sustainable Future: Coal Combustion Products Utilization in the United States

The history of coal combustion products (CCPs) utilization is a success story of economic productivity, technical innovation, and environmental sustainability. CCPs have been used for decades to build the infrastructure of the U.S. – our highways and roads, bridges and tunnels, tallest skyscrapers, commercial structures, and residential buildings. Products containing CCPs can be found in nearly every American home, from the fly ash in concrete foundations and driveways to the synthetic gypsum in wallboard to the boiler slag in shingles on rooftops.


This report looks back at the economic and policy factors that influenced CCP production and utilization over the past 40 years, and looks ahead to the availability and demand for CCPs over the next 20 years. This look forward is based on econometric models of historical CCP data, projections for coal-fueled electric generation, and U.S. economic factors to forecast CCP production and utilization over the next two decades.

CCP production has increased 93 percent since 1974, growing at an average annual rate of 1.7 percent. The Clean Air Act (CAA) amendments accelerated CCP production, as coal-fueled utilities installed emissions control equipment to comply with the regulations. As more CCPs were produced, markets for their beneficial use emerged. CCPs were recognized as cost-competitive materials with distinct advantages over other materials commonly used in construction, agriculture and mine reclamation. Engineering standards were developed to guide CCP utilization in technically- sound, environmentally-protective ways.

CCP utilization has dramatically increased since 1974, growing by 500 percent to 51.6 million (short) tons beneficially used in 2013. This quantity represents materials diverted from disposal that

enhance product performance and reduce impacts to our land, air, and water resources.

Coal will continue to account for a significant percentage of U.S. electric generation during the next two decades. As a result, CCP production is expected to remain steady, increasing by five (5) percent through 2033. The future of CCP utilization is equally bright. Growing demand in construction markets is expected to increase CCP utilization by over 48 percent. Forecast models project that CCP utilization rises to 63 percent of production by 2033. Even under alternative scenarios of accelerated coal-fueled electric generating unit retirements, CCP production is still expected to exceed overall demand.



***Production of CCPs,
particularly fly ash and
FGD materials, is
forecast to **exceed**
future demand***

40 Years of Innovation and Sustainability

The use of CCPs as a substitute for mined or manufactured materials lowers construction costs, decreases water and energy use, and results in substantial carbon emissions reductions. For every ton of coal fly ash used as a replacement for portland cement in concrete, approximately one ton of carbon emissions are avoided. Using CCPs in place of mined materials reduces the land use impacts associated with extraction.

Equally important, products made with CCPs typically perform better and have greater longevity than non-CCP products. For example, concrete made with fly ash is less permeable and more resistant to acid, sulfates and other destructive chemical reactions than concrete made with portland cement alone. Reusing CCPs is environmentally responsible and supportive of a sustainable economy.

Since 1974 the American Coal Ash Association (ACAA) has tracked the production and use of CCPs in the U.S. Statistics are derived from a voluntary annual survey of the coal-fueled electric utility industry to track quantities of CCPs produced and beneficially used. ACAA's annual Production & Use Survey Report

has been used by government agencies such as the Environmental Protection Agency (EPA) and the Department of Energy (DOE), and is considered the authoritative source for CCP production and use data in the U.S. Recent ACAA Production and Use Reports are available at: <http://www.acaa-usa.org/Publications/Production-Use-Reports>. ACAA commissioned the American Road and Transportation Builders Association (ARTBA) to conduct an economic analysis of historical CCP production and use data, and the linkages to construction markets and regulatory policies. Historical data and economic linkages were used to construct econometric models that forecast CCP production and use through 2033. The historical and forecast studies are presented in two separate reports:

- Production and Use of Coal Combustion Products in the U.S.: Historical Market Analysis¹
- Production and Use of Coal Combustion Products in the U.S.: Market Forecast Through 2033²

This report is a synopsis of those two studies, providing key findings for CCP market participants, builders and architects, permitting authorities, and policymakers.



*Every ton of coal fly ash used in concrete
reduces carbon emissions by one ton*

¹ ARTBA. 2015. *Production and Use of Coal Combustion Products in the U.S.: Historical Market Analysis*. American Road and Transportation Builders Association.

² ARTBA. 2015. *Production and Use of Coal Combustion Products in the U.S.: Market Forecast Through 2033*. American Road and Transportation Builders Association.

Clean Air Act Compliance Increased CCP Production

CCPs are produced as a byproduct of coal-fueled electric generation. Coal accounted for 44 percent of U.S. electric generation in 1974, climbing to a peak share of 57 percent in 1988. Since 1988 the use of coal for electric generation has declined, to 40 percent in 2013. However, due to increasing electric demand over time, overall coal consumption for electric power generation has remained higher than 1988 levels.

The production of CCPs has grown from 59.5 million tons produced in 1974 to 114.7 million tons in 2013. This volume represents the second largest industrial byproduct stream in the U.S. In comparison, 254 million tons of municipal solid waste was generated in the U.S. during 2013.

The increase in CCP production over the last four decades is due to a combination of regulatory and market factors, reflecting the reliance on coal for a significant percentage of the country's electric power generation and capital investments undertaken to comply with environmental regulations. The Clean Air Act (CAA) and amendments in 1970, 1977 and 1990 set national air quality standards for criteria pollutants, including particulate matter, sulfur dioxide (SO₂) and nitrogen oxides (NO_x). In response to these regulations, emissions control equipment installed at

coal-fueled electric power plants has resulted in larger quantities of CCPs being generated and captured. CCPs have varied chemical and physical characteristics, and include fly ash, bottom ash, flue gas desulfurization materials, boiler slag and fluidized bed combustor (FBC) ash.

The production of fly ash, which is captured from the exhaust flue gases, increased as emissions control equipment has been deployed at more power plants. Fly ash production increased from 40.4 million tons in 1974 to 53.4 million tons in 2013. Production of fly ash increased by 2.2 percent annually between 1990 and 2008.

Synthetic gypsum, a high-value byproduct formed in flue gas desulfurization (FGD) systems known as scrubbers, increased significantly as these systems have been installed to reduce SO₂ emissions. Scrubbers capture sulfur emissions using a calcium-based reagent, producing synthetic gypsum that is typically higher purity than mined natural gypsum. Gypsum is the primary ingredient used in wallboard manufacturing.

Of the operational scrubber units in 2012, nearly 70 percent went into service after 1990. The production of FGD materials (which



Clean Air Act Compliance Increased CCP Production

includes synthetic gypsum, wet scrubber, and dry scrubber materials) has increased 148 percent since 1987, rising to 35.2 million tons in 2013. This represents an annual average growth rate of 3.5 percent, far outpacing the 0.3 percent growth in coal-fueled electric generation during this same period. This growth is due to increased production of synthetic gypsum, accounting for over 70 percent of total FGD materials production.

Together, fly ash and FGD materials now account for 77 percent by weight of total annual CCP production. Bottom ash, the heavier CCPs collected at the bottom of coal-fueled boilers, increased one percent annually to 14.5 million tons in 2013.

Ash produced from fluidized bed combustors (FBC), which can burn coal with lower energy content, increased from 1.2 million tons in 2002 to 10.3 million tons in 2013. The only category of CCPs for which production has decreased is boiler slag, which is produced in cyclone boilers, many of which are being retired. Boiler slag production has declined by 72 percent since 1974 to 1.4 million tons in 2013.

The growth in CCP production over the last 40 years relative to major air regulations is shown in Figure 1.



Production of CCPs has grown at an average annual rate of 1.7 percent

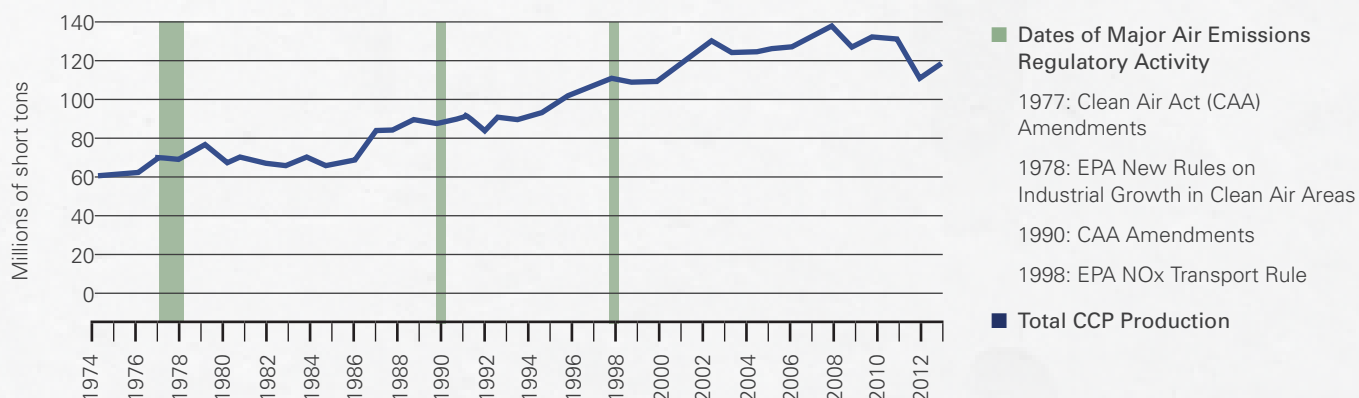


Figure 1. CCP production has increased due to coal consumption for electric power and installation of emissions control systems

As CCP Production Grew, Standards and Markets Emerged

CCPs are used in a number of construction-related products and applications. CCPs are used as supplementary cementitious materials (SCM) in concrete and cement products, in gypsum panel products, and as a replacement for aggregates in structural fills and embankments. Nearly two-thirds of CCPs are used in construction-related markets. Significant quantities of CCPs are also used in mining applications such as reclamation, as the alkaline nature of some types of CCPs mitigates the effects of acid mine drainage.

Overall CCP utilization has increased from 8.7 million tons in 1974 to 51.6 million tons in 2013 – a cumulative increase of nearly 500 percent. Over the history of ACAA recordkeeping, 1.2 billion tons of CCPs have been used, rather than disposed.

CCP utilization has evolved as markets for CCPs matured and standards governing use have been implemented. Numerous technical and engineering standards for CCP utilization have been developed by federal and state agencies. Standards for CCP use have been developed by ASTM International, American Concrete Institute (ACI), American Association of State Highway and Transportation Officials (AASHTO), Federal Highway Administration (FHWA), Army Corps of Engineers (ACE), Federal Aviation Administration (FAA), National Ready Mixed Concrete Association (NRMCA), American Society of Civil Engineers (ASCE) and numerous state departments of transportation (DOTs).

Because CCPs improve the strength and durability of concrete, demand for ready mixed concrete is a primary driver for CCP utilization, particularly for fly ash. The demand for ready mixed concrete is closely correlated with construction markets and overall U.S. economic growth. Highway construction is also a

major end market, as CCPs are used in pavements and bridges, and provide stability benefits in road base, structural fills and embankments.

The utilization rate of fly ash has grown from 8.4 percent of production in 1974 to 43.7 percent in 2013, when 23.3 million tons were beneficially used.

Technologies to improve ash quality, logistics and infrastructure to transport CCPs efficiently and wider recognition that CCPs are high-value materials have contributed to utilization. Demand for synthetic gypsum has been supported by the commercialization of wallboard manufacturing and market preference for the uniformity and lower cost of FGD gypsum compared to virgin (mined) gypsum. Wallboard manufacturers have co-located

production facilities adjacent to coal-fueled power plants to streamline manufacturing.

Currently about 50 percent of the gypsum panel products manufactured in the U.S. are made with synthetic (FGD) gypsum. In 2013, 7.4 million tons of synthetic gypsum were utilized for wallboard products. FGD materials are also used in mining applications and as an agricultural amendment to improve soil quality, reduce nutrient run-off and boost crop yields. Overall, 12.9 million tons of FGD materials were utilized in 2013, with synthetic gypsum accounting for 92 percent of use.

CCPs are usually less expensive than the materials they replace, and the utilization of CCPs has increased, rather than decreased, during recessions. Fly ash utilization has increased during three of the last five recessions, while bottom ash utilization has increased following the beginning of every U.S. recession since 1973. Notably, CCP use increased steadily even when the real value of pavement work and new housing starts declined between 2000 - 2008.



Regulatory Uncertainty Hinders CCP Beneficial Use

While CCP utilization has grown by an average 5.1 percent annually, total utilization as measured in tons has fallen since 2008. CCP utilization had increased to an all-time high of 60.6 million tons in 2008 – after the start of the most recent recession that began in December 2007. That peak was followed by six years of downturn in CCP utilization, where overall use declined by 15 percent.

This downturn occurred after the Environmental Protection Agency's (EPA) decision to reconsider the classification of CCPs as hazardous waste following the coal ash storage pond failure at Tennessee Valley Authority's Kingston power plant.

In June 2010, EPA proposed regulating CCPs as either solid waste under Subtitle D of the Resource Conservation and Recovery Act (RCRA) or as a hazardous waste under Subtitle C of RCRA. The final rule was published on April 17, 2015 – more than six years after the Kingston release.³

This period of regulatory uncertainty had significant implications for CCP utilization. Regulation of CCPs as a hazardous waste

under Subtitle C would require expensive changes to CCP management and transport. In addition, the label of hazardous waste could impact consumer acceptance of building materials made with CCPs. As a result, CCP markets were negatively impacted.

While the downturn in CCP utilization coincided with the recession from December 2007 to June 2009, economic analysis has shown that the contraction in construction market activity was not solely responsible for the sharp decline in CCP utilization. Bottom ash utilization – which had previously increased following the start of the last five recessions – declined at an average annual rate of seven percent between 2008 and 2013. Fly ash utilization fell to 23.3 million tons in 2013, a decline of 18 percent from 2008 levels

Although production of ready-mixed concrete in 2013 was still below pre-recession levels, the market bottomed out in 2010 and demand has increased annually since that time. Meanwhile, fly ash utilization had continued to remain depressed.



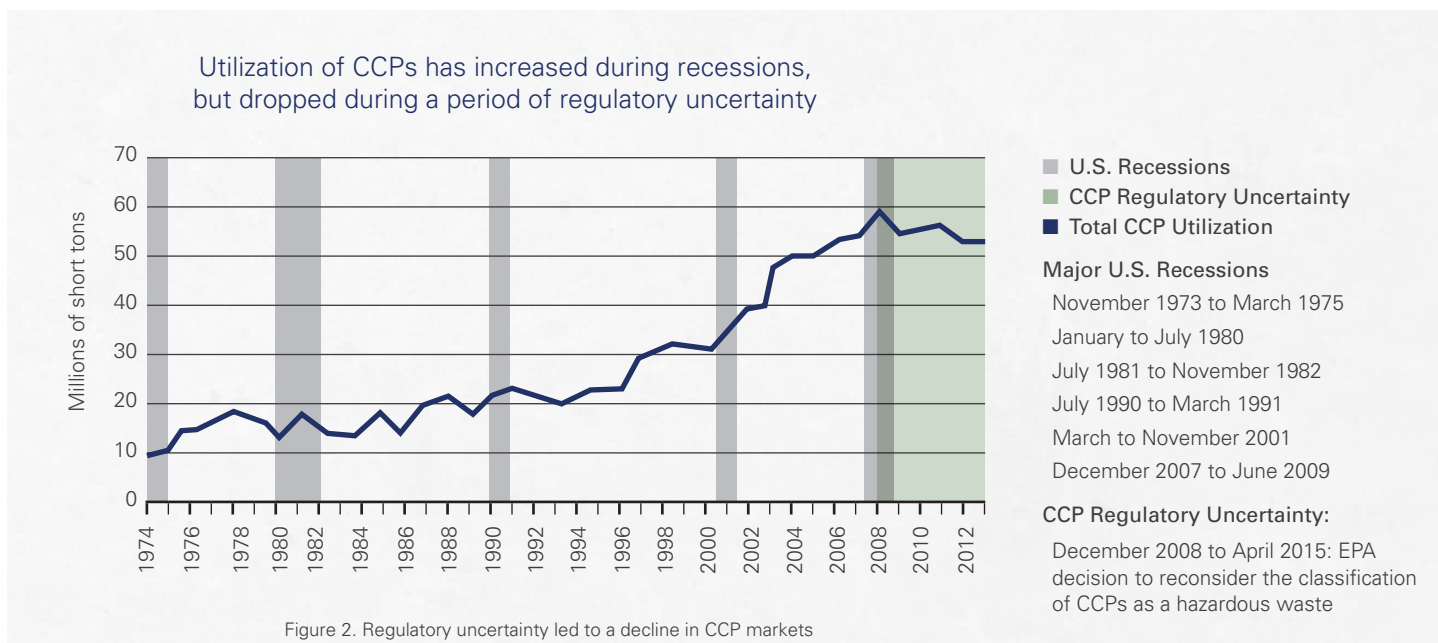
*CCP utilization has increased during prior recessions but **declined** 15% since 2008 due to **regulatory uncertainty***

³ 80 Fed. Reg. 21301. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities.

Regulatory Uncertainty Hinders CCP Beneficial Use

The 2015 final rule regulating CCPs as nonhazardous and retaining the Bevill exemption for CCPs that are beneficially used restores certainty to markets. In addition, in 2014 EPA affirmed the safety of using fly ash in concrete and FGD gypsum in wallboard using a risk-based scientific methodology. EPA found that the environmental performance of fly ash concrete and synthetic (FGD) gypsum wallboard were comparable to non-CCP products and concluded “these beneficial uses provide significant opportunities to advance Sustainable Materials Management.”⁴ As a result, EPA “supports the beneficial use of coal ash in an appropriate and protective manner, because this practice can produce positive environmental, economic, and product benefits.”⁵

The regulatory certainty provided by these two EPA actions is important for investment in CCP markets, and for CCP beneficial use to recover and surpass 2008 levels. The utilization of CCPs during recessions and the period of regulatory uncertainty is shown in Figure 2.



⁴ U.S. EPA. 2014. Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard. Available at: http://www.epa.gov/waste/conserve/imr/ccps/pdfs/ccr_bu_eval.pdf

⁵ U.S. EPA. 2014. Coal Ash Reuse. Available at: <http://www2.epa.gov/coalash/coal-ash-reuse>

Steady Production Will Support Future CCP Market Growth

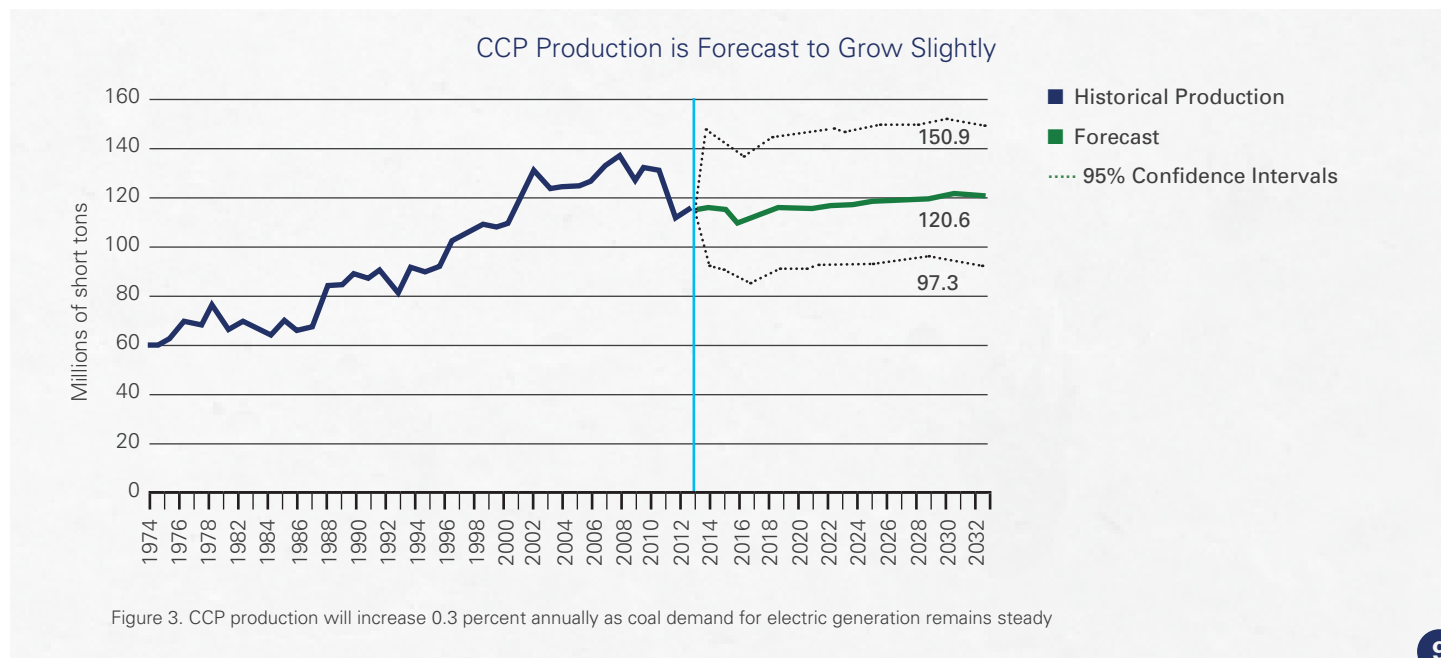
Coal once accounted for 50 percent of electric generation in the U.S., but declined to a low of 37.4 percent of in 2012. With 40 gigawatts (GW) of coal-fueled electric power capacity projected to retire through 2040, coal's role in the U.S. power system continues to evolve. The availability of CCPs for beneficial use and the potential for utilization over the next two decades was forecast using a series of econometric models using Box-Jenkins methods. These models were based on historical relationships between coal-fueled generation, construction market demand, and CCP production and utilization.

Despite the retirement of coal-fueled capacity, power generation from coal is expected to remain relatively steady through 2033 due to electric demand growth, according to the U.S. Energy Information Administration (EIA). As a result, CCP production is forecast to increase by five (5) percent over the next twenty years, from 114.7 million tons in 2013 to 120.6 million tons in 2033. Figure 3 shows the forecast utilization with 95 percent confidence intervals from the model results.

Fly ash and bottom ash production are each projected to increase annually by 0.1 percent over the next 20 years. Fly ash production



is forecast to reach 54.6 million tons in 2033, and bottom ash production is projected to increase to 14.7 million tons. The production of FGD materials will not be significantly impacted by coal unit retirements, as most of these retiring units are older and lack scrubber systems. For units that will continue to operate, scrubbers have already been installed or are planned, reflecting investments already committed to comply with the Mercury and Air Toxics (MATS) rule. These new and planned scrubbers will increase the supply of FGD materials – particularly gypsum. Production of FGD materials is expected to surge 10 percent over the next 20 years under the baseline scenario, increasing to 38.8 million tons by 2033.



Ready Mixed Concrete Demand and U.S. Economic Growth Drive Future Beneficial Use

Total CCP beneficial use is forecast to increase 48 percent from current levels to 76.5 million tons in 2033. As a result, overall utilization of CCPs is forecast to grow to 63 percent of production, as shown in Figure 4. Drivers of CCP utilization over the next two decades are growth in the U.S. economy, new housing starts, and increased demand for ready mixed concrete. Historically, ready mixed concrete demand has grown at an average annual rate of three percent.

Based on ready mixed concrete market projections, fly ash utilization is forecast to increase to 35.7 million tons in 2033 – a 53 percent cumulative increase over the next two decades.

FGD materials utilization is forecast to grow at three percent per year, to 22.3 million tons by 2033. It is expected that most of the materials utilized will be synthetic gypsum, consistent with historical use patterns and active markets for gypsum.

Significantly, the overall FGD material utilization rate is projected to grow from 37 percent currently to 58 percent by 2033.

Bottom ash utilization is forecast to increase 28 percent to 7.2 million tons in 2033, tied to demand from construction markets.

FBC ash utilization is projected to increase from 8.8 million tons in 2013 to 10.6 million tons in 2033, maintaining the average historical utilization rate of 89 percent of production. FBC ash has been used extensively for mine reclamation to mitigate acid mine drainage and restore landscapes.

It is important to note that the forecast models assume regulatory certainty based on the final EPA rule – that CCPs will be regulated as nonhazardous materials. The forecasts for each category of CCPs compared with 2013 production and utilization are shown in Table 1.

*U.S. economic growth, new housing starts, and demand for ready mixed concrete is forecast to **increase CCP utilization by 48%***

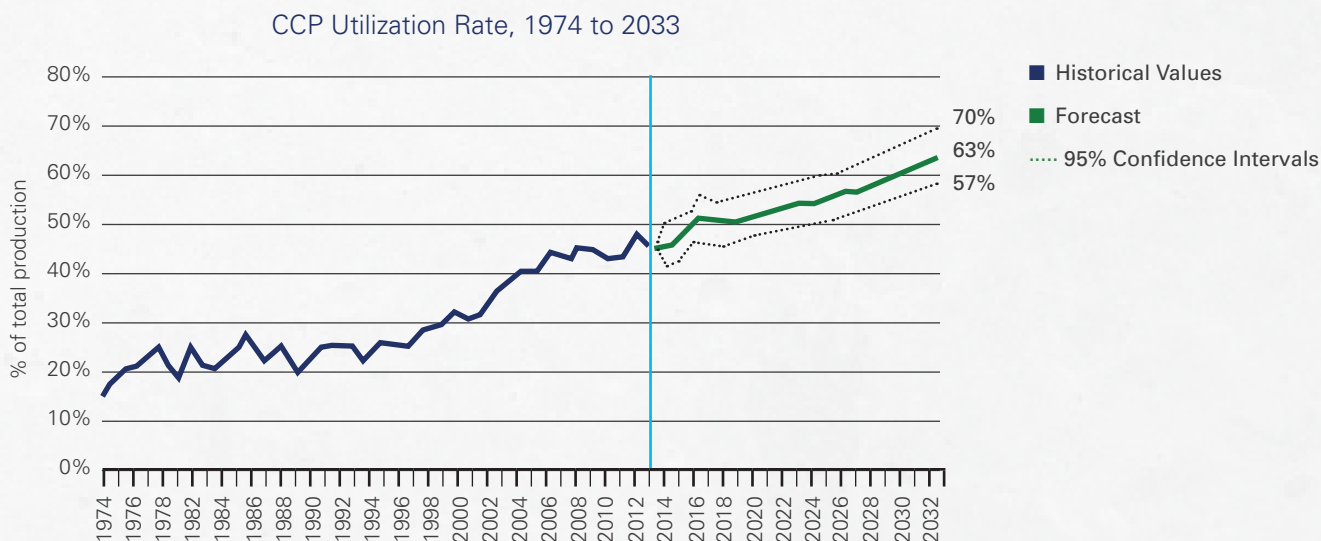


Figure 4. The percentage of CCPs utilized is expected to increase due to strong end market demand

Ample CCP Supplies Will Support Future Utilization

Alternative scenarios for “low growth” and “high growth” in fly ash, FGD materials and total CCP production were also modeled based on historical production patterns and different modeling techniques. Under the low growth scenario, which represents accelerated retirements of coal-fueled electric generating units, CCP production is forecast to drop 0.9 percent to 94.8 million tons in 2033. Fly ash production under the “low growth” scenario would decrease to 44.5 million tons in 2033. FGD materials production under this scenario would decrease by 2.1 percent annually to 23.0 million tons. Fly ash and FGD materials production for the “low growth” scenario would still exceed forecast utilization.

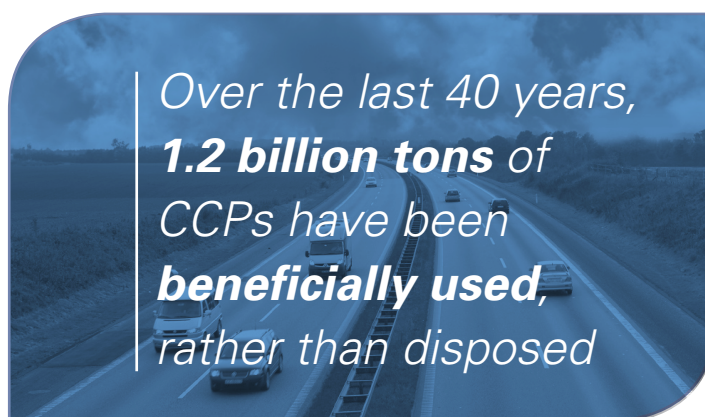
The “high growth” scenario is based on higher production growth for fly ash and FGD materials following the enactment of CAA regulations. Under this growth scenario, total CCP production is projected to grow 1.7 percent annually to 161.5 million tons in 2033. Fly ash production would grow by 0.9 percent annually, to 64.5 million tons. FGD production under the “high growth” scenario would reach 69.7 million tons in 2033.

Table 1. Forecast CCP production and utilization by category

	2013 Volume (million short tons)	2033 Forecast Volume (million short tons)	Projected Total Growth	Projected Average Annual Growth
PRODUCTION				
Fly Ash	53.4	54.6	2.2%	0.1%
FGD Materials	35.2	38.8	10.1%	0.5%
Bottom Ash	14.5	14.7	1.2%	0.1%
Boiler Slag	1.4	0.8	-43.2%	-2.8%
FBC Ash	10.3	11.8	14.5%	0.7%
Total Production	114.7	120.6	5.2%	0.3%
UTILIZATION				
Fly Ash	23.3	35.7	53.1%	2.2%
FGD Materials	12.9	22.3	72.9%	2.8%
Bottom Ash	5.6	7.2	28.4%	1.3%
Boiler Slag	0.9	0.8	-16.1%	-0.9%
FBC Ash	8.8	10.6	20.2%	1.0%
Total Utilization	51.6	76.5	48.3%	2.0%

Technologies and Logistics Enable New CCP Supplies

In addition to new production, ample supplies of CCPs are available from surface impoundments and landfills. Beneficiation technologies that treat CCPs for residual carbon, moisture and other undesirable properties are used to create ash that meets technical specifications, such as ASTM standards for use in concrete. These technologies have been successfully commercialized and are used throughout the U.S.



EPA regulations establishing disposal standards for CCPs as well as steam electric effluent limitations guidelines (ELG) will result in some CCP impoundments and landfills being closed.

Beneficiation technologies provide an opportunity to reclaim materials that had been previously disposed. Further, as more utilities convert to dry CCP handling to comply with these environmental regulations, the quality and quantity of CCPs suitable for beneficial use will increase.

Engineers, planners, architects and construction professionals recognize the strength, durability and sustainability benefits that CCPs deliver. With demonstrated excellent technical performance of CCPs in various applications from construction to mine reclamation to agriculture, CCPs have become a high-value material resource. Forecast models project that sufficient quantities of CCPs will be available for beneficial use over the next two decades. Given regulatory certainty, CCP markets will continue to grow this recycling success story.

