

# AN OVERVIEW OF THE UNITED STATES DEPARTMENT OF ENERGY'S COAL COMBUSTION BY-PRODUCT UTILIZATION PROGRAM<sup>1</sup>

by

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**Abstract.** The onset of utility deregulation now makes it apparent that coal combustion by-product (CCB) utilization is one key area that may help utilities better manage their available resources. Every avoided cost dollar from the use of a by-product versus straight land filling is better than a dollar in gross revenue since there is an associated overhead cost with revenue generation. The economic incentive becomes even greater when the by-product can be sold rather than given away. Because current utilization rates of CCB's are relatively low, the United States Department of Energy is actively co-sponsoring a variety of coal combustion by-product utilization projects, along with projects that seek to characterize the by-products resulting from newer, "clean" coal combustion or gasification technologies. Most recently, these by-products are being tested to stabilize metal-laden characteristically hazardous waste at a Pennsylvania municipal waste treatment center, control acid-mine drainage problems in West Virginia Coal mines, control surface subsidence in Southern Illinois coal mines, and provide high value-added products through the beneficiation of fly-ash and expansion of slag materials throughout the country. By providing the framework for regulatory, economic, and marketing considerations which influence CCB management decisions and demonstrating successful pilot scale applications, it is hoped that the total utilization rate for CCB's can reach 50% by the year 2010.

**Additional Key Words:** fly ash, flue gas desulfurization, fluidized bed combustion, low-NO<sub>x</sub> burners

## Introduction

Although worldwide coal consumption has increased only about 10% the past 15 years, U. S. coal consumption has increased by 25%. The U. S. produced approximately 1 billion short tons of coal in 1996 and possesses over 200 years of coal reserves based on current production estimates. In comparison, it is projected that the U. S. has only 20-40 years of oil reserves and 25-65 years of natural gas reserves. Electric utilities consume about 90% of the coal produced annually in the United States. Additionally, electricity generated from coal accounts for almost 60% of the annual U. S. production with oil, natural gas, and hydropower producing less than 10% each. These statistics indicate that coal should continue to be an economically viable fuel source for several decades (Energy Information Administration 1996).

As a result of coal's dominance of the U. S. electricity market, a necessary residual has been and will continue to be the accompanying production of large amounts of CCB's. In 1996, more than 100 million short tons of solid by-products were generated in the U. S. (indicating combustion of almost one billion short tons of coal). If coal maintains its current position as the fuel of choice for electricity generation, more attention must be given to the challenges and opportunities that increased CCB utilization presents.

Table 1 indicates how the 100 million tons of material produced in 1996 for the primary CCB categories were distributed (American Coal Ash Association 1997). The low percentage utilization figures are why the U.S. Department of Energy has significant interest in this area. Various applications of coal combustion by-products are listed in Table 2, as well as the amount utilized for that purpose, if specified for 1996.

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## Program Objectives

The Fossil Energy Coal Combustion By-Product Utilization Program has the following four short-term goals:

Table 1. 1996 Coal Combustion By-Product Production and Utilization (in short tons)

	<u>Production</u>	<u>Utilization</u>	<u>Percent Utilized</u>
Fly ash	59,355,009	16,234,488	27.4%
Bottom ash	16,060,672	4,868,253	30.3
Boiler slag	2,568,349	2,396,070	93.3
FGD materials	23,854,328	1,656,132	6.9
<b>TOTAL</b>	<b>101,838,447</b>	<b>25,154,943</b>	<b>24.7</b>

Table 2. Uses of Coal Combustion By-Products

Application	Bottom Ash	Fly Ash	Boiler Slag	FGD Residue	FBC Solids	Amount Utilized
Aggregate, block	X				X	
Aggregate, lightweight		X				
Agricultural lime				X	X	27,089
Blasting grit			X			2,342,450
Cement manufacture		X				8,860,150
Concrete, ready-mix		X				"
Drybed material	X					
Drying agent				X		
Fill, flowable		X				1,211,085
Fill, structural	X	X			X	2,940,755
Filter media	X	X				
Fuel, alternate		X				
Ice control	X					780,245
Ladle topping		X				
Landfill liner				X		
Pipe bedding	X					
Potting soil filler		X				
Road base				X	X	1,590,057
Road surfacing			X			
Running tracks			X			
Soil amendment		X		X	X	247,651
Wallboard gypsum				X		887,064
Waste stabilization				X		2,241,686

- To characterize waste from coal powered production technologies and ensure safe disposal and utilization practices.
- To develop technologies for solid waste minimization, waste disposal, and underground mine reclamation.
- To perform institutional analysis that provides the framework for regulatory, economic, marketing, and other considerations which influence waste management decisions.
- To coordinate/facilitate information transfer from DOE sponsored or co-funded projects to the private sector.

As these short term goals are achieved, they contribute to the program's long-term objectives of:

- By the year 2010, demonstrate the acceptability of large volume uses of advanced CCB's in such things as surface and underground mine reclamation such that utilization rates for CCB's approach 50%.
- By 2010, complete sampling and characterization of clean coal technology by-products such that the public and regulatory agencies accept disposal or utilization of coal by-products as routine business practices.

#### Program Description

The Fossil Energy Coal Combustion By-Product Utilization Program involves managing by-products from a wide spectrum of coal technologies including conventional coal combustion processes, coal preparation and coal slurry fuel systems, and advanced coal utilization and conversion systems, (primarily clean coal technology projects). The program seeks to fund projects which characterize, monitor, and demonstrate high volume uses of the solid material in actual field applications. Laboratory and large-scale technology development projects are monitored to assess the behavior of these materials in these applications. This data is then used to perform the institutional analysis required to evaluate the non-technical aspects of by-product utilization management. This analysis focuses primarily on the influence of regulatory, economic and marketing issues associated with CCB's. Information transfer of the results generated by the DOE CCB management program to the user community is essential to meet the long-term objectives.

The United States Department of Energy has actively been involved in co-sponsoring the utilization of coal combustion by-products (CCB's) for the past several years. DOE traditionally partners with universities, small businesses, state and other federal agencies, as well as larger industrial partners including coal producers and utilities interested in the use of coal combustion by-products. Normally, a government solicitation is issued to which a proposer responds with an assembled team that may include a university supplying technical characterization work, an industrial partner supplying in-kind materials or engineering services, and some state agency contributing financial support because it has the goal of promoting economic support for the use of coal produced in that particular state. DOE provides significant cost-sharing initially. However, once a technology gets closer to commercialization, DOE reduces its financial commitment thereby allowing the market to eventually decide the outcome.

Several potential commercial technologies involving the beneficial application of coal combustion by-products for environmental remediation have been proven. The placement of fluidized bed combustion by-products (fly-ash, bed ash, and flue-gas desulfurization products) into both abandoned and active mine settings are showing the ability to reduce acid-mine drainage, prevent surface subsidence, and improve mining productivity by allowing feasible reclamation of abandoned coal pillars. Additionally, several projects throughout the country are demonstrating that high value-added products can be developed through the beneficiation of high carbon fly-ash and expansion of slag materials. Figure 1 illustrates the current geographical location of the most recently funded DOE projects in this program. Figure 2 displays the Department of Energy's current portfolio of projects and their support of the CCB program mission.

#### Expectations and Roles of Stakeholders and Customers

Our stakeholders have many agendas which need to be addressed in order to call the program a success. Often these agendas are contradictory; for example, a CCB user's need for a consistent product quality may require an increase in cost or other operational change on the part of the utility producing the CCB's. Listed below are the items that DOE has identified as being critical toward supporting or accomplishing our program:

- Characterization and development of new applications for by-products from the DOE-sponsored Clean Coal Technology Program.

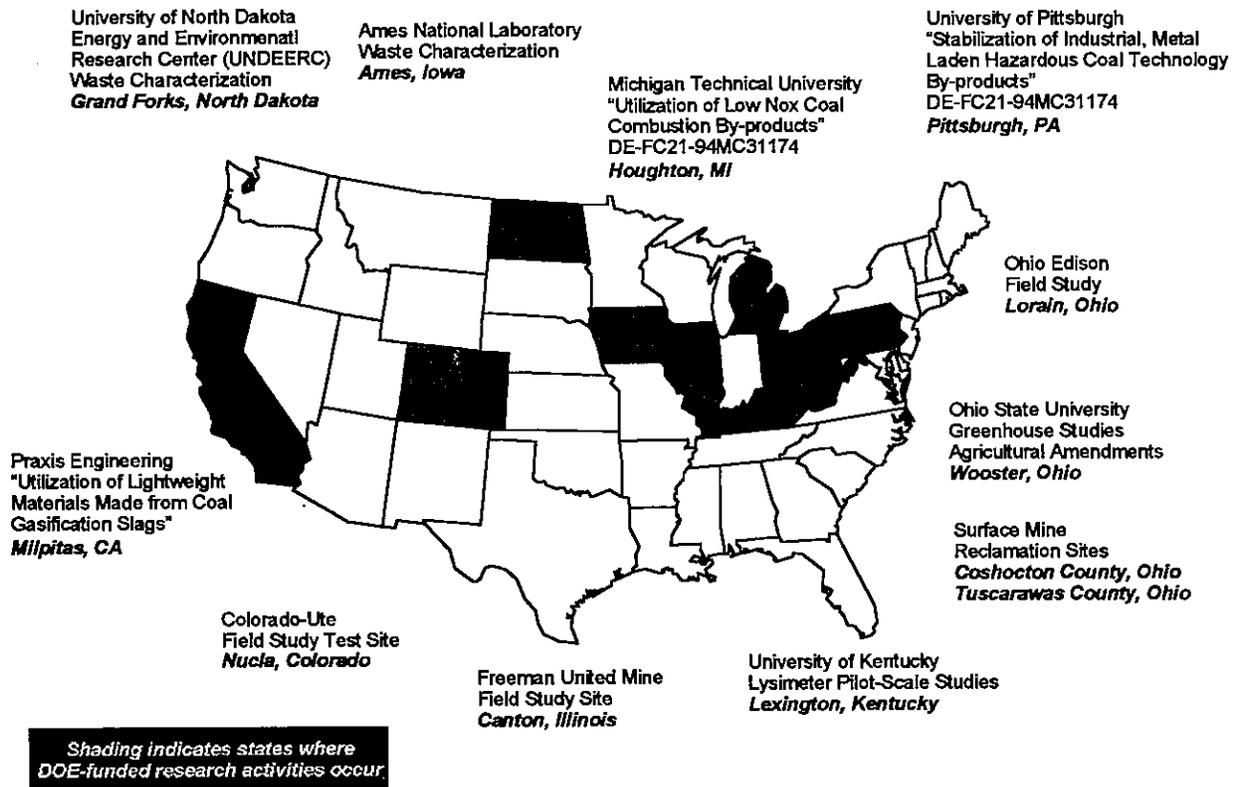


Figure 1. Major Demonstrations and Activities

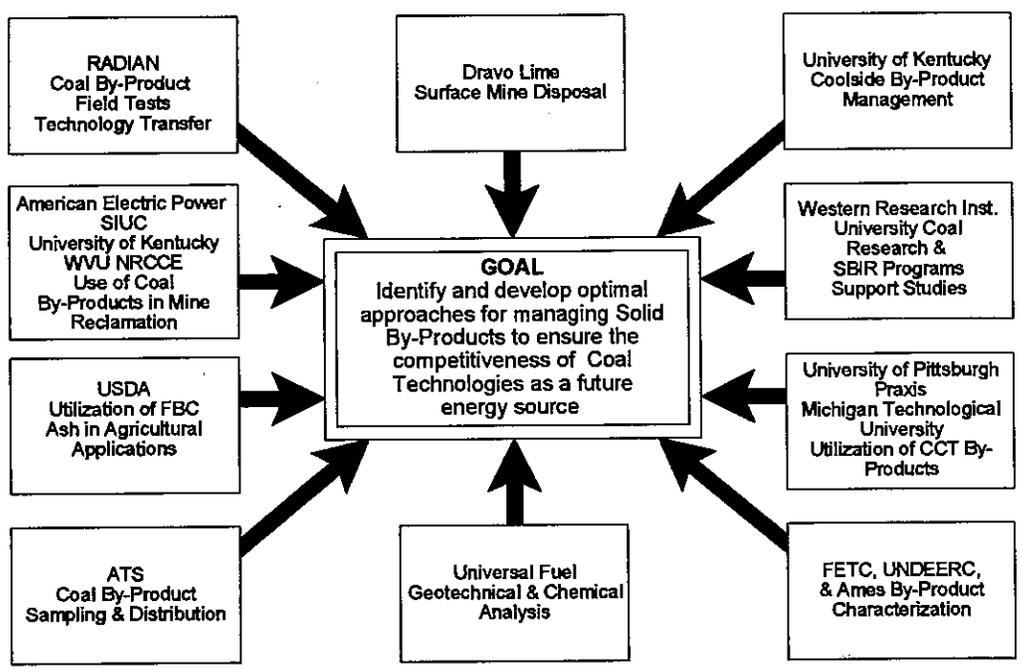


Figure 2. U.S. DOE CCB Management Program

- Evaluation of long-term water quality effects, when coal is mined, cleaned, and stored, and when CCB's are utilized or stored.
- Development of a better understanding of the durability and range of conditions CCB based products can tolerate.
- Demonstration of technically and economically viable processes and products using CCB's
- Development of standardized state regulations regarding appropriate uses.
- Effective technology transfer mechanisms

#### Key Success Factors

In order for any Government program to be successful, some metrics should be developed which allow the program administrators the opportunity to benchmark their position at any point in time versus some earlier point. DOE will evaluate the long-term results of our program by analyzing the changes in several of the items listed below.

- Cost-sharing from industry
- EPA ruling on FBC ash
- Communicating technical results from past and ongoing DOE sponsored CCB projects to the appropriate regulatory officials.
- Increasing cost for landfill permits in deregulated environment.
- Eliminating the term "waste" from common vernacular and replace with "coal combustion byproduct".
- Utilizing CCB's as a method to reduce the cost of electricity (COE) for deregulated utilities.
- Improving the overall utilization rates of CCB's (especially FGD and fly ash)
- Previously impenetrable markets accepting CCB products

#### Strengths and Weaknesses of the Program

The use of coal combustion by-products (CCB's) is a cross cutting area that benefits all coal-based power producers. Strengths include the fact that a national

program is required in order to provide and validate environmental monitoring of projects that attempt to beneficially use CCB's. DOE has been actively involved in the CCB area for the past several years and has started to establish itself as an asset to user and regulatory communities.

Weaknesses of the program mainly center around perceptions of the material as being hazardous. The fact that this combustion by-product is actually a remnant of a more important product, electricity, from the utility's viewpoint, also implies that CCB's will continue to be a secondary consideration.

#### CCB's Relative Competitive Strength

CCB's relative competitive strength is that when the particular CCB has properties similar to those of a competing resource, it should be more economically attractive to the end user. Utilities may be able to achieve some payback for technology cost by either using some products internally or by selling them. The rationale behind this is that utilities can spend anywhere between \$8-\$25/ton for disposal costs. If the generator can realize some profit, no matter how small, it not only provides revenue, but allows a greater gain via a reduction in disposal expenses. Therefore, avoided costs should dictate how much a generator can afford to subsidize transportation, if needed. In most other products, shipping is an additional charge to the base product cost. Power generators should also be able to build some goodwill with environmentalists by safely utilizing the by-product and devoting less acreage to relatively unproductive landfills. Although unquantifiable in economic terms, this may have a large impact on future decisions to allow various utilities to build power plants in their communities.

#### CCB's Relative Cost Position and Cost Competitiveness

The final cost of most of the various DOE-sponsored processes that utilize CCB's has not yet been defined at the large-scale demonstration stage. We know that any process (such as mine emplacement or hazardous waste stabilization) or CCB-based item must, at a minimum, be as cheap to operate or buy versus its competition. Given the uncertainty that still exists, CCB's most likely will have to be 15-20% cheaper to penetrate strong existing markets like the wallboard industry. Given the wide range of disposal costs for various geographical locations, each generator must determine how utilization of CCB's will fit into its overall economic plan. However, since industry spent nearly 1 billion dollars in 1996 for disposal of all CCB's, it will be to their advantage to consider other non-disposal options.

## U. S. Market Analysis for CCB-Derived Products

Companies participating in the CCB industry include generators (utilities), marketers (distributors), and customers (users). Technology innovation is relatively minimal as it appears as though most high volume utilizations have been explored. Several smallscale (less than 1 million tons CCB/year) but high-value applications may still have potential.

The utilization of CCB's has not always been an integral part of the industry. In order to avoid liability issues, a generator would just as soon dispose of this material as try to beneficially utilize it. Since the mid to late 1980's, more companies have been utilizing their own CCB's for on-site projects so as to avoid the off-site liability issues. Most generators still have excess landfill capacity but as new landfill space is needed, the increasing cost of permitting will drive generators to other options which should move utilization towards the eventual goal of 50% by the year 2010.

Obviously, product characteristics need to be similar to competition and the more material that can be used in a particular process or product, the cheaper it becomes. Essentially the entire utility coal-fired boiler population faces the issues of CCB disposal and utilization.

Profitability will be very specific to the individual utility based on numerous factor's such as residential versus commercial market share, fuel type, geographic location, etc. There is ample opportunity for utilities to use CCB's in a manner that lower their overall cost of electricity. Deregulation should force companies to explore any technology that allows them to operate at a profit in order to satisfy stockholders and to remain a leader in the business of providing electric power.

The U. S. market size and growth rate for several potential CCB markets are as follows (Parsons Power Group, Inc., 1996):

(1) The acid mine drainage remediation market is considered to be at 100 million tons/year which would result in \$750 million dollars in savings by eliminating solid waste disposal costs. The cost benefit for water cleanup also need to be considered.

(2) The agricultural soil amendment market is approximately 2.8 million tons CCB/year which could represent savings up to \$200 million per year.

(3) The portland cement market is near 80 million tons of cement produced/year. At an estimated price of \$20/ton, the sale of low carbon ash (production of a

maximum amount of 28 million tons) for cement represents an annual market of \$560 million plus avoided costs of \$200 million for disposal.

(4) pozzolan cement, although the market size not accurately known, it is assumed to be capable of taking the entire portion of CCB's produced by FBC power plants. The latest number is estimated at 765,000 tons CCB/year utilized in this market for a savings of 5.5 million per year.

(5) The flowable fill market is assumed to consist of fly-ash from conventional and low NOx boilers. Assuming the byproduct will not be competitive outside local or regional distribution, competitiveness will be based on transportation charges. 60 million tons of flyash is produced annually with typical flowable fill costing around \$13.50/ton, the national potential market size for this application represents \$835 million in sales with \$565 million in avoided costs.

(6) The structural fill and roadbed material represents a market of 34 million tons of CCB's used annually. Assuming a structural fill selling price of around \$10/ton, this would account for \$340 million in sales with \$270 million in avoided disposal costs.

(7) The gypsum market is potentially 26 million tons of gypsum used/year but only 24 million tons were produced according to the last American Coal Ash Association survey. With by-product gypsum selling for about \$4/ton, the maximum total sales are \$96 million with disposal savings of \$70 million.

### Driving Forces/Trends: Political, Economic, Social, Technological

There are several driving forces which will have a major influence on the selection of future projects in the DOE CCB Program:

- 1998 EPA ruling on classification of FBC By-Product Ash. [political]
- Increasing costs for utilities to permit land disposal facilities. [economic, social]
- Increasing transportation costs for trucking of by-product to an efficient/economical production facility. [economic]
- The need to establish ASTM standards regarding different uses of CCB's. [economic, technical]
- Increasing environmental national benefits in that a reduction in both the amount of solid waste

material land filled and overall CO2 emissions from displaced by-product competitors may be achieved. [social, economic, political]

- The need to establish consistent state regulations regarding classification and uses of CCB's. [political]
- Increase in NIMBY (Not in My Backyard) Syndrome which causes communities to battle placement of greenfield coal-fired power plants or expansion of landfills for additional by-product disposal by existing utilities. [social, political]
- The upgrades being made to meet federal Clean Air Act Standards has caused excessive growth in the area of flue gas desulfurization by-products. Table 1 shows that only 7 % of these solid by-products are being used beneficially. Additionally, Title 3 may eventually require regulation of hazardous air pollutants such as mercury. Current and future wet scrubbers may also address the removal of these pollutants. However, water discharges from the plants may need to be scrutinized for water quality much better than is presently done. [technical, social]
- Coal mine drainage treatment is influenced by the requirements under the Surface Mine Control and Reclamation Act (SMCRA) and the Clean Water Act. States have water quality standards and prohibit discharges in violation. The Abandoned Mine Land Program (funded from a tax on every ton of coal mined) enables states to reclaim polluted waterways on public lands. Additionally, under the above laws, coal and mineral storage runoff is covered, and solutions to environmental problems benefit the power and mining companies, respectively. Waste water from coal preparation plants would similarly be addressed. [political, social]
- Projected increase in energy demands in the future could mean more coal usage, thus affecting the amount of coal preparation and coal utilization. This would have a significant impact on solid waste and water usage from the mining and coal preparation operations as well as the combustion and flue gas cleanup areas. [social, political]
- Although several superfund sites (CERCLA) in western states must cleanup sludge produced from metal mine drainage, research with sludge produced from coal mine drainage is applicable to these superfund sites. [technical]

### Future Opportunities

Answers to questions such as, "Who will make the next move?" or "What will the next move be?" include some important planning assumptions. Indications are that EPA will issue the FBC ruling in mid 1998. From past DOE projects and other projects using CCB's, there doesn't appear to be a case for a "hazardous" classification. This would allow FETC to continue the development of CCB technologies involving the use of FBC ash and other Clean Coal Technology (CCT) byproducts just now being generated. Additionally, a lot of companies have retrofitted their units with FGD units which has caused FGD byproducts to increase rapidly. With FBC ash utilization issues addressed in the current FETC project portfolio, future work should concentrate on this growing FGD area. Another key issue seems to be the unburned carbon in ash issue evolving from the low NOx boiler installations. Since most fly ash is currently utilized in cement production, an increase in flyash carbon, a problematic constituent of concrete, could jeopardize the whole concrete flyash market and as such, it appears as though some effort should be put into addressing this issue also.

There are several other agencies that have an interest in CCB's. EPA is carrying out research for their final ruling on whether FBC ash is hazardous. The U. S. Dept. of Agriculture and Office of Surface Mining have contributed to projects in the past. EPRI has a separate CCB program that member utilities pay to belong to. Several states have coal development offices which often use funds for by-product research to provide practical demonstrations which support the sale of high sulfur coal. There is great potential for collaboration and cost-sharing with industry, universities, and other federal and state agencies. As a result, DOE is in putting together a CCB consortium that will leverage federal funds with funds from several of these interested sources. The consortium will (1) seek to develop new applications for the few clean coal technology projects which have come on-line this past year including Pinon Pine and Tampa Electric; (2) look to cost-share CCB utilization projects with various watershed organizations; (3) provide funding for long-term water quality evaluation for those CCB projects completed; and (4) begin some new projects in the area of unburned carbon in flyash, large volume FGD applications, or biomass ash characterization and utilization. It is expected that DOE will provide a maximum cost share of fifty-percent with at least one industrial partner and one university.

### Conclusions

As a result of coal's dominance of the U. S. electricity market, a necessary residual will be the continued production of large amounts of CCB's. In 1996, more than

100 million tons of solid by-products were generated in the U. S. with an overall utilization rate of 25%. If coal maintains its current position as the fuel of choice for electricity generation, more attention must be given to the challenges and opportunities that increased CCB utilization presents.

Because utilization rates of CCB's are relatively low, the U. S. Department of Energy has actively co-sponsored coal combustion by-product projects for the past several years. The program has the long term goal of achieving 50% total utilization of CCB's by the year 2010. The DOE role is to help promote improved power generating systems by demonstrating the feasibility of large volume uses of advanced CCB's in uses such as surface and underground mine reclamation and complete sampling and characterization of clean coal technology by-products to a level acceptable by public and regulatory agencies so that disposal or utilization of coal by-products becomes routine business practice.

The program has several key strategic barriers to achieving this long term goal. These issues include an upcoming EPA decision on FBC ash, a high cost of CCB transportation, the lack of engineering data due to inconsistent by-product quality, CCB pricing relative to competitive products, and unknown long-term (greater than 5 years) environmental and health risks and associated liability, if any.

DOE has identified several stakeholders who may be willing to help develop both product and commercialization strategies to overcome these barriers.

These include Federal agencies, state level environmental agencies, state level coal marketing offices, trade associations such as the American Coal Ash Association and Electric Power Research Institute, industrial partners such as coal companies, electric utilities, vendors of equipment or chemicals used in off-gas treatment, and businesses that could replace an existing product with a cheaper and/or better product made from coal combustion by-products.

Avoided cost from the use of a by-product versus land filling is a great economic incentive which becomes even better when the by-product can be sold rather than given away. Because there still are several unsaturated CCB markets, the onset of utility deregulation now makes it apparent that coal combustion by-product utilization is one key area that may help utilities better manage their available resources.

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