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Utilization of Ohio Coal Combustion Products

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ABSTRACT

Ohio generates approximately 10 million tons of Coal Combustion Products (CCPs) annually, and utilizes about 20% of them in various application technologies. The remaining 80% are typically disposed in landfills or surface impoundments. Ohio generates a significant amount of wet FGD material (3.8 million tons) annually to comply with the Clean Air Act Amendments of 1990, which restricted SO_2 emissions from many coal-fired facilities that used high-sulfur coal. A recently completed market research report for Ohio (Butalia and Wolfe, 2000) has shown that many of these CCPs, if treated and applied properly, can be low-cost substitutes for conventional raw materials in highway and related civil engineering applications, reclamation uses, manufacturing industry, and agricultural applications. The market study summary presented in this paper focuses on CCPs generated in the state of Ohio and their existing and future utilization potential. Potential high volume uses for FGD materials exist in highway and related civil engineering applications throughout the state, reclamation in the eastern third of the state, and wallboard manufacture. High value markets exist for CCP uses in the manufacturing industry. Agricultural uses generally will be low volume and low value uses for the CCP provider. However, they are attractive low cost alternatives that are generating increased interest and demand by the agricultural community. Significant environmental benefits from mine reclamation work can result due to reduction in acid mine drainage and sedimentation problems. The key to the success of CCP utilization will be to maintain and expand the volume of current CCP use application technologies and to develop high volume, high value new innovative uses for FGD and fly ash.

INTRODUCTION

The combustion of over 50 million tons of coal annually in the state generates enormous quantities (approximately 10 million tons annually) of solid by-products, referred to as Coal Combustion Products (CCPs). CCPs can be used, or disposed in landfills and surface impoundments. Developing economic and environmentally sound alternatives to expensive and non-productive landfilling of coal combustion products (CCPs) is of vital importance to the state of Ohio.

This paper is a summary of a market research report prepared by the Coal Combustion Products Extension Program at The Ohio State University.[1] The extension program promotes the responsible uses of coal combustion products, including fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) material. The study presented in this report focuses on the existing and potential uses of all CCPs, particularly FGD and fly ash, generated in the state of Ohio.

Traditionally, the majority of coal combustion products (CCPs) generated in Ohio have been disposed in landfills or stored in surface impoundments. Identification and promotion of cost-effective programs for the use of these raw materials (particularly FGD and fly ash), instead of storage and disposal, has been one of the important considerations of the energy strategy for Ohio.[2] The recycling of these raw materials is important to help maintain the economic competitiveness of high-sulfur Ohio coal.

STATUS OF CCP INDUSTRY IN OHIO

Current coal consumption for Ohio exceeds 50 million tons annually, with almost half of this coal being mined in the state. Coal-fired electric utilities account for 90% of the coal consumed and supply nearly 90% of the state's electricity. The combustion of such a large quantity of coal leads to enormous amounts of CCPs (fly ash, bottom ash, boiler slag, and FGD material) CCPs can be utilized, or disposed in landfills and surface impoundments. The annual production of CCPs for the state is nearly 10 million tons. Total annual tonnage of CCPs generated in Ohio equals that of Portland cement and ranks behind only crushed stone, sand, and gravel among all non-fuel mineral commodities (refer to Table 1).

Table 1: Annual Production of Selected Non-Fuel Mineral Commodities for Ohio

Type of non-fuel mineral	**Production (million tons/year)**
Crushed stone	69
Sand	29.8
Gravel	28.4
Coal combustion products	10
Cement	10

(Sources: Wolfe[3]; ODNR-Division of Geological Survey; CCP survey by authors)

Currently, CCPs are exempt from Subtitle C of the Resource Conservation and Recovery Act (RCRA), and are regulated by most states as solid wastes. A recently published final regulatory determination for all CCPs by USEPA (Federal Register of May 22, 2000, Part III, EPA, 40 CFR Part 261) concluded that CCPs do not warrant regulation under Subtitle C of RCRA and that USEPA is retaining the hazardous waste exemption for CCPs under RCRA Section 3001(b)(3)(C). However, EPA determined that voluntary Subtitle D (non-hazardous) national standards need to be developed for CCPs disposed in landfills or surface impoundments, and used in filling surface or underground mines. USEPA also determined that no additional regulations were warranted for CCPs that are used beneficially (other than for minefilling). In the regulatory determination, USEPA supported increases in beneficial uses of CCPs, such as additions to cement and concrete products, waste stabilization, and use in construction products such as wallboard. More detailed background information and updated documents on USEPA's determination can be obtained from http://www.epa.gov/epaoswer/other/fossil/index.htm.

Ohio regulates fly ash, bottom ash, boiler slag, and FGD as solid wastes through the Ohio Environmental Protection Agency (OEPA). In particular, non-toxic fly ash, bottom ash, and slag are regulated as exempt wastes, i.e., they are exempt from the statutory definition of solid waste. FGD is considered to be an air pollution control waste and is regulated as a residual solid waste. The regulation of FGD as a residual solid waste, as compared to non-toxic fly ash as an exempt waste, has resulted in increased regulatory restrictions on the use of FGD materials. The beneficial use policy of OEPA was replaced with an Interim Alternative Waste Management Program (IAWMP) in 1997, which effectively replaced beneficial use with alternative disposal option. Under IAWMP, two types of alternative disposal options were made available, engineered use and land application. The IAWMP regulatory procedures currently followed by OEPA depend on the type of CCP and its intended use as well as the proposed use of the facility. The beneficial use policy developed in 1994 by the Division of Surface Water is still regarded as a guidance / policy document. The Long Term Alternative Waste Management Program (LTAWMP) was scheduled to be in place by July 1999. While some progress on the issue has been made, the deadline has not been achieved.

ADVANTAGES AND LIMITATIONS OF UTILIZATION

The advantages of using CCPs instead of the current practice of landfilling are - 1) emphasis on recycling and decrease in the need for expensive landfill space, 2) conservation of natural resources of the state, 3) better products and significant technical benefits, 4) reduction in the cost of energy production for utilities, 5) substantial savings for end-users, 6) continued economic competitiveness of high-sulfur Ohio coal, 7) cleaner and safer environment, 8) reduced social costs, and 9) greater economic development. The potential drawbacks and limitations of CCP utilization are - 1) increased haulage cost and associated disturbance, 2) variability of material, 3) opposition from established raw material marketers, 4) potential for long-term effects, 5) increased design and monitoring costs, 6) bulky nature of FGD, 7) litigation potential, and 8) durability concerns. These technical, environmental, social, and economic issues need to be in balance for the effective use of a CCP for a particular application. Successful CCP uses will be those that are technically safe, environmentally sound, socially beneficial, and commercially competitive, as with any other raw material or product of commerce.

CCP PRODUCTION AND UTILIZATION

Thirty-three coal-fired facilities in the state of Ohio were surveyed by the authors. A list of surveyed coal-fired facilities is presented in Table 2 and shown in Figure 1. The 1997 production and utilization data for CCPs generated at surveyed Ohio plants was compiled on a plant basis and is presented in Table 3.

Ohio coal-fired facilities generated approximately 9.23 million short tons (MST) of CCPs in 1997 (on a dry weight basis). This consisted of 4.76 MST of fly ash, 0.97 MST of bottom ash, 0.35 MST of boiler slag, 2.68 MST of FGD (dry weight basis), and 0.47 MST of mixtures of fly ash, bottom ash, boiler slag, and cenospheres. The FGD production in the state is high due to the use of high-sulfur coal by FGD scrubbers complying with Clean Air Act Amendments of 1990. The Gavin plant (GAV) produced 25% of all CCPs and accounted for nearly 60% of FGD generated in the state. The largest generator of fly ash and bottom ash in the state was the J.M. Stuart station (JMS). The Muskingum River plant (MUS) generated 42% of all boiler slag produced in Ohio. Fly ash and bottom ash combined account for nearly 67% of CCP production, while FGD generated in the state was 29% of all CCPs produced in 1997.

The state has five FGD generating facilities. Four of these facilities, Zimmer, Conesville, Gavin, and Niles, employ a wet scrubbing process, while the OSU McCracken power plant generates a spray dryer ash. Table 4 lists these plants, amount of FGD generated at each facility, the quantity of coal and lime/limestone used in 1997, and the design sulfur content for the scrubbers. Removal of SO_2 from the flue gases at these five plants required approximately 0.73 MST of lime / limestone sorbent. This resulted in the generation of more than 2.6 MST (dry weight) of FGD. The NLS plant generates FGD gypsum, and the ZIM plant that currently produces stabilized FGD is expected to start generating FGD gypsum in year 2000. The moisture content of wet FGD typically ranges from 30% to 60%. Hence, the amount of wet FGD generated in the state for 1997 ranged between 3.4 MST and 4.2 MST, with an average annual production rate of approximately 3.8 MST per year.

Of the CCPs generated in Ohio, 21% were utilized. Approximately 23.4% of combined fly ash and bottom ash generated, 74.7% of bottom ash generated, but only 8.4% of FGD generated in the state was utilized. Of the total CCPs utilized, fly and bottom ash accounted for 75% of the use, boiler slag (13.4%), and FGD (11.6%). The various types of end uses for fly ash, bottom ash, boiler slag, and FGD were also investigated and the results are shown in Table 5. For fly ash and bottom ash, over 40% of the use was in cement / concrete / grout applications while structural fills accounted for 32.5% of use. About 86% of the boiler slag utilized was for blasting grit and roofing granules. Other boiler slag uses were structural fills, and snow and ice control. For FGD material, major uses included wallboard industry consumption (33.3%), mining and reclamation applications (24%), and miscellaneous uses (42.7%). Miscellaneous uses included FGD feeding and hay storage pads and material used for various research and field demonstration projects.

The production and use of coal combustion products in Ohio were compared with ACAA Region 3 states (Illinois, Indiana, Kentucky, Michigan, Ohio, and Wisconsin), as well as the United States (refer to Table 6). ACAA Region 3 states included USPEPA Region 5 states and the state of Kentucky. Ohio generates about 8.8% of CCPs produced in the

United States and of the total amount utilized across the nation, the state accounts for 6.6% use. Fly ash and bottom ash, boiler slag, and FGD production is 8%, 12.7%, and 10.6%, respectively, of the US national production. Fly ash and bottom ash, boiler slag, and FGD use in Ohio is 5.9%, 10.1%, and 10.3%, respectively, of the US national use. The Ohio CCP utilization rate of 21.0% is lower than the national utilization rate of 27.8% as well as the ACAA Region 3 utilization rate of 25.6%.

Table 2: Ohio Coal-Fired Facilities Surveyed

Plant designation	Plant name	Type of facility	Owner / operator of facility	County	City
WHG	W.H. Gorusch Station	EU	AMP	Washington	Warren Township
CAR	Cardinal	EU	AEP, Buckeye Power	Jefferson	Brilliant
MIF	Miami Fort	EU	CIN	Hamilton	North Bend
ZIM	W.H. Zimmer	EU	CIN / AEP / DPL	Clermont	Moscow
WCB	Walter C. Beckjord	EU	CIN	Clermont	New Richmond
CON	Conesville	EU	AEP	Coshocton	Conesville
PIC	Picway	EU	AEP	Pickaway	Columbus
JMS	J.M. Stuart	EU	DPL	Adams	Aberdeen
KIS	Killen Station	EU	DPL	Adams	Manchester
HUT	O.H. Hutchings	EU	DPL	Montgomery	
DOV	Dover	EU	City of Dover	Tuscarawas	Dover
COH	Hamilton	EU	City of Hamilton	Butler	Hamilton
GAV	Gen. J.M. Gavin	EU	AEP	Gallia	Cheshire
MUS	Muskingum River	EU	AEP	Morgan	Beverly
KYG	Kyger Creek	EU	OVEC	Gallia	Cheshire
ORR	Orrville	EU	City of Orrville	Wayne	Orrville
PNS	Painesville	EU	City of Painesville	Lake	Painesville
SML	Shelby Municipal Light Plant	EU	City of Shelby	Richland	Shelby
SMR	St. Marys	EU	City of St. Marys	Auglaize	St. Marys
AST	Ashtabula	EU	FE	Ashtabula	Ashtabula
AVN	Avon Lake	EU	FE	Lorain	Avon Lake
ELK	Eastlake	EU	FE	Lake	East Lake
LKS	Lake Shore	EU	FE	Cuyahoga	Cleveland
NLS	Niles	EU	Orion / FE	Trumbull	Niles
BRG	R.E. Burger	EU	FE	Belmont	Shadyside
SMS	W.H. Sammis	EU	FE	Jefferson	Stratton
BYS	Bay Shore	EU	FE	Lucas	Oregon
CHM	Champion Hamilton Mill	NUPP	Champion International	Butler	Hamilton
OSU	McCracken Power Plant	NUPP	Ohio State University	Franklin	Columbus
OUP	Ohio University Physical Plant	NUPP	Ohio University	Athens	Athens
MCO	MCO Steam Plant	NUPP	Medical College of Ohio	Lucas	Toledo
GPP	Goodyear Power Plant	NUPP	Goodyear Tire & Rubber	Summit	Akron
MDC	Mead Corporation	NUPP	Mead Corporation	Ross	Chillicothe

EU: Electric utility
NUPP: Non-Utility Power Producer
AEP: American Electric Power
AMP: American Municipal Power-Ohio
CIN: Cinergy
DPL: Dayton Power & Light
FE: FirstEnergy
OVEC: Ohio Valley Electric Corporation

(Sources: Energy Information Administration[4] , CCP survey by authors)

Note: Refer to Table 2 for plant name abbreviations
(Source: CCP survey by authors)

Figure 1: Surveyed Coal-Fired Facilities in Ohio

Table 3: CCP Production and Use - 1997

Plant designation	Fly ash & bottom ash (1000 ST)		Boiler slag (1000ST)		FGD Material (Dry 1000 ST)		CCP total (1000 ST)		Percent Uilization
	Production	Use	Production	Use	Production	Use	Production	Use	
WHG	120	0					120	0	**0.0%**
CAR	490	14.7					490	14.7	**3.0%**
MIF	402	288					402	288	**71.6%**
ZIM	368	368			750	not reported	1118	368	**32.9%**
WCB	449	267					449	267	**59.5%**
CON	342	47	34	34	272	150	648	231	**35.6%**
PIC	21	11					21	11	**52.4%**
JMS	876.5	12.8					876.5	12.8	**1.5%**
KIS	200	0					200	0	**0.0%**
HUT	195	0					195	0	**0.0%**
DOV	4.4	1					4.4	1	**22.7%**
COH	14.1	14.1					14.1	14.1	**100.0%**
GAV	781	92			1578	0	2359	92	**3.9%**
MUS	270	0	145	145			415	145	**34.9%**
KYG	98	0	121	33			219	33	**15.1%**
ORR	-	-					-	-	**-**
PNS	7.9	1.4					7.9	1.4	**17.7%**
SML	6	0					6	0	**0.0%**
SMR	3.3	0					3.3	0	**0.0%**
AST, AVN, ELK, LKS, NLS, BRG, SMS, BYS*	1479	322	48	48	75	75	1602	445	**27.8%**
CHM	11	11					11	11	**100.0%**
OSU	-	-			5.4	0	5.4	0	**0.0%**
OUP	1.3	1.3					1.3	1.3	**100.0%**
MCO	2.5	0					2.5	0	**0.0%**
GPP	14.8	0					14.8	0	**0.0%**
MDC	49.2	0					49.2	0	**0.0%**
Totals =	**6206**	**1451.3**	**348**	**260**	**2680.4**	**225**	**9234.4**	**1936.3**	
% Utilization =		**23.4%**		**74.7%**		**8.4%**		**21.0%**	

(Source: CCP survey by authors)

Table 4: FGD Material Production - 1997

Plant designation	FGD material generated (Dry 1000ST)	Dry/ Wet FGD	Quantity of coal received (1000 ST)	Design sulfur content (%)	Lime / Limestone sorbent used (1000 ST)
ZIM	750 (estimated)	Wet	3252	4.5	231
CON	272	Wet	4235	7.9	76.2
GAV	1578	Wet	7061	3.5	400.8
NLS	75 (estimated)	Wet	502	3	24.1
OSU	5.4 (FGD+FA+BA)	Dry	14	3	1.5
Totals =	**2680.4**		**15064**		**733.6**

Table 5: Estimated CCP Utilization by Type of Use – 1997

Type of Use	Fly ash & bottom ash		Boiler slag		FGD Material		All CCPs	
	Quantity (1000 ST)	Percent used	Quantity (1000 ST)	Percent used	Quantity (1000 ST)	Percent used	Quantity (1000 ST)	Percent used
Cement/Concrete/ Grout	618.4	42.6%	4.7	1.8%	0.0	0.0%	623.1	32.2%
Flowable Fill	19.6	1.4%	0.0	0.0%	0.0	0.0%	19.6	1.0%
Structural Fills	471.4	32.5%	18.4	7.1%	0.0	0.0%	489.8	25.3%
Road Base/Subbase	73.2	5.0%	0.3	0.1%	0.0	0.0%	73.6	3.8%
Mineral Filler	3.0	0.2%	0.0	0.0%	0.0	0.0%	3.0	0.2%
Snow and Ice Control	69.4	4.8%	11.8	4.5%	0.0	0.0%	81.1	4.2%
Blasting Grit/Roofing Granules	0.0	0.0%	223.2	85.9%	0.0	0.0%	223.2	11.5%
Mining Applications	141.6	9.8%	0.0	0.0%	54.0	24.0%	195.6	10.1%
Wallboard	0.0	0.0%	0.0	0.0%	75.0	33.3%	75.0	3.9%
Waste Stabilization/ Solidification	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Agriculture	5.5	0.4%	0.0	0.0%	0.0	0.0%	5.5	0.3%
Misc./Other	49.3	3.4%	1.5	0.6%	96.0	42.7%	146.8	7.6%
Total Use	**1451.3**		**260.0**		**225.0**		**1936.3**	

(Sources: CCP survey by authors; American Coal Ash Association)

Table 6: Comparison of CCP Production and Use for Ohio, Regional States, and the United States – 1997

Region	Fly ash & bottom ash (1000 ST)		Boiler slag (1000 ST)		FGD material (1000 ST)		CCP total (1000 ST)	
	Production	Use	Production	Use	Production	Use	Production	Use
Ohio	6,206	1,451 23.4%	348	260 74.7%	2,680	225 8.4%	9,234	1,936 21.0%
ACAA Region 3*	20,948	6,207 29.6%	1,494	1,334 89.3%	10,888	981 9.0%	33,330	8,522 25.6%
United States	77,169	24,414 31.6%	2,742	2,579 94.1%	25,163	2,183 8.7%	105,074	29,176 27.8%

*: Illinois, Indiana, Kentucky, Michigan, Ohio, and Wisconsin (Region 5 of USEPA and Kentucky)
(Sources: CCP survey by authors; American Coal Ash Association)

CCP PRODUCER ECONOMICS

The interest of the CCP producer (typically the utility) towards utilization instead of landfill disposal is economically driven to a large extent by the avoided landfill cost. The avoided landfill cost is the cost avoided by the utility due to use of the material instead of landfilling it.

The total landfilling cost is generally higher than avoided landfilling cost. The total and avoided landfill costs can be significantly different for utilities with and without captive landfills. CCP producers with existing captive landfills would have made a significant capital investment in their landfills and generally have low landfill operating costs. CCP generators without captive landfills have no capital invested in any landfill and generally pay high landfilling operating costs depending on the distance from the CCP production facility to the landfill and costly tipping fees.

Considering the total landfill cost to be the sum of landfill capital cost and landfill operating cost, it can be observed that for captive landfill CCP producers, the use of any CCP material (instead of landfilling) results in 100% savings of operating costs but only partial savings of the capital cost associated with the new phase of landfill development. On the other hand, utilities without captive landfills have zero capital cost investment, but high operational costs. Any material beneficially utilized and not sent to the landfill results in much higher cost savings for CCP generators without captive than those with existing captive landfills.

Current CCP landfilling costs (capital and operating) within the state range from about $3 to $35 per ton for CCP producers with and without captive landfills. CCP producers with captive landfills have low total landfill costs (approximately $3 to $15 per ton). Cost of landfilling FGD material is generally lower than that of fly ash. The landfill operating cost for CCP producers with captive landfills can range from 30% to 90% of total landfilling cost. FGD material, in general, has a higher landfill operating cost as a percentage of total landfill cost compared with fly ash. However, CCP generators without captive landfills generally have much higher total landfilling costs (about $10 to $35 per ton) due to high tipping fees and longer haulage distance.

OVERVIEW OF EXISTING AND POTENTIAL USES

Many coal combustion products are separated from other product streams. If treated and applied correctly, they can have versatile properties that make them suitable raw materials for many applications. The potential uses are divided into: highway, reclamation, agricultural, manufacturing, other civil engineering and miscellaneous uses. Several different types of application technologies for each broad category are identified and are listed in Table 7. It can be observed from Table 7 that wet and dry FGD have promising applications for many different types of uses. The potential high-volume uses for FGD are in highway construction and maintenance all over the state and related civil engineering applications, reclamation in the eastern one-third of the state, and wallboard manufacture. High-value markets exist for CCP uses in the manufacturing industry. Agricultural uses will generally be low-volume and low-value uses for utilities but are increasing in demand by the agricultural community. Significant environmental benefits from reclamation can result due to reduction in acid mine drainage, offsite sedimentation, and subsidence problems. Economic benefit to utilities will be greater for high-volume and high-value applications compared to low-volume and value products. Economic benefits for end users can be significant and will depend mainly on the cost of competing conventional materials, processing of CCPs (if any needed), haulage distance and its associated costs.

SOCIAL COSTS AND BENEFITS

Social costs and benefits from an economic perspective refer to the aggregation of individual producer and consumer measures of full willingness to accept or pay compensation. Social cost-benefit analysis is concerned with estimating the full willingness to pay and willingness to accept measures of economic value regardless of whether or not those values are currently reflected in market price.[5] Social cost associated with landfilling loosely refers to the potential reduction in property values in vicinity of a landfill. Social benefit refers to the potential increase in property values in vicinity of a landfill due to beneficial use instead of landfilling a material.

Social costs associated with FGD landfill disposal in Ohio are estimated to range between $0.10 and $0.35 per ton. Using reasonable estimates for social costs for various FGD generating facilities, the total welfare loss for Ohio due to landfilling of FGD is estimated to be about $0.8 million annually. Further, assuming that the social benefit per ton from use of other CCPs is similar to that of FGD, the annual economic benefit to society if all CCPs are utilized will exceed $2.5 million. This represents a significant societal benefit that can be realized from the recycling of CCPs as raw materials instead of the existing practice of disposing of them in landfills. In addition, the reclamation of abandoned mine lands using FGD material can result in a few cents per ton of social benefit.

EFFECT OF LANDFILLING COSTS ON POTENTIAL UTILIZATION AND DISPOSAL

Results of a linear optimization model[6-8] for the three main high volume uses of CCPs, highway applications, reclamation of current surface mine and abandoned mine lands with an adoption rate of 10% were investigated. In the model, landfilling was considered to be the fourth but least desirable option. It was assumed that the highway applications could be used for road construction and repairs in all 88 counties. For reclamation purposes, FGD was considered as a soil amendment in 21 eastern counties and for the landfill option, four existing FGD landfills in vicinity of the Gavin, Conesville, Zimmer, and OSU McCracken power plants were considered. The transportation cost was assumed to be $.10 per ton per mile and was considered to be borne by the utility or FGD supplier. The source destinations were set at the centers of the 88 Ohio counties. The cost of application was assumed to be $3.50 per ton for the highway and reclamation uses. For mine reclamation, an application rate of 250 tons per acre was incorporated into the analysis.

A sensitivity analysis was presented by Dick et al.[7] to determine the effect of landfilling costs on the quantity of FGD that could be potentially used versus landfilled. The sensitivity analysis results are shown in Figure 2. Table 8 shows the amount of FGD that would be potentially utilized and landfilled for landfilling costs varying from $5 to $27.50 per ton. It can be observed that a statewide average landfilling cost of $27.50 per ton would result in 64% of the FGD material generated in the state being utilized and only 36% being landfilled. A reduction of landfilling costs from $27.50 per ton to $20 per ton results in relatively little impact on the amount of FGD that would be utilized since landfilling is still a high cost option. As the landfill costs drop below $20 per ton, FGD use for highway or mine reclamation becomes less attractive than landfilling. At $15 per ton landfilling cost, 43% of the FGD generated would be utilized, whereas at $10 per ton, only 29% of FGD material would be utilized. For landfilling cost less than $10 per ton, the utilization rate falls rapidly. At a landfilling cost of $5 per ton, only a small amount (3%) of FGD would potentially be used and the rest (97%) would be landfilled.

The landfilling cost for FGD in Ohio ranges from $3 to $10 per ton for generators with captive landfills and varies from $10 to $35 per ton for FGD generators without captive landfills. More than 95% of FGD material generated in the state is produced by CCP generators with captive landfills and hence the average statewide FGD landfilling cost ranges between $3 and $10 per ton with a mean cost of about $6.50 per ton. A statewide mean landfilling cost of $6.50 per ton corresponds to utilization of 0.65 MST of FGD or 16% utilization (refer to Figure 2). This projected utilization rate is almost double the 1997 utilization rate of 8.4% for FGD material. Results of the linear optimization model showed that there is significant economic incentive for utilities to promote the use of FGD for highway construction and maintenance, and surface mine reclamation. The current statewide FGD utilization rate of 8.4% can be doubled to 16% in the short term if utilities continue to subsidize the transportation costs up to the breakeven point and the end user pays for the processing costs. However for the long term, an FGD utilization rate much greater than 16% is needed. This will necessitate that the processing and transportation costs be borne by the end-user in the long run for successful and productive utilization of FGD materials across the state of Ohio.

FUTURE PROJECTIONS AND ESTIMATES

The future projections for the quantity and quality of CCPs generated in Ohio will depend on several factors including shifts in coal-based energy production in the state, competitiveness of high-sulfur Ohio coal, and future emission control restrictions. If all the current Ohio plants were to use high-sulfur coal and install FGD scrubbers, the production of FGD material in the state would range between 12 to 16 million tons per year. At the present time, three additional FGD scrubbers are being installed or planned in Ohio. These will be located at City of Hamilton (COH), Ohio University (OUP), and the Medical College of Ohio (MCO). All of these proposed facilities use small amounts of coal and will be using dry scrubbing technology. New coal-fired power plants are not expected to be installed in the state in the next 10-15 years. However,

Table 7: Existing and Potential Uses of CCPs in Ohio

Potential Use	**Type of coal combustion product**				
	Fly ash	Bottom ash	Boiler slag	FGD material	
				Wet	Dry
Highway applications					
Cement/Concrete/Grout	O	X	X	X	X
Embankment / Structural fill	O	O	X	X	X*
Flowable fill	O	O		X*	X*
Road base / subbase	O	O	X	O	X
Snow and ice control		O	O		
Synthetic aggregate	O			X*	X
Wetland liner				X*	X
Reclamation uses					
Abandoned surface mine reclamation	O			O	X*
Reclamation of existing surface mined lands	O			X*	X*
Subsidence remediation and control	O	X		X	X
Underground placement to mitigate AMD	X*			X*	X
Wetland and pond liner				X*	X
Treatment of coal refuse				O	X
Agricultural applications					
Agricultural liming substitute				X	X*
Soil amendment	O	X		X*	X*
Pond & animal manure holding facility liner				X*	X
Livestock feedlot and hay storage pad	O			O	X*
New soil blends	O	O			X
Commercial fertilizer	X				X*
Treatment of biosolids	O	X		X	O
Manufacturing uses					
Paint	O				
Wallboard				O	
Roofing granules		O	O		
Cement industry	O			X	X
Steel industry	X			X	X
Fillers (plastics, alloys and composites)	O				X
Mineral wool insulation	X				
Ceramic products	X				X
Recovery of metals	X			X	X
Other Civil Engineering uses					
Brick	O				X
Concrete block	O	X		X*	X
Landfill liner, daily cover, cap	O			O	X
Blasting grit		O	O		
Pipe bedding		O	O		
Water filtration			O		
Drainage media		O	O		
Waste stabilization / solidification	O	X		X	X
Treatment of sewage sludge				X*	
Pond liner	X*			X*	X

O: Existing or past use in Ohio other than demonstration projects X: Potential for use in Ohio
*: Research and/or demonstration project completed or in progress in Ohio

existing coal-fired plants will continue to provide the base load electricity to the state, while peaking electric loads are expected to be generated from natural gas or renewable sources. Compliance with Phase II of the Clean Air Act Amendments by January 2000 by Ohio coal-fired power plants is expected to result from a combination of a) fuel switching / and or blending with lower sulfur coals, b) obtaining additional SO_2 allowances, c) installing FGD equipment, d) using previously implemented emission controls, e) retiring units, f) boiler re-powering, g) substituting Phase II units for Phase I units, and h) compensating Phase I units with Phase II units. A review of the current online Phase II compliance methods for Ohio projected by the USEPA shows that fuel switching / and or blending with lower sulfur coals will be the preferred option of choice in the state. Fuel switching and blending from high-sulfur to lower sulfur coals will result in higher amounts of fly ash production. The quality of CCPs generated are expected to be impacted severely by the proposed NO_x rules due to an increase in the carbon and ammonia contents in the ash. The public response to the release of Toxic Release Inventory (TRI) information by utilities may have some negative impact on the marketing of CCPs. Identification of barriers to CCP use in the state, finding innovative solutions to reduce and overcome these barriers, as well as their positive implementation will result in an increase in the utilization of CCPs throughout Ohio.

CONCLUSIONS

Coal combustion products (CCPs) will continue to be generated in the state of Ohio. The current practice of disposing about 80% of these materials in landfills and surface impoundments can be avoided with significant social benefits. Many of these CCPs, if treated and applied properly, can be low-cost substitutes for conventional materials in highway and related civil engineering applications, reclamation uses, manufacturing industry, and agricultural applications.

The potential high-volume uses for FGD are in highway construction and maintenance all over the state and related civil engineering applications, reclamation in the eastern one-third of the state, and wallboard manufacture. High-value markets exist for CCP uses in the manufacturing industry. Agricultural uses will generally be low-volume and low-value uses for generators but will be attractive to the agricultural community (as evidenced by the increased interest and demand in the past several years). Significant environmental benefits from mine reclamation work can result due to reduction in acid mine drainage and sedimentation problems. The key to the success of CCP utilization in the state will be to maintain and expand the volume of current CCP use application technologies and to develop high-volume and / or high-value new innovative uses for FGD and fly ash.

The potential large-volume utilization of CCPs as raw material substitutes for conventional natural materials have significant technical benefits, economic advantages for utilities and end users, and environmental as well as social benefits.

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Complete updated electronic version of the two-volume Ohio CCP marketing research report (Butalia and Wolfe, 2000) may be downloaded from the following internet web sites:
http://ccpohio.eng.ohio-state.edu/ccpohio/
http://www.odod.state.oh.us/tech/coal/

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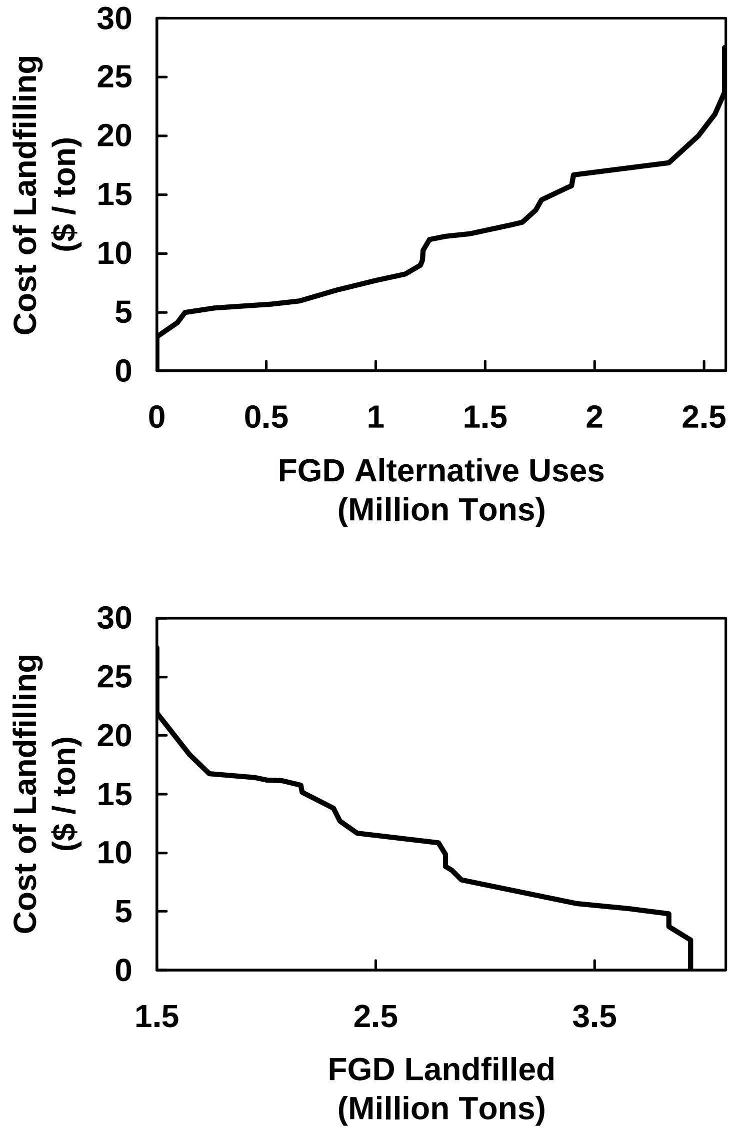
Table 8: Effect of Landfilling Cost on Amount of FGD Potentially Used and Landfilled

Cost of landfilling	**Amount of FGD projected to be utilized**	**Amount of FGD projected to be landfilled**
$27.50	2.55 MST (63.8%)	1.45 MST (36.2%)
$25	2.55 MST (63.8%)	1.45 MST (36.2%)
$20	2.45 MST (61.3%)	1.55 MST (38.7%)
$15	1.72 MST (43.0%)	2.28 MST (57.0%)
$10	1.17 MST (29.3%)	2.83 MST (70.7%)
$5	0.13 MST (3.3%)	3.87 MST (96.7%)

(Source: Dick et al.[7])



(Source: Dick et al.[7])

Figure 2: Effect of Landfilling Cost on Amount of FGD Potentially Used and Landfilled