



# Coal Combustion Products Extension Program

# Fact Sheet

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## Landfill Cost Model for Disposal of Coal Combustion Products

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Approximately 100 million tons per year of Coal Combustion Products (CCPs) are generated in the United States. As existing coal-fired power plants install flue gas desulfurization (FGD) systems to meet environmental requirements, the quantity of CCPs generated in the US will increase significantly.

CCPs typically generated include fly ash, bottom ash, boiler slag, and FGD materials. An overview of these CCP types can be accessed at <http://ohioline.osu.edu/aex-fact/0330.html>.

Most CCPs are currently being landfilled. This disposal option is currently favored due to its perceived low cost. However, most of the existing landfills were developed when environmental laws regulating their design and operation were less stringent, sites were plentiful, and public opposition was virtually non-existent. All of these factors have changed, resulting in significantly higher costs for landfills constructed today. However, many generators may not be completely aware of these higher costs and thus do not consider other options for disposal or beneficial use. With existing landfill space being filled rapidly, CCP generators need a tool to help them make up-to-date, informed environmental and economic decisions for disposal of CCPs when existing landfill space is exhausted.

### Model Relevance

The computer model presented in this fact sheet quantifies the cost of new CCP landfill development, which may ultimately encourage generators to consider the alternative beneficial use of these materials. The cost components include capital, operating and maintenance, and post-closure costs. The landfill costs generated by the model provide a benchmark against which use options can be compared. Thus, the model can be a valuable tool to agencies and organizations working towards the beneficial use of CCPs.

The program provides the user with the option of treating the landfill as a commercial operation and analyzing costs as an investment decision and establishing a landfill disposal price to meet a specified return on investment. For example, the user can specify the project life, inflation rate, tax rate, and a desired internal rate of return (IRR). The landfill disposal fee (\$/ton) required to meet this investment objective would then be calculated. Costs are generated for staged construction (one cell at a time) or for the entire landfill all at once.

The model is also applicable to existing landfills, for which the operating and maintenance, and post-closure costs are relevant.

### Computer Program Overview

The landfill design and cost computer model predicts the capital, operating and maintenance, and post-closure costs of CCP landfills. The model is constructed with a high degree of flexibility to provide accurate estimates under a variety of possible scenarios. The program encompasses regulations specific to the states of Ohio (OH), Pennsylvania (PA), and Kentucky (KY). It includes design and cost algorithms to account for different land topographies and CCP types (fly ash, bottom ash, and FGD materials). It also includes design options to meet anticipated future landfill design regulations and cost escalation factors to maintain its accuracy over a long period of time.

The computer model is available in Microsoft EXCEL 2000/Visual Basic for Applications (VBA) software platform. A copy of the program and its user's manual can be accessed at: <http://ccpohio.eng.ohio-state.edu/ccpohio/>

Each input field variable has a suggested range of values as well as a default value. The user can choose a default value or input a specific value, from the range of suggested values. This provides a significant amount of flexibility in the

program so that it can be used by experts as well as those new to the subject.

### Program Input

The computer model input module consists of the following components:

- State regulations (specific to OH, PA, KY, or input specific options for other states)
- Quantity of CCPs (life of landfill, quantity of CCPs generated annually or estimated from power plant characteristics)
- Scrubber inputs if program is to calculate the quantity of CCPs (choice of no scrubber, forced oxidation, natural oxidation, thiosorbic lime, or lime spray dryer; operating details for each scrubber type, etc.)
- Landfill geometry selection (choice of topographies of flat terrain, valley fill, and side hill)
- Capital costs (direct capital costs, such as site preparation, roads, drainage systems, installation of layers, erosion and sediment control, leachate collection, sediment pond, closure activities, etc.; and indirect capital costs, such as site selection and characterization, permitting fees, site engineering, purchase of land, etc.)
- Operating and maintenance costs (groundwater, leachate, and surface water monitoring and management; waste characterization; intermediate cover; general site maintenance; placement of materials in landfill; transportation; compliance certifications; management and supervisory costs; etc.)
- Post-closure costs (number of years of monitoring required; groundwater, leachate, and surface water monitoring and management; maintenance of cover system; deed notification; final certification; etc.)
- Economic input (year equipment installed, total ordinary tax rate, depreciation rate, inflation rate, bond rate, chemical engineering cost index for current year)

Defaults and suggested ranges are provided for all inputs.

### Program Output

The output of the computer program is an itemized list of capital costs, operating and maintenance costs, as well as post-closure costs for the landfill configuration chosen. Each of these costs are also available on a \$ per ton and \$ per cubic yard basis. The economic analysis consists of a yearly (from opening of landfill to end of post-closure) listing of working capital, cash margin, tax, investment, and cash flow.

### Illustrative Example

Illustrations 1 and 2 show an example of the input data and results for a test case generated for a landfill with a life of 20 years built on a flat terrain under Ohio Class III code regulations for a 510 MW power plant. The program output summarizes the design parameters, capital costs, operating and maintenance costs, post-closure costs, and total calculated costs based on desired IRR.

### More Information

The model is also available on CD-ROM free of charge from CONSOL Energy Inc.:

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More information on the uses of coal combustion products can be obtained from the Internet web site <http://ccpohio.eng.ohio-state.edu> or by contacting the CCP Extension Program Coordinator:

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### Bibliography

Kosmack, D.A., Lewandowski, D.A., Brendel, G.F., Barnes, G.F., Landfill Cost Model for Coal Combustion Products, Nineteenth Annual International Pittsburgh Coal Conference, Pittsburgh, Pennsylvania, September 23 – 27, 2002

Butalia, T., Wolfe, W., Dick, W., Limes, D., Stowell, R., Coal Combustion Products, The Ohio State University Extension Fact Sheet, AEX-330-99, The Ohio State University, Columbus, Ohio, 1999

Butalia, T.S., and Wolfe, W.E., Market Opportunities for Utilization of Ohio Flue Gas Desulfurization and Other Coal Combustion Products, Volume 1: Executive Summary, Volume 2: Findings, Recommendations, and Conclusions, Technical Report, The Ohio State University, May 2000

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## Illustration 1: Critical Input Data for Example Case

Flat terrain under Ohio Class III code with geomembrane for liner

<u>Description</u>	<u>Value</u>	<u>Description</u>	<u>Value</u>
<b>State:</b>	Ohio	<b>Number of Monitoring Wells:</b>	10
<b>Code:</b>	Class III – with geomembrane	<b>Waste type/location:</b>	FGD/20% from stockpile & 80% from plant bin
<b>Geomembrane:</b>	Primary liner – PVC, Secondary liner – none, Cap – none	<b>Hauling:</b>	Public paved roads with 2 round trips/hr using triaxle trucks
<b>Drainage type :</b>	Aggregate/geotextile	<b>Management, supervisory, and overhead costs as percent of total O&amp;M cost :</b>	12.5%
<b>CCP Produced:</b>	Unknown volume of CCPs produced	<b>Profit as percent of total O &amp; M costs:</b>	15%
<b>Coal:</b>	12,500 Btu/lb, 2.5% sulfur, 10% ash	<b>Post-Closure period:</b>	15 years
<b>Power Plant:</b>	510 MW, 9600 Btu/kWh, 65% capacity factor	<b>Management and engineering design as percent of total post-closure costs:</b>	10%
<b>Scrubber:</b>	Natural Oxidation	<b>Remedial costs as percent of total post-closure costs:</b>	15%
<b>Geometry:</b>	Flat fill – input height: 40 feet, depth of excavation: 2 ft, input width: 2030 feet	<b>Internal Rate of Return:</b>	15%
<b>Operating Life:</b>	20 years		
<b>Construction Stages:</b>	1		

## Illustration 2: Results for Example Case

### SUMMARY FOR CAPITAL COSTS

<b>Landfill Design Calculations</b>		
Landfill Life Volume	cubic yd	5,388,183
Landfill Life Volume	tons	6,437,625
Type of Landfill Selected	text	Flat Fill
Waste Fill Height	ft	39.5
Fill Height Below Surface for Flat Terrain	ft	0
Final Landfill Height - Above Surface for Flat Terrain	ft	44.00
Final Landfill Height - Above Surface for Valley or Side	ft	Valley or Side not Selected
Acreage for CCPs	acre	95.95
Total Acreage Needed for CCPs and Support of Landfill	acre	119.94
Surface Area of Liner	ft^2	4182279.63
Front Width of Landfill	ft	2030.00
Back Width of Landfill	ft	2030.00
Length of Landfill	ft	2573.71
Depth of Material Removed	ft	2.00
 <b>Economic Calculations</b>		
Site Selection		\$100,000
Site Characterization		\$100,000
Permit Application/Fees		\$150,000
Design/Site Engineering		\$150,000
Total Indirect Costs		\$500,000
Land Purchase		\$599,704
Total Site Preparation		\$2,473,306
Total Roads		\$528,000
Total Drainage		\$2,199,724
Total Installed Layers		\$14,267,812
Total Erosion Control		\$372,952
Total Sediment Pond Liners		\$284,779
Total Closure Activities		\$15,000
Total Miscellaneous Items		\$10,000
<b>TOTAL CAPITAL COST OF LANDFILL</b>		<b>\$21,251,277</b>
Total Capital Cost: dollars/cubic yard		\$3.94
Total Capital Cost: dollars/ton		\$3.30

## Illustration 2 – Results for Test Case Continued

### SUMMARY FOR OPERATION & MAINTENANCE COSTS

Landfill Life	years	20			
Landfill Life Volume	cubic yd		5,388,183		
Landfill Life Volume	tons		6,437,625		
			Subtotal	Total	
Total Groundwater Monitoring			\$458,000		
Total Leachate Monitoring			\$312,000		
Total Surface Water Monitoring			\$524,200		
Total Waste Characterization			\$28,000		
<b>TOTAL MONITORING AND CHARACTERIZATION COSTS</b>				<b>\$1,322,200</b>	
			Subtotal		
Total O&M of Leachate Collection/Treatment Systems			\$31,871		
Total O&M of Cover System			\$1,521,089		
Total O&M of Surface Water Management System			\$243,480		
General Site Maintenance			\$1,609,406		
<b>TOTAL MAINTENANCE</b>				<b>\$3,405,845</b>	
			Subtotal		
<b>TOTAL FILLING</b>				<b>\$7,787,492</b>	
			Subtotal		
<b>TOTAL TRANSPORTATION</b>				<b>\$8,869,616</b>	
			Subtotal		
Compliance Certifications				\$120,000	
Certification of Closure				\$4,000	
			Subtotal		
Subtotal Monitoring, Operating & Maintenance Management, Supervisory and Overhead Costs as Percent of Total O&M Costs	%	12.50%		\$2,688,644	
Profit as Percent of Total O&M Costs	%	15.00%		\$3,226,373	
			Subtotal		
<b>TOTAL MONITORING, OPERATING &amp; MAINTENANCE</b>				<b>\$27,424,170</b>	
Total O&M Cost: dollars/cubic yard				\$5.09	
Total O&M Cost: dollars/ton				\$4.26	

### SUMMARY FOR POST-CLOSURE COSTS

Number of Years for Post-Closure	years	15			
			Subtotal	Total	
Total Ground Water Monitoring			\$292,500		
Total Leachate Monitoring			\$234,000		
Total Surface Water Monitoring			\$135,600		
<b>TOTAL GROUND, LEACHATE, SURFACE MONITORING</b>				<b>\$662,100</b>	
			Subtotal		
Total Maintenance of Leachate Collection/Treatment System			\$23,903		
Total Maintenance of Ground Water Monitoring Wells			\$42,000		
Total Maintenance Cover System			\$1,063,715		
Total Maintenance of Surface Water Management System			\$0		
Total Maintenance of Access Control Structures			\$390,439		
<b>TOTAL MAINTENANCE</b>				<b>\$1,520,057</b>	
			Subtotal		
Deed Notation				\$5,000	
Final Certification Upon Completion of Post-Closure Care Period				\$5,000	
			Subtotal		
Subtotal Monitoring, Operating & Maintenance Management and Engineering Design as Percent of Total Post-Closure Costs	%	10.00%		\$219,216	
Remedial Costs as Percent of Total Post-Closure Costs	%	15.00%		\$328,824	
			Subtotal		
<b>TOTAL MONITORING, O&amp;M FOR POST-CLOSURE</b>				<b>\$2,740,196</b>	
Total Post-Closure Cost: dollars/cubic yard				\$0.51	
Total Post-Closure Cost: dollars/ton				\$0.43	

### SUMMARY OF TOTAL COST FOR LANDFILL

Total Capital, O&M, and Post-Closure Costs	\$51,415,644
Total Capital, O&M, and Post-Closure Costs: yr 2001 dollars/cubic yard	\$9.54
Total Capital, O&M, and Post-Closure Costs: yr 2001 dollars/ton	\$7.99

### SUMMARY OF TOTAL COST FOR LANDFILL ADJUSTED FOR IRR

Total Capital, O&M, and Post-Closure Costs: yr 2001 dollars/cubic yard	\$19.51
Total Capital, O&M, and Post-Closure Costs: yr 2001 dollars/ton	\$16.33