159.
8-1-78

th. 305

Department of Energy

BNL 50708

Regional Studies Program

MASTER

AN ASSESSMENT OF THE SOLID WASTE IMPACT OF THE NATIONAL ENERGY PLAN

February 1978

Brookhaven National Laboratory

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

BROOKHAVEN NATIONAL LABORATORY REGIONAL ENERGY STUDIES PROGRAM

AN ASSESSMENT OF THE SOLID WASTE IMPACT OF THE NATIONAL ENERGY PLAN

P. Meier, E. Rubin, T. Le, R. Stern
with contributions by
E. Kaplan, F. Barvenik, and K. Blumer

MASTER

February 1978

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

POLICY ANALYSIS DIVISION
NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS
Brookhaven National Laboratory
Associated Universities, Inc.
Upton, New York 11973

PREPARED UNDER CONTRACT NO. EY-76-C-02-0016 WITH THE
UNITED STATES DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy (DOE), nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy \$5.25; Microfiche \$3.00
May 1978 790 copies

PREFACE

This report addresses coal related solid waste management issues arising from the Administration's National Energy Plan (NEP) as proposed early in 1977. Although the legislation that will likely emerge from the Congressional deliberations of late 1977 and early 1978 can be expected to differ quite significantly from the original plan, distribution of this report at the present time appears warranted in light of the general interest in the environmental impact of increased coal utilization, a topic addressed directly by the discussions of this analysis.

It should be noted at the outset, however, that this analysis of NEP impacts assumes full implementation of the Best Available Control Technology (BACT) provisions of the 1977 Clean Air Act Amendments, with both of the scenarios that form the basis for assessment (a 1985 Base Case, and a 1985 NEP Case) requiring new coal capacity to comply with BACT beyond 1982. The impact of the BACT requirements themselves on solid waste management problems, which prove to be far greater than those of NEP, are addressed as a separate issue for the Northeastern Region of the United States in another report (BNL 23606, Coal Utilization in the Northeast Vol. VIII; Solid Waste Management Issues, February 1978).

TABLE OF CONTENTS

	<u>Page</u>
Major Findings	1
I. Introduction	3
II. Impact of Electric Utilities	5
2.1 Introduction	5
2.2 Scope	5
2.3 Assumptions	6
2.4 Limitations	12
2.5 Regional Residuals	13
2.6 Constraint Analysis	18
III. Impact on Industry	26
3.1 Introduction	26
3.2 Scope	27
3.3 Assumptions	27
3.4 Limitations	31
3.5 Regional Residuals	33
3.6 Constraint Analysis	35
Notes	40
Appendix A	47
Appendix B	53

MAJOR FINDINGS

1. The only significant effect of the National Energy Plan (NEP) on solid waste management in electric utilities will be to shift the regional distribution of impacts. Nationally, NEP may result in an increase of ash by 1%, and a decrease in the scrubber sludge disposal area requirement by up to 10%.
2. The Southwest is the only region that may experience significant increases in electric utility solid waste residuals; ash production will increase 20%, and scrubber sludge production by about 33%. The land areas involved, however, are very small, amounting to annual increases of 30 and 80 acres, respectively. The major offsetting impacts occur in the South Atlantic, Midwest, and Central regions, where decreases in both ash and scrubber sludge can be expected. These decreases, however, also involve very small amounts of land.
3. Based on a nationwide survey of electric utilities planning coal-fired units in the 1980's, we find that sites are generally of sufficient size to accommodate on-site ash and FGD system sludge disposal, even where utilities are not currently planning FGD systems.
4. Using current technology for fixation of scrubber sludge, ultimate disposal by landfill, and subsequent revegetation, utilities can provide environmentally acceptable methods of scrubber sludge disposal at a small fraction of the total cost of FGD system installation and operation. While the total cost of sludge management may represent up to 20% of the total FGD system cost, the incremental cost of sludge fixation and landfill, over a base case of unstabilized disposal in an unlined pond, constitutes only some 5%-10% of the total FGD system cost.
5. In light of the above, one can conclude that solid waste management problems should not significantly impede implementation of the NEP in the electric utility sector; and in some regions NEP may result in somewhat reduced solid waste generation.
6. A significant fraction of coal using industries will use FGD systems that produce liquid effluents rather than sludge residuals, with discharge to municipal sewage systems or to water bodies. This will increase dissolved solids concentrations in the receiving waters, but at concentrations that are

not expected to be of environmental concern except in the arid regions of the west, where any increments to already high dissolved solids concentrations may prove unacceptable, and in such areas where municipal sewage treatment effluents are recycled.

7. Because of the significant cost of sludge transportation, industries that have inadequate land for on-site disposal may incur significant cost penalties for sludge disposal, in addition to facing opposition at the local level to the use of regional or municipal disposal facilities.

8. The largest industrial solid waste impact will occur in the Midwest, accounting for almost one third of the additional sludge residuals due to the NEP. The South Atlantic, Southwest, and Mid-Atlantic regions follow, each accounting for a further 15% of the national total.

9. In contrast to the utility sector, the question of whether solid waste management problems would pose a significant impediment to the industrial coal conversion goals of the NEP cannot be definitively assessed at the present time. Although we see no general environmental problems arising from the use of currently available technology, only a site specific analysis can fully account for the particular local environmental, economic and institutional context that industry would face. The key environmental uncertainty is the fate of trace and heavy metals at industrial facilities using liquid scrubbing systems and subsequent liquid waste treatment processes, for which no adequate data currently exists.

I. INTRODUCTION

The objective of this assessment is to identify the degree to which solid waste management problems may impede attainment of the coal utilization objectives embodied in the National Energy Plan. It uses as its basis the Administration's estimates of increased coal utilization attributable to specific NEP initiatives, and is concerned primarily with the immediate planning horizon through 1985.

The focus of the assessment is limited to solid waste management concerns at the point of coal use, excluding in particular the problems of mining wastes. Thus, in the electric utility sector, the focus is on the impact on scrubber sludge disposal requirements, and, to a lesser extent, on increased levels of ash production due to a slight overall increase in utility coal consumption.¹ In the industrial sector, which accounts for 177 of the total 199 million tons/yr increase in coal use expected under NEP by 1985,² the concern is with the rather more significant increases in ash and scrubber sludge production. Because some of the scrubber systems in industry over the next decade will likely result in liquid wastes, discharged to municipal sewers and receiving waters, rather than solid wastes, these systems have also been included in this analysis.

The nature of the solid waste management problems faced by utilities and industry is quite different, and warrant separate technical discussions. Utilities will require a relatively small number of large sites for waste disposal, but have some flexibility in on-site disposal in areas generally under fewer land constraints. Industry, however, will require a larger number of small sites, and is thereby more likely to become embroiled in off-site, local solid waste management controversies; on the other hand, industry has greater flexibility in the choice of FGD technology, where required to meet applicable environmental standards. Specific assumptions in this regard are discussed later in this report.

In general, the approach has been to establish conservative assumptions in the key areas of uncertainty that materially affect the important impact measures such as the area required for disposal landfill. For example, in the electric utility sector, it is assumed that all new FGD systems will be of

the lime/limestone type, in the knowledge that any unexpected market penetration of regenerative or double alkali systems would lessen computed landfill requirements.³

The approach also emphasizes analysis of the environmental engineering issues that arise at the site level, in the belief that a proper identification of any constraints that might impede implementation of the NEP will arise not so much from consideration of aggregate waste residuals, as much as from knowledge of individual utility, industrial and regulatory practices and constraints pertinent to the facility and disposal site level at which decisions affecting coal use will actually be made.

2. IMPACT ON ELECTRIC UTILITIES

2.1 Introduction

This chapter analyses the impact of NEP on solid waste management problems in the electric utility sector. The analysis proceeds as follows:

- . a brief examination of the scope of the problem,
- . documentation of the assumptions for quantitative analysis,
- . discussion of the limitations of our analysis,
- . analysis of the solid waste residuals at the national and regional level, focussing on the additional residuals attributable to NEP over a 1985 Base Case, using a comparable definition of Best Available Control Technology (BACT) in both cases,
- . discussion of the environmental, land availability and economic issues associated with disposal of ash and scrubber sludges.

The conclusions of this analysis can be summarized as follows:

- . The additional quantity of ash attributable to NEP by 1985 is insignificant, amounting to an increase of 1% over a 1985 Base Case.
- . Only the Southwest and Western regions experience an increase in scrubber sludge production due to NEP; nationally, a decrease can be expected, possibly as high as 10%, as lower electric demands, resulting from NEP conservation initiatives, reduce coal fired generation primarily in areas using higher sulfur coals.
- . The additional solid waste residuals attributable to NEP can be accomodated in an environmentally sound manner using current technology, and without significant additional burden on the consumer.
- . Utilities should not experience significant problems in accomodating these NEP attributable increases in solid waste residuals, since on-site disposal is generally possible.

2.2 Scope

The scope of the probable impact of NEP on solid waste management in the electric sector can be estimated from a consideration of the total increase in utility coal use. By 1985, NEP is expected to result in a 16 million tons/year increase in utility coal utilization, over a 1985 Base Case utility use of 763 million tons/year. Therefore, a first order estimate of increased

solid waste residuals attributable to NEP would be a 2% increase in both ash and scrubber sludge production,⁴ proportional to this increase in coal use. This suggests that NEP may have little, if any, impact on utility solid waste management, a finding confirmed by the more detailed analysis of residuals presented below.

2.3 Assumptions

In order to compute solid waste residuals, assumptions are necessary for the following:

- . The characteristics of the coal and the degree to which sulfur and ash in the coal enter the flue gas and ash waste streams.
- . The technology used for FGD systems, since this determines the relationship between SO_2 in the flue gas and the quantity and quality of the solid waste residuals.
- . The physical and chemical characteristics of the sludges and methods used for sludge treatment prior to disposal.
- . The method used for sludge disposal.
- . The specific land requirements necessary for land disposal.

2.3.1 Coal Characteristics

To derive quantitative estimates of solid waste, all ash in coal is assumed to be converted to bottom ash, collected with an efficiency of 100%, and to flyash, collected with an efficiency of 99.5% (reflecting the assumed use of an electrostatic precipitator). Although bottom ash is likely to contain a few percent of the sulfur as well, the present analysis simply assumes that all of the sulfur enters the flue gas stream. And although fly ash and SO_2 are removed simultaneously in many FGD systems, the present analysis tracks the two separately in terms of weight and volumes. However, since a substantial quantity of ash is currently utilized as construction and fill material, we assume that 11% of fly ash and 24% of bottom ash do not enter the waste stream, reflecting the existing level of ash utilization.⁶

Average heating value, ash content and sulfur content of coals used in each region were assumed to correspond to those currently in use by electric utilities,⁷ but excluding certain low sulfur coals shipped over long

distances for blending to meet State Implementation Plan Requirements (SIP's)⁸. This definition of coal characteristics corresponds, at the Federal Region level, to locally available coals that will likely be in use under the BACT provision of the 1977 Clean Air Act Amendments.

2.3.2 FGD System Technology

Lime/limestone systems can be expected to dominate the market for FGD systems at coal fired utility boilers over the next 10 years and the numerical computations assume that all new plants constructed with FGD systems are of this type.⁵ The validity of this assumption is documented on Table 1 which shows a breakdown of FGD systems currently in operation, under construction, or planned, by process. To the extent that regenerative systems, such as the Wellman Lord and Magnesium Oxide processes, make significant market penetrations, the computed results would overstate the volume of solid wastes. Similarly, because the double alkali process produces a sludge of a somewhat higher bulk density, landfill disposal requirements computed on the basis of lime/limestone bulk densities would also be conservative.

TABLE 1
BREAKDOWN OF FGD SYSTEMS BY PROCESS

	<u>New</u> ²		<u>Retrofit</u> ²	
	<u>Gw</u>	<u>%</u>	<u>Gw</u>	<u>%</u>
Lime/Limestone	27.478	93.3	4.062	67.8
Sodium Carbonate	.759	2.5	.250	4.2
Wellman Lord	.375	1.2	.455	7.6
Double Alkali	.825	2.8	.277	4.6
Magnesium Oxide	-	-	.846	14.1
Aqueous Carbonate	-	-	.1	1.7

²Excluding units planned for which no selection of process has yet been made
Source: PEDCO Environmental, "Flue Gas Desulfurization Systems Summary Report," May-June 1977, p. 215.

Given the use of this technology, we have assumed that 80% of total annual SO₂ emissions would be captured by the FGD system, and enter the sludge waste stream. This 80% removal assumption is consistent with the BACT definition used in the analysis of air pollution impacts of the NEP,⁹ and is premised on a 90% efficiency of SO₂ removal in a system of about 90% availability.

2.3.3 Waste Characteristics

The lime and limestone wet scrubbing systems both generate a calcium sulfite/sulfate sludge as the end product. The sludge is produced in large quantities and separation of the water is difficult. Untreated, the sludge has the consistency of heavy mud and will remain physically and chemically unstable even after drying.¹⁰

The sludge from lime/limestone FGD units consists primarily of calcium sulfite ($\text{CaSO}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$), calcium sulfate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), unreacted calcium carbonate (CaCO_3), and the ash stream that is generally added to the sludge.¹¹ Table 2 shows typical analyses from a number of operating facilities. The ratio of sulfite to sulfate is important from two standpoints; first is that the sulfite exerts an oxygen demand, and limits some potential disposal options, such as ocean dumping. Second, the ratio determines the bulk density of the sludge product, which in turn determines the landfill space necessary for disposal. The question of trace elements and other chemical properties is taken up in Section 2.6.2.

TABLE 2
Characteristics of Sludge From Operating SO_2 Scrubbers

Facility (MW)	Weight Percent on a Dry Basis				Solids Content of Dewater Sludge Weight Percent
	$\text{CaSO}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	CaCO_3	Ash	
Lawrence 4 (125)	10	40	5	45	50
Lawrence 5 (400)	10	40	5	45	50
Hawthorn 3 (125)	20	25	5	50	40
Hawthorn 4 (140)	17	23	15	45	40
Will County (165)	50	15	20	15	35
LaCygne (820)	40	15	30	15	35
Cholla (125)	15	20	0	65	50
Paddy's Run 6 (70)	94	2	0	4	40
Mohave 2 (160)	2	95	0	3	65

Source: Ifeadi and Rosenberg, Batelle-Columbus, "Lime/Limestone Sludge Disposal--Trends in the Utility Industry," AIChE 67th Meeting, Washington, D.C., December 1974.

Normal pond settling with untreated material will probably result in a final settled density of less than 50 percent solids, at which they have low bearing and compressive strength. Untreated sludges show a tendency to rewater after being subjected to dewatering operation if subsequently exposed to rainfall,¹² making unstabilized sludge unsuited for final disposal by landfill. Thus, emphasis has been placed in recent years on methods of sludge treatment to improve its compressive strength and resistance to rewatering. These methods, referred to as "fixation" or "stabilization", make the sludge more suited to landfill disposal and subsequent reclamation and revegetation, reduce the volume of sludge, and minimize the danger of potential environmental problems from leachates infiltrating into the groundwater (as noted below in Section 2.6.2). A number of vendors are currently marketing such treatment systems, most of which produce a stable inert material that has high resistance to the release of toxic metals and soluble species, and of sufficient compressive strength to support buildings.¹³

However, because of the considerable variation in the amount of sludge volume reduction among these proprietary systems, our quantitative analysis will assume a solids content of 50% by weight, which will result in an overstatement of land acreage for disposal where certain proprietary processes are employed. We shall also assume that each pound of SO_2 removed from the stack gas results in 2.83 lbs of sludge solids, a figure derived from the average of the weight percentages of the major sludge constituents shown on Table 2.

2.3.4 Disposal Options

Table 3 indicates current sludge disposal practices at plants with FGD systems, with most plants disposing unstabilized sludge in unlined ponds. However, this pattern must be expected to change in the future, with much greater utilization of chemical stabilization (or "fixation") prior to disposal. One point of uncertainty in this regard is the status of FGD sludge as a "hazardous waste" under the terms of the Resource Conservation and Recovery Act;¹⁴ EPA's Office of Solid Waste Management has indicated that it will so classify FGD sludges, whereas State officials in Pennsylvania, Ohio and Kentucky have indicated that based on leachate constituents they would not classify lime/limestone sludge as hazardous.¹⁵ Resolution of this difference must await promulgation of regulations authorized in Section 3001 of this Act, which will set forth the identifying characteristics of hazardous wastes.

TABLE 3
Current Sludge Disposal Practice by Number of Units
(Corresponding capacity in Mw in parentheses)

	<u>Sludge</u>		<u>Disposal Pond</u>	
	<u>Stabilized</u>	<u>Unstabilized</u>	<u>Lined</u>	<u>Unlined</u>
Lime	6 (2397)	2 (305)	-	8 (2702)
Lime/Alkaline Ash	-	1 (720)	-	1 (720)
Limestone	2 (367)	5 (3400)	2 (1557)	5 (2210)
Sodium Carbonate	-	1 (375)	-	1 (375)

Source: PEDCO FGD Systems Status Report, May-June 1977, Table 11.

If EPA does finally classify FGD sludge as hazardous, then powers granted EPA to regulate such materials (via the usual route of state plans being acceptable to the EPA administrator) will strengthen the trend to sludge treatment and landfill disposal, rather than unlined ponding.

This analysis, therefore, assumes that land disposal will be utilized at all electric utility plants. Two other alternatives, offshore disposal and deep mine disposal, have been suggested, but for a number of reasons we regard the former as unlikely and the latter as applicable to only special situations.¹⁶ The principal objection to offshore disposal is economic, since on the Northeastern Seaboard, where such an alternative might be most likely, environmental considerations would require deep ocean dumping, rather than near coastal dumping on the continental shelf.¹⁷ Waste disposal in mines is applicable primarily to mine mouth plants; in the eastern regions of the country, however, where groundwater tables are generally high, acid mine drainage would generally result in acidic leaching of waste materials resulting in unacceptably high levels of trace and heavy metal contaminants.

2.3.5 Land Requirements

There is little uniformity in the quantity of land required for sludge disposal. Table 4 shows land areas utilized at a sample of plants; methods range from an evaporation pond in the arid west to the use of an impounded

TABLE 4

Typical Land Area Requirements

<u>Plant</u>	<u>Utility</u>	<u>Mw</u>	<u>FGD System</u>	<u>Land Requirement (Acres)</u>	<u>Comments</u>
St. Clair #6	Detroit Edison	170	Limestone	12	2 years capacity settling pond
Reid Gardner	Nevada Power	375	Sodium Carbonate	50	5 acre settling pond & 45 acre evaporation pond
LaCygne #1	Kansas City P & L	820	Limestone	160	-
Widows Creek #8	TVA	550	Limestone	100	30 ft dike, storage for 7 years
Sherburne	Northern States Power	1390	Limestone	62	Clay lined Settling pond, 45 ft. deep
Colstrip	Montana Power Co.	720	Lime/Alkaline Ash	137	520 acre-ft holding pond & 2218 acre-ft disposal pond
Paddy Run #6	Louisville Gas & Electric	65	Carbide Lime	10	Offsite Landfill
Lawrence #4 & 5	Kansas Power and Light	525	Limestone	48	-
Cholla #1	Arizona Public Service	115	Limestone	Not Available	Evaporation Pond
Bruce Mansfield 1-3	Pennsylvania Power & Light	2505	Lime	900	420 ft. impoundment, Entire valley of 1400 acres purchased

ravine in Pennsylvania to create what in effect is a sludge lake. Because of this variability in climate, topography and disposal practice a statistically significant relationship between plant size, climate, land requirement and disposal method, based on actual utility experience, could not be determined. Instead, we derive in Appendix A an analytical method of computing acre-ft of sludge storage volume.

This methodology estimates that for a typical plant burning 3.5% sulfur coal and with 80% SO₂ removal, the storage requirement computes to .47 acre ft/Mw/yr for sludge, and .16 acre ft./Mw/yr for ash. Assuming a 32 ft. depth and a 1000 Mw plant, this translates to a total disposal area of 590 acres over the

30 year lifetime of the plant. This is conservative in that chemical fixation will result in a substantial volume reduction, and landfill disposal is not necessarily limited to a 32 ft. height. Plants burning low sulfur coal would require proportionally less area for sludge disposal.

2.4 Limitations

The principal limitation of the analysis is the restricted time horizon of 1985. Because of the long construction lead time for new utility plants, NEP can do little to change the capacity mix in the electric sector by 1985; beyond this date, however, the oil and gas replacement program is likely to have more impact, with larger increases of coal capacity, over, say, a 1990 base case. It follows that increases in solid waste residuals beyond 1985 attributable to NEP would be more significant. Beyond 1985, however, advanced FGD systems producing either a useful byproduct or using regenerable scrubbing agents will likely become more widespread; these systems provide an inherently satisfactory solution to any solid waste problems that do emerge. Larger NEP increases in coal use beyond 1985 will thus be offset by a lower overall rate of solid waste generation.

Since we assume that all of the sulfur removal is by use of FGD systems, a second limitation of our analysis concerns the possible use of coal cleaning in conjunction with FGD systems. However, since any change in the definition of BACT would apply to both Base and NEP cases, any redefinition of BACT to include coal cleaning would therefore result in NEP impacts at the point of combustion that are even smaller than those indicated in our computations of Section 2.5, although offset by roughly similar increases that would be generated at the location of the coal cleaning plants.

Moreover, the characteristics of the washing process are specific to almost the particular coal seam in question, with wide variations in pyritic sulfur content and physical properties, thus making any specific assumptions applicable to regional averages questionable.¹⁸ In any event the additional quantity of solid waste produced at the coal cleaning plant would result in waste disposal problems which are similar to those encountered at the boiler location. This analysis does not address these problems because of their dependence on a specific site.

Finally, since the residuals are directly related to the level of coal use in each region, a clear limitation of this study is that only the levels and distributions predicted by PIES model are considered quantitatively.¹⁹

2.5 Regional Residuals

Table 5 displays the computation of ash residuals by Federal Region consistent with the preceeding assumptions and the methodology of Appendix A. The States in each Federal Region are identified in Figure 1. The following points should be noted:

- . Nationally, the increase in ash residuals is about 1%, with a similar increase in land requirement for disposal.
- . Even though total utility coal consumption under NEP increases by 16 million tons per year (or 2% over the Base Case) generation from coal under NEP stays virtually unchanged (a decrease of about 0.1 percent). This is because the NEP results in a shift to the use of higher ash content coals, which, for the same total generation, requires a higher tonnage of coal to be mined.
- . The Southwest and West are the only regions experiencing significant NEP attributable increases in coal fired generation; most other regions experience decreases. But since locally available coal in the Southwest has a higher than average ash content, this is the only region to experience a substantial NEP increase in ash residuals (a 20% increase over the Base Case). However, because land is relatively abundant in both the West and Southwest, and because the absolute amounts of acreage are small (an additional 5 and 30 acres per year, respectively, due to NEP), the regional impact is not significant.

Table 6 shows the computations for scrubber sludge residuals, by Federal Region. In contrast to the computations for ash residuals, for which the PIES model results could be used directly for estimates of total coal use (which governs ash production), the PIES model cannot estimate the

TABLE 5

Ash Residuals in the Electric Sector

FEA Region	1985 Base Case			1985 NEP Increments		
	Ash (MMT/YR)	Ash Landfill (ACRES/YR)	Geperation 10 ⁶ Kwh ^a	Ash (MMT/YR)	Ash Landfill (ACRES/YR)	Geperation 10 ⁶ Kwh ^b
Nw-Eng.	.42	7.53	31.18	.03	.54	2.22
NY/NJ	1.89	33.87	93.57	.02	.35	.97
Mid-Atl	5.87	105.24	230.03	-.07	-1.33	-2.90
S.-Atl	9.94	178.32	417.75	-.38	-6.83	-15.99
Midwest	10.35	185.57	447.03	-.21	-3.73	-8.98
S.West	7.77	139.30	187.32	1.66	29.85	40.14
Central	2.68	48.12	112.64	-.44	-7.93	-18.56
N-Cntrl	1.27	22.70	58.55	-.18	-3.29	-8.50
West	.81	14.50	45.57	.30	5.45	17.12
N.-West	.52	9.25	14.57	-.25	-4.55	-7.17
National Total	41.51	744.39	1638.21	.48	8.53	-1.65

^aFrom PIES Run A 148542C, Table 17^bFrom PIES Run A 158569C, Table 17

Figure 1. Definition of Federal Regions.

degree of scrubber use by region in the Base Case.²⁰ Consequently, the Base Case computations of Table 6 are based on scrubbers currently in use plus existing FGD system commitments (as per the EPA-PEDCO data base)²¹ plus an estimate of additional scrubber use in the years 1982-1985 that would result from the implementation of the BACT provision of the Clean Air Act.²² The 1985 increments attributable to NEP are based on the difference in coal generation, by region, between the PIES model estimates for 1985 NEP and the Base Case, with the additional assumption that any difference in these two cases would occur in plants that have scrubbers. This would tend to overstate the impact on sludge residuals, since some of the difference would occur at plants that do not have FGD systems, and which therefore would not affect scrubber sludge residuals. The analysis thus provides a maximum estimate of impact, with actual impacts likely to be somewhat less than those computed.

Inspection of Table 6 leads to the following observations:

- . Total national land requirements for sludge disposal will decrease by about 10% under NEP, with roughly similar decreases in total sludge volumes and weights.

TABLE 6

Scrubber Sludge Residuals in the Electric Sector

FEA Region	Sludge Solids (MMT/yr)	Wet Sludge (MMT/yr)	Sludge Volume (MMCU. ft./yr)	Sludge Landfill (Acres/yr)	Total Land Committed (Acres)	Sludge Solids (MMT/yr)	Wet Sludge (MMT/yr)	Sludge Volume (MMCU. ft./yr)	Sludge Landfill (Acres/yr)	Total Land Committed (Acres)	Generation MMMKwh/yr
Nw-Engl	.13	.27	.27	5	150	.08	.16	.16	3	90	2.22
NY/NJ	.19	.38	.38	7	210	.03	.07	.07	1	30	.97
Mid-Atl	1.63	3.26	3.27	63	1890	-.11	-.22	-.22	-4	-120	-2.90
S.-Atl	4.55	9.10	9.16	177	5310	-.75	-1.51	-1.52	-29	-870	-15.99
Midwest	4.96	9.93	9.99	193	5740	-.48	-.96	-.96	-18	-540	-8.98
S. West	2.06	4.13	4.16	80	2400	.72	1.45	1.45	28	840	40.14
Central	1.88	3.77	3.79	73	2190	-1.16	-2.33	-2.33	-45	-1350	-18.56
N-Cntrl	.96	1.91	1.92	37	1110	-.12	-.25	-.25	-4	-120	-8.50
West	.41	.82	.83	16	480	.16	.32	.32	6	180	17.12
N.-West	0.00	0.00	0.00	0	0	-.10	-.20	-.20	-3	-90	-7.17
National Total	16.78	33.57	34.63	651	19530	-1.73	-3.47	-3.49	-65	1950	-1.65

- . At a regional level, some areas of the country experience increases in sludge residuals, some experience decreases. The land requirement in the Southwest increases by some 35%, consistent with the more rapid increase in coal generation in this region. The additional 840 acres of land that must be committed to sludge disposal (over the lifetime of the facilities in place by 1985), however, are not significant in view of the very large sites typical of utilities in this region (a subject discussed below in Section 2.6.1).
- . The largest decreases in land requirement occur in the Central, South Atlantic, and Midwestern regions; these occur because the total coal generation in these regions also decreases under NEP, and, consistent with our assumptions, all such decreases are assumed to occur at plants with FGD systems. Coal generation under NEP decreases because total electricity generation by 1985 under NEP decreases by some 7% (in terms of Btu consumption), in consequence of the conservation and load management provisions of NEP.
- . By the same token as the sludge increases in the Southwest are of no significant concern, so will the decreases in land requirement in the other regions provide little significant benefit. Recall from Section 2.3.5 that a 1000 MW plant requires about 600 acres of land for sludge disposal over its lifetime; thus the 3090 acre saving in the 6 regions showing a land decrease under NEP implies that at most 5 GW of coal capacity would be affected. That represents 2% of the 258 GW 1985 Base Case coal capacity in these 6 regions.

Not only are the incremental NEP impacts small, and in some regions beneficial, but also the total quantity of electric utility scrubber sludge generated in 1985 under the future envisaged by NEP is quite small. The 30 million tons a year of utility scrubber sludge should be contrasted with other activities generating sludge wastes:²³

Municipal Sewage Sludge	55 million tons in 1980 (est.)
Phosphate Rock Slime	760 million tons in 1970
Acid Mine Drainage Sludge	8 million tons in 1970
Gypsum from Fertilizer	
Manufacturing	28 million tons in 1973
Taconite Tailings	1100 million tons in 1971

2.6 Constraint Analysis

While the analysis of residuals by region is helpful in assessing the overall scope of the solid waste management problem, it is the assessment of the implications of such impacts that is key to any credible judgment as to the degree to which solid waste problems constrain the implementation of the NEP. Thus we consider, at the scale of site implementation, the key potential constraints; land availability, environmental problems, and the economic penalties of mitigating measures.

2.6.1 Land Availability

Land requirements for sludge disposal are not so excessive as to be considered a crucial constraint. The sharp growth in the number of throwaway lime/limestone systems now planned suggests that most utilities have coped with the sludge disposal problem quite well, and certainly there is little evidence that land availability will be a problem in most areas of the country. Even in the Northeast, where there have been few commitments to FGD systems and where one might expect greatest difficulties in site selection in view of high population densities, review of recent utility and power pool planning reports suggests that the utilities have still been able to assemble sites of 1000 to 3000 acres to accommodate future coal fired plants in the 1980's and early 1990's. This makes them of sufficient size to accommodate sludge disposal on-site for units planned at these sites.²⁴

By way of example, consider the New York Power Pool, and the sites currently under study by the utilities for coal-fired base load units expected in the 1980's and early 1990's,²⁵ as shown in Table 7. Of the six sites identified in the most recent site inventory, one already is planned to include FGD. The remaining five plants are planned to burn low sulfur coal to meet existing NSPS and SIP requirements without scrubbers, yet even these plants appear to have adequate land area for waste disposal for throwaway lime/limestone FGD systems. However, it is perhaps doubtful that the Sheridan site could accommodate a sufficient space for more than one FGD over its entire life and the Cayuga site may be ill-suited for a large sludge pond (although might well be able to accommodate a landfill operation).

TABLE 7
Sites in New York^a

	Capacity MW	Expected Service Date	Site Size, Acres	Necessary Area for Waste Dis- posal with FGD ^b (Acres)	Anticipated Problems for on- site disposal ^c
Cayuga	850	1983	915	398	Terrain difficulties
Somerset	850	1983	955	398	Appears suited
Sheriden	850	1985	986	796	Appears suited
	850	1987			
Pomfret	850	1985	1054	796	Appears suited
(alternate to Sheriden)	850	1987			
Sterling	600	Early 1990's	2800	562	Hilly terrain, but impoundments possible
	600	Early 1990's			
700 MW PASNY Staten Island	700	1982			FGD system planned

^aSource: New York Power Pool, note 25

^bBased on 0.5 Acre ft/Mw/yr, 32 ft depth; Area is for entire 30 year life of the units indicated.

^cBased solely on a brief review of the applicable quad sheets, and not on any detailed geotechnical assessment.

In order to confirm these findings at a national scale, we conducted a national survey of utilities that presently have plans for coal fired units in the early 1980's. The results of this survey are displayed on Figure 2, which shows the site size as a function of planned capacity at that site, identified by Federal Reliability Council Region. The cross-hatched area indicates the range of necessary land requirement for sludge and ash disposal over the lifetime of a plant assuming .63 acre-ft/Mw/year for storage depths of 32 ft and 16 ft.²⁶ All of the planned facilities surveyed have adequate acreage to accommodate on-site FGD waste disposal. Many of the utility engineers indicated that contingency plans existed if FGD systems were to be required. And many other facilities were planning to exploit some unique site specific characteristic, from reclamation of old, nearby

Figure 2. Site size by plant capacity and reliability council region.

strip mines to the construction of a 45 ft revegetated berm to mitigate noise and aesthetic impacts of the facility itself.

These results indicate that on-site FGD system waste disposal is technically feasible even at plants which do not presently plan to use such systems and would only in rare cases pose a serious problem. Assembly of large land areas for coal burning plants also seems well within the capabilities of the utilities. We conclude, therefore, that availability of sludge disposal sites will unlikely constrain increased coal utilization in the electric utility sector.

2.6.2 Environmental Issues

There is a considerable research and monitoring effort at existing facilities to assess the potential environmental problems from ash and scrubber sludge disposal. The general conclusions to date include the following:

- . Sludge liquors (the overflow of a simple ponding operation) contain concentrations of heavy metals and dissolved solids that may pose some threat under certain circumstances;
- . Leachates from unfixed sludge disposal sites or unlined ponds contain heavy metal and trace element concentrations that are generally below levels considered to be hazardous, but with dissolved solids contents that are still much higher than what would be acceptable in groundwater used for drinking water;
- . Impermeable disposal pond linings may be necessary in some cases to afford protection to nearby groundwater;
- . Chemical fixation of the sludge reduces the concentration of major species (although not of trace elements) in leachates by a factor of 2 to 4, in addition to providing other benefits such as volume reduction, decreased permeability and greater compressive strength.²⁷

These general conclusions are exemplified by the data of Table 8; column (1) shows the concentration in the sludge liquor from an eastern coal lime-stone scrubber operation; (corresponding to the overflow of a simple pond)²⁸ Column (2) the untreated leachate at the same plant; Column (3) the groundwater contaminant limits of the State of New York,²⁹ one of the few states to have set specific limits for contaminant concentrations entering groundwater;³⁰ Column (4) the 1962 US Public Health Service Drinking Water Standards, which for these elements marked with an asterisk coincide with the 1975 EPA Standards promulgated under the Safe Drinking Water Act³¹ and Column (5) the leachate concentrations after fixation by the Dravo Chemfix process. Note that Arsenic, Lead, Selenium, Chloride, Fluoride, Sulfate and Total Dissolved Solids (TDS) concentrations in the liquor are substantially in excess of the groundwater contaminant limits and drinking water standards; that only sulfates and TDS exceed the standards in the leachate; and that sulfates and TDS exceed the limits even after fixation.

The general conclusion that pond linings, chemical fixation and landfill disposal provide adequate environmental protection does not imply, however, that the potential for environmental problems is absent. Considerable research is still underway to address the key uncertainties. These include:

- . The length of time over which leachates are of concern, since provision of lined ponds designed to provide an impermeable barrier for several decades may be overly conservative under certain sludge fixation methods; conversely, a 30 year liner life may be inadequate for unstabilized sludge that may be unstable indefinitely.
- . The degree to which alternatives to the lime/limestone FGD system results in sludges that pose a different potential for leaching (the double alkali process, for example, produces a sludge that has physical properties making it more suited as landfill, but has a higher soluble salt content than lime/limestone sludge).
- . The fate of trace elements over long time spans.
- . The permanence of stabilization, especially under microbial action.

TABLE 8
Comparison of Chemical Constituents (Mg/l)
(See Text for Source)

	(1) <u>Liquor</u>	(2) <u>Leachate Untreated</u>	(3) <u>New York State limit for ground- water contaminants (Schedule II)</u>	(4) <u>U.S. Public Health Service Drinking Water Standards</u>	(5) <u>Leachate, after fixation by Chemfix Process</u>
Arsenic	<u>0.14</u>	0.01	0.1	.05*	0.006
Cadmium	0.003	<0.001	0.02	.01*	<0.001
Chromium	<u>0.09</u>	0.003	0.1	.05*	<0.001
Copper	0.01	0.01	0.4	1.0	0.005
Lead	<u>0.25</u>	0.01	0.1	.05*	<0.001
Mercury	< <u>0.05</u>	<0.00005	-	.002*	<0.0005
Selenium	<u>0.08</u>	0.006	0.02	.01*	0.002
Zinc	0.2	0.045	0.6	5.0	0.065
Chloride	<u>2300</u>	120	500	250	60
Fluoride	<u>6.2</u>	<0.2	3.0	1.4-2.4*	0.2
SO ₄	<u>10,000</u>	<u>1,200</u>	<u>500</u>	250	<u>650</u>
TDS	<u>15,000</u>	<u>2,400</u>	<u>1,000</u>	500	<u>1,500</u>
pH	<u>8.3</u>	<u>5.0</u>	6.5-8.5		6.01

Underlined values exceed the Drinking Water Standards.

* Also the new EPA Standard under the Safe Drinking Water Act of 1975.

Vegetation cannot generally be established on FGD or coal ash disposal areas without additional preparation and unstabilized sludge may not have sufficient compressive strength.³² However, sludge fixation and a 2 to 3 ft. layer of soil overburden will usually suffice to aid in the establishment of vegetation, and thus reclamation of disposal areas is within current technical abilities.

In conclusion, given proper engineering judgment in the selection of disposal sites, the treatment process used, the decision as to whether or not to line an intermediate ponding operation, and the ultimate mode of disposal, environmentally sound disposal of throwaway lime/limestone scrubber sludges will generally be possible.

2.6.3 Economic Issues

Although the costs of chemical fixation of sludge and holding pond linings are substantial, they can become small in comparison to the costs of sludge transportation.³⁴ Table 9 illustrates the relative importance of various subsystem costs. These estimates are consistent with recently reported total cost estimates in actual practice.³⁵ A range of \$5-\$15 per ton of dry solids would be a representative figure, equivalent to an additional generation cost of about .6 to 2.0 mills/kwh. In terms of capital requirements, the sludge disposal system, including all necessary land acquisitions, will represent between 10 and 30% of the total FGD system capital cost requirement. The total sludge disposal cost of .6-2.0 mills/kwh should be contrasted with the overall cost of an FGD system, which can be expected to be in the range of 5 to 13 mills/kwh. Thus, sludge disposal will account for between 15 and 20% of the total FGD system cost. More importantly, the additional cost incurred by chemical fixation and proper landfilling disposal represents only about an additional 5%-10% of total FGD system cost. For a typical residential user of 500 kwh/month, total FGD system costs are thus \$30-\$78 per year; of which proper sludge disposal accounts for \$4-\$12; and of which only \$1.20-\$2.40 represents the cost of chemical fixation.

TABLE 9
IMPACT OF VARIOUS SUBSET SLUDGE DISPOSAL OPTIONS
ON THE ANNUALIZED COST OF SLUDGE DISPOSAL^a

	<u>Mills/KWH</u>	<u>\$/Dry Ton</u>	<u>\$/Wet Ton</u>
Unlined Pond/No Fixation	0.463	7.54	4.53
Synthetic Lining	0.451	7.35	4.41
Fixation	0.204	3.32	2.00
Trucking - 5 miles	1.023	16.67	10.00
Trucking - 10 miles	2.046	33.33	20.00
Trucking - 15 miles	3.069	50.00	30.00
Pumping - 5 miles	0.224	3.65	2.19
Pumping - 10 miles	0.336	5.47	3.28
Pumping - 15 miles	0.448	7.30	4.38
Retrofit	(0.040) ^b	(.65)	(.39)
Low Sulfur	(0.337)	(7.17)	(4.30)

^aThe various costs shown are additive to the cost of an unlined pond without chemical fixation.

^bNumbers in parentheses are negative.

Source: PEDCO, note 21.

3. IMPACT ON INDUSTRY

3.1 Introduction

This chapter examines the impact of the NEP on solid waste management in industry. As in the case of the utility sector, we proceed as follows:

- . a brief examination of the scope of the problem,
- . documentation of the assumptions for quantitative analysis,
- . discussion of the limitations of the analysis,
- . an analysis of the solid waste residuals at the national and regional level,
- . a discussion of any constraints to solid waste disposal, addressing in particular the questions of land availability and environmental impacts.

The conclusions of this analysis can be summarized as follows:

- . Ash production at coal burning industrial installations will approximately double by 1985 as a result of the NEP, as measured over the corresponding 1985 Base Case.
- . The production of FGD system sludge at coal-burning industrial facilities will increase at most by 60% nationally as a result of NEP, again as measured over a corresponding 1985 Base Case.
- . Significant additional sludge disposal problems must be anticipated for industries that have inadequate land for on-site disposal, and who may therefore incur high transportation cost penalties for disposal at off-site, regional or municipal waste disposal sites. The exact extent of these difficulties, however, can only be assessed on a case-by-case basis at the site level.
- . As a result of these difficulties many industries will utilize FGD systems that produce a liquid rather than solid waste, generally resulting in the discharge of sodium sulfate into municipal sewers and receiving waters.
- . The concentrations at which sodium sulfate would enter the environment from such systems is generally low, and unlikely to be of concern except in the arid west, where any increase in salinity may be unacceptable.

3.2 Scope

Of the total 199 million tons/year additional coal use expected by 1985 as a result of the NEP, 177 million tons/year will occur in the industrial sector.³⁶ Nationally this increase implies about an almost threefold increase in coal use by industry over the 1985 Base Case.³⁷ Ash disposal by coal-using industries will increase roughly in proportion to total coal use. Sludge disposal increases would be less than proportional because smaller industrial facilities would likely be under less stringent emission limitations under currently expected definitions of BACT.

The bounds of the problem at the regional level are illustrated on Table 10, which shows the compound annual growth rate and total increase in coal use, under both the 1985 Base Case and NEP. In relative terms, coal use in industry under NEP will grow fastest in the West, the Southwest and New England; in absolute terms, however, (Col. 3) the Southwest and the key industrial areas of the Midwest and East (Regions 3,4 and 5) will be the most significantly affected. It is in these areas, therefore, that solid waste management problems due to NEP are expected to be most acute.

3.3 Assumptions

Estimation of the solid waste impacts of increased industrial coal use stemming from the NEP is based primarily on assumptions with regard to the following items:

- . Level and location of increased industrial coal use in each region of the country as a result of NEP, as well as the level of coal use expected in the absence of any plan.
- . Characteristics of coals used by various industrial facilities, in particular their average heating value, sulfur content, ash content, and ash composition.
- . Characteristics of the combustion technologies used by industrial sources, in particular the fractions of ash and sulfur in coal that are directed to environmental control systems.
- . Air pollution control regulations applicable to the types and sizes of industrial combustors used in each region of the country.
- . Extent to which environmental control technologies are utilized by industrial sources for the control of sulfur and particulate

TABLE 10

PIES MODEL PREDICTIONS OF GROWTH RATES IN INDUSTRIAL COAL USE^a

FEA/EPA Region	Compound Annual Growth Rate (percent)		Absolute increase 1985 NEP over 1985 Base
	Base Case	Initiatives	(10 ¹² Btu/yr)
1. New England	0.2	34.7	86.9
2. NY/NJ	3.2	19.3	282.5
3. Mid-Atlantic	1.5	11.0	553.1
4. South Atlantic	5.7	16.4	597.0
5. Mid-West	6.1	11.1	615.0
6. South West	10.2	41.9	1155.2
7. Central	1.0	8.3	84.9
8. North Central	7.2	22.1	264.6
9. West	15.3	46.9	370.4
10. North West	10.3	22.3	123.8
U.S. Total	5.1	16.6	4133.3

^aExcluding Metallurgical Coal.

emissions, and the characteristics of these technologies in terms of their collection efficiencies, energy penalties and the quantity and chemical/physical nature of sludges, liquids or other waste streams emanating from them.

3.3.1 Levels and Location of Future Industrial Coal Use: Levels of future industrial coal use were taken to be the values projected for 1985 by the Project Independence Evaluation System (PIES) model for both Base Case and NEP initiatives scenarios.³⁸ The Base Case reflects a situation with no new government initiatives to stimulate increased use of coal, while the NEP Case reflects the effect of the entire National Energy Plan on industrial coal use. The location of industry is based on historical trends, and allocates future industrial growth to areas that are currently the important industrial centers.

3.3.2 Combustion Technology and Coal Characteristics: All coal utilized in the industrial sector is assumed to be combusted in a manner characteristic of industrial boiler facilities. Although combustion characteristics for non-boilers may differ from this, such differences depend on specific industrial processes, and are generally not well understood or quantified at the present time. In terms of solid waste impacts, however, this assumption is conservative for two reasons: (1) coal use in non-boilers is likely to result in lower solid waste generation as a result of less stringent air pollution control regulations, and (2) some portion of coal wastes is likely to be retained in the process product (e.g., retention of sulfur by cement in coal-fired cement kilns).

To derive quantitative estimates of solid waste residuals, similar assumptions to those used in the electric sector are used, with all coal sulfur entering the flue gas stream as SO_2 (See Section 2.3.1). However, unlike the utility sector, we make the conservative assumption that all collected ash must be disposed of, since no reliable data on utilization of ash from industrial boilers is available.

The average heating value, ash and sulfur content of coals used in industry was also derived in a manner similar to that described for the electric sector (Section 2.3.1), again reflecting the assumption that locally available coal will be most likely under implementation of BACT. The ash and sulfur contents assumed for the analysis of industrial residuals are displayed on Appendix Tables 17 and 18, respectively.

3.3.3 Air Quality Scenarios

Consistent with NEP analyses of air pollution impacts, we assume that best available control technology will apply to industrial coal use in all new large boilers (greater than 25 MW). This is interpreted to mean an 80% reduction in potential SO₂ emissions. Sulfur dioxide emissions from new small boilers (less than 25 MW) are assumed to be limited to 1.5 lbs/million Btu of coal input to the boiler. BACT for particulate control is assumed to limit emissions to 0.05 lb/million Btu for both large and small boilers, implying a 99.5% collection efficiency for flyash, well within the performance of current particulate removal technology. For existing sources we assume State Implementation Plan requirements, consistent with other NEP air pollution analyses. The assumed use of FGD systems in each region for each of the major categories (existing, new large, new small) is documented in Appendix B, Table 13, and is again consistent with the NEP air pollution analysis.⁴⁰

These assumptions for BACT are assumed to apply to both the 1985 Base Case and the NEP case, consistent with the premise that BACT will be implemented under the provisions of the 1977 Clean Air Act Amendments.

3.3.4 Control Technology

Control of particulate matter is assumed to be universally required for any facility burning coal. It is assumed that the control levels called for are achieved either by dry collection of fly ash (e.g., using electrostatic precipitators or baghouses), or by wet collection (scrubbing), possibly in conjunction with a dry mechanical collector. All of these represent currently available technologies. The specific choice of control technology depends on a number of factors including whether or not desulfurization technology is also required.

Consistent with other NEP analyses, the present analysis also assumes that a flue gas desulfurization (FGD) system is the technology of choice for complying with BACT. The detailed assumptions used to derive a quantitative estimate of this appear in Appendix B, Tables 14-16. The FGD system is assumed to be either a dual alkali system, producing a wet solid sludge for disposal, or a chemical liquid scrubbing system, producing a liquid waste stream for disposal that is discharged to municipal sewers or receiving waters after neutralization.⁴⁰ These are most representative of the systems now used with industrial boilers. According to the best available estimates of industrial FGD use, liquid scrubbing systems are approximately three times more prevalent than sludge-producing systems (Table 11). Regenerative FGD systems that recover a useful byproduct are currently employed in selected industries (such as sulfuric acid manufacture) but not considered a likely choice for typical industrial boiler applications. The added solid waste impacts of industrial FGD systems will thus be distinct in form as well as in magnitude from those of electric utility FGD installations, where the prevalent technology is a lime/limestone system producing a wet sludge.

Because of the difficulties of predicting a precise mix of the two major FGD system types, the computation of residuals is for two extreme cases; one case in which all industries are assumed to use liquid scrubbing systems, a second case in which all industries are assumed to be using double-alkali systems producing a sludge waste.

3.4 Limitations

One limitation of the analysis is that the solid waste impacts of technologies for the control of sulfur and/or particulate emissions other than FGD are not considered. Alternative technologies for sulfur control could include fluidized bed combustion (FBC) and low-Btu gasification. The former is a promising technology which captures sulfur directly in the boiler rather than in a downstream control system, and may recover it as a useful byproduct. However, FBC is not yet commercially available and is not likely to be used significantly before 1985.⁴¹ Low-Btu gasification is another currently available technology that first transforms coal into a gaseous fuel. Sulfur is removed in the form of hydrogen sulfide rather than as SO_2 , and is

TABLE 11: SUMMARY OF SOME EXISTING INDUSTRIAL FGD SYSTEMS

Company Name	Location	Start-Up	Status (New or Retrofit)	Source Rating	Source Characteristics	Control Process	Removal Efficiencies		Sludge Disposal
INDUSTRIAL BOILERS									
Alphex Pipeline Service Co.	Valdese, NC	7/77	Construction, New	13 MW	Fuel Oil (0.03% Sulfur)	FWC Sodium Scrubbing	TSP	SO ₂	H ₂ SO ₄ /SO ₂ Aerated + transferred to wastewater treatment plant
AKCO/Polysar, Inc.	Roscoe, PA	mid-1979	Planning, Retrofit	100 MW	Coal (3.5% Sulfur)	Wellman-Lord	N/A	94%	Makes liquid of SO ₂
Arco Steel Corp.	Middletown, OH	N/A	Operational	15 MW (2)	Coal	Roch Lime Scrubber	N/A	N/A	N/A
Caterpillar Tractor Co.	E. Peoria, IL	9/74	Operational, Retrofit	10 MW	Met. Gas, Coal (0.8% Sulfur)	FWC Sodium Scrubbing	80-90%	70%	Na ₂ SO ₄ /SO ₂ liquor Disposed to Holding Ponds
Caterpillar Tractor Co.	Mapleton, IL	1978	Construction, 2 New, 2 Retrofit	100 MW (4)	Coal (3.2% Sulfur)	FWC Double Alkali	N/A	90%	60% Solids (CaSO ₃) sludge directly to landfill
Caterpillar Tractor Co.	Mapleton, IL	9/74	Operational, Retrofit	18 MW (2)	Coal (3.2% Sulfur)	Dunn Double Alkali	N/A	N/A	60% Solids (CaSO ₃) sludge to drying point - landfill
Caterpillar Tractor Co.	Mapleton, IL	1977	Construction, New	100 MW (3)	Coal (3.2% Sulfur)	FWC Double Alkali	N/A	N/A	60% Solids (CaSO ₃) sludge directly to landfill
Caterpillar Tractor Co.	Mapleton, IL	1978	Planning, Retrofit	12 MW	Coal (3.2% Sulfur)	Dunn Double-Alkali	N/A	N/A	60% Solids (CaSO ₃) sludge to drying pond - landfill
Caterpillar Tractor Co.	Mapleton, IL	10/75	Operational, 1 New, 3 Retrofit	57 MW (4)	Coal (3.2% Sulfur)	FWC Double Alkali	N/A	N/A	60% Solids (CaSO ₃) sludge directly to landfill
FWC Soda Ash Plant	Green River, WY	1975	Operational, New	150 MW (2)	Coal (1.0 - 1.1% Sulfur; 5% Ash)	FWC Sodium Scrubbing	99.5%	95%	Na ₂ SO ₄ /SO ₂ liquor disposed to collection ponds
General Motors Corp.	Dayton, OH	5/76	Operational, New	150 MW (2)	Coal (0.7 - 1.3% Sulfur; 5 - 9.5% Ash)	OW Sodium Scrubbing	85%	80%	Na ₂ SO ₄ Liquor @ 33 gpm to onsite facility
General Motors Corp.	Palma, CA	9/74	Operational, Retrofit	32 MW (4)	Coal (2.5% Sulfur; 7.1% Ash)	OW Double Alkali	83%	90%	50% Solids (CaSO ₃) sludge to drying pond + landfill
General Motors Corp.	St. Louis, MO	4/76	Operational, New	26 MW	Coal (0.84% Sulfur; 8.5% Ash)	OW Sodium Scrubbing	85%	N/A	5% Solids Slurry dewatered and to landfill
General Motors Corp.	Tonawanda, NY	2/72	Operational, Retrofit	25 MW (2)	Coal (3.2% Sulfur; 10% Ash)	OW Sodium Scrubbing	90%	90%	Na ₂ SO ₄ Oxidized to Na ₂ SO ₄ , pH neutralized and discharged
Georgia-Pacific Paper Co.	Cromwell, CT	6/75	Operational, New	32 MW	Coal (1-1.5% Sulfur; 8-10% Ash)	OW Sodium Scrubbing	Removed	90	Na ₂ SO ₄ /SO ₂ Waste Liquor Dewatered
Great Southern Paper Co.	Cedar Springs, GA	1/75	Operational, New	96 MW	Bark + Oil or Coal (11-15% Sulfur)	Air Pol Caustic Scrubbing	90%	80%	pH Neutralized then discharged to sewers
ITV Rayonier, Inc.	Parandina Beach, FL	1/75	Operational, Retrofit	100 MW (2)	Bark + Oil or coal (1-2% Sulfur)	Air Pol Caustic Scrubbing	99.1%	85 - 90%	Clarification followed by ponding and river discharge
Kerr-McGee Chemical Co.	Troy, CA	1/77	Construction, New	120 MW (2)	Coal (1.5-2.5% Sulfur)	Air Pol Caustic Scrubbing	97%	80 - 85%	Clarification followed by ponding and river discharge
Stamwood Paper Co.	Stamwood, AL	11/77	Construction, New	160 MW (2)	Coal, Oil (0.5-5% Sulfur)	CEA Soda Ash Scrubbing	99.8%	99%	Scrubber effluent is clarified, then put into mineral deposit
MCB-Appleton	Boaring Springs, PA	3/75	Operational, New	60 MW (2)	Oil (1.5-3% Sulfur)	Air Pol Caustic Scrubbing	90%	95%	Recovered solution
Whitcomb Papers, Inc.	Ashdown, MD	5/76	Operational, New	52 MW	Coal (1-1.5% Sulfur)	Air Pol Caustic Scrubbing	N/A	N/A	N/A
Quality Mills, Inc.	St. Mary, NC	2/76	Operational, New	12.5 MW	Coal (1-1.5% Sulfur)	Air Pol Caustic Scrubbing	98 - 99%	99%	SO ₂ recovered from sodium sulfite/sulfate liquor and recycled
Richmanbacker AFB	Columbus, OH	5/70	Not Operating, Retrofit	52,000 lb/hr Steam (3)	Fuel Oil	CFM Scrub-Alz	80 - 95%	47%	Scrubbing liquor discharged to neutralization pond
St. Regis Paper Co.	Centerville, OH	1973	Operational, Retrofit	20 MW	Coal (3.6% Sulfur)	Research-Cottrell/Naecholime Scrub	98%	90%	Unstabilized CaSO ₃ /SO ₄ sludge to lined ponds
Tranco Textiles, Ltd.	Augusta, GA	3/75	Not Operating, New	20 MW	Met. Gas; Bark + Oil (2-3% Sulfur)	Air Pol Caustic Scrubbing	94.5%	80 - 85%	Sludge charged to onsite treatment plant
U.S. Optical Co.	Calumet, PA	N/A	Not Operating, New	19,300 GCH (4)	Coal	FWC Sodium Scrubbing	N/A	80 - 85%	Sludge to pond for drying; then landfill
U.S. Optical Co.	Calumet, PA	N/A	Not Operating, New	19,300 GCH (4)	Coal	Air Pol Double Alkali	N/A	80 - 85%	Sludge to pond for drying; then landfill
SULFURIC ACID PRODUCTION									
Allied Corporation	Calumet, IL	11/72	Operational, Retrofit	500 TPD Sulfuric Acid	Contact Acid Plant	Davy Powergas Wellman-Lord	N/A	99%	Concentrated SO ₂ stream recycled to front of acid plant
American Cyanamid	Waukegan, IL	mid-1978	Planning, New	1,600 TPD Sulfuric Acid	Contact Acid Plant	Research-Cottrell	N/A	99%	Product SO ₂ utilized for increased H ₂ SO ₄ production
C.F. Chemicals, Inc.	Bartow, FL	7/75	Operational, Retrofit	1,000 TPD Sulfuric Acid (2)	Contact Acid Plant	Davy Powergas Wellman-Lord	N/A	99%	Ammonium sulfate is crystallized
Columbia Nitrogen	Moultrie, GA	9/73	Operational, Retrofit	70 TPD Sulfuric Acid	Lead Chamber Acid Plant	Met. Systems Washline	N/A	90 - 99%	Scrubber effluent to limestone pits
Coulton Chemical Co.	Pyramide, OH	9/73	Operational, New	200 TPD Sulfuric Acid	Spent Acid Regeneration Plant	Union Carbide "Acid-Sol" Adsorption	N/A	85 - 89%	Desorbed SO ₂ recycled to acid plant
Detroit Chemical Works	Detroit, MI	2/73	Operational, New	200 TPD Sulfuric Acid	Contact Acid Plant	Barton Sulfate Adsorption	N/A	99%	Desorbed SO ₂ recycled to acid plant
Farmaland Industries	Bartow, FL	1974	Construction, Retrofit	1,000 TPD Sulfuric Acid (4)	Contact Acid Plant	Davy Powergas Wellman-Lord	N/A	99%	Ammonium sulfate utilized as fertilizer material
Qlin Corporation	Curtis Bay, MD	5/73	Operational, Retrofit	1,000 TPD Sulfuric Acid	Contact Acid Plant	Davy Powergas Wellman-Lord	N/A	99%	Concentrated SO ₂ stream recycled to acid plant
Qlin Corporation	Palmdale, CA	7/70	Operational, Retrofit	700 TPD Sulfuric Acid	Contact Acid Plant	Barton Sulfate Adsorption	N/A	99%	Desorbed SO ₂ stream recycled to acid plant
Shell Wood River	Wood River, IL	1974	Operational, New	200 TPD Sulfuric Acid	Contact Acid Plant	Davy Powergas Wellman-Lord	N/A	99%	Desorbed SO ₂ stream recycled to acid plant
US Agricultural Chemical	Bartow, FL	7/75	Not Operating, Retrofit	800 TPD Sulfuric Acid	Contact Acid Plant	Peabody Limestone Scrubbing	N/A	90%	Non-flashed slurry to unlined pond
US Agricultural Chemical	Port Head, FL	7/75	Not Operating, Retrofit	1,500 TPD Sulfuric Acid	Contact Acid Plant	Peabody Limestone Scrubbing	N/A	90%	Non-flashed slurry to unlined pond
CLASP PROCESS TAIL GAS									
Clasp, Inc.	Texas City, TX	1976	Operational, New	400 TPD Sulfur	Clasp Plant Tail Gas (CPTG)	IFP-1500	N/A	93%	N/A
Charter, Inc.	Houston, TX	1973	Operational, New	250 TPD Sulfur	CPTG	IFP-1500	N/A	89%	N/A
Commonwealth Oil Refining	Ponca, PA	1973	Operational, Retrofit	60 TPD Sulfur	CPTG	IFP-1500	N/A	80%	N/A
FWC Corporation	S. Charleston, WV	1975	Operational, New	220 TPD Sulfur	CPTG	IFP-1500	N/A	93%	N/A
Phillips/Monsanto	Avon, CA	1975	Operational, Retrofit	180 TPD Sulfur	CPTG	IFP-1500	N/A	94%	N/A
Phillips Petroleum	Borger, TX	1975	Operational, New	45 TPD Sulfur	CPTG	IFP-1500	N/A	90%	N/A
Phillips Petroleum	Borger, TX	1975	Operational, Retrofit	100 TPD Sulfur	CPTG	IFP-1500	N/A	94%	N/A
Phillips Petroleum	Lawrence, TX	1971	Operational, Retrofit	45 TPD Sulfur	CPTG	IFP-1500	N/A	94%	N/A
Standard Oil of California	El Segundo, CA	9/72	Operational, New	825 TPD Sulfur	CPTG	Wellman-Lord	N/A	90%	N/A
LOCAL									
SOCAL	El Segundo, CA	9/72	Operational, New	450 TPD Sulfur	CPTG	Wellman-Lord	N/A	99%	N/A
SOCAL	Richmond, CA	1/78	Operational, New	125 TPD Sulfur	CPTG	Wellman-Lord	N/A	99%	N/A
SOCAL	Richmond, CA	6/75	Operational, New	700 TPD Sulfur	CPTG	Wellman-Lord	N/A	99%	N/A
Stauffer Chemical Co.	Dulles, VA	1972	Operational, Retrofit	N/A	N/A	IFP-1500	N/A	93%	N/A
FOURNEY, CUPOLA									
Cumberland Foundry	Cumberland, MD	8/75	Operational, Retrofit	5 T/hr	Coke (1% Sulfur); Scrap Iron	Rep. Dynastor Sodium Scrubbing	97%	99%	None Created
Harrington Foundry	Lawton, OK	9/76	Operational, Retrofit	3.5 T/hr	Coke (0.5% Sulfur); Scrap Iron	CFM Scrub Air	90 - 95%	47%	Direct Discharge
Southern Foundry	Baltimore, MD	1/77	Construction, Retrofit	5.0 T/hr	Coke (0.5% Sulfur); Scrap Iron	CFM Scrub Air	90 - 95%	47%	Direct Discharge
Standard Foundry & Mfg.	Buckingham, NC	12/75	Operational, Retrofit	5.0 T/hr	Coke (0.5% Sulfur); Scrap Iron	CFM Scrub Air	90 - 95%	47%	Direct Discharge
Stovall's Foundry	Gastonia, NC	5/75	Operational, New	5.0 T/hr	Coke (0.5% Sulfur); Scrap Iron	CFM Scrub Air	90 - 95%	47%	Direct Discharge
Tennessee Publishing Co.	Hughes, TN	3/77	Construction, Retrofit	5.0 T/hr	Coke (0.5% Sulfur); Scrap Iron	CFM Scrub Air	90 - 95%	47%	Direct Discharge
Trotman Foundry	Statesville, NC	12/75	Operational, Retrofit	5.0 T/hr	Coke (0.5% Sulfur); Scrap Iron	CFM Scrub Air	90 - 95%	47%	Direct Discharge
TILES AND ONE ROASTING									
Gretilite, Inc.	San Clemente, CA	1973	Operational, New	600 ps/day	Clay Kiln (clay: 5% Sulfur; Met. Gas: 0.5% Sulfur)	Century FWP-100	97%	50 - 60%	N/A
Doral Sierra Corp.	Saharita, AZ	1970	Operational, New	4.0 T/hr (2 roasters)	Molybdenum Chloride Roaster; Molybdenum Sulfide	V.O.P. Lime Scrubber	N/A	95 - 98%	A bleed stream is pH conditioned
FWC Industrial Chemical Division	Roberto, CA	1971	Operational, Retrofit	2 klines	Benzene Shortumore & Coke (6-12% Sulfur) fired w/Met. Gas	FWC Double Alkali	N/A	99%	Filler Coke to landfill
Formosa, Inc.	Corcoran, CA	1974	Operational, New	25 T/hr (2 klines)	Coal (3-4% Sulfur)	Century FWP-100 Scrubbing	97%	50 - 60%	Sludge is cycled to pond then trucked to quarry
Corchem/Chemicals Products Div.	Sacramento, CA	7/75	Operational, Retrofit	Confidential (2 klines)	H ₂ O production, perlase process, Met. Gas firing	Kaiser High Density Scrubber	99%	90%	Thickened slurry, overflow back to scrubber
PULP AND PAPER PROCESSING									
Budger Paper Co.	Madison, WI	1973	Operational, Retrofit	100 T/Day Pulp	Calcium-Based Pulp Mill	Carleton Engineering/Peabody Eng.	Not Tested	Not Tested	Calcium Sulfite/Bisulfite liquor recycled
Boise Cascade Paper Co.	Salmon, OR	7/72	Operational, New	315 T/Day Pulp	Ammonium-Based Pulp Mill	Solite Cascade Ammonia-Scrubbing	95 - 98%	85 - 98%	(NH ₄) ₂ SO ₄ /MgSO ₄ liquor recycled
Flint-Pruyn and Co., Inc.	Glenn Falls, NY	1960	Operational, Retrofit	254 T/Day Pulp	Ammonium-Based Pulp Mill	CEA-Finch Proxm. MTS Scrubbing	90%	99%	Scrubbing liquor returned to pulp process
Georgia-Pacific Paper Co.	Louisville, KY	1973	Operational, Retrofit	174 T/Day Pulp	Sulfite-Based Pulp Mill	Carleton Eng./Kron Eng.	99.2-99.6%	90%	Sodium Carbonate/Sulfite/Sulfate liquor
Great Southern Paper Co.	Cedar Springs, GA	N/A	Operational, New	N/A	Paper Mill	Air Pol Caustic Scrubbing	N/A	N/A	Scrubbing liquor returned to pulp process
Whitcomb Papers, Inc.	Port Edwards, WI	1974	Operational, Retrofit	325 T/Day Pulp	Ammonium-Based Pulp Mill	CFM Magniflex Scrubbing	Collected	90%	Magnesium Sulfite/Bisulfite liquor recycled
Witac Paper Co.	Buffalo, NY	N/A	Operational, New	14.5 MW (2)	Paper Mill	Carleton Engineering	N/A	N/A	Sent to scrubber of nearby plant
Publishers Paper Co.	Oregon City, OR	6/74	Operational, Retrofit	500 T/Day Pulp	Ammonium-Based Pulp Mill	Rich Rink Scrubber	N/A	94%	Bleed stream is pH neutralized
Scott Paper Co.	Everett, WA	1/74	Operational, New	500 T/Day Pulp	Ammonium-Based Pulp Mill	Scott Paper Scrubber	95%	90%	(NH ₄) ₂ SO ₄ /MgSO ₄ recycled to pulp process
Sherman Paper Co.	Green Bay, WI	N/A	Operational, New	53.5 MW (1)	Paper Mill	Rich Scrubber	N/A	N/A	Neutralize with NaOH
TEXTILE PROCESSING									
American Thread Co.	Merion, NC	N/A	Operational	4 MW (3)	Textile Mill	W. W. Sly Caustic Scrubbing	N/A	N/A	N/A
Canton Textile Co.	Canton, GA	N/A	Operational	6 MW	Textile Mill	FWC Double Alkali	N/A	N/A	N/A

Sources: Fed Co and EEA

typically recovered as elemental sulfur, thereby eliminating the need for FGD. The high relative cost of gasification technology, however, has prevented its substantial use in this country. This will likely continue to be the case in the foreseeable future, according to a recent study by Battelle Memorial Institute.⁴² But with the incentives for coal utilization provided in the NEP, low-Btu gas and FBC may well appear more attractive relative to FGD technologies. The ensuing effects on solid waste impacts, however, are not considered in this analysis.⁴³

The assumption of a single set of coal characteristics for each Federal region represents a limitation on the analysis since other characteristics would affect the level of environmental control needed, and, therefore, the amount and type of solid waste generated. In most cases the average sulfur and ash content per unit energy of locally available coal is quite similar to the average for all coals actually used in each region at the present time. In general, the assumption of a locally available coal is a conservative one since this leads to a situation in which desulfurization technologies, with their ensuing solid waste impacts, are used to the maximum extent. The range of impurities in local coals, however, can be considerable (e.g., a factor of two for sulfur in many regions), and this could affect any quantitative results should future average regional characteristics shift away from present values.

Finally, since solid waste generation is related directly to the level of coal use, a clear limitation of this study is that only the levels and regional distributions predicted by PIES are considered quantitatively.

3.5 Regional Residuals

Quantitative estimates of the regional solid waste residuals are displayed on Table 12.

Ash Residuals: Columns 1 and 2 show the estimated dry weight of ash collected from the combustion of coal. Some 14 million tons must be disposed of nationally in 1985 in the absence of the NEP, while the increased use of coal anticipated by the NEP would triple this requirement to about 44 million tons per year. Since much of this ash might be collected or temporarily stored in a holding pond prior to disposal, the actual weight of the ultimate waste could be as high as twice these tonnages since typical sedimentation and clarification systems yield a sludge that is generally 40 to 60% solids by

TABLE 12

1985 RESIDUALS BY REGION ASSUMING EACT (in million tons/year)

	<u>1985 Dry Ash Production^a</u>		<u>Maximum Production of FGD Dissolved Solids^c</u>		<u>Maximum Production of FGD Wet Sludges^b</u>	
	<u>Base Case</u>	<u>NEP Increase</u>	<u>Base Case</u>	<u>NEP Increase</u>	<u>Base Case</u>	<u>NEP Increase</u>
1. New England	.017	.306	.004	.093	.010	.253
2. NY/NJ	.456	1.491	.202	.710	.542	1.908
3. Mid-Atlantic	2.567	3.722	.454	1.257	1.217	3.342
4. South Atlantic	2.313	3.747	.457	1.135	1.226	3.045
5. Mid-West	6.135	3.624	2.899	2.033	7.772	5.452
6. South West	1.038	12.590	.057	.894	.153	2.399
7. Central	.485	.494	.139	.387	.374	1.041
8. North Central	.571	1.528	.050	.187	.139	.503
9. West	.169	1.730	.016	.171	.043	.460
10. North West	<u>.637</u>	<u>1.150</u>	<u>.041</u>	<u>.970</u>	<u>.111</u>	<u>.262</u>
U.S. Total	14.451	30.382	4.319	6.964	11.587	18.665

^aActual wet weight will be approximated twice as great for ash that is ponded prior to disposal; this is most likely to be the case where a sludge producing FGD system is also required.

^bAssumes 11.80 lb wet sludge/lb of sulfur removed, characteristic of calcium sulfite/sulfate mixtures from dual alkali systems dewatered to 50% solids.

^cAssumes 4.44lb dissolved solid/lb sulfur removed, characteristic of sodium sulfate from an alkaline liquid scrubbing system; all industrial systems are assumed to be of this type.

weight. Regionally, the greatest disposal needs will occur in the Southwest (Region 6) which is estimated to have the greatest increase in industrial coal use (See Table 10). Locally available coal in the region also contains approximately twice as much ash as in other regions of the country, further adding to the ash disposal problem. The overriding requirement in all regions will be the availability of economically and environmentally acceptable sites for the disposal of collected ash.

Residuals from dissolved solids-producing FGD systems: Columns 3 and 4 show the maximum estimate of the dissolved solids that would result if all industrial FGD systems were of the liquid scrubbing type, with complete oxidation to sulfates. Geographically, the most substantial impacts would occur in the Midwest (Region 5) as well as in the Middle Atlantic and South Atlantic regions of the country (Regions 3 and 4). It is here that the high level of coal use combined with the high sulfur content of local coals produces the greatest quantity of sulfur-bearing wastes to be disposed of.

Residuals from sludge-producing FGD systems: These same regions are also the most significantly affected under the alternative assumption that sludge-producing rather than liquid-producing FGD systems are universally employed in the industrial sector (Columns 5 and 6). Here, quantitative estimates of maximum solid waste impacts are derived assuming a dual alkali system, which is the most prevalent sludge-producing system currently used by industry. For this technology, the environmental disposal problem is similar to that faced by electric utilities using lime/limestone; i.e., the waste sludge is one containing calcium sulfate, calcium sulfite and limestone with an overall solids content of about 50% by weight. As in utility FGD systems, disposal of industrial FGD sludge can be environmentally acceptable if accomplished in the manner elaborated in Section 2.3.5, and if sufficient land is available for disposal.

3.6 Constraint Analysis

Application of the two major categories of FGD system likely to be in use by industry over the next decade will be constrained by rather different considerations of solid waste management. For systems producing a sludge, the key concern will be the availability of disposal sites, whereas for the liquid scrubber systems, the key issue concerns the impact of dissolved solids discharges into municipal sewer systems and natural water bodies.

3.6.1 Land Availability

In contrast to the utility sector, where, as we have seen in Section 2.6.1, sites are frequently of a size that will allow on-site sludge disposal, the ability of industry to dispose of sludge on-site will be much more limited. An exact answer would require analysis at the individual site level, an analysis that goes beyond the scope of this preliminary assessment.

One can, however, derive estimates of the maximum impact at the county level by comparing the magnitude of the sludge produced by industrial FGD systems with municipal refuse and municipal sewage treatment plant sludges produced in the same county. To the extent that the sludge is unstabilized, which, as noted in Section 2.3.3, implies that it would be unsuited for direct landfill disposal, the appropriate comparison is with the quantities of municipal wastewater treatment plant sludge generated at the county level, since a common disposal method would be indicated. Order of magnitude computations for the Northeast, reported elsewhere,⁴⁴ indicate that the increases in sludge attributable to NEP by 1985 represent between 100 and 500% of the wet weight of such municipal treatment plant sludges. Given the well known problems of sludge disposal at municipal sewage treatment plants,⁴⁵ this suggests the presence of strong incentives to provide stabilization of the industrial FGD sludges prior to disposal (or to use a liquid waste producing FGD system).

For a stabilized sludge, that could readily be disposed of in a landfill operation, the appropriate measure of impact is the ratio of additional sludge weight attributable to the NEP to the weight of municipal refuse generated. For the Northeast, the area where solid waste management problems are most severe, order of magnitude computations indicate that the maximum increases at the county level are in the range of 1 to 20%.⁴⁶ This suggests that the additional FGD sludge could probably be accommodated. However, the economics of such stabilization at the industrial plant scale are not well known; and off-site regional processing centers to serve a number of industries would incur significant organizational and institutional obstacles.

3.6.2 Environmental Issues

The environmental impacts of industrial FGD sludge disposal by landfill are quite similar to those indicated for the utility sludges in Section 2.6.2. In general one should note, however, that the sludge produced by the typical

industrial double alkali system has somewhat different physical and leaching characteristics to lime/limestone sludges.

For a number of reasons it is likely that industries that cannot accommodate on-site sludge disposal would move to a liquid scrubbing system. Discharge could be to an existing wastewater treatment system, to a sewer system or a natural watercourse. Whenever off-site sludge disposal is necessary, the cost of sludge transportation dominates the disposal economics, as illustrated earlier on Table 9. Beyond the economic considerations, the "hassle" associated with involvement in local solid waste management problems provides a powerful incentive to use a liquid system, especially where an industry already has other liquid waste streams for which it must provide treatment and neutralization.

The maximum impact of these dissolved solids discharges at the county level have been estimated for the Northeast.⁴⁷ The results indicate a 1985 increase in dissolved solids concentrations in municipal sewer systems attributable to NEP in the range of 20 ppm to 1100 ppm, under worst case assumptions of all industries electing to use such liquid FGD systems. The fact that these concentration increases vary by orders of magnitude from county to county again indicates that more detailed study is warranted.

As to the environmental significance of the dissolved solids (DS) levels indicated, this again is a matter that can only be addressed at the site level. In areas where municipal sewage treatment plant effluents are being considered for recycling (as on Long Island) even small increases of dissolved solids may be unacceptable, since DS will gradually accumulate after many cycles of re-use, and are removed only at great cost and with great difficulty. Similar restrictions may apply in Western areas where already high total dissolved solids levels are of concern. In and of itself, however, a higher DS content of municipal sewage will not affect the usual sewage treatment processes,⁴⁸ and the ions of concern, sodium and sulfate, are neither regarded as hazardous at the concentrations indicated, nor do they constitute algal nutrients that may be of concern where sewage is discharged to lakes and estuaries. However, high sulfate levels (beyond 500 ppm) may be regarded as unacceptable for a drinking water supply.⁴⁹

It is clear, however, that some industries may discharge directly into water bodies, rather than sewage systems, where dilution volumes are such that increased dissolved solids concentrations attributable to industrial discharges would be much less than for DS in sewage. For the Northeast, the likely annual average DS increases in the Connecticut, Hudson and Merrimack Rivers can be computed to 0.71, 1.47 and 3.21 mg/l, respectively, levels that are unlikely to be of concern. During periods of low flow, however, the increases may be more significant. This computation rests on assignment of the FGD system DS discharges from counties to the corresponding river basin, using the total annual basin runoff as the dilution volume.⁵⁰ But a corresponding computation for the Colorado and Rio Grande River basins results in a dissolved solids concentration increase of about 25 ppm, an increase that in view of already serious concerns over the salinity of these rivers may well be unacceptable.⁵¹ These computations, however, are an upper bound in that all industries requiring FGD systems are assumed to elect a system producing a liquid waste. Of course, in these arid areas, an evaporation pond might be used as an alternative disposal strategy; but this option raises the question of the acceptability of additional consumptive water use by evaporation.

An important uncertainty is that the fate of trace and heavy metals in such industrial liquid FGD systems is unknown; and until the data are improved some caution should be exercised, since the nature of the discharge may in fact be much less benign than a consideration of only dissolved solids might indicate.

As to the regulatory aspects of such discharges, it should be noted that under provisions of the 1972 Amendments to the Water Pollution Control Act, industries whose wastes are discharged to publicly owned treatment works (POTW) are required to pretreat their wastes to render harmless substances which would interfere with the operation of the POTW.⁵² Specific pretreatment standards exist for such substances. However, since dissolved solids and sulfates will not generally affect normal POTW operation, and since an industry that discharges into a POTW does not require a permit under PL 92-500,⁵³ there does not appear to be a regulatory obstacle to discharge of FGD system DS provided that the oxidation of sulfite to sulfate is complete. If that process is incomplete, the

sulfite may exert an oxygen demand, in which case treatment operations would be affected. In any event, municipal laws may require a permit even where Federal Law does not so mandate.⁵⁴

In the event of a direct discharge into a water body, industries are required to obtain permits. However, in the EPA development document for the Effluent Limitation Guidelines for the Steam-Electric Power Generating Point source category,⁵⁵ sulfites, sulfates and total dissolved solids (TDS) were rejected as pollution parameters requiring regulation on the basis of their not being controllable. This decision was upheld when EPA published steam electric power generating point source category pretreatment standards for existing sources.⁵⁶ EPA has noted the objectionable character of these pollutants and has identified air pollution devices for SO₂ removal as one of their sources. But, at the present time, sulfates and TDS are not regulated for steam electric power plant discharges, direct or pretreated, for the aforementioned reasons.⁵⁷ Thus it seems unlikely that smaller industrial boilers would be treated any differently.

3.6.3 Economic Issues

There are only very isolated data for the cost of industrial FGD systems, and no reliable reports on the sludge treatment and disposal cost component. At this point, then, very little can be said quantitatively about the economic trade-offs that exist between various FGD systems and waste management options. Precise answers would require a site and industry specific analysis, including the assessment of existing treatment practices for other liquid and solid waste streams that may provide scale incentives to move to either a liquid or sludge producing FGD system. Potential difficulties in off-site sludge disposal arrangements, including the extent of transportation penalties for disposal at regional or municipal facilities, would also need to be evaluated on a case by case basis.

Notes

1. This may be masked, however, if Best Available Control Technology (BACT) to be implemented under the 1977 Amendments to the Clean Air Act, results in the substitution of Interior and Appalachian coals for Western Coal, which have different ash contents.
2. Executive Office of the President, Energy Policy and Planning, "Replacing Oil and Gas with Coal and other Fuels in the Industrial and Utility Sectors," June 2, 1977, p. III-3.
3. The alternative of making exact estimates for the level of market penetration among the currently available systems would impart to the analysis a spurious level of precision that would be quite misleading in view of the uncertainties that prevail.
4. Assuming that all of the additional coal use attributable to NEP is subject to BACT.
5. This assumption is consistent with the judgement of many utilities; the Commonwealth Edison Company, in testimony to the EPA Public Hearing on New Coal Fired Steam Generators SO₂ Emissions, May 26, noted
 "....We further believe that the limestone wet slurry scrubber technology is the only one which could be built today with any hope of satisfactorily reliable operation. Our recent experience with the proposals for a 425 megawatt (MW) installation at our Powerton Station supports this position. The RFP's were issued to six vendors with no constraints imposed as to scrubber technology. We received four responses, with all but one vendor bidding either a limestone or lime wet slurry system. That one vendor bid a regenerative system which has not been tested at demonstration scale."
6. Based on data from the National Ash Association.
7. As based on 1975 FPC data on coal deliveries to Steam Electric Plants. "Annual Summary of Cost and Quality of Steam Electric Plant Fuels, 1975" FPC Staff Report, May 1976.
8. In 1975, for example, 5000 tons of 0.6% sulfur coal were delivered to New York Utilities from Colorado for blending purposes (FPC, note 7, supra, p. 44).
9. EPA, Office of Planning and Evaluation and Executive Office of the President, Energy Policy and Planning "Air Pollution Impacts of the Oil and Gas Replacement Program in the Industrial Sector" June 13, 1977.
10. The sodium alkali and double alkali processes also generate a calcium sulfite/sulfate sludge, but of a different composition than the limestone systems. The result of the double alkali processes is a sludge that is drier and more stable with better handling characteristics than that from a lime or limestone process.

11. For a review of ponding practices, see e.g., Radian Corp "Evaluation of Lime/Limestone Sludge Disposal Options", Report to EPA, Nov. 1973 (NTIS PB 232022). It should be noted that the practice of disposing the ash together with the FGD sludge is quite widespread, and thus many of the potential leachable elements may originate from the ash rather than the sludge itself. Moreover, although ash ponds have been in operation for many years, there has been little concern with environmental contamination either by dissolved solids or by trace elements. On the other hand, due to the very slow rate of leachate movement through soils, it could be many years before a groundwater contamination problem would be discovered by some user downstream of the site.
12. In contrast to these properties of lime/limestone sludges, preliminary results for double alkali scrubbers indicate that unfixed, dewatered sludge resists rewetwatering and forms an air-dried skin soon after disposal-- See e.g., J. FitzPatrick "Control of Leachate from Double Alkali SO₂ Scrubber Sludge Disposal" Joint Power Generation Conference, Long Beach California, Sept. 1977.
13. For a good summary description of these processes, see e.g., Environmental Science and Technology, Vol. 9,7, p. 623, July 1975 ("The Stabilization Game").
14. Relevant federal legislation pertaining to waste disposal includes the Solid Waste Disposal Act of 1965, as amended, the EPA Guidelines for the Land Disposal of Solid Waste, and the recently passed (Oct. 1976) Resource Conservation and Recovery Act (RCRA). The RCRA amends both the Disposal Act and the Guidelines; however, regulations and programs which it authorizes will not be promulgated or implemented until at least 18 months after enactment, i.e., March 1978.
15. See Lunt et al, note 16, infra, p. 191.
16. At the present time no FGD sludge is disposed of in this manner, and a recent comprehensive assessment by the Inter-agency Energy Environment R&D Program concluded that in addition to the usual need for careful case-by-case evaluation, economic feasibility of the most promising environmental option was far from clear cut (R. R. Lunt et al, "An Evaluation of the Disposal of the Flue-Gas-Desulfurization Wastes in Mines and the Ocean: Initial Assessment," EPA-600/7-77-051, 1976, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.) The key problem is the oxygen demand of the sludge, which depends on the proportion of calcium sulfite to calcium sulfate in the sludge. Other potential problems include (1) Inadequate initial dilution of the sulfite-rich sludge would result in sulfite concentrations in excess of lethal doses for fish under laboratory conditions. The effects of sludges under field conditions has not been studied in detail. (2) The solubility of trace metals within the sludge matrix is not known, but during the dumping process the concentration of several trace metals suspended in seawater would exceed recommended levels. (3) Unconsolidated sludge materials dumped on the sea floor would significantly alter the environment of benthic organisms, resulting in substantial population changes, and (4) Suspended sludge particles in transit through the water column may have detrimental effects on fish and other organisms.

17. The continental shelf in the New York Bight, for example, is already undergoing oxygen stress. In 1976 a massive kill of fish and benthic organisms with a catastrophic effect on commercial fisheries occurred off the New Jersey coast. The causes for this oxygen depletion covering thousands of bottom square miles are not thoroughly understood, but may be related to an unusual bloom of phytoplankton plus the combined effects of pollution from the Hudson estuary, sewage sludge dumping and dredge spoil dumping. See e.g., F. W. Barvenik, et al, "An Analysis of Time Dependent Factors Leading to Anoxic Conditions within the Middle Atlantic Bight during 1976," BNL-21943. Brookhaven National Laboratory, Upton, New York 11973 (Special Symp. Conf., International Decade of Ocean Exploration (IDOE), Washington, D.C.) October 15, 1976.
18. See e.g., J. Cavallaro, et al. "Sulfur Reduction Potential of the Coals of the United States" Bureau of Mines Report RI 8118, 1976.
19. The two PIES model runs used by the Administration for estimating the 1985 impacts of the NEP initiatives, over a 1985 base case that corresponds to business as usual with no new significant government incentives, are numbered A148542C (Base Case) and A158569C for the NEP Case.
20. For the Base Case, the problem is that the PIES model cannot accurately simulate the mix of high sulfur coal plants with scrubbers plus low sulfur coal plants without scrubbers that corresponds to the actual situation, where in each region the utilities make their own, and usually different, choices.
21. PEDCO Environmental, "Flue Gas Desulfurization Systems Summary Report," May-June 1977, p. 215.
22. This was based on an examination of the most recent Electric Reliability Council reports to FPC; all coal fired plants listed as coming on line in the years 1982-1985 were assumed to be subject to BACT, and, consistent with the assumptions of this report, would be fitted with scrubbers. The BACT adjustment, therefore, is the total of such capacity minus such plants as listed in the PEDCO report as already having a commitment to scrubbers.
23. FEA "Coal Conversion Program, Final Environmental Impact Statement" Vol. 1, May 1977, p. IV-31.
24. That is not to say, of course, that such sites are necessarily liconced by state and federal agencies without difficulty; the point is more to illustrate that land availability in and of itself does not appear to represent a crucial constraint.
25. Report of Member Electric Systems of the New York Power Pool pertinent to Section 149b of the Public Service Law of New York State, Vol. 2, April 1, 1977.
26. This is based on .47 acre ft/Mw/year for sludge disposal plus .16 acre/ft/Mw/year for ash disposal, as indicated in section 2.3.5 for 80% SO₂ removal and 3.5% sulfur coal. It is obviously conservative for plants scrubbing low sulfur western coal.

27. See e.g., P. P. Leo and J. Rossoff "Control of Waste and Water Pollution from Power Plant Flue Gas Cleaning Systems; First Annual R&D Report", EPA-600/7-76-018, Oct. 1976.
28. Adapted from various tabulations in Lunt et al, note 16, supra.
29. As per New York State Groundwater Classification and Standards, Part 703.
30. See e.g., J. P. Woodyard "The Regulation of Flue Gas Desulfurization Sludge Disposal--Present and Proposed Approaches", Joint Power Generation Conference, Long Beach, California, Sept. 1977.
31. Public Law 93-523; Interim Regulations proposed by EPA in March 1975 (40 Federal Register 11991, March 14); promulgated Dec. 1975.
32. There is considerable research underway to investigate the growth of vegetation directly on flyash disposal sites without the need for additional soil overburden. Research in the U.K. has found that several grasses and vegetables were tolerant of flyashes from alkaline type coals and several studies have been conducted at the Morgantown Energy Research Center on the use of flyash for strip mine reclamation (see e.g., J. P. Kappand and D. W. Gilmore "Soil-making Potential of Power Plant Flyash in Mined-land Reclamation" Third Ash Utilization Symposium IC-8640, U.S. Bureau of Mines, p. 258-279).
33. One conclusion of the first Annual R&D Report of the Inter-Agency Energy-Environment R&D Program perhaps bears mention here (Leo and Rossoff, note 27, supra) "...In summary, chemical treatment by the methods evaluated by this study (Chemfix, Dravo, IUCS) do not tend to reduce leachate concentrations of trace elements but do reduce the concentrations of the major species by a factor of 2 to 4 relative to untreated sludge leachates. However, other effects resulting from chemical treatment, such as reduced permeability and superior disposal placement treatment, are considered significant in reducing the release rate of all the constituents to the soil beneath the treated wastes."
34. PEDCO Environmental "Flue Gas Desulfurization Process Cost Assessment" Report to EPA, May 1975.
35. Specific Cost Estimates are to be found in the 1976 FGD Symposium Proceedings EPA 600/2-76-136a (May 1976); and McGlamery et al "Detailed Cost Estimates for Advanced Effluent Desulfurization Processes" EPA 600/2-75-006, Jan. 1975.
36. Executive Office of the President, note 2, supra.
37. The coal consumption figures in industry for 1975, 1985 Base Case, and 1985 NEP Case are 63, 101 and 278 million tons/yr, respectively.
38. Runs 158569C and 148542C, respectively.
39. EPA, Office of Planning and Evaluation and Executive Office of the President, Energy Policy and Planning, "Air Pollution Impacts of the Oil and Gas Replacement Program in the Industrial Sector" June 13, 1977; our assumptions correspond to Case 2 of page 14.

40. A typical example is a process using a sodium sulfite solution to scrub SO_2 from the flue gas. This forms a solution of sodium bisulfite which is then bled off and neutralized by the addition of sodium carbonate (soda ash), regenerating sodium sulfite. The chemistry is such that half of this can be recycled to the scrubber while the remaining half represents spent solution to be discharged. This waste stream is typically aerated to convert sodium sulfite to sodium sulfate in order to reduce the chemical oxygen demand (COD) of the waste. Table 11 shows that the waste stream is then often discharged directly to a river or sewer system. The oxygen demand of this discharge depends on the level of sodium sulfite still remaining. If the conversion of sulfite to sulfate is complete, the dissolved solids level of the waste stream represents the principal wastewater pollutant associated with this technology.
41. "Application of Fluidized Bed Technology to Industrial Boilers," Exxon Research and Engineering Co. Report to FEA, ERDA and EPA, January 1977.
42. "Synthetic Fuels in the Future of Energy," in Proceedings of the 5th National Symposium, ASME Air Pollution Control Division, June 1977.
43. For a preliminary qualitative assessment of the ramifications of FBC on Solid Waste Management, See e.g., "Preliminary Assessment of the Health and Environmental Impacts of Fluidized Bed Combustion of Coal as Applied to Electric Utility Systems" Argonne National Laboratory, Feb. 1977.
44. T. Le, P. Meier and E. Rubin "Coal Utilization in the Northeast, Vol. VIII: Solid Waste Management Issues and Impacts" BNL 23603, Brookhaven National Laboratory, Upton, NY, February 1978.
45. The controversial disposal of sewage treatment plant sludge from major Northeastern cities by ocean dumping is indicative of these problems, requiring expensive alternative solutions as such dumping is phased out.
46. Le, et al, note 44, supra.
47. Ibid.
48. To the extent that the oxidation of sulfite to sulfate is incomplete (see note 40, supra), however, some impact on municipal sewage treatment plants may be expected, since any remaining sulfite exerts an oxygen demand. Also, under anaerobic conditions, reduction of sulfates to hydrogen sulfide may be of concern. However, such anaerobic conditions in sewer systems are indicative of other problems in municipal waste management and would not be due to increased sulfate discharges.
49. With regard to sulfate, the National Academy of Sciences Recommendations to EPA on drinking Water and Health (Federal Register, Monday, July 11, 1977) noted "No adverse health effects have been noted for concentrations of sulfate in drinking water less than about 500 mg/liter. Diarrhea is the only physiological effect observed at concentrations greater than 1,000 mg/liter. The taste threshold for sulfate in water lies between 300 and 400 mg/liter for most persons, but some are able to detect as little as 200 mg/liter." And for Sodium, the Academy noted "Specification of a 'no-observed-adverse-health-effect' level in water, for which the effect

is associated with total dietary intake and for which usual food intake is already greater than a desirable level, is impossible. Since adult fluid intake averages 1.5-3 liters/day, sodium intake from drinking water represents less than 10 percent of the habitual total intake of 3000-4000 mg so long as the sodium content of the water does not exceed 200 mg/liter. Adverse health effects may be anticipated with sodium concentrations in water greater than 20 mg/liter only for that special risk group restricted to total sodium intake of 500 mg/day, because it is not feasible to reduce intake from food below 440 mg/day. For this group, whose diets must be medically supervised, knowledge of the sodium ion concentration of the drinking water permits prescription of bottled water low in sodium when necessary."

50. As per North Atlantic Regional Water Resources study, Appendix C, U.S. Corps of Engineers, North Atlantic Division, 1972.
51. The normal DS range in the Colorado and Rio Grande Rivers is 100-2000ppm (see e.g., discussion in "Water Quality Criteria", Report by National Technical Advisory Committee to the Secretary of the Interior, Apr. 1968.)
52. FWPCA 402 (b)-(f).
53. Federal Environmental Law, E. L. Dolgin and T. G. P. Guilbert, ed, West Publishing Co. (1974).
54. However, the POTW itself requires an EPA discharge permit, the terms of which may be violated by pollutants introduced into the POTW. In such cases the discharges into the POTW may be subject to restrictions. (FWPCA 4.02 (h)). In some POTW's users may be required to pay a "proportional share" of the construction, Operation and maintenance costs of the facility. (FWPCA 204(b) and 402(b)(9).)
55. U.S. EPA, Development Document for Effluent Limitations Guide for the Steam Electric Power Generating Point Sources Category", 10/74.
56. Federal Register 42:56, pp. 15690-15696, 2/23/77.
57. Note that removal of TDS from waste water is one of the more difficult and expensive treatment procedures, particularly when applied to sodium, calcium and potassium ions. Processes for TDS reduction include reverse osmosis, distillation, ion exchange and electrodialysis, all very expensive.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix A
A Methodology for Electric Utility
Residuals Estimation

This Appendix sets forth the algorithms used to compute the residuals from coal-fired power plants. The dimensions of each term are noted in brackets.

1. Notation

- S = Sulfur content of coal, %
 A = Ash content of coal, %
 G = Generation, in 10^9 Kwh/yr
 f = Required removal fraction for SO_2
 σ = Sludge solids generation rate (lb sludge solids/lb SO_2 removed)
 h = Plant heat rate (Btu/Kwh)
 ρ_s = Specific gravity of sludge solids
 m = Solids content of sludge, weight fraction
 H = Heat content of coal (Btu/lb)
 C = Plant capacity (Mw)

2. Electricity generation, G, from a power plant of capacity C.

If the plant capacity, in Mw, is C, and the plant factor is ρ_f , then

$$G = C \cdot 8760 \cdot \rho_f \cdot \frac{1}{10^9} \cdot 10^3$$

$$\left[\frac{10^9 \text{ Kwh}}{\text{Yr}} \right] \left[\text{Mw} \right] \left[\frac{\text{hrs}}{\text{yr}} \right] \left[\right] \left[\frac{10^9 \text{ Kw}}{\text{Kw}} \right] \left[\frac{\text{Kw}}{\text{Mw}} \right] \quad (1)$$

3. Sulfur content in lb SO_2 /10⁶ Btu [S']

$$S' = S \cdot \frac{1}{100} \cdot \frac{1}{H} \cdot 1.9 \cdot 10^6$$

$$\left[\frac{\text{lb } SO_2}{10^6 \text{ Btu}} \right] = \left[\frac{\text{lb S}}{10^2 \text{ lb Coal}} \right] \left[\frac{10^2 \text{ lb Coal}}{\text{lb Coal}} \right] \cdot \left[\frac{\text{lb Coal}}{\text{Btu}} \right] \left[\frac{\text{lb } SO_2}{\text{lb S}} \right] \left[\frac{\text{Btu}}{10^6 \text{ Btu}} \right]$$

$$= \frac{19000 \text{ S}}{H}$$

Note that exact stoichiometry would require 1.998 lb SO₂/lb S - the difference being that some fraction of the sulfur remains in the ash. 1.9 is the factor in general use.¹

4. Required SO₂ Removal Fraction, f

Four cases must be considered, as follows

(a) For 80% SO₂ removal, f = .8

(b) For 90% SO₂ removal, f = .9

(c) For NSPS of 1.2 lb SO₂/10⁶ Btu

$$f = 1 - \frac{1.2 H}{19000 S} \quad \text{if } f > 0$$

$$f = 0 \quad \text{if } f \leq 0$$

(d) For NSPS of 0.6 lb SO₂/10⁶ Btu

$$f = 1 - \frac{0.6 H}{19000 S} \quad \text{if } f > 0$$

$$f = 0 \quad \text{if } f \leq 0$$

5. Ash Production, 10⁶ tons/yr [W_A]

Defining f_F = fraction of ash to bottom ash

ε = precipitator efficiency

$$W_A = G \cdot 10^9 \cdot h \cdot \frac{1}{H} \cdot \frac{A}{100} [1 - f_F(1 - \epsilon)] \cdot \frac{1}{2000} \cdot \frac{1}{10^6}$$

$$\left[\frac{10^9 \text{ Kwh}}{\text{Yr}} \right] \left[\frac{\text{Kwh}}{10^9 \text{ Kwh}} \right] \left[\frac{\text{Btu}}{\text{Kwh}} \right] \left[\frac{\text{lb}_c}{\text{Btu}} \right] \left[\frac{\text{lb}_{\text{Ash}}}{\text{lb}_c} \right] \left[\frac{\text{ton}}{\text{lb}} \right] \left[\frac{\text{MMt}}{\text{ton}} \right]$$

$$= \frac{G h A \{1 - f_F(1 - \epsilon)\}}{200 H} \left[\frac{\text{MMt}}{\text{yr}} \right] \quad (2)$$

6. Ash Landfill Acreage Requirements, acres/yr [L_A]

If δ_A is the disposal density of ash solids, then

¹See e.g. AP42, "Compilation of Air Pollution Emission Factors" EPA, 2nd Edition, April 1973.

$$L_A = W_A \cdot 2 \times 10^9 \cdot \frac{1}{\delta_A} \cdot \frac{1}{d} \cdot \frac{1}{43560}$$

$$\left[\frac{\text{MMt}}{\text{yr}} \right] \left[\frac{\text{lb}}{\text{MMt}} \right] \left[\frac{\text{cu.ft}}{\text{lb}} \right] \left[\frac{1}{\text{ft}} \right] \left[\frac{\text{acres}}{\text{ft}^2} \right]$$

$$= \frac{45913 W_A}{\delta_A d} \left[\frac{\text{acres}}{\text{yr}} \right] \quad (3)$$

7. Sludge Solids, in MMt/yr $\left[W_s \right]$

$$W_s = G \cdot 10^9 \cdot h \cdot \frac{19000S}{H} \cdot \frac{1}{10^6} \cdot \frac{1}{2000} \cdot \sigma \cdot f \cdot \frac{1}{10^6}$$

$$\left[\frac{10^9 \text{Kwh}}{\text{yr}} \right] \left[\frac{\text{Kwh}}{10^9 \text{Kwh}} \right] \left[\frac{\text{Btu}}{\text{Kwh}} \right] \left[\frac{\text{lb SO}_2}{10^6 \text{Btu}} \right] \left[\frac{10^6 \text{Btu}}{\text{Btu}} \right] \left[\frac{\text{tons}}{\text{lb}} \right] \left[\frac{\text{lb Solids}}{\text{lb SO}_2} \right] \left[\right] \left[\frac{\text{MMt}}{\text{tons}} \right]$$

$$W_s = \frac{.0095 G h s \sigma f}{H} \left[\frac{\text{MMt}}{\text{y}} \right]$$

For lime/limestone scrubber, σ has a typical value of 2.83.²

8. Wet weight of sludge, MMt/yr $\left[W_w \right]$

$$W_w = \frac{W_s}{m} = \frac{.0095 G h s \sigma f}{mH} \left[\frac{\text{MMt}}{\text{yr}} \right] \quad (4)$$

9. Sludge Volume, in MM cu.yds/yr $\left[V \right]$

If ρ_s is the density of sludge, in lb/cu.ft

hence $V = W_w \cdot 2 \times 10^9 \cdot \frac{1}{\delta_s} \cdot \frac{1}{27} \cdot \frac{1}{10^6}$

$$\left[\frac{\text{MMt}}{\text{yr}} \right] \left[\frac{\text{lb}}{\text{MMt}} \right] \left[\frac{\text{cu.ft}}{\text{lb}} \right] \left[\frac{\text{cu.yd}}{\text{cu.ft}} \right] \left[\frac{\text{MM cu.yd}}{\text{cu.yd}} \right]$$

$$= \frac{74.07 W_w}{\delta_s} \left[\frac{\text{MM cu.yd}}{\text{yr}} \right]$$

²As based on results reported to EPA from 9 plants using either lime or limestone wet scrubbers, and presented in the Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Steam Electric Generating Point Source Category, #440-1-73/029, March 1974. This value is also used in the FEA Final Environmental Impact Statement for ESECA.

10. FGD Sludge Landfill Acreage Requirements, in acres/yr $[L_s]$

If d = depth of the pond, in ft,

$$\begin{aligned}
 L_s &= V \cdot 27 \cdot \frac{1}{d} \cdot 10^6 \cdot \frac{1}{43560} \\
 &\left[\frac{\text{MM cu.yd}}{\text{yr}} \right] \left[\frac{\text{cu.ft}}{\text{cu.yd}} \right] \left[\frac{1}{\text{ft}} \right] \left[\frac{\text{cu.yd}}{\text{MM cu.yd}} \right] \left[\frac{\text{acre}}{\text{ft}^2} \right] \\
 &= \frac{619.83}{d} V
 \end{aligned} \tag{5}$$

11. Assumptions used in this report

Unless otherwise noted, the following assumptions are used in this report to determine solid waste production from a new coal fired power plant of capacity C Mw:

- . Plant heat rate, h = 10,000 Btu/Kwh
- . Plant factor, $P_f = 0.65$
- . Fraction of ash to bottom ash, $f_F = .50$
- . Precipitator efficiency, $\epsilon = .995$
- . Depth, in feet, of disposal pond, d = 30
- . Disposal density of ash solids, $\delta_A = 80$
- . Sludge solids generation rate (lb of sludge solids/lb of SO_2 removed),
- . Solids content of sludge, weight fraction, m = 0.5
- . Density of sludge solids, $\rho_s = 80$
- . Required SO_2 removal fraction, f = 0.80

With those assumptions and equations (1) to (5) above, we obtain:

. Ash production, 10^6 tons/yr/MW $[W_A]$

$$W_A = 0.284 \frac{A}{H} \tag{6}$$

. Ash landfill acreage requirement, acres/yr/MW $[L_A]$:

$$L_A = 5.433 \frac{A}{H} \tag{7}$$

$$\begin{aligned}
 & \cdot \text{ Wet weight of FGD sludge, } 10^6 \text{ tons yr/Mw} \quad \left[\dot{W}_W \right] : \\
 W_W &= 2.449 \frac{S}{H} \quad (8)
 \end{aligned}$$

$$\begin{aligned}
 & \cdot \text{ FGD Sludge landfill acreage requirement, in acres/yr,} \quad \left[L_S \right] \\
 L_S &= 46.848 \frac{S}{H} \quad (9)
 \end{aligned}$$

Thus a 1,000 Mw power plant using coal of heat content 11,000 Btu/lb with a 12% ash content and 3% sulfur content will produce about 310,000 tons of dry ash and 570,000 tons of wet FGD sludge per year, requiring disposal areas of 6 and 13 acres respectively.

Appendix B:
Supporting Tables For Industrial Analysis

TABLE 13
ASSUMED USE OF FGD SYSTEMS IN 1985
 (As a percent of all coal used in the indicated category)

<u>FEA/EPA Region</u>	<u>With Current Air Pollution Standards (a)</u>			<u>With BACT Air Pollution Standards (b)</u>		
	<u>Existing Sources</u>	<u>New Large</u>	<u>New Small</u>	<u>Existing Sources</u>	<u>New Large</u>	<u>New Small</u>
1 New England	0	75	0	0	100	75
2 NY/NJ	90	90	90	90	100	90
3 Mid-Atlantic	15	70	15	15	100	50
4 South-Atlantic	0	60	0	0	100	15
5 Mid-West	30	75	30	30	100	35
6 South West	0	10	0	0	100	10
7 Central	0	30	0	0	100	30
8 North Central	15	15	15	15	100	15
9 West	50	50	50	50	100	50
10 North West	15	50	15	15	100	50

(a) Corresponding SO₂ removal efficiency is assumed to be as follows: for new large sources (>25Mw), 80% in all regions; for new small sources and existing sources, 68% in Region 2, 59% in Region 3, 72% in Region 5, and 80% in Regions 8, 9, 10. This meets NSPS levels for new large sources, SIP levels for existing and new small.

(b) Corresponding SO₂ removal efficiency is assumed to be 80% for all new sources (large and small), and the same as in footnote (a) for all existing sources. This is assumed to yield an 80% reduction for new large sources and an average emission rate of 1.5 lb SO₂/10⁶ Btu for new small sources.

Source: Executive Office of the President.

TABLE 14
DISTRIBUTION OF INDUSTRIAL COAL USE: 1985 BASE CASE
(10¹² Btu)

FEA/EPA Region	Total Coal Use(a)	Existing Sources		New Large Source (>25Mw) ^(c)			New Small Sources (<25Mw)		
		Total ^(b)	FGD ^(d)	Total	FGD w/ NSPS ^(d)	FGD w/ BACT ^(e)	Total	FGD w/ SIP ^(d)	FGD w/ BACT ^(e)
1 New England	4.8	3.29	0	0.75	0.56	0.75	0.75	0	0.56
2 NY/NJ	86.5	44.14	39.73	21.17	19.05	21.17	21.17	19.05	19.05
3 Mid-Atlantic	382.8	231.02	34.65	75.87	53.11	75.87	75.87	11.38	37.94
4 South Atlantic	368.4	147.76	0	110.32	66.19	110.32	110.32	0	16.55
5 Mid-West	1044.1	406.65	122.00	318.72	239.04	318.72	318.72	95.62	111.55
6 South West	99.8	26.54	0	36.62	3.66	36.62	36.62	0	3.66
7 Central	83.3	52.80	0	15.26	4.58	15.26	15.26	0	4.58
8 North Central	98.8	34.63	5.19	32.09	4.81	32.09	32.09	4.81	4.81
9 West	36.2	6.10	3.05	15.05	7.53	15.05	15.05	7.53	7.53
10 North West	68.6	17.98	2.70	25.30	12.65	25.30	25.30	3.80	12.65
U.S. Total	2270.6	968.35	207.32	651.14	411.18	651.14	651.14	142.19	218.88

(a) Based on PIES model coal projections.

(b) Assumes existing (1975) sources retire at 3% per year during 1975-85, and that all sources have same load factor.

(c) Assumes large and small new sources each consume 50% of coal used by all new sources(based on 1974 MFBI survey).

(d) Allocated according to Table 13, under current regulation.

(e) Allocated according to Table 13, assuming BACT.

TABLE 15

DISTRIBUTION OF 1985 REGIONAL COAL USE INCREASES DUE TO NEP

(10¹² Btu)

FEA/EPA Region	Increase Over 1985 Base Case (a)	Existing Sources		New Large Sources (>25Mw ^(c))			New Small Sources (<25Mw)		
		Total ^(b)	FGD ^(d)	Total	FGD w/ NES ^(a)	FGD/ BACT ^(e)	Total	FGD w/ SIP ^(d)	FGD w/ BACT ^(e)
1. New England	86.9	49.92	0	18.40	13.86	18.48	18.48	0	13.86
2 NY/NJ	282.5	39.94	35.95	121.30	109.17	121.30	121.30	109.17	109.17
3 Mid Atlantic	553.1	49.92	7.49	251.59	176.11	251.59	251.59	37.74	125.79
4 South Atlantic	597.0	49.92	0	273.55	164.13	273.55	273.55	0	41.03
5 Midwest	615.0	89.86	26.96	262.56	196.92	262.56	262.56	79.76	91.90
6 South West	1155.2	0	0	577.58	57.76	577.58	577.58	0	57.76
7 Central	84.9	0	0	42.43	12.73	42.43	42.43	0	12.73
8 North Central	264.6	0	0	132.29	19.84	132.29	132.29	19.84	19.84
9 West	370.4	0	0	185.18	92.59	185.18	185.18	92.59	92.59
10 North West	123.8	0	0	61.90	30.95	61.90	61.90	9.28	30.95
U.S. Total	4133.3	279.55	70.39	1926.86	874.06	1926.86	1926.86	347.38	595.62

(a) Based on PIES model coal projections.

(b) Assumes existing (1975) sources retire at 3% per year during 1975-85, and that all sources have same load factor.

(c) Assumes large and small new sources each consume 50% of coal used by all new sources (based on 1974 MFBI survey).

(d) Allocated according to Table 13, current Standards.

(e) Allocated according to Table 13, BACT Standards.

TABLE 16

ESTIMATED FGD USE ASSUMING BACT

10¹² Btu of coal scrubbed^a
(Approx. no. of combustors^a)

	1985 Base Case (b)				Increases Due to NEP (c)			
	Existing Sources	New Large	New Small	Total	Existing Sources	New Large	New Small	Total
1 New England	0 (0)	.75 (1)	.56 (1)	1.31 (2)	0 (0)	18.48 (11)	13.86 (32)	32.34 (43)
2 NY/NJ	39.73 (23)	21.17 (12)	19.05 (44)	79.95 (79)	35.95 (21)	121.30 (70)	109.17 (251)	266.42 (342)
3 Mid-Atlantic	34.65 (20)	75.87 (44)	37.94 (87)	148.46 (151)	7.49 (4)	251.59 (14)	125.79 (290)	384.87 (308)
4 South Atlantic	0 0	110.32 (63)	16.55 (38)	125.87 (101)	0 0	273.55 (156)	41.03 (95)	314.58 (251)
5 Mid-West	122 (70)	318.72 (183)	111.55 (256)	552.27 (509)	26.96 (15)	262.56 (150)	91.90 (212)	381.42 (377)
6 South West	0 0	36.62 (21)	3.66 (8)	40.28 (29)	0 0	577.58 (330)	57.76 (133)	635.34 (463)
7 Central	0 0	15.26 (9)	4.58 (11)	19.84 (32)	0 0	42.43 (24)	12.73 (30)	55.16 (54)
8 North Central	5.19 (3)	32.09 (18)	4.81 (11)	42.09 (32)	0 0	132.29 (76)	19.84 (46)	152.13 (122)
9 West	3.05 (2)	15.05 (9)	7.53 (17)	25.63 (28)	0 0	185.18 (106)	92.59 (213)	277.77 (319)
10 North West	2.70 (2)	25.30 (15)	11.65 (27)	39.65 (44)	0 0	61.90 (35)	30.95 (72)	92.85 (107)
U.S. Total	207.32 (120)	651.14 (375)	217.88 (500)	1,076.35 (995)	70.40 (40)	1,926.86 (972)	595.62 (1374)	2,592.88 (2386)

^aApprox. No. of combustors indicated in parentheses: assumes all units at 50% annual average capacity factor, with average plant sizes of 40 Mw for existing and new large facilities, 10 Mw for new small units.

^bfrom Table 14.

^cfrom Table 15.

TABLE 17

ESTIMATED PRODUCTION OF DRY ASH FOR ALL AIR POLLUTION CONTROL SCENARIOS
(million tons per year)^(a)

FEA/EPA Region	Average Coal Ash ^(b) (lbs/10 ⁶ Btu)	1985 Base Case				Increase Due to NEP			
		Existing Sources	New Large	New Small	Total	Existing Sources	New Large	New Small	Total
1 New England	7.1	0.012	0.003	0.003	0.017	0.176	0.065	0.065	0.306
2 NY, NJ	10.6	0.233	0.112	0.112	0.456	0.211	0.640	0.640	1.491
3 Mid-Atlantic	13.4	1.555	0.511	0.511	2.567	0.336	1.693	1.693	3.722
4 South Atlantic	12.5	0.928	0.693	0.693	2.313	0.313	1.717	1.717	3.747
5 Mid-West	11.7	2.390	1.873	1.873	6.135	0.538	1.543	1.543	3.624
6 South West	21.7	0.289	0.399	0.399	1.088	0	6.295	6.295	12.590
7 Central	11.6	0.308	0.089	0.089	0.485	0	0.247	0.247	0.494
8 North Central	11.5	0.200	0.185	0.185	0.571	0	0.764	0.764	1.528
9 West	9.3	0.028	0.070	0.070	0.169	0	0.865	0.865	1.730
10 North West	18.5	0.168	0.235	0.235	0.637	0	0.575	0.575	1.150
U.S. Total		6.111	4.170	4.170	14.451	1.574	14.404	14.404	30.382

(a) Actual wet weight will be approximated twice as great for ash that is ponded prior to disposal; this is most likely to be the case where an FGD system is also required.

(b) Assuming use of locally available coal.

TABLE 18
ESTIMATED MAXIMUM PRODUCTION OF FGD DISSOLVED SOLIDS
ASSUMING BACT^a (million tons/yr)

FEA/EPA Region	Average Coal Sulfur(b) (lb SO ₂ / 10 ⁶ Btu)	1985 Base Case				Additional NEP Impacts			
		Existing Sources	New Large	New Small	Total	Existing Sources	New Large	New Small	Total
1 New England	3.3	0	.002	.002	.004	0	.053	.040	.093
2 NY/NJ	3.1	.092	.058	.052	.202	.083	.330	.297	.710
3 Mid-Atlantic	3.7	.084	.247	.123	.454	0.017	.827	.413	1.257
4 South Atlantic	4.1	0	.397	.060	.457	0	.987	0.148	1.135
5 Mid-West	6.1	.590	1.712	.598	2.899	.130	1.409	.494	2.033
6 South West	1.6	0	.052	.005	.057	0	0.813	0.081	0.894
7 Central	8.0	0	.107	.032	.139	0	.298	.089	0.387
8 North Central	1.4	.006	.038	.006	.050	0	.163	.024	.187
9 West	0.7	.002	.010	.004	.016	0	.114	.057	.171
10 North West	1.2	<u>.003</u>	<u>.026</u>	<u>.012</u>	<u>.041</u>	<u>0</u>	<u>.065</u>	<u>.032</u>	<u>.097</u>
U.S. Total		.777	2.649	0.894	4.319	.230	5.059	1.675	6.964

^a Assumes 4.44lb dissolved solid/lb Sulfur removed, characteristic of Sodium Sulfate from an alkaline liquid scrubbing system.

TABLE 19
ESTIMATED MAXIMUM PRODUCTION OF WET SLUDGE ASSUMING BACT^a
(million tons/year)

FEA/EPA Region	Average Ccal Sulfur ^b (lb SO ₂ /10 ⁶ Btu)	1985 Base Case				Additional NEP Impacts			
		Existing Sources	New Large	New Small	Total	Existing Sources	New Large	New Small	Total
1 New England	3.3	0	.005	.005	.010	0	.144	.109	.253
2 NY/NJ	3.1	.247	.156	.139	.542	.224	.887	.797	1.908
3 Mid-Atlantic	3.7	.224	.663	.330	1.217	.047	2.197	1.098	3.342
4 South Atlantic	4.1	0	1.066	.160	1.226	0	2.648	0.397	3.045
5 Mid-West	6.1	1.581	4.587	1.604	7.772	.349	3.781	1.322	5.452
6 South West	1.6	0	.139	.014	.153	0	2.180	0.219	2.399
7 Central	8.0	0	.287	.087	.374	0	0.800	0.241	1.041
8 North Central	1.4	.017	.106	.016	.139	0	.437	.066	.503
9 West	0.7	.005	.026	.012	.043	0	.307	.153	.460
10 North West	1.2	.058	.071	.033	.111	0	.174	0.088	0.262
U.S. Total		2.081	7.106	2.400	11.587	0.620	13.555	4.490	18.665

^aAssumes 11.80 lb Wet Sludge/lb of sulfur removed, characteristic of Calcium Sulfite/Sulfate Mixtures from dual alkali systems dewatered to 50% solids.

^bAssuming use of locally available coal.