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**ANALYSIS OF ENVIRONMENTAL FACTORS AFFECTING TECHNOLOGY
DEPLOYMENT: A CASE STUDY**

By
Caldwell D. Meyers
Edward H. Pechan

September 1979

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Caldwell D. Meyers
Environmental Consultants
Baltimore, Maryland

U. S. DEPARTMENT OF ENERGY

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AFFECTING TECHNOLOGY DEPLOYMENT:
A CASE STUDY

PREPARED BY:

CALDWELL D. MEYERS
AND
EDWARD H. PECHAN

FOR:

U.S. DEPARTMENT OF ENERGY, OFFICE OF RESOURCE APPLICATIONS

Caldwell D. Meyers
Environmental Consultants
Baltimore, Maryland

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EXECUTIVE SUMMARY

This report results from a study conducted to assess the market potential and the environmental implications of achieving this potential for atmospheric and pressurized fluidized bed and combined cycle electric generation technologies. The time frame for the study was between the present and the end of the century. Three utility power pools representing areas expecting significant increases in electric demand were assessed.

Results from the study indicate that a significant share of projected air pollution emission increases can be prevented by new technology deployment. While firm data are not available, it is likely that emission increases of the magnitude of those expected in the absence of new technology availability will not be permitted, even under present environmental standards, such as nonattainment or prevention of significant deterioration (PSD) provisions. Thus, deployment of the new technologies would not only provide social benefits by reducing pollution but perhaps permit further use of the nation's abundant coal reserves.

The potential benefits of the new technologies are both economic and environmental. If these advantages are to be substantially realized before the beginning of the next century, however, additional Federal efforts will be required to demonstrate the viability of the new technologies.

I. INTRODUCTION

A. Overview

A study was conducted for the Office of Resource Applications, U.S. Department of Energy (DOE), to assess the potential market and possible market penetration of four electric baseload generating technologies employing coal combustion, in three selected geographic areas of the U.S., within the time frame between the present and the year 1998. The major focus was on quantification of environmental performance of these technologies and relation of environmental performance to environmental constraints identified in the study area.

The technologies under consideration were all coal-fired electric generation of the following types:

- conventional steam-electric generation with flue gas scrubbers for desulfurization* (the baseline technology),
- steam-electric generation utilizing atmospheric fluidized bed combustion (AFBC),
- Steam-electric generation utilizing pressurized fluidized bed combustion (PFBC), and
- electric generation utilizing combined cycle turbines (CC).

Three geographic areas corresponding to utility power pools were selected for study: peninsular Florida, a southern region (most of the states of Alabama, Georgia, and Mississippi), and part of the state of Texas (see Figure 1.1). These selections

* Known as flue gas desulfurization or FGD.

Figure 1.1. Areas selected for study.

were made on the following factors:

- Trends in electrical demand indicating a high potential for growth and, thus, an appropriate market for new electric generation,
- An economic and reliable supply of coal, the fuel under study, and
- The existence of potential siting constraints to location of coal combustion facilities resulting from environmental regulation, such as nonattainment or prevention of significant deterioration (PSD).

A summary of findings and conclusions is presented in the remainder of this chapter; in Chapter 2, the analytic approach is presented; in Chapter 3, the technology specific environmental factors are presented; in Chapter 4, information on the growth in generation is presented; and in Chapter 5, the environmental implications of deployment of the new technologies is explored.

B. Findings

Results of this study lead to the following conclusions:

- Environmental concerns play a significant role in utility planning for growth and in the selection of new technologies. Spokesmen for the utilities indicate that both nuclear and coal figure prominently in growth of the immediate future but evince an active interest in new technologies.
- For the 10-year horizon, technology-based New Source Performance Standards (NSPS) for air emissions appear to be of greater significance than other air regulations (nonattainment or prevention of significant

deterioration provisions) or regulation of water or solid waste. However, our analysis indicates that nonattainment and/or PSD may take on an increasing significance in the future.* In Appendix A, major environmental regulations affecting the utilities industry are reviewed.

- The potential market for new technologies, defined as generation to be added between 1988 and 1998, is projected to range from 22 to 52 units of 600 MWe capacity.
- The new technologies under study here appear to provide substantial environmental benefit. Emission reductions of almost 50% for Total Suspended Particulates (TSP) and approximately 75% for Sulfur Oxides (SO_x) and Nitrogen Oxides (NO_x) are possible when compared to baseline emissions. These reductions are significant even when measured against total regional emissions. New technology penetration of 50% of the anticipated 1988 to 1998 coal-fired generation could result in reductions in incremental 1985 to 1995 SO_x and NO_x emissions of more than 20% in the Texas area and more than 10% in the Florida and Southern states areas.

* A possible problem could occur for the new technologies if stringent NSPS regulations are imposed which would adversely affect their current economic advantage.

C. Conclusions and Recommendations

These results indicate that a significant share of projected emission increases can be prevented by deployment of AFBC, PFBC, and CC units. While firm data are not available, it is likely that emission increases of the magnitude of those projected to occur in the absence of new coal-using technology deployment (shown in Table 5.3) will not be permitted, even under present nonattainment or PSD provisions. Thus, deployment of the new technologies would not only provide social benefits by reducing pollution but perhaps permit further use of the nation's abundant coal reserves.

The potential benefits of the new technologies are both economic and environmental. If these advantages are to be substantially realized before the beginning of the next century, however, additional Federal efforts will be required to demonstrate the viabilities of the new technologies. Based on nearness to commercial acceptability, the technologies under study would rank as follows:

- Atmospheric Fluidized Bed Combustion
- Pressurized Fluidized Bed Combustion
- Combined Cycle

Based on environmental performance, the new technologies rank in the opposite order:

- Combined Cycle
- Pressurized Fluidized Bed Combustion
- Atmospheric Fluidized Bed Combustion

The reluctance of utility officials to commit to these new technologies is not surprising given the regulatory structure of the utility industry; there is simply no incentive for selection of a technology involving a higher degree of risk. Since the utilities feel that they can meet environmental requirements in their service areas through conventional technologies (at least in the area under study), environmental regulations alone are unlikely to trigger selection of unusual technologies. This situation will probably continue for the next decade, the period of immediate utilities planning.

II. ANALYTIC APPROACH

A. Introduction

As indicated in the introduction, the purpose of this study was to assess potential markets for "near-term" coal-fired base-load electric generating technologies and to examine the environmental implications of various levels of market penetration and electric demand.

Major factors influencing the analytic approach were: (1) the technologies under consideration, (2) the study areas selected, and (3) environmental factors. The technologies were identified by the study sponsor, Resource Applications; the study areas were selected by the contractor and approved by Resource Applications. The set of environmental factors examined here developed from our identification of issues of likely significance; the availability of data also influenced this selection.

B. Technologies Studied

The overview presented in this section includes (a) characteristics of the technologies, (b) environmental controls required for their operation, and (c) the status of their development.

1. Conventional

a. characteristics

Conventional or baseline technology is a direct-

fired system in which the heat of combustion produces steam in a boiler to drive a steam turbine. Characteristics of the units depend on design specifications.

b. environmental controls

Current NSPS require flue gas desulfurization (FGD) scrubbers for SO_x control and baghouses* for particulate control. NO_x control is achieved through adjustments in the flame.

c. status of development

This technology is readily available although serious reservations have been expressed regarding reliability of the FGD controls, an entirely separate and intricate technology.

2. Fluidized Bed Combustion

a. characteristics

In this direct-fired system, coal is burned in a bed of inert ash and limestone or dolomite. The bed is "fluidized" by air injection through the bottom of the bed. As in the conventional technology, combustion heat is used to produce steam and drive a steam turbine.

* It appears unlikely that new TSP standards can be met with only electrostatic precipitators.

b. environmental controls

Most of the sulfur contained in the coal is captured in the bed by bonding to calcium, in effect containing the sulfur in a solid form. The bed can be adjusted for rate of capture by particle size of the stone and by air injection, both design features of the units. Increasing sulfur removed by these methods increases operating costs. Particulate emissions due to the particles of the stone and unburned coal must be controlled by baghouses to meet the new NSPS standards. As with conventional technologies, NO_x is controlled by flame adjustments.

c. status of development

Atmospheric fluidized bed combustion is in a more advanced state than pressurized; pilot AFBC units are in operation in a number of locations in the U.S. with a major experiment under way in Alliance, Ohio. Problems with the technology include corrosion of boiler tubes, difficulties in distributing air to the bed and high carry-off of unburned coal particles.

3. Combined Cycle

a. characteristics

Combined cycle conceptually differs from the other technologies since hot combustive gases directly drive a turbine without the intermediary of steam. Heat

exhausted from the turbine is captured to heat water to steam in a conventional boiler and this is used in a subsequent steam turbine stage. Direct use of this heat increases the thermal efficiencies of this technology over the others.

b. environmental controls

Combustion gases in combined cycle must be cleaned prior to their introduction into the first stage turbine; thus, environmental control is an inherent and necessary part of the process.

c. status of development

Combined cycle uses oil or gas (may be coal-derived) as fuel but it is not yet a well-advanced technology. Problems lie in materials to withstand the heat and corrosive impact of particles in the hot gases.

C. Areas Selected

The areas selected have (1) relatively high growth in demand for electricity, (2) coal available and in current use, and (3) potential benefits from improved environmental performance of generating technologies.

An initial examination identified several large areas meeting these criteria: Federal Regions IV, V, VI and IX (see Table 2.1). We considered analysis at the following levels: Federal Regions, Reliability Council regions, states and power pools. A draft report prepared for Resource Applications and summarizing the

Table 2.1. Federal Regions and component states identified as possible areas of study

<u>Federal Region</u>	<u>Component States</u>
IV	Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee
V	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin
VI	Arkansas, Louisiana, New Mexico, Oklahoma, Texas
IX	Arizona, California, Nevada

advantages and disadvantages of each is provided as Appendix F. Findings presented in this report resulted in the decision to perform the analysis at the power pool level primarily because decisions concerning technological deployment are made at that level; each power pool is self-sufficient and must justify the results of its planning to the member utilities and their stockholders.

From the Federal Regions mentioned above, three power groups were finally selected: the Southern Company System, the Florida subregion, and the Texas Utilities Company System. California, constituting part of Federal Region IX, was not selected because of its size and demographic complexity, lack of recent coal use, and the stringency of state environmental regulations.

Utilities in the three areas are shown in Table 2.2.

Results from the study reinforced our initial conviction that power pools were the best available unit for analysis. Siting options and constraints, environmental or otherwise, planning units used by the utilities, correspond to these areas; selection of larger areas, such as Federal Regions, is not appropriate for this study because these are essentially artificial regional designations set up for data collection, not utility planning. For example, demand in the state of Michigan is unlikely to be met through increased generation in the state of Wisconsin; yet these states are in the same Federal region.

Table 2.2. Power pools and major associated utilities under study.*

<u>Power Pools</u>	<u>Associated Utilities</u>
Texas Utilities Company System	Dallas Power and Light Co. Texas Electric Service Co. Texas Power and Light Co.
Florida Electric Power Coordinating Group	Florida Power and Light Co. Florida Power Corporation Tampa Electric Company Jacksonville Electric Authority Orlando Utilities Commission
Southern Company System	Alabama Power Company Georgia Power Company Gulf Power Company Mississippi Power Company

* Where appropriate, smaller municipally-owned systems were included. Many of these systems do not themselves own generating facilities, but purchase power from the larger firms for distribution.

III. ENVIRONMENTAL FACTORS

A. Introduction

The objective of the analysis of environmental factors conducted here is to characterize pollutant emissions that might influence selection of new technologies. Using these characteristics, the technologies can then be ranked and compared with conventional generation within constraints of the study areas to determine those most advantageous in terms of environmental performance. An initial list of technology characteristics was supplied by DOE. In addition, we conducted an extensive search to identify other data from published literature and from industrial, trade and regulatory organizations. It has become clear that environmental data relevant to the three technologies are extremely limited. We have, therefore, concentrated on emissions of criteria air pollutants, total consumptive water use and total quantities of solid waste produced. Some sparse data exist on the discharge of metals to air, but these are neither reliable nor extensive enough to be useful.

B. Air Emissions

Air emissions for the baseline and the new technologies are presented in Table 3.1.

Limits for conventional steam-electric generation were determined from the New Source Performance Standards recently promul-

Table 3.1. Air pollution emissions for the technologies under study.

(pounds per million BTU heat input)

	<u>Baseline</u>	<u>New Technologies</u>					
	Conventional coal-fired with FGD	<u>AFBC</u>		<u>PFBC</u>		<u>CC</u>	
		<u>DOE</u>	<u>Lit.</u>	<u>DOE</u>	<u>Lit.</u>	<u>DOE</u>	<u>Lit.</u>
Total Suspended Particulates (TSP)	0.03*	0.03	0.10 ¹	0.03	N/A	0.02	N/A
Sulfur Oxides (SO _x)	0.6-0.8*	1.03	0.66 ⁴ -1.1 ³	0.69	0.61 ⁴	0.20	0.29 ⁴
Nitrogen Oxides (NO _x)	0.5-0.6*	0.27	0.26 ³ -0.40 ³	0.15	N/A	0.4-0.65	N/A
Hydrocarbons	0.0115	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Monoxide	0.0385 ⁵	N/A	N/A	N/A	N/A	N/A	N/A

NOTES: DOE values supplied by the Office of Resources Applications.

* indicates values derived from utility NSPS.

Lit. indicates values from the literature.

N/A indicates data not available.

Superscripts refer to References, p. 45.

gated by the Environmental Protection Agency.⁷ Ranges are based on our analysis of the NSPS as they will be applied to the coal types available in the three study areas. The NSPS for NO_x is based on the type of fuel used, while the SO_x standards are derived from a formula which computes the allowable rate of SO_x emission based on fuel quality, required SO_x removal, etc.

Resource Applications estimates and those developed from the literature appear in the tables; however, these data are incomplete. In some cases, no values could be found in the open literature; in others, such as the PFBC values developed by TRW,² available values contained mathematical errors. We did not report any suspect figures we found.

Values for two other criteria pollutants, hydrocarbons and carbon monoxide, were available only for the baseline technology (see Table 3.1); these pollutants are not regulated by an NSPS requirement. While we did not discover emission values for these pollutants among the new technologies, similarities in the basic combustion process leads us to conclude that these would be comparable with those from conventional combustion.

For TSP, published values for AFBC and PFBC were 0.10 lbs per million BTU's. However, the reports from which these values were taken predate recent changes in the NSPS emissions to 0.03 lbs per million BTU's. It is our best estimate that these technologies can meet these more stringent requirements using baghouses, with an economic penalty comparable to that of the baseline technology.

Figure 3.1 shows the range of values for TSP, SO_x and NO_x for each of the technologies under consideration based on the figures provided in Table 3.1. These figures include both those supplied by RA and those from the literature. The magnitudes of the ranges are not related to the relative certainty of the values since only one figure existed for some parameters. Most attention has been focused on SO_x, TSP, and NO_x, in that order.

Values reported in Table 3.1 and Figure 3.1 correspond to terminology required by EPA standards. Due to differences in conversion efficiencies, however, the figures in Table 3.1 do not accurately reflect emissions for equal quantities of energy output. Since the new technologies are more efficient, their emissions per equivalent unit of electrical output would be less. Values in Table 3.1 must be divided by a factor for efficiency adjustment to standardize them to emissions per unit of energy output. Derivation of these values is shown in Table 3.2. Since they are expressed in terms of emissions per unit of heat input rather than energy output, the current NSPS do not give credit for the greater thermal efficiencies achieved by the new technologies. In essence then, the standards are more stringent for the new technologies.

Actual projected emissions for each technology from a commercial-scale (600MWe) plant are shown in Table 3.3; these are based on the midpoint ranges from Figure 3.1 adjusted for tech-

Figure 3.1. Emission ranges of selected air pollutants.

Table 3.2. Absolute and relative efficiencies of the technologies under study.

<u>Technology</u>	<u>Assumed Thermal Conversion Efficiency</u>	<u>Relative Efficiency (Baseline technology= 1.0)</u>
Baseline	34%	1.00
AFBC	36%	1.06
PFBC	39.25%	1.15
CC	41%	1.21

Source: MITRE Corporation⁴

Table 3.3. Estimated emissions from a commercial-scale (600 MWe) plant by technology.

<u>Technology</u>	<u>Emissions in Tons Per Year*</u>		
	<u>TSP</u>	<u>SO_x</u>	<u>NO_x</u>
<u>Baseline:</u>			
Conventional coal-fired steam-electric generation with flue gas desulfurization	530	12,367	9,716
<u>New:</u>			
Atmospheric Fluidized Bed Combustion	500	14,666	5,500
Pressurized Fluidized Bed Combustion	461	9,985	2,304
Combined Cycle	292	3,577	7,665
<u>Emissions difference between baseline and the cleanest new technology</u>			
	238	8,790	7,412

- * Based on a 600 MWe facility operating at the midpoint of emission estimates from Figure 3.1 at a 0.65 capacity factor. Conversion efficiency assumed based on data from Table 3.2.

nology efficiency. The differences between the baseline and cleanest new technology for each pollutant is also shown in Table 3.3, in terms of tons per year.

There is a considerable difference between tonnage of emissions from the cleanest of the new technologies and baseline, particularly for SO_x and NO_x . A combined cycle plant, for example, would emit approximately 3,600 tons/year of SO_x compared to over 12,000 tons/year for conventional.

Projected emissions of the new technologies are shown in Table 3.4 as a percentage of conventional. SO_x emissions from AFBC are slightly higher than the baseline. TSP and SO_x emissions from both combined cycle and PFBC* are considerably lower than the baseline.

Based on the figures from Table 3.4, each of the new technologies can be ranked by level of pollutant emissions (see Table 3.5). Combined cycle is clearly the most advantageous from an environmental perspective, followed by AFBC, then PFBC. The right-hand column of Table 3.5 ranks the technologies based on nearness to commercial availability (conventional coal-fired is available now). It should be noted that the ranking by availability is the inverse of the environmental ranking. According to data developed for this study, maximum environmental advantage will not be achieved until combined cycle is available as a coal-fueled technology.

* Note that extremely low NO_x emissions attributed to PFBC rest on a single data point.

Table 3.4. Emissions from a 600 MWe new technology plant as a percentage of emissions from a 600 MWe baseline plant.

<u>Technology</u>	<u>TSP</u>	<u>SO_x</u>	<u>NO_x</u>
Atmospheric Fluidized Bed Combustion	94	119	57
Pressurized Fluidized Bed Combustion	87	81	24
Combined Cycle	55	29	79

Table 3.5. Technology rankings based on selected air emissions and technology availability.

	<u>By Pollutant</u>			<u>For All Three Pollutants</u>	<u>By Technology Availability</u>
	<u>TSP</u>	<u>SO_x</u>	<u>NO_x</u>		
1.	CC	CC	PFBC	CC	Base
2.	PFBC	PFBC	AFBC	PFBC	AFBC
3.	AFBC	Base	CC	AFBC	PFBC
4.	Base	AFBC	Base	Base	CC

Base = Baseline

AFBC = Atmospheric Fluidized Bed Combustor

PFBC = Pressurized Fluidized Bed Combustor

CC = Combined Cycle

C. Other Environmental Factors

The range of estimates for consumptive water use and total solid waste production included in these analyses (see Table 3.6 and Figure 3.2) is quite wide. All of the new technologies, however, require less water than the baseline. This is, in part, due to greater thermal efficiencies for the new technologies; less waste heat causes less evaporative water loss.

It is difficult to rank the technologies due to variation in the production of solid waste; it appears comparable among the technologies.

Based on our analysis of current environmental regulation, we do not feel that water quality or solid waste issues play a major role in selection of coal-fired technologies at the present time. This situation could change if either effluent regulation of toxic water pollutants or hazardous waste regulations are promulgated which differentially affect the technologies. There are no data at present with which to assess these factors.

Table 3.6. Other environmental factors for technologies under study

	<u>Baseline</u>	<u>New Technologies</u>					
	<u>Conventional coal- fired with FGD</u>	<u>AFBC</u>		<u>PFBC</u>		<u>CC</u>	
		<u>DOE</u>	<u>Lit.</u>	<u>DOE</u>	<u>Lit.</u>	<u>DOE</u>	<u>Lit.</u>
Consumptive water use (gal./kwhr)	0.82-1.1 ¹	0.16	0.76 ¹	0.55	0.40 ²	0.36	--
Total Solid Waste Produced (lbs/kwhr)	0.14 ¹ -0.26	0.13-0.26	0.19 ¹	0.25	0.19 ²	0.24	--

NOTE: Unreferenced values under "Baseline" were supplied by DOE.
 DOE values supplied by the Office of Resource Applications.
 Lit. indicates values obtained from the literature.
 N/A indicates data not available.
 Superscripts refer to references identified on page 45.

Figure 3.2. Range of water use and solid waste production.

IV. POTENTIAL MARKET IN THE STUDY AREAS

A. Summary

The estimation of the potential market for new coal-fired generation is central to these analyses. Projections of electric generation between the present and 1998 are collected by the Department of Energy under authority of the Federal Power Act. These were supplemented with data collected by telephone interview from the power pools and their planning staffs in each of the three regions. (See Appendix D for a list of individuals contacted and Appendix E for a summary of comments received.)

The net anticipated annual growth in generation over the 1979 to 1998 period ranged from a low of 4.0 percent in the Texas power pool to a high of 4.3 percent in the Southern states pool. At these rates of increase, 1998 generating capacity will be from 2.1 to 2.2 times the size of capacity as of 1979. Projected retirements from 1979 to 1998⁹ range from 1.7 to 15.4 percent of the 1979 generating capacity.

B. Analysis of Market Potential

Major factors affecting growth in generation are:

- load growth due to population increases, increased electrification, and
- retirement of existing facilities.

Major factors affecting the types of fuel and types of

generation selected by the power pools are:

- the economics and availability of the fuels,
- availability of technologies, and
- environmental regulation and other constraints.

Present generation and projections to 1988 and 1998 are shown in Table 4.1. Projections to 1988 were derived from planned additions and retirements for each utility in each power pool studied. Projections to 1998 were estimated from the trend of power pool shares of the total generation reported by Reliability Councils totals. The 1998 projections are not likely to be as precise as those for 1988. In Table 4.2 these data are expressed as annual percentage rates of increase. The increases between 1979 and 1998 are considerably lower than the 5 to 7 percent increase projected prior to the 1974 changes in world oil prices, and also lower than the one-year projections between 1978 and 1979.

Most of the additional capacity expected by 1988 is either under construction or in a late state of regulatory approval or facility design. Since details on fuel types to be used for added generation beyond 1988 are not available, our analyses assumed a continuation of the trends in fuel use selections as documented by 1979-1988 plans.

Present and projected coal-fired generation and its share of total generating capacity is shown in Table 4.3. From this it appears that only the southern area can be considered heavily

Table 4.1. Current and projected generating capacity (MWe).

	<u>Texas</u>	<u>Florida</u>	<u>Southern</u>
1979 Capacity	16,586	21,774	23,500
1988 Projected Capacity	22,358	32,900	34,472
1998 Projected Capacity	34,757	47,587	52,323
1979-1988 Retire- ments as a % of 1979 Capacity	15.4	2.3	2.6

Table 4.2. Demand growth in the study areas.

	(as an annual percentage increase)		
	<u>Texas</u>	<u>Florida</u>	<u>Southern</u>
1979-1988	3.4	4.5	4.3
1988-1998	4.5	3.9	4.3
- - - - -			
1979-1998	4.0	4.2	4.3
- - - - -			
1978-1979	6.2	5.1	4.8

Table 4.3. Present and projected coal-fired generation.

	<u>Texas</u>	<u>Florida</u>	<u>Southern</u>
<u>1979</u> MWe	5,299	2,477	15,821
% of total	31.9	11.4	67.3
<u>1988</u> MWe	10,580	8,436	23,331
% of total	47.3	26.0	67.7
<u>1998</u> MWe	19,470	19,345	34,687
% of total	56.0	40.7	66.3

dependent on coal and the coal-fired share of generating capacity is expected to remain at about two-thirds of the total. In Texas and Florida areas the share of coal-fired capacity is expected to increase dramatically, from 11 to 41 percent in Florida and from 32 to 56 percent in Texas. Thus, a significant potential market for new generation exists in all the study areas. Table 4.4 shows present and projected capacity for each region arrayed to show changes to 1988 and later changes to 1998.

Conservation may result in annual growth rates lower than the 4.0 to 4.3 percent rates projected by the utilities and may, thus, influence market potential for new technologies in two ways: first, it may reduce demand for new capacity; and second, utilities may extend the time to bring units under construction or in planning into their system until 1990, 1991 or later. To examine this possibility, we reanalyzed growth assuming (1) a 3% growth rate between 1979 and 1998, and (2) an extension of time for increases in capacity. The results of this analysis are shown in Table 4.5, both in terms of total capacity and in 600 MWe equivalent units. A summary of projected coal-fired units under the two growth scenarios is shown in Table 4.6. The resultant market potential in the three areas ranges between 22 and 52 plants of 600 MWe size.

Table 4.4. Present and projected utility generating capacity in the study areas.

		(MWe)		
<u>Year</u>	<u>Description</u>	<u>Texas</u>	<u>Florida</u>	<u>Southern</u>
1979	1979 Capacity*	16,586	21,774	23,500

	Retirement Ex- pected 1979-1988**	(2,559)	(492)	(606)
	Facilities Under Construction or Planned for 1988*	6,681	4,405	9,386
1988	Facilities in Design or Planning for 1988			
	●● Coal-fired	1,650	4,467	1,940
	●● Other	-0-	2,281	252
	Projected 1988 Capacity	22,358	32,435	34,472

	Net Additions Ex- pected by 1998			
	●● Coal-fired	8,890	10,909	11,356
	●● Other	3,509	4,243	6,495
1998	Projected 1998 Capacity	34,757	47,587	52,323

Table 4.5. Projected planned and unplanned coal-fired generating requirements under utility and low demand growth assumptions.

	(in MWe)					
	<u>Texas</u>		<u>Florida</u>		<u>Southern</u>	
	<u>Utility</u>	<u>Low Growth</u>	<u>Utility</u>	<u>Low Growth</u>	<u>Utility</u>	<u>Low Growth</u>
Projected 1998 Capacity	34,757	29,084	47,587	38,181	52,323	41,207
Planned Generation	22,358		32,435		34,472	
Remaining Needs by 1998	12,339	6,726	15,152	5,746	17,851	6,735
Projected share of needs to be met by						
• Coal	8,890	4,823	10,909	4,137	11,356	4,285
• Other	3,509	1,903	4,243	1,609	6,495	2,450

(in 600 MWe units)						
Projected share of needs to be met by						
• Coal	15	8	18	7	19	7
• Other	6	3	7	3	11	4

NOTES: Utility rates based on growth rates given in Table 4.2.
Low growth rates assume an annual 3% per year increase in generation.

Table 4.6. Range of new technology market potential.

(number of 600 MWe units)		
<u>Projected Coal-fired Units</u>		
<u>System</u>	<u>3 %/year Growth</u>	<u>Utility Estimated Growth</u>
Texas	8	15
Florida	7	18
Southern	<u>7</u>	<u>19</u>
Total	22	52

V. DISCUSSION OF RESULTS

A. Air Emissions

When compared to total regional emissions, the emissions from a single 600 MWe conventional steam-electric plant range from 0.1 percent (for TSP in the Southern area) to 5.3 percent (for SO_x in the Texas area [see Table 5.1]). Except for TSP, all of these percentages are greater than 0.5. The relative share of the cleanest of these new technologies is considerably lower (see Table 5.1). Emissions from the model 600 MWe plant are greater than 1.0 percent of regional emissions only for SO_x in the Texas area.

In these three areas, from 22 to 52 new plants of 600 MWe capacity will be required between 1988 and 1998. Thus, the potential from new coal-fired generation can be significant. As Appendix C indicates, emissions are expected to increase in each of the study areas. Primary factors influencing emissions change are:

- economic growth,
- retirement of existing facilities,
- fuel use changes, and
- compliance of existing facilities with new regulations.

To examine the implications of the required new generation, we compared total regional emissions from the range of new coal-

Table 5.1. Relative air emission impact from a commercial-scale plant.

(Expressed as a percentage of 1975 area emissions*)			
	<u>Texas</u>	<u>Florida</u>	<u>Southern</u>
Emissions at a 600 MWe Conventional Plant			
TSP	0.2	0.3	0.1
SO _x	5.3	1.7	0.7
NO _x	2.6	1.6	0.9
Emissions of lowest emitting technology for a 600 MWe plant			
TSP (CC)**	0.1	0.2	0.1
SO _x (CC)**	1.5	0.5	0.2
NO _x (PFBC)**	0.6	0.4	0.2

* As indicated in Appendix C, 1975 emissions are estimated using the Regional Emissions Projection System (REPS)

** Indicates lowest emitting technology

fired plants anticipated between 1988 and 1998 with total projected emission increases from all sources between the years 1985 and 1995.* Results from these analyses are shown in Table 5.2 for three new technology penetration scenarios. The first assumes that all new capacity will be conventional. For example, the addition of only conventional technology for the years 1988 to 1998 is projected to result in utility shares of incremental NO_x emissions of:

50 to 70% in the Texas area,
20 to 50% in the Florida area, and
20 to 50% in the Southern area.

The second scenario assumes 100 percent penetration of the best new technology (evaluated separately for each pollutant). Under these assumptions, the utility share of NO_x emissions would be:

10 to 30% in the Texas area,
5 to 10% in the Florida area, and
5 to 10% in the Southern area.

The final scenario assumes new capacity will be 50% new technology and 50% conventional. As expected, the results fall midway between the first two scenarios.

As is evident, major changes occur in SO_x and NO_x emissions; TSP emissions do not change greatly under any scenario. A summary of these comparisons is shown in Table 5.3. This table provides insights concerning the ability of the utilities to continue

* These are based on energy demand forecasts specified in Appendix C; forecasts for the years 1985 and 1995 were used because forecasts for 1988 and 1998 were not available.

Table 5.2. Environmental implications of new technology success

System/Technology Scenario*	Projected percentage share of 1985-1995 emissions growth used by coal-fired utilities*		
<u>Texas</u>	TSP	SO _x	NO _x
100% Conventional	5	70->70	50->70
50% Conventional, 50% Best New	5	30-70	30-70
100% Best New	5	20-30	10-30
<u>Florida</u>			
100% Conventional	5-10	20-50	20-50
50% Conventional, 50% Best New	5-10	10-30	10-30
100% Best New	5	5-20	5-10
<u>Southern</u>			
100% Conventional	5	20-50	20-50
50% Conventional, 50% Best New	5	10-30	10-30
100% Best New	5	5-20	5-10

* Best New is CC for TSP and SO_x and PFBC for NO_x

** The low value is based on 3% per year demand growth and the high value is based on utility projections.

Table 5.3. Summary of projected emission changes.

	<u>Projected 1985-1995 emission increase as a percentage of 1985 emissions</u>		<u>Approximate percentage of 1985-1995 emission increase which could be reduced by using new technologies*</u>	
	<u>SO_x</u>	<u>NO_x</u>	<u>SO_x</u>	<u>NO_x</u>
TEXAS	30	23	40-→50	20-→40
FLORIDA	45	37	10-30	10-40
SOUTHERN	21	26	10-30	10-40

* Range based on 50% conventional, 50% best new and the low growth scenario and 100% best new and the utility generation scenario.

Since TSP effects are relatively small, they are omitted.

siting coal-fired plants beyond 1988. The magnitude of projected increases in emissions shown in the left-hand side of Table 5.3 is rather significant; e.g., SO_x increases of 30% in the Texas area and 45% in the Florida area. The right-hand side of Table 5.3 shows the share of the increase, in percent, which could be abated if the new technologies are deployed.

These results indicate that a significant share of projected emission increases can be prevented by new technology deployment. While firm data are not available, it is likely that emission increases of the magnitude of those shown in Table 5.3 will not be permitted, even under present nonattainment or PSD provisions. Thus, deployment of the new technologies would not only provide social benefits by reducing pollution but perhaps permit further use of the nation's abundant coal reserves.

B. Other Factors

Technology-based new source performance standards (NSPS) are expected to be the most significant environmental regulatory influence over technology selection. The NSPS for coal-fired utilities requires sulfur dioxide scrubbers on all new, conventional steam plants. Other ambient air-based environmental standards, primarily nonattainment and prevention of significant deterioration, are not expected to be as limiting as the NSPS between now and the end of the decade because the utilities appear to have sufficient siting options within the power pool areas to satisfy these regulations. This situation could change

as emissions increase in the study areas or if new ambient standards are promulgated. Other environmental factors, particularly solid waste disposal, are of concern but are unlikely to approach the significance of air emissions.

To the extent that utilities begin to face nonattainment and/or PSD problems,* the technologies under study offer significant advantages. Specifically, emissions of criteria air pollutants (TSP, SO_x and NO_x) are expected to be less than those emitted from the baseline technology. Each new technology will produce lower emissions of at least two of the three criteria pollutants (compared to baseline) and is expected to meet current NSPS standards at a lower penalty in reliability and cost. This would result in greater flexibility in siting near Class I PSD areas and reduce the necessity of purchasing nonattainment offsets.

While utility spokesmen in the three power pools under study were informed and articulate regarding the possible deployment of innovative technologies by their firms, largely in hopes of meeting environmental regulations within the constraints of fuels regulation and availability, these innovations did not include AFBC, PFBC or CC due to their absence as a commercial technology.

The expected environmental and economic performance of the new technologies is less than adequately characterized. This

* Our analysis indicates a significant growth in emissions. Further, it appears that TSP nonattainment may become a problem in southern Florida which may not be amenable to siting modifications.

fact limits the confidence we can place on our results. Our review of technological environmental performance indicates that they are based on extremely limited results from bench tests and less than commercial-scale facilities; therefore, results may not be applicable to full-sized plants.* Furthermore, information on the tradeoffs of possible economic/environmental performance using the new technologies is under development, and while it may be possible to achieve a level of performance from commercial-scale facilities equivalent to that projected from bench tests, costs may be quite high.

* For example, analyses in 1985 Air Pollution Emissions show uncontrolled TSP emissions from small boilers (less than 100 MWe [heat]) are 80% or less of large boiler emissions.

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APPENDIX A

MAJOR ENVIRONMENTAL REGULATIONS AFFECTING THE UTILITY INDUSTRY

The main focus of this Appendix is on those regulations likely to affect technology selection and those with high economic effect on utility construction. The discussion here is, of necessity, considerably simplified.

A. Air Regulation

Major provisions of the Clean Air Act Amendments of 1977 which affect the utility industry are National Ambient Air Quality Standards (NAAQS) and New Source Performance Standards (NSPS). NAAQS have been promulgated for seven pollutants: TSP, SO_x, NO_x, hydrocarbons, CO, photochemical oxidants, and lead. Two standards may be designated for each pollutant: a primary standard, to protect human health with an "ample margin of safety"; and a secondary standard, which protects vegetation, property and natural ecosystems.

The states are responsible for the development of plans (State Implementation Plans: SIP's) which may require abatement for existing and new sources in order to meet and maintain NAAQS. In areas not meeting the NAAQS primary standards (termed non-attainment areas), under Federal regulation, new sources must install control devices on existing sources or take other steps resulting in no net increase in overall emissions within the non-

attainment area. This is what is known as the offset policy. Analysis of the effects of the offset policy is extremely complex since it depends on the definition of nonattainment areas, cost to the new source of purchasing offsets, and other factors. In some cases, costs may be quite high.

Areas which meet NAAQS may be subject to prevention of significant deterioration provisions (PSD). These are designed to prevent rapid or significant degradation of air quality in areas where air is relatively clean. Regions within a state may be designated Class I, II or III, depending on the allowable increment. Many areas have been classified Class I (the most stringent) by statute. Since large sources may measurably affect air quality for over a hundred miles, PSD Class I areas may act as a significant deterrent to new sources and to cause stringent controls on existing sources. Visibility requirements under the PSD provisions may also influence technology deployment.

NSPS are technology-based standards which are required for all new facilities of a specific type. As improved emission control technologies become available, these regulations can be tightened. For example, the new NSPS for large solid-fueled boilers were recently made more stringent, requiring FGD on all new plants and TSP removal efficiencies of 99.5% on all sources.

The new NSPS tend to favor the new technologies since they are designed for improved environmental performance at lower cost. In addition, PSD and nonattainment requirements should be more easily met; however, further analyses are definitely needed toward this point.

B. Water Regulation

The major water regulations affecting the utilities are those controlling thermal effluents under the Clean Water Act and preceding legislation. These regulations basically require closed-cycle cooling except under extraordinary circumstances. Power plant discharges of chemical substances has not been as great a problem but may come under increasing scrutiny as EPA develops technology-specific discharge limits for an additional 129 pollutants.

Unlike air quality where states set standards for existing facilities, uniform Federal effluent discharge limits are set by industry type and by pollutant, based on the available control technology.* These technology-based standards are the major force behind progress toward clean water, rather than ambient conditions. However, states may establish water quality standards (based on EPA criteria) and force dischargers to meet more stringent standards.

Thermal discharges from the new technologies under study here are expected to be lower than the baseline due to improved combustion and thermal efficiencies. The lack of commercial-scale plants prevents assessment of possible chemical discharges of significance.

* The legislative language is "best available technology economically achievable."

C. Solid Waste

Under the Resource Conservation and Recovery Act, EPA can regulate hazardous industrial solid waste disposal. At present, utility generated sludges and other solid wastes have been classified as nonhazardous; however, if this should change, significant increased costs could be incurred.

APPENDIX B - CONVERSION FACTORS

<u>CONVERSION FROM</u>	<u>CONVERSION TO</u>	<u>MULTIPLY BY FACTOR</u>	<u>REMARKS</u>
Air emissions in lbs/million BTU	Air emission in tons/year for a 1000 MWe plant	29,444 ÷ f	Assumptions: 65% capacity factor, 34% thermal effici- ency, use f=1.0 for baseline, 1.06 for AFBC, 1.15 for PFBC and 1.21 for CC.
Air emissions in tons/year for a 1000 MWe power plant	Air emissions in tons/year per 10**12 BTU output.	19,4328	Assumptions: 65% capacity factor, 33% thermal efficiency
Solid waste in lbs per KWH	Solid waste in tons/ year for a 1000 MWe plant	4,380,000	Assumptions: 65% capacity factor
Gallons per KWH water used	Million gallons per year for a 1000 MWe plant	5,694	Assumptions: 65% capacity factor
Acre feet water	Gallons water	325,900	
Acre feet water	Cubic feet water	43,560	

APPENDIX C. STUDY AREA EMISSIONS

Present and projected emissions*

(thousands of tons)

	<u>1975</u>			<u>1985</u>			<u>1995</u>		
	TSP	SO _x	NO _x	TSP	SO _x	NO _x	TSP	SO _x	NO _x
TEXAS	243	234	379	455	552	588	565	717	726
FLORIDA	190	724	622	235	841	1,022	319	1,220	1,405
SOUTHERN	567	1,734	1,107	636	1,916	1,708	802	2,321	2,144

* Florida includes Air Quality Control Regions (AQCR) 48, 50, 51, 52 and the Florida portion of AQCR 49; Southern includes AQCRs 1-6, 54, 56, 57, 59, 134, 135 and the Georgia portion of AQCRs 49, 53, 54 and 58; and Texas includes AQCR 215 and the Texas portion of AQCR 22.

Emissions were computed using the Regional Emissions Projection System (REPS) model (see E. Pechan, 1985 Air Pollution Emissions, Government Printing Office, December, 1977). Projections for 1995 are based on the "Series C medium" forecast of DOE's Midterm Energy Forecasting System (MEFS) model (see Energy Information Administration, 1978 Annual Report to Congress, July, 1979).

APPENDIX D.

LIST OF CONTACTS

A. For Environmental Data

Anthony Dvorak Kenneth Wilzback	Argonne National Laboratory
Garland Samuels	Oak Ridge National Laboratory
Ernest Hall Francis J. Biros Bruce Henschel	Environmental Protection Agency
Steve Freedman Karl Summers	Department of Energy
Al Christensen Moe Carino Dick Roberts	General Electric Corporation
Tony Anthony Joe Yantsig	National Coal Association
Marie Newman Terry Lund Bill Slaughter	Electric Power Research Institute
Dick Bonk	Babcock and Wilcox
John Larsen	MITRE Corporation
Dale Keairns	Westinghouse Corporation

B. For Informal Utilities and Power Pool Interviews1. Extended Discussion

Donald Benjamin	Florida Electric Power Coordinating Group (Power Pool)
John Sullivan	Florida Power and Light (Utility)
Max H. Tanner, Jr.	Dallas Power and Light (Utility)

Willy Keel

Texas Electric Service
(Power Pool)

Bob Hart

Southern Company Service
(Power Pool)

2. Contact

Ned Spake
Maurice Hebb

Florida Power Corporation
(Utility)

Lew Fikar

Texas Utilities Service, Inc.
(Power Pool)

Bob Gary

Texas Utilities Generating
(Utility)

Steve Bradley

Alabama Power Company
(Utility)

Scott Harrington

Gulf Power Company
(Utility)

Donald Dana

Mississippi Power Company
(Utility)

APPENDIX E.

KEY POINTS FROM INTERVIEWS

1. Viable choices among the available fuel technologies continue to be coal and nuclear power.
2. Environmental constraints, especially air quality control, play a large role in selection of fuel types and the ultimate technology deployed.
3. Innovative technologies under consideration by the utilities and power pools interviewed include solvent-refined coal and in situ lignite gasification.
4. Small-dam hydro and pumped storage are non-combustive technologies with anticipated application in the Southern Company System.

APPENDIX F.

SELECTION OF REGIONS FOR ANALYSIS

Several levels of regions/aggregations were considered for this analysis. Among these, we felt that those with the most potential for analysis would be:

- (1) Federal Regions,
- (2) Reliability Council regions,
- (3) states, and
- (4) power pools.

The major advantages and disadvantages of the regional groupings are shown in Table 1. Based on our reviews of this material, we recommend that the power pool level of aggregations be selected. Our major reasons are:

(1) We feel that Federal Regions and Reliability Councils are too large, i.e., growth in electric demand in one subregion would be typically met from within the subarea, not the region as a whole--these subareas are, in fact, the power pools.

(2) We feel that problems of allocating generation from power pools to states is inherently more difficult from an analytic standpoint than allocating background statistical and environmental information to power pools, particularly since the latter is often available by county and can readily be aggregated to power pools.

We have identified the four candidate power pools shown in Table 2; we selected three of those for analysis since they

TABLE 1

	FEDERAL REGIONS	RELIABILITY COUNCILS	STATES	POWER POOLS
ADVANTAGES	(1) commonly used (2) compatible with available demographic statistics	(1) compatible with aggregated electric utility statistics	(1) appropriate size (2) demographics good (3) political boundaries	(1) planned growth at this level (2) may be compatible with states in certain cases
DISADVANTAGES	(1) too large to easily assess utility needs (2) would include growth and non-growth areas	(1) not a generation planning unit (2) not compatible with other statistics	(1) not compatible with available generation data (2) usually not compatible with utility planning	(1) lack of demographic statistics unless state-compatible or state-aggregate pools are used

TABLE 2

POWER POOLS FOR POSSIBLE ANALYSIS

Southern Company System

Alabama Power Company
Georgia Power Company
Gulf Power Company
Mississippi Power Company

Texas Utilities Company System

Dallas Power and Light Company
Texas Electric Service Company
Texas Power and Light Company

California Power Pool

Southern California Edison Company
Pacific Gas and Electric Company
San Diego Gas and Electric Company

Florida Electric Power Coordinating Group

Florida Power and Light Company
Florida Power Corporation
Tampa Electric Company
Jacksonville Electric Authority
Orlando Utilities Commission

(1) are located in the regions expecting significant growth, (2) are smaller in size than others which could have been selected, and (3) contain fewer utilities than other possible candidates. These latter factors should help simplify analysis. Three of the four power pools--all except the Texas Utilities System--correspond reasonably well with state boundaries.

We recommend that three of the four regions be selected for analysis: the Southern Company System, the Texas Utilities System, and the Florida Operating Committee. We do not recommend selection of the California Power Pool for the following reasons:

(1) the area is extremely large in population and is extreme in demographic diversity;

(2) the area has much stronger interconnections with other utilities, thus partially invalidating the assumptions leading to treatment of power pools as a unit.