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Project Summary

Ohio River Basin Energy Study (ORBES)

The goals of the Ohio River Basin Energy Study (ORBES) are (1) to identify and evaluate the potential consequences of various levels, rates, and patterns of future energy development in the Ohio River Basin, (2) to formulate policy alternatives that could mitigate the undesirable consequences or reinforce the desirable consequences, and (3) to summarize this information and present the results throughout the ORBES region.

Phase I of ORBES, conducted from August 1976 through August 1977, was a preliminary assessment of the potential impacts of four plausible energy development scenarios for the lower Ohio River valley. Phase II, which began in September 1977 represents an extensive in-depth assessment based on the issues identified during Phase I.

This Project Summary was developed by EPA's Office of Environmental Engineering and Technology, Washington, D.C. to announce key findings of an interagency energy/environmental study that is fully documented in a separate report of the same title (see Project Report ordering information at back).*

The ORBES Project

The Ohio River Basin Energy Study (ORBES) began in the fall of 1976 in order to assess the potential environmental, social, and economic impacts of proposed concentration of power plants in a portion of the basin. The U.S. Senate Appropriations Committee had mandated the U.S. Environmental Protection Agency (EPA) to carry out this study just after the Arab oil embargo (1973-74) in response to citizen concern. At that time several utility companies had announced plans to construct additional generating units in the Ohio River Basin.

The Ohio River region offered the electric utilities (and related industries) some of the nation's most suitable power plant sites, particularly since coalfields containing almost half of the nation's reserves by tonnage are within easy reach (see figure ES-1). Some citizens, however, questioned the necessity of adding such a large number of generating facilities, particularly near the Ohio River itself. They also pointed out that the proposed new plants would transmit much of their electricity far from the immediate area.

In an effort to identify the implications of locating future energy conversion facilities in this particular part of the Ohio River Basin, the Senate Appropriations Committee directed EPA to conduct a study "comprehensive in scope, investigating the impacts from air, water, and solid residues on the natural environment and [on the] residents of the region. The study should also take into account the availability of coal and other energy sources in the region."

*Figures and Tables in the Project Summary carry numbers preceded by the letters ES, for "Executive Summary" which is an integral part of the final report and from which this summary was excerpted.

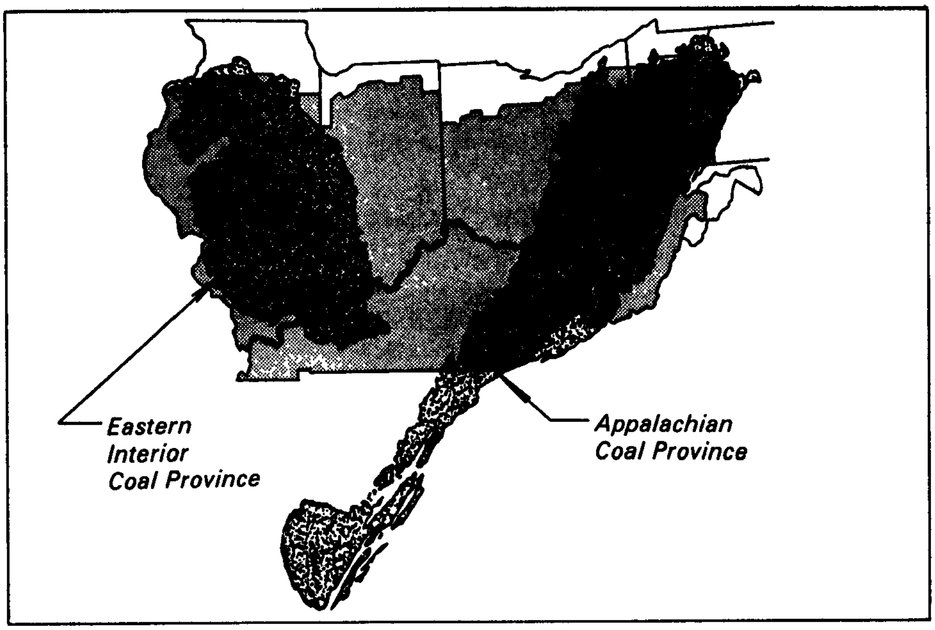


Figure ES-1. *ORBES-Region coalfields.*

General Regional Characteristics

The ORBES region covers 190,377 square miles in 423 counties in the states of Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia (see figure ES-2). The predominant land use in the region is agriculture, which accounts for 54 percent of regional acreage. The types of farming range from vast corn and soybean tracts in Illinois to smaller tobacco farms in Kentucky. Mixed mesophytic, northern hardwood, beech-maple, oak-hickory, and other forests cover another third of the region.

The regional river systems and aquatic life are as diverse as can be found in the United States. These regional water systems range from whitewater canoe and mountain trout streams to deep, clear lakes popular as recreational spots, major rivers both navigable and free flowing, and numerous wetlands and sloughs. These water systems support more than 250 fish specie with several of the navigable rivel containing at least 90 species and som large lakes containing over 125.

The ORBES region contains about 1 percent of the national population an accounts for about 10 percent of th gross national product. The major ecc nomic sector in the region is manufac turing, which accounts for about 3 percent of the gross regional produc followed by trade (16 percent), goverr ment (12 percent), and finance, insu ance, and real estate (11 percent). Th remaining 5 sectors each accounts fc less than 11 percent of the gross re gional product (see figure ES-3); th coal-mining and agricultural sector constitute 3 percent and 4 percen respectively.

Coal is the most significant indigenou fuel in the ORBES region and account for two-thirds of national productior Coal also is the primary fuel used in th region. Coal use accounts for about ha of the total regional fuel consumptior and the electric power industry in th region consumes about two-thirds (this coal. About 95 percent of region electrical generating capacity is co fired. Nonfossil fuels, in general, accour for less than 1 percent of the tot conventional fuel use in the region- approximately the same percentage a in the nation.

Regional Air, Water, and Lan Status in Mid-1970s

Air

Perhaps because of the high coal us air quality standards for sulfur dioxid and particulates were not being met a several locations in the ORBES regio during the study's base period (the mic 1970s). Several other locations wer close to violation. For example, in 197 11 ORBES-region counties violate national ambient air quality standard (NAAQS) for sulfur dioxide, and a additional 13 counties did not hav available the full prevention of signif cant deterioration (PSD) increment fc sulfur dioxide to accommodate ne sources; the ambient concentrations i these counties were at or just below th NAAQS. In the same year, 130 countie in the region violated the NAAQS fc total suspended particulates (TSP), an an additional 5 counties had less tha the full PSD increment available. Man of the counties that violated the TSP an sulfur dioxide NAAQS were clustered i extreme southwestern Ohio and alon

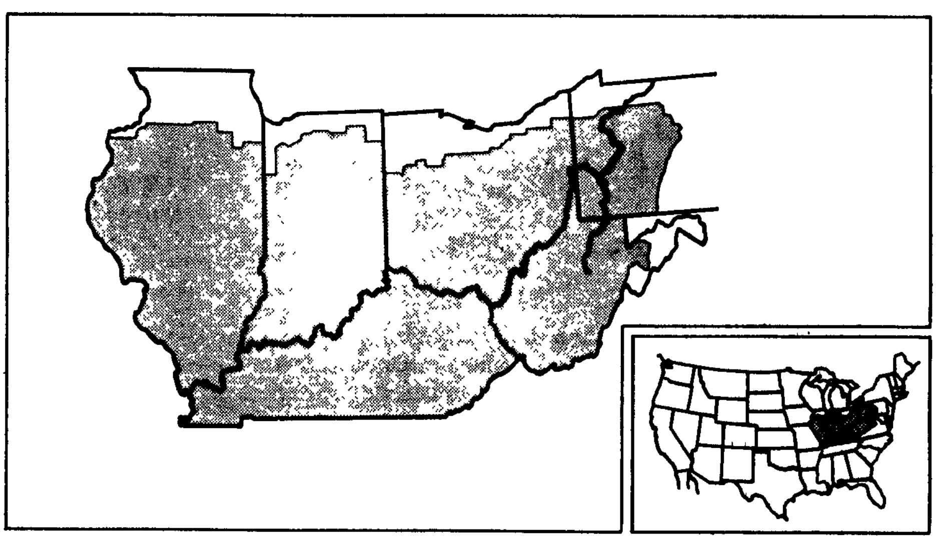


Figure ES-2. *Ohio River Basin energy study (ORBES) region.*

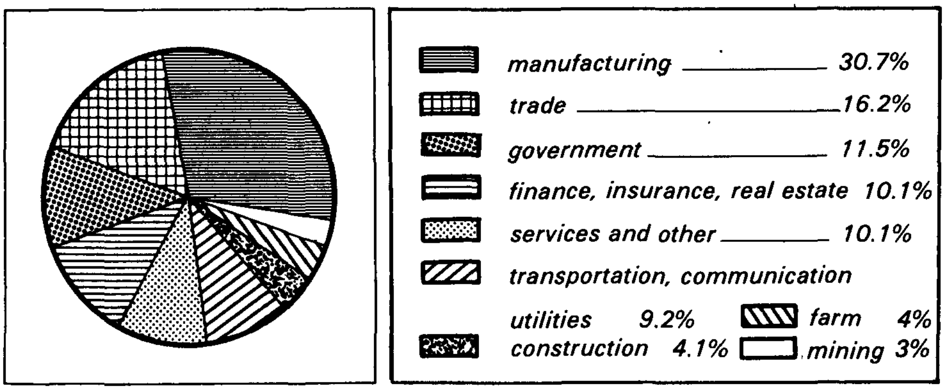


Figure ES-3. *Sectoral contributions to ORBES gross regional product.*

the Ohio-Pennsylvania-West Virginia border. However, since over 50 percent of the counties in the ORBES region are without monitoring for sulfur dioxide or TSP, the number of 1977 violations probably is underestimated.

In all probability, ORBES-region generating units contribute substantially to sulfur dioxide concentrations since they produce about 80 percent of regional sulfur dioxide emissions. In fact, in 1975, regional utility sulfur dioxide emissions constituted 52 percent of national utility sulfur dioxide emissions and 32 percent of national sulfur dioxide emissions from all sources. In contrast, during that same period, about 36 percent of the national coal-fired electrical generating capacity was located in the ORBES region.

ORBES-region utilities contributed smaller but significant shares of the 1975 regional nitrogen oxide and particulate emissions—about 47 percent of regional nitrogen oxide emissions from all sources and about 22 percent of regional particulate emissions from all sources.

However, regional data indicate that long-range transport of emissions, even over distances of several hundred kilometers, was and is an important factor in regional pollutant concentrations. At several locations throughout the region, between 30 to 50 percent of the 25 highest daily sulfur dioxide concentrations are associated with transport by extremely persistent winds. Moreover, under certain meteorological conditions, sulfur dioxide is transformed into sulfates, thereby contributing to regional sulfate concentrations. In addition, since sulfates are, by definition, the total water-soluble component in TSP, such transformation of sulfur dioxide into sulfates ultimately affects the TSP concentrations. Data from the base period confirm the importance of both sulfates and their transport in TSP concentration levels.

It is important to understand the relationship among the transport of sulfur dioxide, its transformation, and regional sulfate episodes. Sulfur dioxide concentrations of 130 micrograms per cubic meter (one-tenth of the secondary three-hour standard) in the presence of current ozone levels have been linked to vegetation damage and crop loss. Also, a growing body of evidence supports the hypothesis that the annual average exposure to sulfates—or something closely related to them—results in an increased mortality rate. In addition, sulfate episodes are correlated with acidic precipitation episodes; acidic precipitation is believed to be due primarily to the presence of sulfate and nitrate ions. Finally, sulfate episodes often are associated with the occurrence of reduced visibility over large areas.

An examination through mathematical modeling of four representative regional sulfate episodes between 1974 and 1976 reveals similarities among the episodes. In general, sulfur dioxide emissions in the lower ORBES region contributed significantly (between 50 and 90 percent) to the sulfate concentrations in the upper region. Moreover, of the sulfate concentrations in the upper region attributable to emissions in the lower region, utility sulfur dioxide emissions in the lower region contributed at least half; in at least two of the four episodes, these emissions contributed over 90 percent. (The lower ORBES region consists of the ORBES state portions of Illinois, Indiana, Kentucky, and western Ohio; the upper region, of the ORBES portions of eastern Ohio, Pennsylvania, and West Virginia.) Similar results are found when the annual sulfur dioxide and sulfate concentrations are examined.

Thus, both data and modeling confirm that long-range transport from the lower region contributes significantly to the concentration averages in the upper region and to violations of NAAQS in that region.

Finally, when the relationship between ORBES-region sulfur dioxide emissions and Canadian concentrations is examined, utility sulfur dioxide emissions from the ORBES region are shown to contribute about 50 percent of the sulfur dioxide and sulfate concentrations estimated to occur in southeastern Canada.

Water

An analysis of the regional water quality in 1976 indicates the presence of high pollutant concentrations. These pollutants can be further concentrated by the diminished flow that occurs under 7-day-10-year low flow. In general, the minimum of the water quality standards in the ORBES states was used as a guide (since these standards vary from state to state and even from river to river). Approximately 19 of the region's 24 largest streams would have violated at least 3 of the 20 pollutant standards at some time in 1976 under 7-day-10-year low flow conditions. Moreover, if such conditions had occurred, aquatic habitat impacts could have been heavy on 14 of these 24 streams. (Heavy impacts are defined as entailing eutrophication, a concentration of heavy metals, possible stream dessication, local fish kills, and a recovery period of possibly five to seven years.)

Land

If all energy-related land uses are considered, such land use through 1976 had affected 1.86 million acres in the ORBES region, or 1.5 percent of the regional land area. Land use for past and present surface mining of coal represents 86.9 percent of this figure (1.6 million acres); electrical generating facilities, 7.6 percent (140,700 acres); and transmission line rights-of way, 5.5 percent (103,000 acres). In general, the reclamation of surface-mined land for permanent land use tends to be a slow process. Data are available only for a quarter of the region's 1.6 million affected acres. These data show that this portion has been affected for 10 years and has not yet been fully reclaimed.

The Issue Areas of Concern in the ORBES Project

The ORBES study investigated possible impacts of an expanded generating capacity in the context of a number of issues. In the area of air quality, the study focused on the regional effects of changes in pollutant concentrations as a result of different levels of electrical generation, different control technologies, emission limitations, generating unit retirement schedules, and other factors. Examined in the context of the air quality analysis were the cost of electricity to the consumer, capital costs for pollution control devices, losses in agricultural output as the result of air pollution, and health impacts related to sulfates. In terms of land impacts, the study focused on land displacement for energy-related uses and the amount of land affected by surface mining. Another area investigated was water quality and quantity, including water consumption by electrical generating units, the effects of this consumption on pollutant concentrations (which increase as the water quantity decreases), and the effects of pollutant concentrations on aquatic habitats. The social areas chosen for analysis included labor demand for coal mining, labor demand for power plant construction and operation, and occupational death, disease, and disability from coal mining, processing, and transportation.

These topics were examined through a technology assessment approach. A variety of scenarios, all regionally based, were decided on and examined. Each scenario is thus an "as if" statement that does not predict what might happen. Rather, a scenario represents what *one* future might be like *if* assumed conditions are present in the ORBES region. Nine scenarios are compared in this report. First, those scenarios that assume an emphasis on coal as a fuel are compared. Next, those scenarios that assume a substitution of other fuels for coal or that emphasize conservation are compared with each other and with the coal-dominated scenario designated as the base case. The assumed economic and energy growth rates, as well as the assumed regional electrical generating capacity under each scenario in the year 2000, appear in table ES-1.

Coal-Dominated Scenarios

The five scenarios chosen for the most detailed analysis assume that coal will continue to be the dominant fue[l] used for regional electrical generatio[n] through the year 2000. The primar[y] scenario of these five is the base case the scenario to which all others ar[e] compared. Variations in base cas[e] environmental controls characteriz[e] two of the remaining four scenarios— the strict environmental control cas[e] and the noncompliance case. Variation[s] in base case electricity demand growt[h] account for the remaining two scenarios the high electrical energy growth cas[e] and the electricity exports case. Th[e] latter case is so named because it als[o] assumes that additional installed ca- pacity in the ORBES region will transmi[t] electricity to the northeastern Unite[d] States to replace oil-fired capacity i[n] that part of the country.

For the three scenarios that assum[e] the same environmental standards— the base case, the high electrical energ[y] growth case, and the electricity export[s] case—air and land standards are define[d] in terms of what currently exists a[s] applied to present and future sources o[f] pollution; in other words, these thre[e] scenarios reflect the full implementa- tion of current air and land environ- mental policies. For water, the standard[s]

Table ES-1. *Growth Rates and Installed Capacity, ORBES Region, Annual Averages (1974-2000), by Scenario*

Scenario	*Economic Growth*	*Electricity Growth*	*Coal Growth*	*Natural Gas Growth*	*Refined Petroleum Growth*	*Energy Growth*	*Installed Capacity Year 2000 (MWe)*
Base Case	*2.47%*	*3.13%*	*2.40%*	*-0.40%*	*0.37%*	*1.49%*	*153,245*
Strict Environmental Controls	*2.47%*	*3.13%*	*2.47%*	*-0.40%*	*0.37%*	*1.53%*	*153,245*
Noncompliance with State Implementation Plans	*2.47%*	*3.13%*	*2.40%*	*-0.40%*	*0.37%*	*1.53%*	*153,245*
High Electrical Energy Growth	*2.47%*	*3.90%*	*N/A*	*-0.40%*	*0.37%*	*N/A*	*178,372*
Exports of Electricity	*2.47%*	*3.20%*	*2.77%*	*-0.39%*	*0.43%*	*1.73%*	*173,395*
Natural Gas Substitution	*2.47%*	*2.00%*	*0.74%*	*3.55%*	*0.51%*	*1.61%*	*113,595*
Nuclear Fuel Substitution	*2.47%*	*3.11%*	*1.52%*	*-0.40%*	*0.37%*	*1.50%*	*145,295*
Alternative Fuel Substitution	*2.47%*	*2.69%*	*1.73%*	*-1.20%*	*0.15%*	*0.95%*	*134,395*
Conservation Emphasis	*2.47%*	*0.90%*	*0.20%*	*-0.31%*	*-0.54%*	*0.10%*	*104,495*

onsist of current practices for the design and construction of industrial and municipal facilities. Power plant effluents, however, were assumed to be uncontrolled. The strict environmental control case, on the other hand, calls for more stringent environmental regulations. In the case of air, strict controls mean that the generally stringent pollutant emission standards for urban areas—which are set by current (as of September 1978) state implementation plans (SIPs)—would be applied throughout a state. For water, power plant effluent levels were assumed to be ıbout 5 percent of base case levels. Strict environmental controls on land reclamation call for interim and permanent performance standards under the Surface Mining Control and Reclamation Act of 1977, but with strengthening of site-specific applications. Special nterim and permanent standards are ıpplied to steep-slope mining, mounaintop removal, the mining of prime armland, and the surface effects of underground mining. Under the noncompliance case, it is assumed that emission limits in state implementation plans will not be met, but that the water and land environmental policies will be he same as under the base case.

Three of the five coal-dominated scenarios assume the same electricity demand growth rate: the base case, the strict environmental control case, and the noncompliance case assume an average annual rate of 3.13 percent through the year 2000. The electricity exports case, however, assumes an electricity demand growth rate of 3.2 percent, and the high electrical energy growth case assumes a rate of 3.9 percent. The high rate of electricity demand growth under the latter scenario is that suggested in recent estimates made by the National Electric Reliability Council (NERC).

The coal-dominated scenarios are further defined by a variety of energy and fuel use characteristics; growth rates for various sectors under each scenario appear in table ES-1. Also given in table ES-1 is the regional installed capacity that is projected to occur by 2000 under each scenario because of the electricity demand growth rates.

The same population, fertility, and economic growth rates were assumed for all five coal-dominated scenarios. Similarly, all scenarios assume that the coal to supply regional generating units will come from Bureau of Mines (BOM) districts in the six ORBES states (districts 1 through 4 and 6 through 11). All scenarios also assume that the regional generating units announced by the utility companies as of December 31, 1976, including both coal-fired and nuclear facilities, will be built as planned and that these facilities will come online on the dates announced by the utilities. Finally, all scenarios assume that sulfur dioxide emissions will be controlled through the use of flue gas desulfurization systems (scrubbers) or the use of local, blended low- and high-sulfur coals.

Comparison of Coal-Dominated Scenarios

Emissions, Concentrations, and Air-Quality-Related Impacts

For all of the coal-dominated scenarios, utility emissions are the most important regional factor since their magnitude and their distribution consistently correlate with ambient air concentrations and, thus, with crop losses and mortality related to air quality. Under all coal-dominated scenarios, utility sulfur dioxide emissions would decrease by the year 2000 from their 1976 levels. However, the rate of decrease and the actual totals in 2000 would vary among the scenarios (see figure ES-4). Because of the scenario assumptions that produced the differences charted in figure ES-4, several observations can be made about possible strategies to reduce sulfur dioxide emissions at the individual plant level from their high 1976 levels. A discussion of mitigation strategies in an organizational context appears later in this summary.

Sulfur Dioxide

SIP Compliance

First, the base (compliance) case, the high electrical energy growth case, and the noncompliance case demonstrate how sensitive regional sulfur dioxide emissions are to compliance with and enforcement of SIP standards. Both the base case and the high growth case assume that complete SIP compliance will occur by 1985. As a result, under both scenarios, sulfur dioxide emissions are reduced continuously and dramatically between 1976 and 1985, and at about the same rate (see figure ES-5). The noncompliance scenario, however, assumes that there would be no utility compliance schedule; the SIP units would continue burning historical coals and using emission controls as in 1976. Thus, under this latter case, sulfur

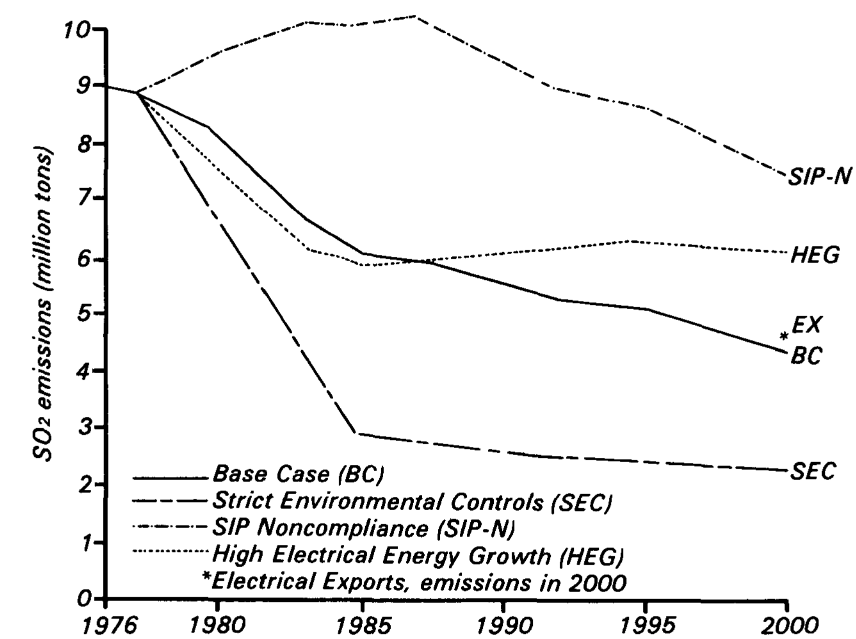


Figure ES-4. *Electric utility sulfur dioxide emissions in the ORBES region, coal-dominated scenarios.*

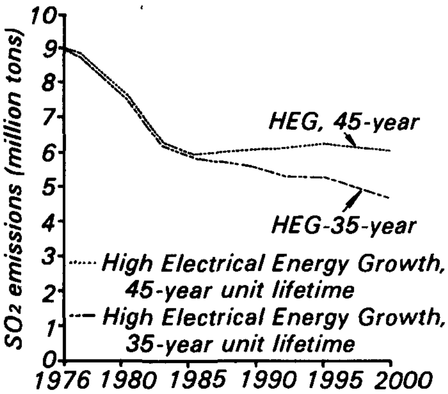


Figure ES-5. *Electric utility sulfur dioxide emissions in the ORBES region, high electrical energy growth case.*

dioxide emissions actually would increase between 1976 and 1985, ensuring that the base period air quality problems would continue and perhaps get worse (see figure ES-6). Since nearly the same electrical generation is assumed in all three of these scenarios in 1985, the immediate benefits of SIP compliance are clear: total utility sulfur dioxide emissions could be reduced by one-third by 1985.

Plant Retirements

Utility sulfur dioxide emission patterns between 1985 and 2000 demonstrate yet another way to control emissions of this pollutant. After 1985, the level of utility sulfur dioxide emissions under the same three scenarios depends on the retirement of SIP units and the replacement and addition of present generating capacity by units governed by revised new source performance standards (RNSPS). Both the base case and the noncompliance case assume that SIP units will be retired after 35 years; the high growth case, on the other hand, assumes 45-year generating unit lifetimes. As figure ES-4 indicates, sulfur dioxide emissions thus decrease under the first two scenarios and increase slightly under the last scenario.

However, given the costs of installing new generating capacity and the costs of complying with the stricter NSPS and RNSPS controls, it is quite possible that utilities may postpone the retirement of SIP units. Under two scenarios—noncompliance and high growth—this possibility was examined briefly. Figure ES-5 indicates the sulfur dioxide emission levels that would occur under noncompliance if 35-, 45-, or 55-year generating unit lifetimes are assumed. Figure ES-6 compares the high growth case that assumes 45-year lifetimes with a variation that is identical except for a 35-year lifetime assumption. Both of these figures demonstrate the difference that early retirement of SIP units could have on regional sulfur dioxide emission levels.

The periodic maintenance of an existing plant can result in a substantial renovation of that plant. The effect of such an alteration is that the plant may not be retired as early as it would have been otherwise. If, however, certain modifications were considered major enough to warrant the reclassification of SIP units from an existing to a new source category, such a revised definition might result in a utility's evaluation of the relative merits of (1) continuing to use an existing unit or (2) building a new unit. If existing SIP units were retired through such an evaluation, substantial emission reductions could result.

The 35-year retirement of SIP units still would not wholly alleviate the air quality problems stemming from regional sulfur dioxide emissions. Even in 2000, SIP-regulated units would account for the bulk (at least 67 percent) of utility sulfur dioxide emissions, regardless of whether a 35- or 45-year life is assumed. However, SIP units would account for no more than 28 percent of the electrical generation in the year 2000 under any of the coal-dominated scenarios. Thus, the emissions contributed by SIP units would be disproportionate to the benefits of SIP generation in the year 2000. SIP units comprise such a major portion of the total utility emissions in 2000 and such a low percentage of the generation because they emit about five to six times more sulfur dioxide than a new plant supplying the equivalent amount of electricity.

Stricter Controls

One way to achieve a more balanced emission-generation ratio would be to make stricter the SIP compliance strategies currently in existence. The strict environmental control case offers an example of what might be expected if such stricter controls were enacted and enforced. This latter case assumes that in each ORBES state the urban SIPs—which are stricter than rural SIPs—would be applied throughout the ORBES portion of that state. As a result of such strict controls, by the year 2000, sulfur dioxide emissions would decrease more under this scenario than under any other coal-dominated scenario. More-

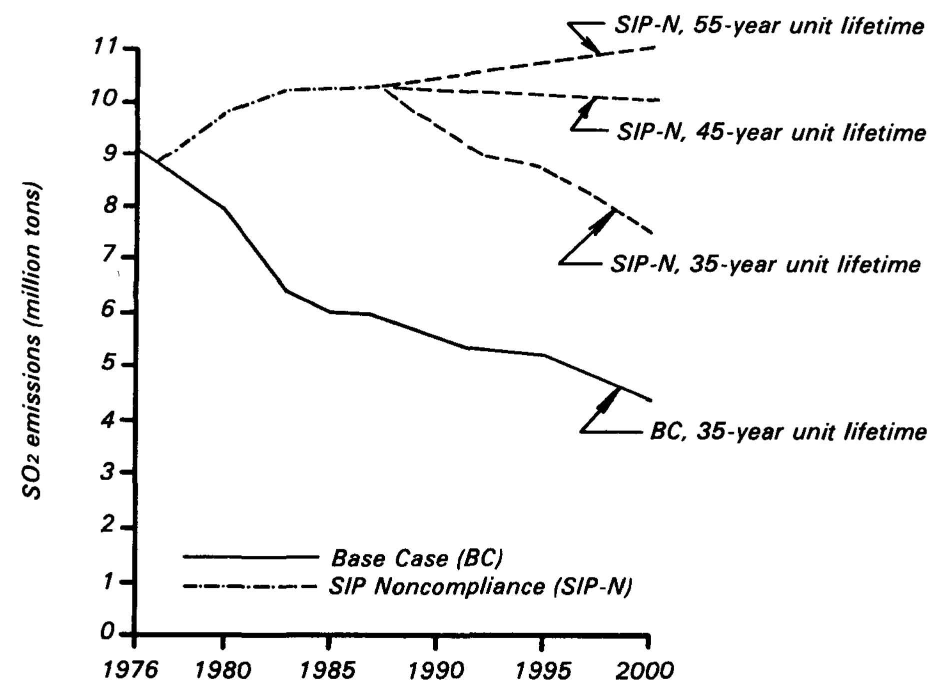


Figure ES-6. *Electric utility sulfur dioxide emissions in the ORBES region, base case and SIP noncompliance case.*

ver, the rate of decrease would be nore rapid (see figure ES-4).

Least Emissions Dispatch

Another way to achieve a more balanced emission-generation ratio would e to use least emissions dispatching. At present, and under all of the coal-lominated scenarios, generating units re loaded (brought on-line) in order of perating costs. As a result, SIP units enerally are the first units dispatched, ince, as discussed previously, newer nits are more expensive to operate. Jnder the high growth case, a variation vas examined that assumed coal-fired nits would be dispatched according to east emissions of sulfur dioxide. Under he least emissions criterion, the units mitting the most sulfur dioxide (on a er Btu basis) would be loaded last. Jnder one such dispatching order, for xample, RNSPS units might be dispatched first, then NSPS units, then rban SIP units, and finally rural SIP nits. However, such a dispatching rder may not always be feasible.

Under this least emissions policy, otal regional utility sulfur dioxide missions would be 55 percent lower han they would be under the least cost olicy in the year 2000 (see figure ES-7). SIP emissions alone would be 35 percent ower under the former case than under he latter case. Moreover, in the year 2000 under the least emissions dispatching variation, a more balanced mission-generation ratio would be chieved. Under least emissions dispatching, SIP units would emit 1.5 million tons of sulfur dioxide—or 45 percent of all utility sulfur dioxide emissions—and generate about 171 million megawatt hours. Under the least cost policy, on the other hand, SIP units would emit 4.32 million tons of sulfur dioxide—or 71 percent of the total emissions—and generate only about 162 million megawatt hours.

As this discussion of sulfur dioxide emissions under the different coal-dominated scenarios thus has revealed, the current emission standards, if complied with, would reduce total sulfur dioxide emissions between 1976 and 1985 from the 1976 levels. Any further reductions would be determined by the lifetime of SIP plants. As will be discussed shortly, such further reductions would be important since episodic concentrations still would result from the 1985 emission levels of most of the scenarios. Before such concentrations are discussed, however, particulate and nitrogen oxide emission trends under these coal-dominated scenarios are examined.

Particulate Emissions

Utility particulate emissions would be reduced significantly by the year 2000 from the 1976 levels under all of the coal-dominated scenarios except the noncompliance case. Moreover, except under the latter scenario, particulate emissions would be reduced at about the same rate and would be about the same in 2000—nearly five times lower than the 1976 emissions (see figure ES-8). In addition, such variations as least emissions dispatching would result in emissions about the same as those charted in figure ES-8. Noncompliance, however, would result in increased particulate emissions through 1985. In 2000 under noncompliance, particulate emission levels would be only slightly

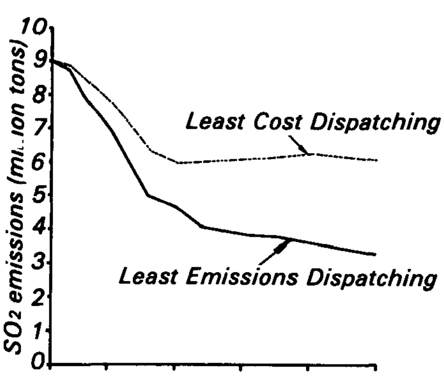


Figure ES-7. *Electric utility sulfur dioxide emissions in the ORBES region, dispatching variations under high electrical energy growth.*

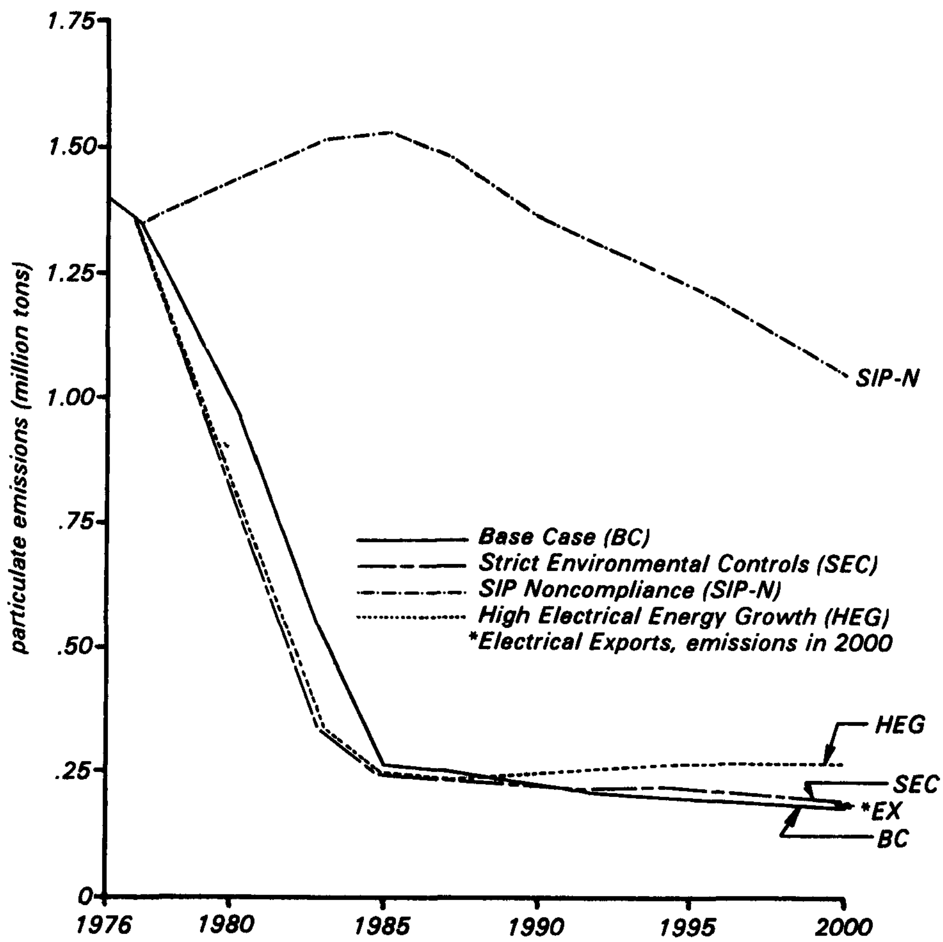


Figure ES-8. *Electric utility particulate emissions in the ORBES region, coal-dominated scenarios.*

lower than the 1976 levels. These scenarios thus suggest that current particulate standards—which are the same in urban and rural settings—will be effective. One major reason for this effectiveness, however, is that particulate removal technology is assumed to be between 85 and 94 percent efficient depending on when the unit was built.

Nitrogen Oxide Emissions

All scenarios would result in increased utility nitrogen oxide emissions. Similarly, except under the high electrical energy growth scenario, utility nitrogen oxide emissions would increase at about the same rate through 1985 and would be nearly the same in 2000—approximately 35 percent higher than 1976 emissions (see figure ES-9). There are two reasons for the similarity among scenarios. First, nitrogen oxide emission limits do not exist for SIP plants in the ORBES region, except in the urban areas of Illinois. Second, the same emission limits were assumed for new units under all scenarios. Thus, nitrogen oxide emissions would increase from the 1976 levels primarily in proportion to electricity demand growth and to the lifetime of SIP units. This fact also explains why, after 1985, nitrogen oxide emissions would increase under the high electrical growth case at a faster rate than under the other scenarios: the high growth case has the highest electricity demand growth and assumes 45-year SIP unit lifetimes instead of the 35-year lifetimes assumed under the other coal-dominated scenarios.

Pollutant Concentrations

The magnitude of changes in utility sulfur dioxide emission levels under each scenario corresponds to changes in annual average (or long-term) and episodic (short-term) regional sulfur dioxide and sulfate concentrations. Moreover, since, as discussed earlier, the transformation of sulfur dioxide into sulfates contributes to concentrations of total suspended particulates, reductions in both utility particulate emissions and utility sulfur dioxide emissions could reduce measured TSP concentrations. However, the ratio of the lower ORBES region's contribution to concentrations in the upper region is not likely to change from the ratio during the base period under any of the scenarios.

Many of the same statements made about emissions under the various scenarios also apply to comparisons of the scenarios and their annual concentrations. For example, regardless of scenario, the regional sulfur dioxide and sulfate concentrations in 2000 attributable to utility emissions would be lower than the present concentrations. Again, it is the strict environmental control case that would reduce the annual average concentrations the most and that would reduce them more rapidly than any of the other scenarios (see table ES-2). Similarly, the high electrical energy growth case and the noncompliance case would result in the least reduction by the year 2000. In fact, the 1976 concentrations would even increase through 1985 under the noncompliance case. In general, most concentration reductions would occur by

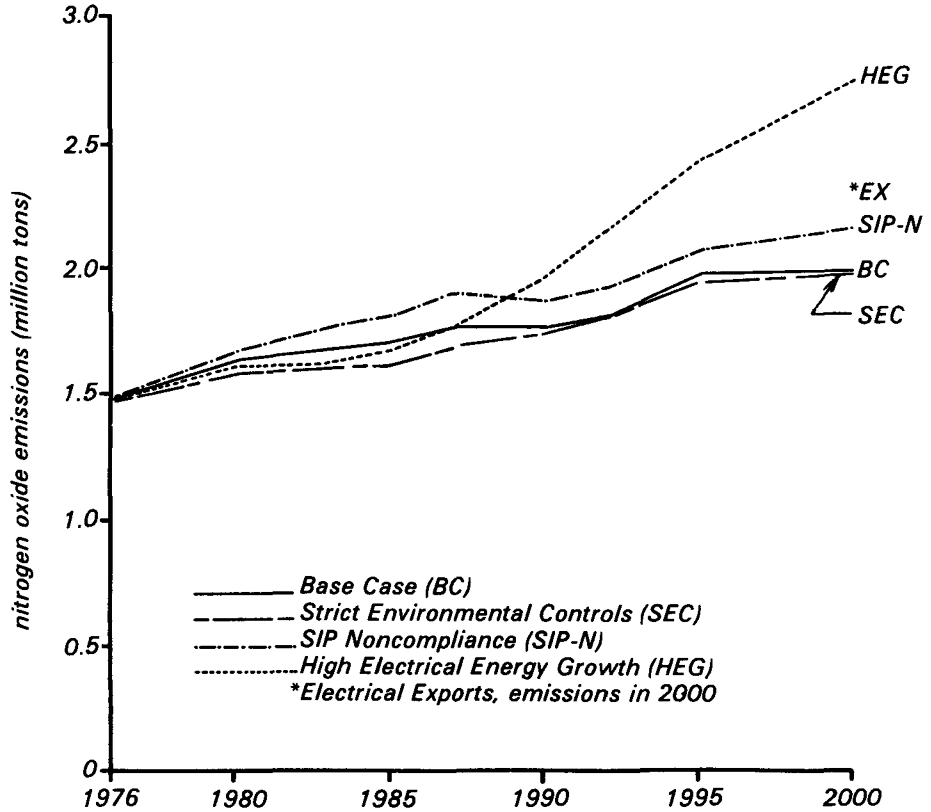


Figure ES-9. *Electric utility nitrogen oxide emissions in the ORBES region, coal dominated scenarios.*

Table ES-2. *Sulfur Dioxide and Sulfate Annual Average Concentrations, ORBES Region, Percent Change from 1976, Highest Concentration Region*

Pollutant	Concentration, 1976 (μg/m³)	Year	Base Case	Strict Environmental Controls	SIP Noncompliance	High Electrical Energy Growth
			(%)			
Sulfur dioxide	25.88	1985	-28	-62	+16	-30
Sulfur dioxide	25.88	2000	-50	-71	-18	-29
Sulfates	9.2	1985	-27	-56	+13	-25
Sulfates	9.2	2000	-49	-66	-20	-25

985—regardless of scenario—if SIP ,plants have complied by that date. Figures ES-10 and ES-11 illustrate the reductions in annual average sulfur dioxide and sulfate concentrations under the base case in 2000 as compared with the 1976 concentrations.

Another benefit of lower utility sulfur dioxide emissions is the probable reduc-ion of the concentrations that would occur under episodic conditions. If the characteristics of the August 27, 1974, ;ulfate episode were to be repeated in 2000 under any of the scenarios, the predicted utility-related, short-term sul-'ur dioxide and sulfate concentrations would be reduced from the utility-'elated, short-term concentrations that were registered during that episode (see able ES-3). However, since these short-.erm concentrations were quite high luring the August 27 episode (the most requently occurring type of episode in he ORBES region) even the 49 and 51 ercent reductions that would occur in !000 under the base case would result n short-term sulfur dioxide levels on he order of 30 micrograms per cubic neter and in short-term sulfate levels hat would be considered marginally pisodic—that is, on the order of 15 nicrograms per cubic meter over a large rea. On the other hand, the strict nvironmental control case would lead o reductions of such magnitude that he short-term levels of sulfur dioxide nd sulfates no longer would be con-idered episodic. As can be deduced, herefore, the noncompliance and the igh growth cases, which reduce emis-ions the least by 2000, would result in 'elatively high episodic concentrations.

Annual average and episodic concen-rations are important in terms of both 'egional crop loss impacts and regional ealth impacts (among other things) ince the reductions in concentrations onsistently correlate with less crop oss and fewer health impacts.

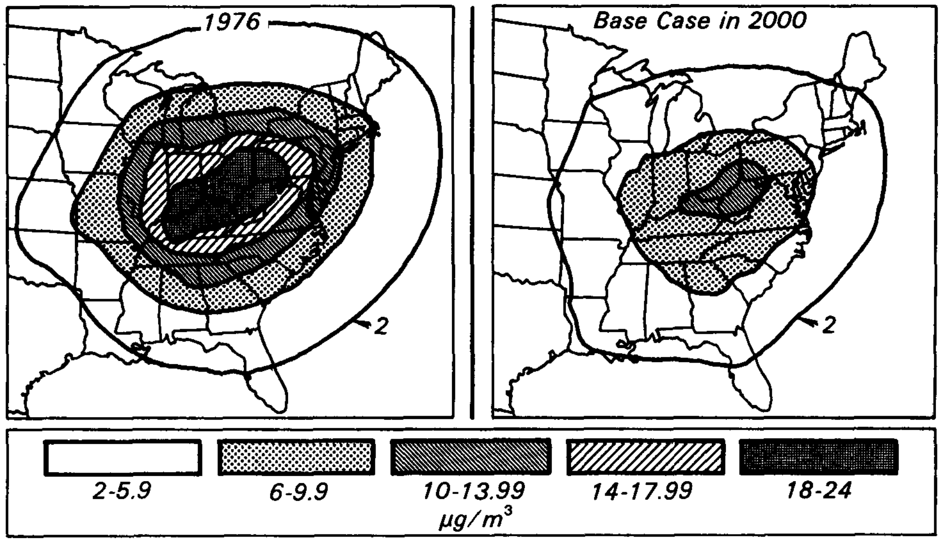


Figure ES-10. *Annual average sulfur dioxide concentrations, electric utility contribution.*

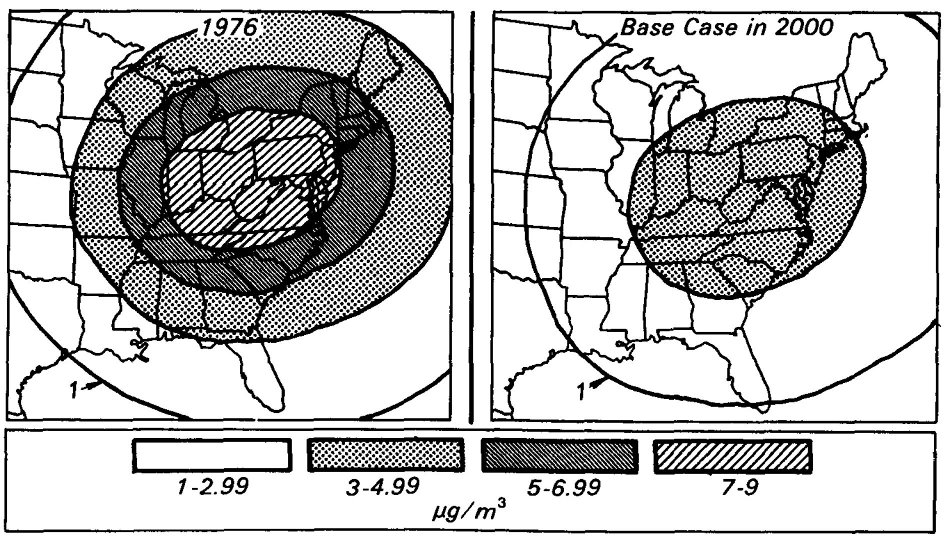


Figure ES-11. *Annual average sulfate concentrations, utility contribution.*

'able ES-3. *Sulfur Dioxide and Sulfate Episodic Concentrations, ORBES Region, Percent Change from August 27, 1974, Episode, Highest Concentration Region*

Pollutant	Concentration, 1976 (µg/m³)	Year	Base Case	Strict Environmental Controls	SIP Noncompliance	High Electrical Energy Growth
			(%)			
Sulfur dioxide	94.04	1985	-31	-68	+18	-34
Sulfur dioxide	94.40	2000	-49	-75	-13	-30
Sulfates	40.10	1985	-25	-76	+16	-23
Sulfates	40.10	2000	-51	-78	-30	-18

Physical Crop Losses

In terms of agricultural impacts, studies have indicated that sulfur dioxide concentrations as low as 130 micrograms per cubic meter (one-tenth of the secondary three-hour standard) in the presence of moderate ozone levels (0.06 to 0.1 parts per million) can affect vegetation. Thus, three coal-dominated scenarios—the base case, the noncompliance case, and the high growth case—were examined to determine the regional acreage that could be affected by the sulfur dioxide concentrations attributable to ORBES-region utility emissions. Each of these three scenarios also was examined to determine the impact of such affected acreage on crop yields, and it was found that crop yield losses would not be as high in both 1985 and 2000 as they were in 1976. However, because utility sulfur dioxide emissions would be higher under the noncompliance case and because more acreage would be affected by the resulting sulfur dioxide concentrations of 130 micrograms per cubic meter, noncompliance would result in the highest losses. Nevertheless, regardless of the scenario, physical crop losses related to utility sulfur dioxide emissions would represent less than 1 percent of the expected regional yield in any given year. Thus, from this regional perspective, the direct effects of sulfur dioxide emissions in the ORBES region on agricultural losses can be thought of as negligible under all three of these scenarios.

The majority of regional crop losses are the result of oxidants formed from hydrocarbons and from nitrogen oxide emissions. Nitrogen oxide emissions in the ORBES region originate primarily from transportation and from electrical generation. However, it is projected that nitrogen oxides from transportation will decrease significantly by the year 2000. Thus, utility nitrogen oxide emissions will begin to constitute a larger proportion of the regional nitrogen oxide emissions, especially since nitrogen oxide standards do not yet exist for SIP units in the ORBES region and since SIP-unit emissions are projected to account for the majority of all utility emissions. As a result, the rate of decrease in ozone production as well as the rate of decrease in ozone-related crop losses may be dictated by utility nitrogen oxide emissions.

In general, regardless of the scenario, losses due to oxidants would constitute about 99 percent of all the losses expected because of sulfur dioxide and ozone. Moreover, the distribution of the losses due to oxidants would vary among state portions. However, the ORBES state portions of Illinois, Indiana, and Ohio would account for about 95 percent of both sulfur dioxide and ozone losses. Finally, the distribution of all crop losses due to air pollution is not merely a local problem—that is, merely in the vicinity of a power plant—but, because of pollutant transport, these losses may occur in areas removed from major point sources. The dollar losses related to crop losses due to sulfur dioxide and all oxidants are given.

Mortality

Substantial controversy exists about the quantification of deaths related to air quality. Yet increasing evidence exists to support the hypothesis that the annual average exposure to sulfates—or something closely related to them—results in an increased mortality rate. Therefore, cumulative sulfate-related deaths between 1975 and 2000 were projected for the coal-dominated scenarios. Such projections depend on the damage function employed since rates between 0 and 9 per 100,000 persons exposed per microgram of sulfates per cubic meter are found in the literature. If a rate of 3 is used, it becomes clear that the magnitude of utility emissions is a dominant factor: the strict control case would result in the lowest number of cumulative deaths, while the noncompliance case and the high growth case would result in the most such deaths. Cumulative sulfate-related deaths under the latter two scenarios also would be nearly 34 and 13 percent higher, respectively, than would the deaths under the base case.

Economic Impacts Related to Air Quality Impacts

The costs to the utilities and to the consumer of the possible reductions in emissions and other air-related impacts also were projected for the five coal-dominated scenarios as well as for the least emissions variation and the high electrical energy growth case with a 35-year lifetime variation. Agricultural monetary losses also were estimated for three scenarios—the base case, the noncompliance case, and the high growth case. Knowing these costs permits comparisons among the scenarios in terms of the social benefits derived from reduced emissions versu the economic impacts of such reduction

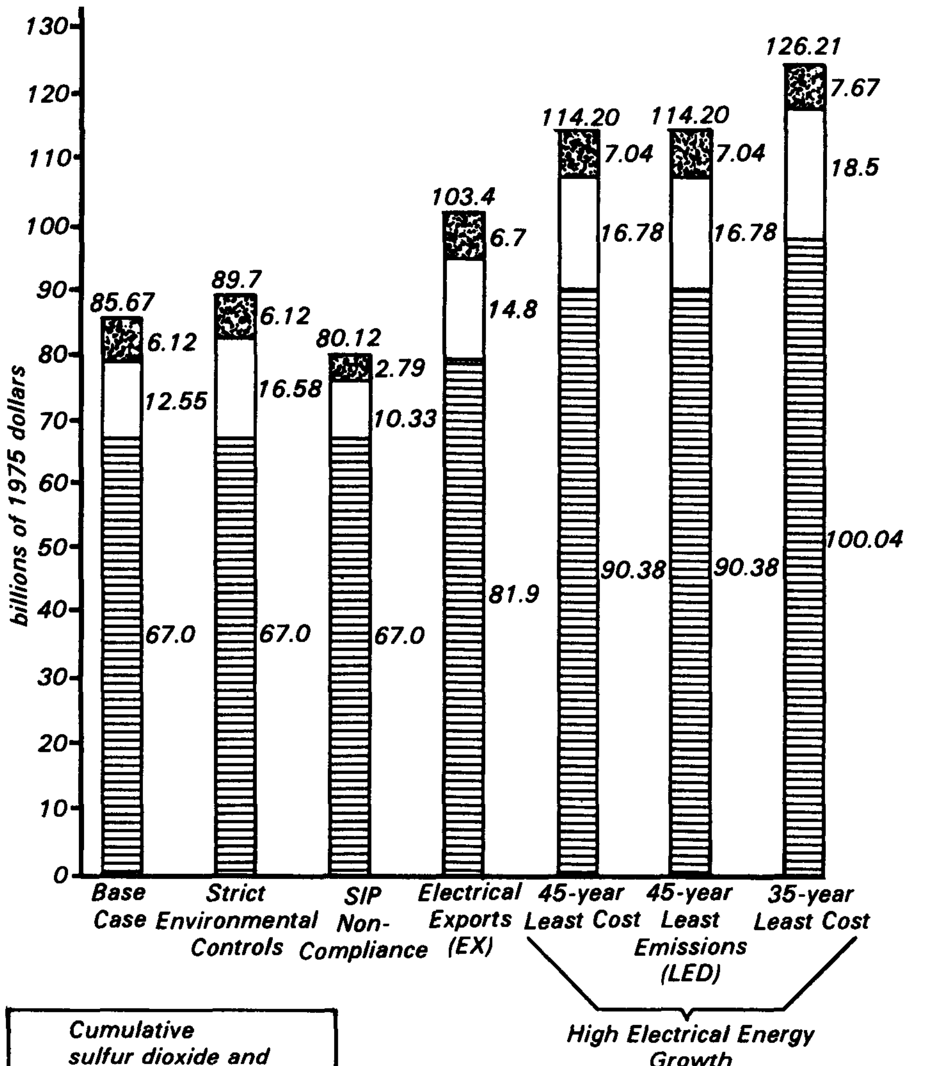
Utility Costs

Figure ES-12 charts the costs to th utilities of installing new coal-fire generating capacity, of installing pollu tion control devices on these new unit and of retrofitting existing units. A shown in this figure, the base case, th strict control case, and the noncompl ance case would result in the sam capital costs but in different pollutio control costs. The differences in pollu tion control costs among these thre scenarios would result entirely from th retrofitting of existing SIP plants wit pollution control devices. Thus, the tot cumulative pollution control costs fc the base case would be higher tha those under the noncompliance cas because under the base case about one third of existing capacity would be retr fitted. Under the strict control case, o the other hand, almost all of the existin capacity would be retrofitted, resultin in the highest cumulative pollutio control costs of the three scenarios.

The high growth case and its variatior and the export case would result i higher costs to the utilities than wou the first three scenarios. These high costs, however, would be due to th costs of installing the expanded gene ating capacity and the pollution contr devices on this new capacity. Thus, the proportion of pollution control cos to total capital costs is examined, th base case and the high growth case a similar: under both scenarios, pollutic control costs would total about 21 to 2 percent of the total costs. It should b noted, however, that these total capit costs do not reflect the operating cost The operating costs are included in th calculation of the price of electricit which reflects all the costs borne by th utilities each year. Thus, for exampl while the high growth scenario and th high growth least emissions variatic are projected to have the same capit costs, there would be differences their operating costs since the lea emissions dispatching variation wou require increased operation of pollutic control devices and the burning greater quantities of cleaned or lov sulfur coals.

Consumer Costs

The direct costs to the consum would increase regardless of scenar In the short run, however, some sc



Cumulative sulfur dioxide and particulate control costs		
Scenario	costs billion $	% total costs
BC	18.67	21.8
SEC	22.7	25.3
SIP-N	13.12	16.4
EX	21.5	20.8
HEG	23.82	20.9
LED	23.82	20.9
35-Year	26.17	20.7

Cumulative capital costs to install new coal-fired generating capacity, 1976-2000

Cumulative costs for sulfur dioxide control, 1976-2000

Cumulative costs for particulate control, 1976-2000

Figure ES-12. *Cumulative capital costs, coal-dominated scenarios, 1976-2000.*

narios may result in a faster rate of increase in the price of electricity (see figure ES-13). Several observations can be made about the electricity prices and their rate of increase. For one, between 1976 and 1985, the price of electricity rises according to the added costs of complying with SIP emission limits, paying for rising fuel and capital costs, and meeting electricity demand. Thus, as figure ES-13 indicates, the price of electricity between 1976 and 1985 would rise similarly when nearly the same degree of compliance is assumed—that is, under all the scenarios but the noncompliance case. The strict environmental control case, however, would result in the greatest increase in electricity prices since complying with stricter SIP standards would cost the utilities more. The price of electricity under the noncompliance case, of course, reflects the absence of such control costs.

Between 1985 and 1995, the rise in electricity prices depends on the annual electricity demand growth rate, capacity replacement, and capacity expansion. Since the base case, the strict control case, and the noncompliance case assume nearly the same replacement, expansion, and growth rates, the price of electricity would rise little between these years. Under the high growth scenario and its variations, however, the price of electricity rises between 1985 and 1995 since more capacity expansion is projected under these scenarios. The greater operating costs of least emissions dispatching also are reflected in the higher price of electricity under this variation.

Between 1995 and 2000, all scenarios show a rise in the price of electricity. This increase would result because additional generating units must be constructed to satisfy electricity demand after the year 2000 and because a significant number of SIP units will retire during these years and must be replaced.

Because some scenarios would cause electricity prices to be higher in the short run, the cumulative costs to consumers between 1976 and 2000 give a better idea of the total consumer costs than the price of electricity in a given year. Under the compliance or base case, such cumulative revenues required from consumers would total $525 billion (1975 dollars, or approximately $709 billion in 1979 dollars). Compared to the base case revenues,

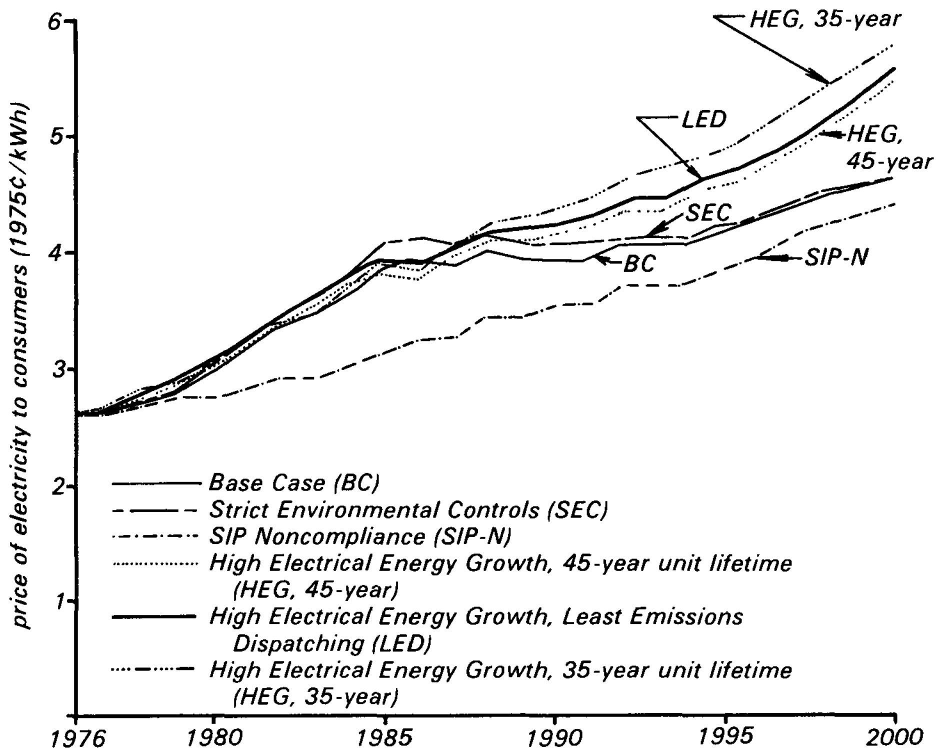


Figure ES-13. *Electricity prices in the ORBES region, coal-dominated scenarios.*

the cumulative revenues required under the strict environmental control case would be about 4 percent higher, while the revenues required under the noncompliance case would be about 10 percent lower. A high electrical energy growth rate would require about 18 percent more revenues than would the base case. Of the two high growth variations, the 35-year variation would require the most revenues (about 21 percent higher than the base case), while the revenues required by the least emissions dispatch variation would be about 19 percent higher than under the base case.

Monetary Crop Losses

When comparing the agricultural monetary losses that would occur because of physical crop losses due to sulfur dioxide and oxidants, some of the same statements made under the physical crop loss discussion can be repeated. First, monetary losses of oxidant-related crop losses would constitute virtually all (about 99 percent) of the economic losses under all of these scenarios. In addition, monetary losses related to the crop losses due to sulfur dioxide emissions would be similar under the three scenarios examined (less than 1 percent of the total monetary losses). Also, the total agricultural monetary losses would be concentrated in certain ORBES state portions (Illinois, Indiana, and Ohio) regardless of scenario. Finally, the high growth case would result in the highest cumulative agricultural monetary losses ($8.4 billion in 1975 dollars, or approximately $11.3 billion in 1979 dollars). The base case and the noncompliance case would result in about the same cumulative agricultural monetary losses ($7 billion in 1975 dollars, or approximately $9.5 billion in 1979 dollars).

Other Impacts Related to Expanded Capacity

Land

The regional impacts of an expanded utility industry on land use would be about the same for three of the coal-dominated scenarios—the base case, the strict environmental control case, and the noncompliance case—since their generating capacity is about the same and their siting patterns somewhat similar. The base case, for example, converts about 184,000 acres, or 0.15 percent of the ORBES region, for generating facility use through 2000. However, although the regional acreage affected would be about the same unde all three cases, affected acreage at th state level would vary slightly. Policie that encourage high electrical energ growth or the export of electricity fron the region would result in much large generating capacities than the thre other coal-dominated scenarios. Thus the land converted would be about 3(percent higher under the high growtl case than under the base case; unde the export case, land conversion woul be about 17 percent higher than i would be under the base case.

Employment

An increase in the employment o power plant construction and operatio workers would be expected under bot the high electrical energy growth cas and the electrical exports case. In fac such employment would rise dramat cally under these two scenarios betwee 1983 and 1987, although the hig growth scenario would require mor workers than the export case (see figur ES-14). However, such rapid change as occur under the high growth cas could result in short-term labor short ages followed by a surplus of labor a experienced workers have a choice c jobs and then few choices. Moreove

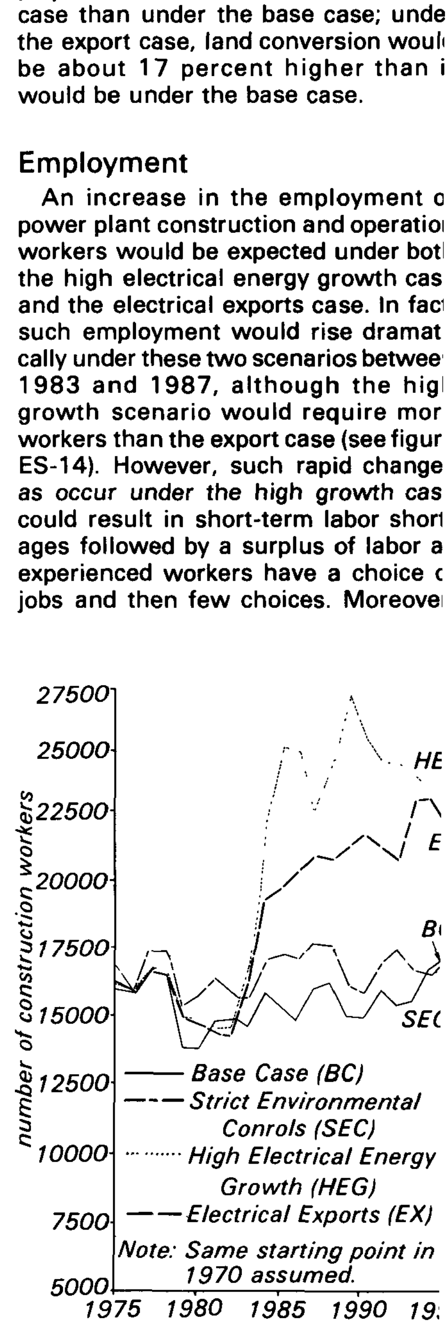


Figure ES-14. *Construction workers coal-dominated scenarios, 1975-95* ıortages of the skilled labor necessary o power plant construction and opera-ion—such as boilermakers, pipefitters, ınd electricians—might accompany the ıigh growth case. In general, however, ;killed labor shortages would not be a najor problem for the region under any ıf the other coal-dominated cases, ılthough local shortages could possibly ıccur.

Annual coal production in the region or all purposes and mining employment vould increase under the base case, the trict environmental control case, and ıe electrical exports case. However, ınnual coal production would be much ıigher in 2000 under the electrical xports case than it would be under the ther two scenarios. Thus, regional ıining employment would rise similarly nder the base case and the strict ontrol case, from a minimum of 36 ercent to a maximum of about 226 ercent, depending on the county. Such mployment would increase from a ıinimum of 42 percent to a maximum f 270 percent under the electrical xports case. It is also projected that at ıast 79 to 88 of the 152 ORBES counties vith a concentration in coal mining vould experience boom-town effects ȷrowth over 200 percent) under all ıree of these scenarios.

Iealth

Under all of the coal-dominated sce-ıarios, the health impacts related to upplying coal to ORBES power plants vould increase. This increase results ıecause, under all scenarios, coal ıroduction as well as electric utility coal :onsumption would rise from current evels. In 1985, the increases in the ıealth impacts in the coal-mining and :oal-processing sectors would be the ;ame under all coal-dominated scenarios. n 2000, three of the scenarios—the ıase case, the strict control case, and he noncompliance case—would result n similar health impacts in these sectors, vhile the high growth case and the ıxports case would result in impacts ıbout 17 percent higher. The health mpacts in the coal transportation sector vere analyzed only for the base case ınd the strict control case and only for he year 2000. Both cases would result n an increase in the fatalities associated vith transport to ORBES electrical ȷenerating facilities, but in the same ıumber of injuries as currently since railroad injuries are projected to decline at a greater rate than fatalities.

Water Quality

A comparison of the water quality analyses conducted for the coal-dominated scenarios reveals that none of these scenarios would result in aquatic habitat impacts very different from each other or from those that could have occurred in 1976 under 7-day-10-year low flow conditions. Thus, whether historical municipal or industrial growth continues, or whether low, high, or base case electricity demand occurs, the region already appears to have the potential to experience its most serious aquatic habitat impacts under 7-day-10-year low flow conditions. However, although overall aquatic habitat impacts change little under most of these scenarios, under the strict control case and the high growth case, some rivers would register perhaps slightly less or more stress than they would under the base case.

Background Concentrations

The reason why the majority of the streams would experience the same impacts under the scenarios as they would under 1976 conditions concerns the high background concentration levels that exist in the region. As noted under the base period discussion, 19 of the 24 streams studied could have violated several of the study's reference concentrations under 7-day-10-year low flow at some time in 1976. Further, the overwhelming majority of these high background concentrations are estimated to be geochemical or to originate from nonpoint sources under conditions of higher flow. Since the likelihood of bringing nonpoint sources under control during the time frame of this study is considered almost impossible by most experts, background levels in the ORBES streams were projected to remain constant between 1975 and 2000 under all scenarios except the strict control case. Under the strict control case it was assumed that background levels would be reduced by half by the year 2000. (It also was assumed under this case that power plant effluent loadings would be reduced 95 percent from the base case loadings.) Such calculations reveal that if such a reduction were to occur, aquatic habitat impacts would remain about the same although slightly less stress would be experienced on all rivers. The results under the strict control case thus suggest that background levels are so high that they would have to be reduced by more than half to avoid serious aquatic habitat impacts under 7-day-10-year low flow conditions.

Loadings

The influence of these background concentrations is further indicated when the effluent loading assumptions of these scenarios are compared. Under all of the coal-dominated scenarios except the strict environmental control case, power plant effluents were not limited. The strict control case, however, along with its assumption of reduced concentrations, assumed that energy conversion facilities would operate at 5 percent of base case levels. However, a comparison of the strict control case with the other coal-dominated cases—the base case, for example—reveals little difference because of the loading assumptions. Although slightly less stress would occur on all rivers under strict controls, aquatic habitat impacts remain the same as under the base case on all but four rivers. If the impacts under the strict control case then are compared to those that could have occurred in 1976, only two rivers would register changes from the 1976 aquatic habitat impacts. Thus, since loading is not a significant factor, background concentrations appear mainly responsible for the substantial impacts that could occur under 7-day-10-year low flow conditions.

Consumption

Power plant consumption would be important on those of the region's smaller streams where little municipal and industrial consumption occurs and where flow under 7-day-10-year low flow conditions would be curtailed drastically. However, if background concentrations were not so high on these small streams, power plant consumption might have little impact. Thus, once again the high background levels are more important than the consumption source.

What the impacts on these small streams suggest is that alternative siting or technology could alleviate almost all power-plant-related impacts on water quality under all scenarios. There is, however, one, perhaps significant, problem with alternative siting of power plants. Although water quality would be protected, air quality would suffer since most of the suitable alternative sites in terms of water quality are located along the Ohio River main stem, where air quality problems exist. A further concentration of power plants in this area thus could exacerbate these air quality problems.

What can be done to avoid the combined effects of natural forces and high background concentrations thus is hard to pinpoint, especially if it is unlikely that nonpoint sources can be brought under control. Preventing the rather minor power-plant-related impacts would necessitate the tradeoff just discussed. Avoiding the potentially significant impacts of municipal and industrial consumption also would involve tradeoffs. If, for example, regulatory bodies were to implement siting restrictions that prohibit the siting of any entity that consumed water along streams having 7-day-10-year low flows less than 100 cubic feet per second, a number of rivers would not be available for growth of any kind. This condition would result in a very limited number of sites for industry, especially for power plants. Thus, as this brief outlining of some possible steps and their limitations suggests, improvements in water quality may require some environmental, social, and economic tradeoffs that would have their own repercussions.

Mitigation Strategies

On a regional scale, existing institutional mechanisms are inadequate to ameliorate air quality impacts, many of which transcend political boundaries both inside and outside the ORBES region, particularly to the northeast.

Technical Strategies

A variety of technical strategies, usually applied on a plant-by-plant basis, could be more effective if implemented regionally. Among the technical strategies discussed in the context of the ORBES scenarios are the use of flue gas desulfurization systems, or "scrubbers"; least emissions dispatching; modified plant retirement schedules; and stricter environmental standards.

Techno-Organizational Strategies

In contrast to technical strategies, which usually are applied at single generating units or within a single utility service area, techno-organizational strategies are broader and could be developed on an interstate, multistate, or regional scale. The need for such strategies arises from transboundary air pollution transport, which can be divided into two types: (1) *local* transboundary air pollution transport (the movement of air masses is over relatively short distances across state lines and the contributions from individual plant sources usually can be identified) and (2) *long-range* transboundary air pollution transport (the air masses travel longer distances, often across several state lines, and the contributions from individual sources are difficult to isolate).

Local Transboundary Transport

Local transboundary air pollution transport is treated in the Clean Air Act, in provisions that attempt to make a state responsible for pollution that originates within its borders but is transported short distances into other states. At present, action is pending on at least three petitions filed by several ORBES-region states in regard to air pollution generated by power plants in neighboring states. Protracted legal proceedings on related local transboundary pollution questions also have taken place in the region within the context of the Clean Air Act.

Long-Range Transboundary Transport

Long-range transboundary air pollution transport, on the other hand, is not covered specifically in the Clean Air Act. However, as discussed previously, long-range transport contributes to violations of NAAQS in the upper ORBES region. Thus, air quality in the ORBES region and beyond could be improved if there were a regionwide techno-organizational strategy for determining expected emissions from coal-burning plants, siting new plants, and operating both existing and new facilities. A coordinated strategy is necessary because of the interdependency of emission reductions, siting, and operations.

A coordinated siting mechanism could help to reduce pollutant concentrations at local "hot spots," where these concentrations are highest. However, total regional pollutant loadings would remain the same whether a regional siting mechanism is developed or not. Thus, regional coordination appears to be required to reduce pollutant loadings and/or to reduce concentrations from long-range transboundary pollution in the ORBES region and beyond.

Utilities and State Governments

If new organizational approaches are to be devised in a meaningful way, both the states and the electric utilities mus participate. Voluntary cooperatio among utility companies is one possibi ity, but it may not be realistic to expe utilities in different states to wor together in activities aimed at th mitigation of negative transboundary a quality impacts. Moreover, cooperatio would have to encompass operations a well as siting if extraregional impac were to be mitigated.

If utilities were to agree upon th desirability of cooperation in eith siting or operations across state line the most appropriate organization arrangements are not clear. At presen utilities are regulated by individu states, and most utility service are follow state lines. Thus, voluntary c operation across state lines probab would be difficult. Yet the utilities c engage in interstate cooperation i several other areas, principally in th assurance of electric power reliability. is conceivable that regional reliabili councils now in operation could stim late further cooperation. Indeed, th expansion of existing federal legislatio might encourage cooperative siting, not cooperative operations. Cooperatio among the states in this regard al should be examined, but prospects not appear promising. In only one ORBE state, Ohio, has the legislature ma dated administrative leaders to se cooperation with other states in deve oping mitigation strategies. Ohio is al the only ORBES state with a "one-sto siting procedure; if similar arrangemen existed in other ORBES states, th might provide a vehicle for intersta discussions on siting problems.

Interstate Compacts

Another potential vehicle is the inte state compact. For example, an existi compact, the Ohio River Valley Wat Sanitation Commission (ORSANC might be expanded in scope to per supplementary agreements, betwe two or more member states, to reso transboundary air pollution confli and other problems related to intersta facility siting and possibly operations

No interstate compact to mitiga long-range transboundary air polluti is known to operate anywhere in t country at this time. However, t Delaware River Basin Compact h organizational elements that could relevant in the consideration of such mechanism for the ORBES region. F example, the Delaware compact h

ɪn instrumental in obtaining inter-
ate approval of power plant sites.

'ther Regional Bodies

The Tennessee Valley Authority (TVA) ınnot be ignored in any consideration mitigation strategies. A portion of ıntucky is included in the TVA area, ıd problems of long-range transboundy air pollution transport are shared by e TVA area and the ORBES region. In :t, the two areas are connected in so ıny ways as to make separate treatınt impossible.

Other regional bodies that should be nsidered in this context are the Ohio ver Basin Commission and the Aplachian Regional Commission (ARC). ıme have suggested that the ARC's nctions be expanded so that this ganization could address air impacts the Ohio River valley and perhaps rticipate in interstate siting. However, ı proposal has found little support.

'deral Action

'he most likely federal initiatives will nter on the Clean Air Act; an upcoming bate in Congress will review the tire act, including the 1977 amendınts. The most extreme possibility, deral preemption, is considered likely.

el Substitution and ›nservation Scenarios

'our scenarios investigate energy 1 fuel use characteristics that differ m those of the coal-dominated sce-'ios (see table ES-1). Three of the ;es assume relatively less emphasis coal use for electrical generation :ause of partial substitution by other els. In the natural gas substitution e, natural gas is substituted for other ıls whenever practicable, but not to ı utility boilers. In the nuclear fuel ›stitution case, nuclear-fueled electrical generating capacity substitutes directly for coal-fired capacity. In the alternative fuel substitution case, a variety of alternative fuels, including biomass and solar energy, partially replace coal-fired capacity. The fourth case assumes that energy growth in the ORBES region is significantly less than under all other scenarios because of the implementation of conservation measures. All four cases are compared with the coal-dominated base case.

The same regional population, fertility, and economic growth rates are assumed in the four scenarios discussed here as are assumed in the coal-dominated case. Moreover, base case environmental controls are assumed under all four scenarios. Finally, the same assumptions as under the coal-dominated scenarios are made concerning the mining for utility coal and the utility-announced capacity.

Comparison of Fuel Substitution and Conservation Scenarios

An analysis of these fuel substitution and conservation scenarios suggests that all of these scenarios would reduce the emission-related impacts that are projected to occur under the coal-dominated base case. Other across-the-board comparisons, however, are more difficult to make.

Emissions, Concentrations, and Air-Quality-Related Impacts

Emissions

Utility sulfur dioxide emissions would be only slightly lower in 2000 under the fuel substitution and conservation secnarios than under the base case (see table ES-4) even though substantially fewer coal-fired units would be added under the substitution and conservation scenarios. The conservation case would reduce sulfur dioxide emissions the most (resulting in emissions 11 percent lower than under the base case), and the nuclear substitution case would reduce them the least (resulting in emissions only 3 percent lower).

The expanded use of SIP generating units under each of the fuel substitution and conservation scenarios explains why these scenarios would result in sulfur dioxide emissions quite similar to those of the base case. Under both the conservation emphasis case and the natural gas substitution case, fewer new generating units would be built than under the base case; under the nuclear fuel substitution case, new units added after 1985 would be nuclear fueled rather than coal fired. As a result, SIP-regulated generating units would be used more than they would under the base case, where some of the electrical generation shifts to the new, cleaner RNSPS units. For example, under the natural gas substitution case, SIP units would account for 32 percent of the electrical generation in the year 2000, whereas they would account for 25 percent under the base case. Thus, while sulfur dioxide emissions from SIP-regulated units would account for 67 percent (or 2.93 million tons) of the sulfur dioxide emitted in 2000 under the base case, under the natural gas case such emissions not only would be higher (3.05 million tons) but also would account for more of the total emissions (78 percent of the 3.93 million tons emitted).

Particulate emissions also would be lower under all of the fuel substitution and conservation scenarios than they would be under the base case. However, again because of the expanded use of SIP units to generate electricity, these emissions would be only slightly lower than under the base case.

'ble ES-4. Sulfur Dioxide, Particulate, and Nitrogen Oxide Emissions, ORBES Region, Fuel Substitution and conservation Emphasis Scenarios, Year 2000

	Sulfur Dioxide Emissions	Particulate Emissions (millions of tons)	Nitrogen Oxide Emissions
976	8.94	1.38	1.49
ase Case	4.35	0.19	2.00
'atural Gas Substitution	3.93	0.16	1.51
'uclear Fuel Substitution	4.21	0.18	1.84
'onservation Emphasis	3.87	0.16	1.47

'lote: Emission levels were not calculated for the alternative fuel substitution case.

Utility nitrogen oxide emissions would not increase as much under the fuel substitution and conservation scenarios as under the base case (see table ES-4) since such emissions rise in proportion to increased generating capacity, and less generating capacity is added under all of the substitution and conservation scenarios than under any of the coal-dominated scenarios.

Although annual and episodic concentrations, crop losses, and emission-related mortality were not examined thoroughly under these fuel substitution and conservation scenarios, a few general observations can be made using the patterns developed under the coal-dominated scenario analyses.

Concentrations

Since the magnitude of sulfur dioxide and particulate emission reductions consistently correlates with reductions in annual and episodic sulfur dioxide and particulate concentrations, and since all of the fuel substitution and conservation scenarios would reduce these emissions more than the base case would, concentrations should be lower in 2000 under any of the fuel substitution and conservation scenarios than under the base case. This observation is confirmed by calculations performed for the natural gas substitution case. Under the natural gas case, episodic sulfur dioxide and sulfate concentrations would be 25 and 15.6 percent lower, respectively, in the year 2000 than they would be under the base case in that year. Annual average concentrations would be about the same in 1985 and about 7 percent lower in 2000 than under the base case.

Physical Crop Losses

Similarly, physical crop losses in the year 2000 due to utility sulfur dioxide emissions should be lower under any of the fuel substitution and conservation cases than they would be under the base case. However, even under the base case such crop losses would represent less than 1 percent of the total regional yield.

It is the crop losses due to oxidants that these substitution and conservation scenarios should reduce the most. As will be recalled, increased utility nitrogen oxide emissions under the coal-dominated base case could contribute significantly by the year 2000 to crop losses. Thus, since the fuel substitution and conservation scenarios would result in utility nitrogen oxide emissions significantly or substantially lower than those under the base case, related crop losses also should be significantly to substantially lower under these scenarios.

Mortality

Finally, mortality related to air quality should decrease under all of these fuel substitution and conservation scenarios. An analysis of sulfate-related deaths under the natural gas substitution case bears out this observation. Under this case, cumulative sulfate deaths related to ORBES-region electrical generation would be 21 percent lower between 1975 and 2000 than they would be under the base case.

Economic Impacts Related to Air Quality Impacts

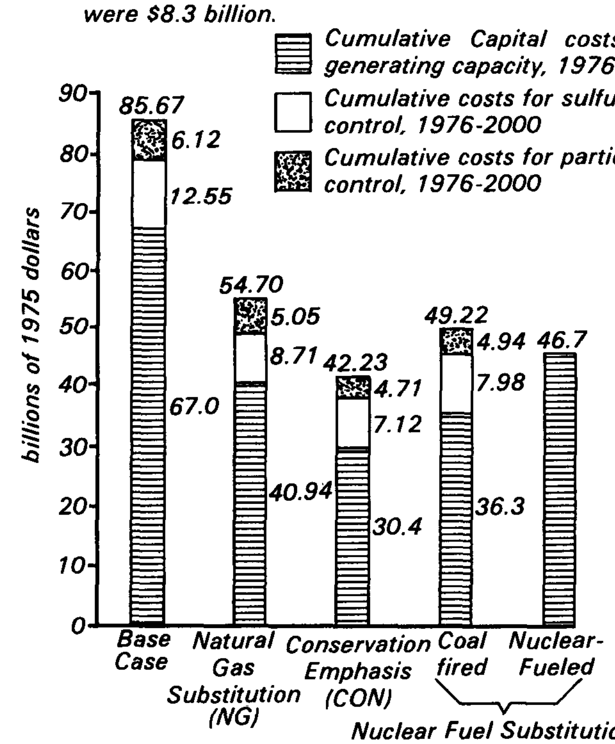
Utility Costs

In terms of the monetary costs to the utilities and to the consumer for the lower emissions, all three of these substitution and conservation scenarios should result in lower cumulative pollution control costs and lower cumulati capital costs to install new coal-fir capacity than would the base case (se figure ES-15). These reductions are tl direct result of decreased coal-fir generating capacity under all of the scenarios. However, when the costs installing nuclear-fueled capacity a added, the nuclear fuel substituti case results in total costs about 1 percent higher than the total cos under the base case. The nuclear su stitution case would result in the higher costs because the cost of buil ing a nuclear-fueled plant is appro mately 20 percent higher than the cc of building a comparable coal-fired pla

Consumer Costs

Consumer costs were calculated on for the natural gas substitution cas Thus, the exact economic benefits f the consumer of reduced pollution co trol costs and of reduced capital cos are unknown for the other fuel su stitution and conservation scenaric Under the natural gas substitution cas however, the total revenues collect

Note: The same nuclear capacity was assumed under all scenarios but the nuclear fuel substitution case. For all scenarios but the nuclear case, cumulative capital costs for nuclear-fueled capacity were $8.3 billion.



Cumulative sulfur dioxid and particulate control costs		
Scenario	Costs billion $	% tot cost.
BC	18.67	21.ɛ
NG	13.76	25.1
CON	11.83	28.(
NF	12.92	26.:

Figure ES-15. *Cumulative capital costs, base case, fuel substitution scenari and conservation emphasis scenario, 1976-2000.*

om consumers between 1976 and)00 would be lower (by about 26 per-ent) than the total revenues collected ınder the base case during the same 'ears. Yet the actual price of electricity ı 2000 under the former case would be ınly 0.2 percent lower in 2000 than it 'ould be under the coal-dominated ase case. The reason for this similarity ı the year 2000 can be traced to the fact ıat similar electricity demand growth ıtes were assumed for these two ;enarios between 1985 and 2000.

ther Impacts Related to 'xpanded Capacity

ealth and Land

As a result of decreased generating ıpacity, decreased coal production, ıd decreased utility coal consumption ıder the fuel substitution and conser-ıtion scenarios, fewer health impacts lated to coal mining, coal processing, ıd coal transport would occur than ould occur under the coal-dominated enarios. Similarly, land conversion)uld be lower under these substitution ıd conservation options than under ıse case. However, even under the ıse case, land conversion would repre-ınt less than 1 percent of regional ;reage, although some state portions)uld be more affected than others.

nployment

Since coal-fired power plant construc-ın and operation would not increase)idly under the fuel substitution and nservation scenarios, neither would lated employment under any of these ses. Compared to the coal-dominated ıse case, for example, the number of ınstruction and operation workers ıeded would be much lower (see ure ES-16). However, employment ıeds related to the increased use of tural gas, nuclear power, or alternative els were not calculated; in fact, these ıeds could compensate for the lower ımand for coal-fired power plant orkers.

Again because fewer coal-fired gen-ating facilities are sited and because owth is lower in all sectors, less coal ould be needed under all of the fuel ıbstitution and conservation scenarios an under the coal-dominated cases, hough such coal demand would be ımewhat higher than at present (see ble ES-1). Thus, coal-mining employ-ent for all purposes would increase om current levels at a slower rate under the substitution and conservation scenarios. Moreover, if county-level population increases should exceed the employment increases, negative county-level population increases should exceed the employment increases, negative county-level impacts that might have been avoided under coal-dominated scenarios might be felt under the substitution and conservation cases.

Water

Regional water quality impacts would be about the same under both the fuel substitution and conservation scenarios and the coal-dominated scenarios. In fact, no changes would be registered in base case protection levels and base case aquatic habitat impacts for any river under any of the fuel substitution and conservation scenarios. This across-the-board similarity, as discussed previously, results primarily from high background concentrations alone or in conjunction with municipal and industrial consumption. In comparison, power plant consumption would have only an incremental impact on most of the streams under all scenarios.

Institutional Considerations: Nuclear Energy, Alternative Fuels, and Conservation

It is considered unlikely that either nuclear energy or alternative fuels will contribute substantially to energy supplies in the ORBES region or the nation, at least by the end of this century. One reason is that a major increase in the proportion of electricity generated by nuclear fuels is not expected to occur in the coal-dominated ORBES region. A second reason is that a major shift to alternative fuels would require more extensive technological and institutional changes than are considered possible in the next 20 years. However, conservation could make significant inroads by the end of the century. Conservation would require improvements in end-use efficiencies and changes in lifestyle, but no radically new technologies. (Existing institutional mechanisms would be ade-

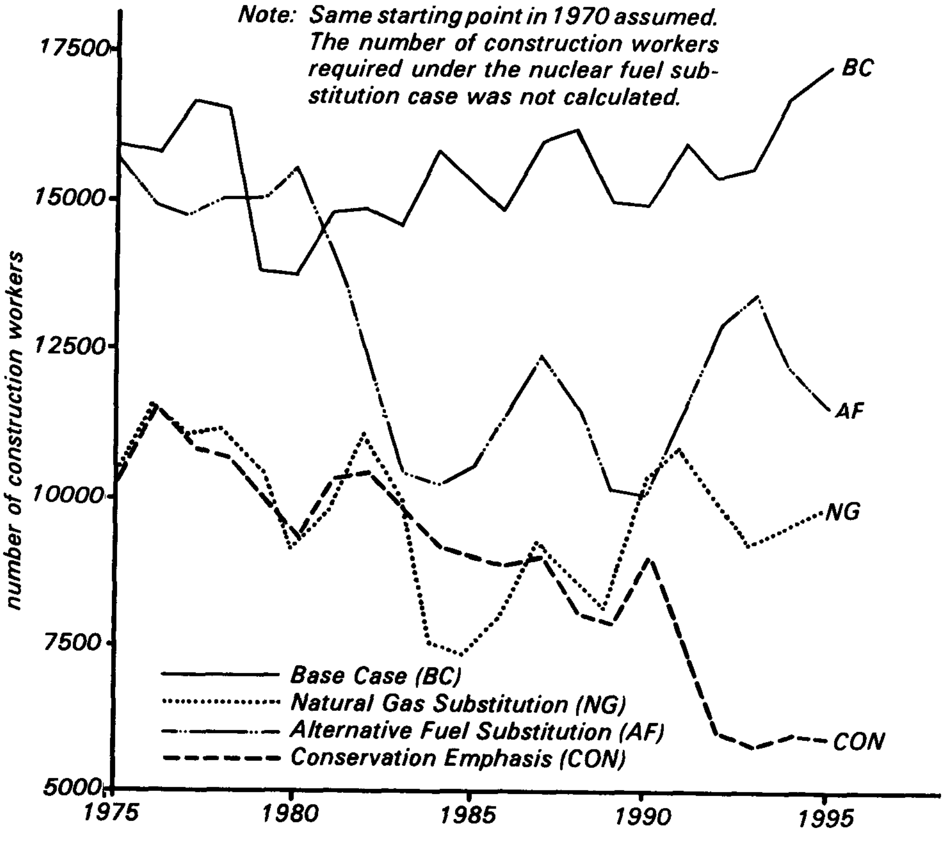


Figure ES-16. *Construction workers, base case, fuel substitution scenarios, and conservation emphasis scenario, 1975-95.*

quate to handle a major increase in the use of natural gas.)

Nuclear Energy

Within the ORBES region, opposition to the use of nuclear energy for electrical generation is particularly visible in Kentucky, Pennsylvania, and West Virginia. Among the factors leading to this opposition are the doctrine of federal preemption, controversy over the health effects of low- and high-level radiation, and growing dissatisfaction with the economics of nuclear energy.

With regard to preemption, the central, unresolved question is whether a state may legally pass legislation to control the placement of nuclear facilities or the transportation or storage of nuclear materials within its borders. With regard to the economics of nuclear-fueled generation, nuclear-fueled units are slightly more expensive to build than are coal-fired units under the current fiscal and regulatory schemes prevalent in the ORBES region. In addition, at least in a representative portion of the region, the cost advantage of coal would be substantially greater without present federal tax and other fiscal policies that favor capital-intensive production (including the nuclear industry).

Alternative Fuels

The alternative fuels case considers the partial substitution of direct and indirect solar energy processes for coal-fired electrical generation in the ORBES region.

Solar Energy

Three broad groups of institutional issues are associated with the introduction of solar energy: legal and physical access to sunlight, integration with existing energy infrastructures and institutions, and government program implementation and management.

The solar access barrier stems from the basic orientation of real property law toward the development of land. That is, the potential investor in a solar energy system is not guaranteed permanent access to sunlight. Changes in nuisance law, zoning, solar easements, and restrictive covenants offer possible remedies. At present, limited solar access laws have been enacted in Illinois and Ohio.

The integration of solar energy systems into existing energy infrastructures and systems raises a number of issues, including (1) the rates paid by utilities for power sold to the grid as well as for back-up power and other services provided to on-site generators, (2) the legal status of on-site generators, (3) the financing and ownership of dispersed capacity, and (4) utility management problems and perceived risks. The first two issues are dealt with in part by the Public Utility Regulatory Practices Act of 1978 (PURPA), part of the National Energy Act. The third issue is handled somewhat by the National Energy Conservation Policy Act. For the fourth issue to be dealt with, utility management techniques would have to change to accommodate a transition to dispersed capacity.

Finally, the present management of government solar programs is hampered by a number of deficiencies within the Department of Energy's Conservation and Solar Energy Programs, such as a constantly changing organizational structure.

Wind Energy

As with solar and other dispersed electric energy systems, the widespread introduction of wind energy conversion systems would raise a number of legal and institutional issues. These include financing, siting, tort liability, and environmental problems.

Biomass

Although biomass is a promising energy source for the ORBES region, its use on a wide scale also would entail the solution of unresolved institutional questions. An issue common to all bioenergy sources is the need to develop programs to provide information and technical assistance to bioenergy users. Also needed is the establishment of reliable supply infrastructures for direct energy uses of biomass resources. In both public and private operations, long-range energy and resource planning and proper resource management would have to take place. Institutional changes would be required to link bioenergy to conventional energy supply infrastructures and users. For example, where biomass is used to produce electricity, provisions must be made to sell surplus power to the grid at equitable rates and to supply back-up power to producers of bio-electricity. Finally, federal administration of bioenergy research, development, and implementation would have to be improved.

Each form of biomass entails additional issues. The primary institutional issue associated with the use of w as energy is the management and c of the resource base, that is, for lands. The primary institutional iss associated with intensive agricult production for energy are the integrat of energy demand for crops into exist markets and the potential for envir mental damage. The use of munic solid wastes for energy raises inst tional issues related to the remova barriers to resource recovery.

Conservation

Only one conservation measur cogeneration—was quantified for us an ORBES scenario. Economic fac are the primary institutional consid tions associated with the introductio cogeneration by industries, notably rate of return on investment in coge ation technology. The most impor cost consideration is the savings real from cogeneration when compared the alternative costs of separate op tions for in-house steam production purchased electricity. Other conce are effects on the environment potential regulatory constraints.

Concluding Note

One important insight gained by ORBES researchers is that the s region, part of which is known popu as the Ohio River Valley, is far n diverse than they had suspected probably more so than most pu officials realize. Failure to recognize diversity most certainly will doo failure any attempt at basinwide ins tional innovations. There is inc balkanization within the ORBES re and with a continued emphasis on ideological divisions probably wil come more pronounced.

The local and long-range transbo ary movement of air pollutants ac state lines is the single issue withi broad context of continued (and per increased) reliance on coal that c produce the most conflict. Since OF began in 1976, this issue has ga increased attention in the regio affects employment levels in the mining industry as well as in indus general. It triggers emotions tha easily translated into political contro

But many of the ORBES research air pollution experts, economists, yers, political scientists, and oth believe that institutional mechan can be devised that will permi region to enjoy the benefits of ɘasonably clean air and a degree of conomic growth. The creation of such mechanisms will require the highest echnological competence, as well as ocial and political imagination. If there s any single finding of the Ohio River asin Energy Study, it is that steps oward both clean air and economic growth in the region can be taken only if ways can be found to unite the various actions. Many residents of the region nave recognized this reality, but they emain separated by ideology. Some elieve that the steps should be initiated y government, while others favor ction within the private sector. It is not e responsibility of ORBES researchers recommend which path should be ollowed. But it is our responsibility to warn that inaction could result in economic stagnation and accompanying ocial problems capable of draining nuch-needed vitality from the region nd from the nation at-large.

This Project Summary was authored by the ORBES Core Team, University of Illinois, Urbana, IL 61801.
***Lowell Smith** is the EPA Project Officer (see below).*
The complete report, entitled "Ohio River Basin Energy Study (ORBES)," (Order No. PB 81-161 788; Cost: $24.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Program Integration and Policy Staff
Office of Research and Development
U. S. Environmental Protection Agency
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