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United States General Accounting Office

GAO

Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce
House of Representatives

April 1986

AIR POLLUTION

Improvements Needed in Developing and Managing EPA's Air Quality Models

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Resources, Community, and
Economic Development Division

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April 22, 1986

The Honorable John D. Dingell
Chairman, Subcommittee on Oversight
and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

In response to your January 30, 1984, request and as clarified in subsequent discussions with your office, this report discusses the Environmental Protection Agency's use of air quality models in carrying out the Clean Air Act.

As arranged with your office, unless you publicly announce its contents, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will send copies to the Administrator, Environmental Protection Agency, the Director, Office of Management and Budget, and to other interested parties. We will also make copies available to others upon request.

Sincerely yours,

J. Dexter Peach
Director

Executive Summary

Mathematical computer models play an important role in the efforts of the Environmental Protection Agency (EPA), state and local governments, and industry to reduce air pollution. However, models are based on assumptions, approximations, and judgments, all of which affect the accuracy of their results.

Concerned about EPA's reliance on modeling, the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, asked GAO to examine

- the accuracy, adequacy, and cost of models used by EPA, and the problems and limitations arising from uncertainties associated with models; and
- the appropriateness of an agreement between EPA and a contractor for developing a utility-sector air quality analysis model.

Background

Air quality models consist of interrelated equations that attempt to depict mathematically the effects of wind speed, wind direction, and other atmospheric conditions on the movement of airborne pollutants.

EPA, state, and local government agencies, and industry use estimations made by air quality models to (1) help determine whether requests for permits to build or modify facilities that emit pollution are justified; (2) supplement actual monitoring data when determining whether air quality complies with national standards; (3) conduct research in air pollution; and (4) design control programs to reduce emissions of air pollution. (See chapter 1.)

Results in Brief

Because of limitations in the current state of the art of model development, air quality models estimate pollution concentrations with wide ranges of uncertainty; the wider the range, the less reliable the model. EPA is in the process of evaluating its air quality models to quantify the ranges of uncertainty associated with each model and, in turn, to modify the models to reduce uncertainties.

However, even if EPA can successfully complete these efforts, EPA officials and other air quality model users believe that additional and more refined models need to be developed to fully implement and monitor the air pollution programs required by the Clean Air Act. Models cost from $50,000 to several million dollars each to develop. The more complex and refined the models are, the more they cost to develop.

In procuring the development of one new model, EPA used a cooperative agreement with a university. Such an agreement does not require delivery of a product—only that the contractor put forth its best effort. EPA's procurement guidelines do not indicate the types of procurement mechanisms that should be used in different situations. EPA used a cooperative agreement because it required the contractor to provide a 5-percent share of the project funding. The agency spent $3 million and 5 years on the project, but EPA did not receive an acceptable product from the contractor. In fact, EPA competitively awarded a contract to another party to complete the project for $500,000 for the base year and $1,000,000 for the 2 option years.

Principal Findings

Accuracy of Models

Although EPA does not know the accuracy of all of its air quality models, the agency still uses them to support regulatory decisions. EPA has recognized that it needed to quantify the uncertainty associated with pollution concentration estimations, and is in the process of assessing the accuracy of its 33 major air quality models. It does this by comparing actual pollution concentrations obtained from ambient air quality monitors to pollution concentrations estimated by the models. EPA found that 7 of the 20 models it has tested make estimations within a range of minus 50 percent to plus 200 percent of actual concentrations. For example, an actual sulfur dioxide concentration of 200 micrograms per cubic meter would be estimated as somewhere between 100 and 400 micrograms per cubic meter. The ranges of the other 13 models are so wide that EPA must perform additional analyses before making regulatory decisions.

According to the Utility Air Regulatory Group, a voluntary non-profit group of electric utilities, models tested by EPA and found to overestimate pollutant concentrations have caused industry to spend millions of dollars on unjustified pollution control equipment, replacement fuel, and studies to justify increased emissions. In addition, the Electric Power Research Institute identified $171 million of actual costs attributed to model uncertainty at 10 utility companies. EPA acknowledges that the uncertainties of the models may have resulted in industry installing additional pollution control equipment but says that such uncertainties will likely become less frequent as it establishes the uncertainties of its models and uses that knowledge in regulating industry. As the uncertainties become known, they are considered in evaluating whether estimated pollution levels meet air quality standards. Agency officials believe that even though there are limitations in the capabilities of models, they are valuable tools in regulating air pollution and in conducting air pollution research. According to EPA, the usefulness of models is enhanced as their uncertainties are quantifiably established and their accuracy is improved. (See chapter 2)

Adequacy of Models

EPA does not believe it has all the models it needs to fully administer the requirements of the Clean Air Act. EPA has 26 models under development. An EPA study has identified an additional 186 regulatory and research applications that have not been met, including one classified as urgent—needed immediately—and 37 classified as high priority. One model can satisfy more than one application need, and EPA is in the process of determining its model requirements. EPA anticipates determining how many models it needs by August 1986. EPA also is considering what actions it should take to develop additional models. (See chapter 2.)

Cost of Models

Depending on a model's complexity and intended use, the cost of developing models ranges from $50,000 to several million dollars. Costs to use a model range from $5 per analysis to $50,000 for each day analyzed.

Most models use previously collected data in their analysis and are inexpensive to use. Other models cannot be used until a costly detailed analysis of air quality and meteorological data is performed. (See chapter 2.)

Cooperative Agreement

In September 1980, EPA awarded a cooperative agreement for the development of a new utility-sector analysis model. The Federal Grant and Cooperative Agreement Act of 1977 specifies that a procurement contract is the correct legal instrument whenever the principal purpose is the acquisition of property or services for the direct benefit of the federal government. In addition, four project management- and administration-related factors delayed the model's development: (1) difficulty in obtaining documentation for a predecessor model; (2) funding uncertainties; (3) fragmented organizational structure for the development effort; and (4) lack of continuity (five project officers) in EPA's supervision of the effort. (See chapter 3.)

Recommendations

Because EPA's efforts to assess and improve the adequacy and accuracy of models are ongoing, GAO is making no recommendations in this area.

However, GAO recommends that the Administrator, EPA, develop and implement a policy that provides guidance on what procurement mechanism should be used in various situations. This guidance should include the stipulation, to the extent possible, that contracts rather than cooperative agreements be used to obtain new computer models.

Agency Comments

GAO discussed the modeling program with EPA program officials and has included their comments where appropriate. However, GAO did not request official agency comments on a draft of this report.

Contents

Abbreviations

AMS	American Meteorological Society
AUSM	Advanced Utility Simulation Model
CEUM	Coal and Electric Utility Model
EIA	Energy Information Administration
EPA	Environmental Protection Agency
GAO	General Accounting Office
NAAQS	National Ambient Air Quality Standards
NCM	National Coal Model
NESHAP	National Emission Standards for Hazardous Air Pollutants
ORD	Office of Research and Development
PSD	Prevention of Significant Deterioration
SAIC	Science Applications International Corporation
URGE	Universities Research Group on Energy
USM	Utility Simulation Model

Introduction

The Clean Air Act[1] was enacted by Congress to protect and improve the quality of the nation's air in order to promote public health and welfare. The Environmental Protection Agency (EPA) administers the act, but delegates operational responsibilities to state and local governments whenever possible.[2] Examples of such responsibilities include:

- reviewing applications for construction of stationary emitting sources (e.g., adding smokestacks to industrial plants) to determine the types and potential amounts of pollution emissions;
- issuing construction permits to sources that comply with mandated pollutant-emission limitations;
- inspecting sources to determine whether they operate within permitted conditions; and
- instituting penalties against those sources that violate their permits.

Among the tools that EPA or designated agencies must use in administering air pollution laws are computerized air quality models. Such models provide estimates of pollution effects, which in turn are used in deciding whether to issue a permit or whether a source complies with air quality standards.

Use of Computer Models

Before a permit can be granted for constructing or modifying any major emitting facility in a clean air area,[3] the applicant must demonstrate that the new source will neither violate any air quality standards nor result in a very high ambient concentration of hazardous air pollutants. This demonstration entails conducting an air quality analysis of the site for each regulated pollutant likely to be emitted, or for which the emission is expected to increase significantly. The analysis includes those pollutants for which national ambient air quality standards exist (National Ambient Air Quality Standards, NAAQS[4]) and other pollutants,

[1]42 U.S.C. 7401 et seq

[2]Delegation means the assumption by a competent and willing state or local government agency of the operational responsibilities of a national program to prevent and control air pollution If these responsibilities were not delegated, they would be performed by EPA

[3]Clean air areas are those areas where air pollution levels are lower than the levels established by the Clean Air Act's national ambient (outdoor) air quality standards

[4]NAAQS have been established for carbon monoxide, lead, nitrogen oxides, ozone, sulfur dioxide, and total suspended particulates

which are regulated on an emission-by-emission basis (National Emission Standards for Hazardous Air Pollutants, NESHAP[5]). The permit-granting agency (EPA, state, or local government) reviews the air quality analysis and grants or denies the permit.

Air quality analyses are generally performed with the aid of computer models, which identify and quantify the effects of all significant pollutants for which air quality standards exist. In using air quality models, analysts use a combination of interrelated equations to manipulate pollution concentration data. The result is a systematic simulation and analysis of the effects of wind speed, wind direction, and other atmospheric conditions on movement of airborne pollutants. As with other computer models, those used for air quality analysis are based on assumptions, approximations, and judgments, all of which affect a model's accuracy, validity, and reliability.

Air quality modeling may be performed by the applicant (the industry proposing construction), by the state, or by a consultant engaged by either party, and must be consistent with procedures recommended in EPA's "Guideline on Air Quality Models" and other EPA modeling guidance. The permit-granting agency (EPA, state, or local government) reviews the model analysis and grants or denies the permit.

Example of Mode Use

In 1982, EPA used data from a model to issue a permit allowing a utility company to construct a new coal-fired power plant. Under the Clean Air Act, the utility was required to obtain a Prevention of Significant Deterioration (PSD) permit demonstrating that the sulfur dioxide emissions would not significantly deteriorate the air quality in the clean air area. As part of the PSD application for the permit, the utility used an air quality dispersion model, VALLEY, to predict the increase in sulfur dioxide concentrations that could be expected from a new power plant in the area.

The model used 5 years of National Weather Service and 1 year of existing pollution concentration data obtained from ambient air quality monitors, as well as estimated pollution emissions from the new plant. VALLEY demonstrated that the new plant would comply with the PSD requirements and that the air quality would not be significantly deteriorated. The EPA reviewed the data used in the model and the assumptions,

[5]NESHAP were established to control pollution emissions from new, modified, or existing sources that cause or contribute to any air pollution that may reasonably be anticipated to cause illness or death

approximations, and judgments on which it was based. From the review, EPA concluded that the utility company would be found in compliance with PSD requirements, and issued the PSD permit allowing construction to begin.

Other Uses of Models

Besides their use as valuable tools in estimating the air pollution effects of new pollution sources, models are also used as a less expensive alternative for estimating pollution levels around existing facilities rather than obtaining actual emissions data from air quality monitors. For example, according to EPA's previous Assistant Administrator for Air and Radiation, in order to get accurate readings of the air surrounding a plant, the plant would have to be encircled by air sampling equipment. It is not economically feasible to do this for the country's over 30,000 major stationary sources of air pollution.

Air quality models are also used by EPA and state and local air pollution control agencies for other general types of applications, such as

- issuing variances for permit requirements that allow pollution emitters to vary from or exceed pollution limits established in their initial permits; and
- conducting research and development in air pollution, including the establishment and periodic review of NAAQS and the creation of control programs to reduce air pollution.

EPA's Office of Air Quality Planning and Standards issues guidance to EPA and state and local air pollution control agencies for use with models. Within EPA, there are three primary organizations that use models:

- EPA regional offices use estimations by models to review model-based permit decisions made by state and local air pollution control agencies. EPA regional offices also use model estimations to aid in permit decisions they make for those programs that have not been delegated to state and local levels.
- EPA's Office of Research and Development uses model estimations for conducting research and development in air pollution. Such research is used in the establishment and periodic review of NAAQS and the creation of new control programs and techniques to reduce air pollution.
- EPA's Office of Policy Analysis uses model estimations for analyzing policy alternatives, including estimating the effects of proposed environmental laws on industries.

Model development within EPA takes place in two laboratories of the Office of Research and Development: Atmospheric Sciences Research Laboratory and the Air and Energy Engineering Research Laboratory. These two laboratories either develop the models or issue contracts for their development to private organizations.

Models Discussed in This Report

Chapter 2 discusses EPA's efforts to determine the accuracy and adequacy of air quality models used to predict the movement and concentrations of air pollutants. These air quality dispersion models, described in the preceding pages, are used mainly in issuing construction and modification permits and in assuring compliance with NAAQS.

Chapter 3 discusses the development of a different type of air quality model that is used in analyzing various options for reducing air pollution—utility-sector analysis models. These models are used to estimate the effects on the U.S. electric utility industry of using alternative air pollution reduction methods during the generation of electricity. This category of models considers the cost of various air pollution control methods to estimate the appropriate air pollution control mechanism. Utility-sector models are used by industry to analyze alternative compliance options and by EPA's Office of Policy Analysis to analyze the impact of proposed air pollution regulations.

Objectives, Scope, and Methodology

As agreed with the Office of the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, we examined

- the accuracy, adequacy, and cost of models used by EPA and the problems and limitations created by the uncertainty associated with models; and
- the appropriateness of an agreement between EPA and a contractor for developing an utility-sector model.

To assist us in determining how many models are used in administering the Clean Air Act, the Chairman requested in April 1985 that EPA provide him with a list of its models used to make air quality predictions. EPA identified 31 models that were being used at the time of our review either internally or by state and local governments in regulatory analysis of their air pollution control programs. We also identified and added two models that EPA officials said they had inadvertently omitted from its list.

For each of the 33 models, we obtained documentation

- justifying why each model was developed;
- describing how each model was developed;
- explaining how each model is used and maintained, including associated costs;
- describing the types of data used in each model;
- evaluating the uncertainties associated with each model; and
- explaining the availability of users' guides.

We discussed each model's development and use with the EPA officials directly involved. We also interviewed EPA regional officials in 4 of the 10 regional offices—Region I (Boston, Mass.); Region III (Philadelphia, Pa.); Region V (Chicago, Ill.); and Region IX (San Francisco, Calif.)—to obtain information on the use and adequacy of models in their regions.

We selected these regions for our work because EPA identified these four regions as having modeling personnel involved in all types of air quality models, and because they provide geographical coverage of the United States. In addition, these four regional offices generally had the highest number of computer-modeling personnel.

To obtain information on the adequacy of computer models, we relied on model evaluations done by others (such as the American Meteorological Society and the American Petroleum Institute), and on interviews with representatives from EPA, the Utility Air Regulatory Group[6], and the California Department of Transportation. We did not independently evaluate the adequacy of the models.

The Chairman's office also was concerned about EPA's use of contractors to develop utility sector models. In particular, we reviewed the appropriateness of the agreements between EPA and ICF, Inc., a modeling contractor who developed two models: the National Coal Model (NCM) and a more refined version, the Coal and Electric Utility Model (CEUM). EPA has not been satisfied with NCM and CEUM and is now developing the Advanced Utility Simulation Model (AUSM) to replace them.

[6]The Utility Air Regulatory Group is a voluntary, non-profit group of 76 electric utilities, the Edison Electric Institute, the National Rural Electric Cooperative Association, and the American Public Power Association They comment on EPA's proposed rules

To obtain documentation on the development of CEUM and AUSM, we visited their developers, EPA headquarters, project officers, and other government agencies. We visited ICF, which owns CEUM, and the Energy Information Administration (EIA), the government agency that owns NCM, which ICF developed and upon which CEUM was based. We also visited the University of Illinois at Champaign, Illinois, the initial developer of AUSM. We discussed the problems encountered in the development of the models and their actual or intended use, and obtained documentation on the contract and cooperative agreement used to procure the development or use of both CEUM and AUSM.

To determine whether EIA had acted properly in providing ICF the NCM after it was delivered under contract to EIA, we reviewed pertinent provisions of the Freedom of Information Act, legislative history, and case law. We also reviewed pertinent provisions of the Federal Grant and Cooperative Agreement Act of 1977 to determine the appropriate instrument to use when procuring products such as AUSM for the federal government.

Our review work was conducted between February and December 1985. We discussed the modeling program with EPA program officials and have included their comments where appropriate. However, in accordance with the requester's wishes, we did not obtain the views of EPA program officials on our conclusions, nor did we request official agency comments on a draft of this report. Except as noted above, this review was conducted in accordance with generally accepted government auditing standards.

Accuracy, Adequacy and Costs of EPA's Air Quality Models

EPA and state and local air pollution control agencies use air quality dispersion models as tools in administering the Clean Air Act These models provide a less costly means of measuring air quality than placing monitoring devices in an area and often are the only option available. However, they frequently yield inaccurate estimations about air pollution. EPA recognizes that there are limitations in its models and has efforts either underway or under consideration to enhance their accuracy and usefulness.

Because EPA recognizes the limitations of its models, it is testing their accuracy by comparing actual monitoring data with a model's estimations. For the 20 models tested so far, out of 33 available, EPA has developed a "range of uncertainty" for each model that tells the agency what the model's precision is in estimating pollution concentration; the wider the range, the less precise the model.

In addition, EPA has not established numerical standards for evaluating model performance, although this effort is underway. These standards will be a range of uncertainties within which model estimations must fall before they can be used for regulatory decisions. As of October 1985, EPA had not found an objective way to set standards due to a lack of scientific experience with performance measures for air quality dispersion models. The EPA believes it will be able to set standards at an unspecified future date.

Model uncertainties have resulted in over- or underestimations of pollution, causing industries to spend millions unnecessarily, or underestimating the effect of pollution.

EPA believes that more and different types of models are needed to implement and monitor fully the programs required by the Clean Air Act. Because model development is costly and basic research in modeling air quality is still incomplete, progress in developing new models has been slow.

EPA Testing Shows Estimations of Models Are Uncertain

Because of limitations in the current state of the art, air quality models estimate pollution concentrations with wide ranges of uncertainties. Nevertheless, EPA officials believe that estimations from models can often be used effectively once a range of uncertainty is established for each model and considered in each decision. This requires that each model's accuracy be quantified by comparing estimations with actual measurements of air quality.

In the early 1980's, EPA began a systematic evaluation of its air quality simulation models, in order to quantify the uncertainty associated with pollution concentration estimations. The agency employed four organizations—the American Meteorological Society (AMS), Systems Applications, Inc., TRC Environmental Consultants, Inc., and H. E. Cramer Company, Inc.—to evaluate the accuracy of selected models. These organizations compared model estimations with measurements of actual pollution concentrations obtained from monitors, and calculated the differences as ranges of uncertainty.

As of October 1985, 20 of the 33 models used in making regulatory decisions or in acid rain research had been tested. According to the Chief, Source Receptor Analysis Branch, the EPA plans to evaluate the remaining 13. (See appendix I for a listing of the models that have been tested and appendix II for those models that have not been tested.) Of the 20 models evaluated, 13 were found to estimate concentrations in a range greater than one-half to two times actual concentrations, which translates to minus 50 percent to plus 200 percent. The range of uncertainty for the 13 models are wide enough that EPA officials must perform additional analyses before making regulatory decisions. For instance, one model's estimations were up to 2,000 percent more than actual concentrations.

Twelve of the model evaluations were performed using performance measures developed in 1980 by the AMS. The EPA, which funded the AMS project, considers these measures to be state-of-the-art for evaluating computer models. However, 8 of the 20 EPA models thus far evaluated were tested before these measures were established. The EPA considers the earlier measures to yield less reliable results than those used by AMS. However, EPA still considers results from the eight tests to be valid. According to EPA's Chief, Source Receptor Analysis Branch, the models are being improved as they are tested (as much as state-of-the-art limitations will allow). The majority of the models tested were conservative by nature, tending to overestimate actual pollutant concentrations. The EPA's use of model results for regulatory decision-making compensates, to some extent, for the models' tendency to overestimate. That is, according to the official, EPA judges a source to be in compliance with air quality standards as long as the lower range of estimated pollution concentrations falls below the national air quality standard.

Table 2.1: Ranges of Model Estimations

Number of models tested	Percent above and below actual concentrations
1	−45%
1	+40% to +112%
1	+103%
2	−50% to +200%
1	+92% to +200%
1	−172%
1	+50% to +1,960%
1	+200 to + 728%
1	−84% to + 314%
3	−80% to + 500%
1	−90% to +1,000%
1	−94% to +1,600%
1	−95% to +2,000%
1	−1,230% to + 30%
Total 17[a]	

[a]Of the 20 models tested, 3 did not yield quantifiable ranges One showed general inconsistencies between estimations and actual data, one generally showed substantial underestimations, and one had insufficient data

Establishing Standards Requires Additional Research

The Clean Air Act Amendments of 1977 require that permits for new construction in certain areas be contingent on a demonstration that probable emissions will stay within established limits.[1] As a practical matter, this necessitates the use of computer models because the emissions data do not exist.

In 1980, EPA asked the AMS, as an impartial expert on atmospheric sciences, to set numerical standards for acceptable model performance. According to the AMS Workshop Chairman, the AMS concluded that model performance standards could not be set at that time (1980) because: (1) the scientific community lacked experience working with performance measures for air quality dispersion models, (2) existing data bases could not provide critical test material, and (3) great potential existed for the misuse of any standard.

According to EPA's Chief, Source Receptor Analysis Branch, based on test results of models evaluated, EPA's most reliable models estimate actual pollution concentration within a range of minus 50 percent to

[1]New construction in non-attainment areas and prevention of significant deterioration areas is subject to the permit requirement 42 U S C 7503, 7475

plus 200 percent For example, an actual sulfur dioxide concentration of 200 micrograms per cubic meter would be estimated as somewhere between 100 and 400 micrograms per cubic meter According to the EPA official, EPA believes the current limitations in the science make more precise results unlikely. Indeed, in 1983 the AMS reviewed eight rural dispersion models for EPA. From their review, the AMS concluded that the scientific community must improve model physics, calculation techniques, and model input in order to obtain more precise results from models. This view is also held by EPA's Chief, Source Receptor Analysis Branch, who said that additional research will be needed before any standards will be set, and it will take several years to reach this goal.

According to an EPA report, industry's doubts about model usefulness occur for two reasons[2] First, uncertainties in the estimations of several models have been demonstrated Second, the resulting debates over the uncertainties of EPA-approved models have delayed permits from air pollution control agencies

The Utility Air Regulatory Group contends that these uncertainties have resulted in costly introduction of unnecessary anti-pollution measures, such as restricting operation of power plants or use of coal with lower sulfur content. Uncertainties also cause industry to conduct unnecessary and costly studies to justify increased emission levels, according to this organization.

Effects of Model Uncertainty

According to EPA, models can be used for making regulatory decisions as long as the agency considers the range any model's estimated concentration represents. For example, according to EPA's Chief, Source Receptor Analysis Branch, a model used to support a construction permit application under EPA's Prevention of Significant Deterioration program showed a new industrial plant would increase the concentration of sulfur dioxide by 200 micrograms per cubic meter. The permit-granting agency considered the range of uncertainty of the model (ie., minus 50 percent to plus 200 percent) and calculated the estimated increase of concentration to be between 100 and 400 micrograms per cubic meter.[3] The permit was granted because the estimations fell under the 3-hour standard of

[2] Synthesis of the Rural Model Reviews, December 1983

[3] According to EPA's Chief, Source Receptor Analysis Branch, EPA is considering the range of one-half to two times actual concentrations as the starting point for the establishment of a standard

512 micrograms per cubic meter.[4] In fact, according to the EPA official, EPA grants permits as long as the lower end of the estimated concentration's range of uncertainty was less than the 512 micrograms per cubic meter.

Although EPA recognizes that a considerable range of uncertainty is associated with models, the agency still uses models to support regulatory decisions. Such decisions include requiring industry to install and use pollution control equipment or techniques and to perform expensive studies.

A 1985 study by the Electric Power Research Institute states that industry lacks confidence in EPA's models. In addition, counsel for the Utility Air Regulatory Group provided us with specific examples from its members of cases where companies spent millions of dollars to comply with EPA decisions that were based on inaccurate model results.

In one instance, a company was required to restrict operations of one of its power plants in 1981 and 1982 because EPA's recommended model estimated violations of the sulfur dioxide standards. The company gathered actual smokestack emissions data to compare to model results Analysis of the data showed that the company could, in fact, operate at full capacity without violating the standards. EPA consequently modified the company's permit to full operation, but the company had spent $1 6 million to replace the energy that the plant had not been permitted to generate

In another example, a company was required to change from 3.5-percent sulfur coal to 2.8-percent sulfur coal when three models run in 1978 and 1979 predicted that the company would violate sulfur-dioxide standards. In 1985, a new EPA-recommended flat terrain model predicted that the standards would be attained without the use of the 2 8-percent coal. The low-sulfur coal cost the company approximately $2 million yearly, for a total of $12 million before the decision was rescinded. In 1985, the Electric Power Research Institute conducted a case study of pollution control costs at 10 utility companies.[5] The study attributed $171 million in actual costs to modeling uncertainties at the 10 utility companies.

[4]The allowable PSD increment for sulfur dioxide for a 3-hour period is 512 micrograms per cubic meter

[5]Case Studies of Utility Industry Costs of Air Quality Modeling Uncertainty

Even though models tend to overestimate concentrattions of the air pollutant, modeling uncertainty can also produce results that understate the pollution effect on the environment For example, two EPA-approved models yielded different estimations of increased pollution emissions at two New York power plants.[6] Using one estimation, EPA proposed to permit the plants to increase their sulfur dioxide emissions. The state of Connecticut then alleged, based on another EPA-approved model, that the increased emissions violated sulfur dioxide standards and exacerbated existing violations of the particulates standard. In this case, the situation was resolved when the EPA Model Clearinghouse—a unit formed to resolve conflicts over selection and use of air quality models—favored use of the model that supported increased emissions

EPA acknowledges that disagreements over interpreting the estimations made by models are likely to become less frequent as the uncertainties of its models are determined and considered in making air quality compliance decisions. In EPA's opinion, if users recognize the model's inherent limitations, the models can be reasonably employed as regulatory and research tools The EPA also believes that their comparative economy of use makes models more desirable than monitors The EPA's previous Assistant Administrator for Air and Radiation told the National Journal that computer modeling is EPA's only viable alternative to the extremely costly process of monitoring pollutant-emitting sources.[7]

Modeling Needs Not Fully Satisfied

Recognizing that the agency's air quality modeling needs were not being fully met, EPA's Office of Air Quality Planning and Standards and the Atmospheric Sciences Research Laboratory of its Office of Research and Development jointly undertook a study to identify and prioritize those needs[8] The 1984 study found that while computer models were needed for 236 regulatory and research applications, only 50 model applications (21 percent of the total needed) were available or under development (24 available and 26 under development). The study recognized that one model could satisfy more than one application need, but did not identify the number of models needed. The study established priorities for each of the 186 remaining needs. Of these, one was classified as being of

[6] EPA's Guideline on Air Quality Models (Revised) lists models that are preferred for use in regulatory air quality programs and alternative air quality models that may be considered on a case-by-case basis for individual regulatory applications

[7] (March 23, 1985), 643

[8] A Planning Tool for Research on Air Pollution Models, Aug 27, 1984

urgent, immediate need (complex terrain model) and 37 were of high priority.

One example of a modeling need is that of estimating pollution effects in complex terrain (countryside higher than smokestacks). In an August 1985 report, we pointed out that EPA has long recognized the need for additional computer models, including those used to predict air pollution in complex terrain.[9] We presented several cases where questions arose over the acceptability of models used to estimate effects in such terrain. At that time, EPA acknowledged they had known the need for refined complex terrain dispersion models for several years. However, the agency added that model development must await the acquisition of detailed descriptive data bases and basic knowledge of how atmospheric variables behave near such terrain. The EPA is continuing its research program in the complex terrain area. A timetable for developing a complex terrain model has not been established.

The EPA's 1984 study did not estimate the cost to meet the needs it identified. The Director of the Atmospheric Sciences Research Laboratory told us that the cost would be high because developing accurate, refined models is expensive

The Laboratory is awaiting a final EPA position on the findings of the 1984 study. As of February 1986, the Assistant Administrator for Research and Development had not decided on the amount of funding for the model development program. The laboratory, while awaiting a decision, is reanalyzing the study results to determine how many models EPA needs to answer its modeling needs. EPA anticipates completing this analysis by August 1986.

Model Costs

The development cost of models ranges from about $50,000 for a simplified screening model to several million dollars for a more refined model that could be used in determining control requirements. A screening model is used for preliminary estimates of air quality. If a screening model indicates a potential problem, then a more refined model is generally required. The more complex and refined the models are, the more they cost to develop.

[9] EPA-Approved Revisions to State Implementation Plans Allowing Increased Sulfur Dioxide Emissions Were Legal (GAO/RCED-85-129, Aug 16, 1985)

Many models, because they can use previously collected data, are inexpensive to operate, several costing about $5 to $25 per analysis. However, some models, such as the Urban Airshed Model used to predict violations of the NAAQS for ozone, are very expensive to use because of the data that must be collected and analyzed Before the Urban Airshed Model can be used, daily air quality and meteorological data must be collected and analyzed to prepare it for input to the model. EPA reported in December 1983 that a total cost of $50,000 for each day depicted by the model can be expected.

Conclusions

Limitations in the current state of the art of air quality model development have produced pollution concentration estimations with wide ranges of uncertainties In some situations, the ranges are so wide that EPA officials must perform additional analyses before making regulatory decisions EPA recognizes it needs more and better models. However, after several years of development, EPA still does not have all the models, or refined enough models, it needs to regulate various pollutants over different terrains in the United States.

In many cases, developing more and better models requires acquiring detailed data bases as well as a better understanding of the effects of atmospheric processes on the dispersion of pollutants. In the meantime, EPA is assessing the precision of its existing models in order to quantify the uncertainties of each model's estimations. Such quantifications are designed to help EPA and other model users in considering the uncertainties of a model when evaluating its results. We believe that this assessment process is desirable and an important step in helping EPA carry out the objectives of the Clean Air Act, including improving the usefulness of models. We also believe that EPA needs to give high priority to completing its assessment of all the air quality models.

Problems Experienced in Developing a Utility-Sector Analysis Model

Models are used for predicting the movement and concentration of air-borne pollutants in regulating industry's efforts to comply with Clean Air Act requirements. Models are also used in selecting the best approach to pollution control when more than one method of control exists. An example of an industry for which alternative methods of pollution control exist is the electric utility industry.

EPA believes a utility-sector analysis model should be developed in order to predict the effects on the U.S. electric utility industry of alternative air pollution reduction methods during the generation of electricity. Two models have been mainly used in the past for these analyses: the Coal and Electric Utility Model (CEUM) and the Utility Simulation Model (USM). According to a study done for EPA, these two models and most of the other existing models for utility-sector analysis are deficient for regulatory use for four reasons.[1] First, their designs do not incorporate sufficient information from various sectors of the electric utility industry (coal supply, transportation cost, etc.) to reliably assess the economic and other effects of air pollution control alternatives. Second, their capabilities to analyze certain key areas, such as the coal industry, are limited or antiquated. Third, the models are also time-consuming and expensive to operate. Finally, they are proprietary in nature, undocumented, or unavailable for unrestricted use by anyone other than the model developer.

EPA has not been successful in developing one of its new models, the Advanced Utility Simulation Model (AUSM). After 5 years of development under a cooperative agreement and expenditures of $3 million, EPA still does not have an operational model. The EPA project officers responsible for AUSM's development stated that the best efforts of the developing organization (a university) fell short of delivering a fully working model. EPA has competitively awarded a $1.55 million contract, including option years, to a different organization to finish the development of AUSM.

Limitations and Applications of CEUM and USM

According to EPA officials, the CEUM is the most widely used existing utility-sector analysis model. ICF developed CEUM by modifying and improving its National Coal Model (NCM). Initially developed in 1977 for the Federal Energy Administration, NCM was delivered by ICF to one of the Administration's successors, the Energy Information Administration

[1] Advanced Utility Simulation Model. Analytical Documentation, November 1984.

(EIA). ICF then suggested that NCM be refined and improved at the government's expense, according to the Branch Chief, Coal Data Analysis and Forecasting, EIA, but EIA declined, saying that the model met its requirements. ICF subsequently requested and received a copy of the NCM under the Freedom of Information Act, and, according to one of its officials, spent its own money to modify and improve the model.[2] The refined version was then named CEUM.

ICF will not allow CEUM to be released outside the company because it spends considerable time and money to keep the model current, and because the model's data bases contain proprietary information obtained from other companies. A company official said that ICF has spent about $250,000 yearly since 1977 to refine and expand CEUM and to keep its data base current. According to the company official, these efforts include maintaining information on the available coal supply. ICF recovers the costs and makes a profit by running CEUM for private organizations and government agencies. The official also said that the company provides written reports of the model's results and allows EPA to review, at its offices, the data bases and other aspects of the model.

The EPA's Office of Research and Development (ORD) does not generally use CEUM because of restrictions resulting from the model's proprietary nature. These restrictions limit the modeling information EPA can share with the industry being regulated, environmental groups, and other researchers. However, ORD officials believe that if these groups were allowed to review and analyze the assumptions made in models, the data bases used, and model output, they would be more apt to accept the model's output. Officials from ORD believe that such acceptance would help prevent misunderstandings and lawsuits.

Besides restricting use of CEUM itself, the proprietary restrictions also prevent EPA from distributing other information about the model. No user's guide explaining how to use CEUM has been published. Because EPA, the states, and the industry being regulated do not have equal access to the proprietary data used in the model, EPA's Guideline on Air Quality Models (Revised) does not include CEUM as a model appropriate for regulatory use.

[2] An examination of the legislative history, case law, and terms of the contract between ICF and the Federal Energy Administration revealed that the NCM qualifies as an agency record and was therefore subject to access by ICF

According to EPA's project officers for AUSM, EPA should also have its own model so that it can control modifications. Without this control, contractors and others could modify parts of a model or its data bases without the agency's knowledge, and thereby cause different estimations to be generated for a permit applicant and the state granting the permit. This could cause confusion and disagreement on the request for a permit.

CEUM Lacks Data Needed for Analyzing Alternative Air Pollution Reduction Methods

The EPA's ORD believes a utility-sector model is needed that has greater analytical capabilities than CEUM. According to EPA, CEUM's capabilities are limited in all areas that affect a utility's decision on what pollution control strategies it will follow.

According to ORD, while CEUM contains detailed information needed on certain categories such as the available coal supply, it lacks categories of data that are needed to analyze fully alternative methods of reducing air pollution resulting from the generation of electricity. For example, CEUM does not contain the data necessary to analyze the financial aspects of alternative methods of reducing air pollution. According to EPA, such data would include the current

- tax treatment allowed for pollution control costs,
- state utility commissions' practices related to how air pollution costs can be used in establishing rates for the electric utility customer, and
- utility financial conditions.

According to EPA, all these categories of information are needed to establish a more realistic baseline for making estimations and evaluating control strategies.

The views of ORD officials are not shared by officials in EPA's Office of Policy Analysis. Office of Policy Analysis officials said they have had good results using CEUM for policy analysis. Unlike ORD, the Office of Policy Analysis's role is to analyze policy alternatives, rather than sharing modeling information with the industry being regulated, environmental groups, or other researchers. Because of this different role, the restrictions associated with a proprietary model do not present a problem. Over the years, the Office of Policy Analysis has used CEUM for many policy evaluations. For example, one analysis evaluated a specific legislative proposal designed to reduce sulfur dioxide emissions from major stationary sources.[3]

USM Has Limitations Similar to CEUM

The Utility Simulation Model (USM) is the other existing utility-sector model principally used in the past Its limitations are similar to those of CEUM—proprietary restrictions and lack of detailed data. Like CEUM, USM was developed and owned (controlled) by a private organization. According to the AUSM project director, it is no longer used because that organization is no longer in business. (It was used in the late 1970's and early 1980's.) Because of USM's private ownership, though, EPA still cannot share information about the model with industry, environmental groups, and researchers.

USM, though quite detailed in the utility sector, does not provide the level of detail needed by EPA and the utility industry to forecast coal prices as part of the model simulation. The University of Illinois, while conducting an energy study for EPA in 1980, noted the shortcomings of USM and submitted a proposal to refine and improve the model.

The Development of AUSM

At the time the University of Illinois made its proposal to refine and improve USM, EPA was becoming more uncomfortable with its dependence on contractors to run and interpret USM and CEUM. EPA was also uneasy with its inability to share the model's data or results with industry. In September 1980, EPA entered a cooperative agreement with the University of Illinois to develop AUSM.[4] The University of Illinois and its subcontractors were collectively known as the Universities Research Group on Energy (URGE).

The AUSM project was to be coordinated by the University of Illinois, and included Cornell University and Carnegie-Mellon University as subcontractors. Each university was responsible for developing different modules (sections) of the models. Other organizations were also involved as contractors to either EPA or the University of Illinois—E. H. Pechan & Associates, Inc., and Science Applications International Corporation (SAIC). The project was scheduled for completion in October 1983, at an

[3] Analysis of a Senate Emission Reduction Bill (S-3041)

[4] A cooperative agreement is a legal instrument used for providing federal assistance to a state or local government, or other recipient Cooperative agreements are used to secure goods or services that are not principally for the direct benefit or use of the government and does not usually require the delivery of a product, only that the organization granted the cooperative agreement do its best to deliver a product

approximate total cost of $3.6 million, with about $3.4 million from EPA and the rest from the URGE group. However, URGE still has not delivered a fully operational model.

EPA Intended AUSM to Overcome Limitations of Previous Models

AUSM was intended to integrate the best aspects of USM and, at the same time, significantly raise the state of the art in computer modeling of air pollution produced by electric utilities.

An EPA report states that, when completed, AUSM will incorporate new developments in both system design and specific analytical capabilities.[5] It will feature extensive, current data bases on all U.S. power plants, fuel supplies, pollution control systems, utility finances, and electricity demand. Several major advantages of the new model are expected:

- Efficiency and economy. AUSM should be less time-consuming and costly to run than its predecessors.
- Flexibility. It should be relatively easy to change many parameters in the model. Users should be able to perform separate analyses with the model's different sections.
- Transparency. It should be fully documented, enabling users to understand the internal operations and assumptions that affect the outcome of any given scenario.
- Ease of maintenance. Automated, easily obtainable data bases are being used to facilitate updating.
- Transferability. It should be capable of use on a number of different computers.

Major Problems Hindered the Development of AUSM

According to the University's project managers and EPA's project officers, URGE encountered four major project management- and administration-related problems in developing AUSM. These were: lack of coordination, funding uncertainties, discontinuity in supervision, and fragmented organizational structure.

Lack of Coordination

According to its agreement with EPA, the USM's owner was to provide URGE with a copy of the model and complete documentation so that AUSM could build upon USM. EPA did not have a copy of USM because it was owned and controlled by a private organization. However, according to the University's project managers, USM's owner balked at turning over

[5] A Summary Description of the Advance Utility Simulation Model, November 1982

the model to URGE because the owner would then lose the ability to earn profit from the model. Although it did eventually provide the computer tapes for USM, the owner withheld the user's manual. Consequently, URGE had to spend 6 months investigating the model and reconstructing its documentation.

Funding Uncertainties

According to the University's project manager, the second impediment to URGE's progress was funding uncertainties. In November 1982, shortly before the start of AUSM work for the 1983 fiscal year, URGE was notified by EPA that project funds for the upcoming year would be cut back from a planned $650,000 to $150,000. Although funding was eventually restored to $450,000, the reduction and the funding uncertainty considerably slowed the group's progress.

Discontinuity in Supervision

In the opinion of AUSM's first three project officers, the numerous turnovers in EPA's project office created considerable discontinuity in supervision. In all, five different project officers were responsible for the AUSM project. The turnover resulted from personnel transfers and reassignments within EPA. The last two project officers said they were not familiar with the problems experienced in the early stages of AUSM's development. Each project officer had a different opinion on how the model should be developed. According to the project officers, the research and changes in direction required by each project officer change took time and effort away from research and caused delays.

Fragmented Organizational Structure

The first three project officers also believe that URGE's organizational structure delayed development of the model. AUSM was to be developed in modules, with researchers at the three universities—Illinois, Cornell, and Carnegie-Mellon—working on separate modules. Under this structure, the developer of each module had to consider the organization of the other modules being developed, since all modules had to be integrated into AUSM, according to the University' project manager. According to the EPA project officers, such a structure at times resulted in a lack of coordination and cooperation among the various researchers, delayed the project, and ultimately contributed to URGE's inability to deliver a usable model to EPA.

Final Product Was an Unfinished Model

On November 30, 1984, URGE delivered a model to EPA. The approximate total cost paid by EPA to URGE for AUSM was $3 million. However, the model could not yet be used as an analytical tool because of problems in three of its seven modules:

- one module was unfinished,
- one module lacked a great deal of necessary data, and
- one module was not properly organized.

After delivery of the model, all five of the EPA project officers for AUSM agreed that it would be in EPA's best interest to terminate funding the project through the academic setting, because they were getting diminishing returns from URGE.

EPA's Choice of a Cooperative Agreement Did Not Require a Finished Product

Because of its choice of a cooperative agreement, EPA could not require URGE to complete the model. In a cooperative agreement, a usable product does not have to be delivered. According to EPA, the organization is required only to make its best effort to adhere to the terms of the agreement, a requirement that EPA officials say URGE met. Only by using a contract as the procurement instrument could EPA have required a completed model to be delivered.

According to EPA's current AUSM project officer, the agency generally uses cooperative agreements when dealing with non-profit organizations. Use of such agreements is financially favorable to the agency, because the non-profit organization must provide a share of the funding. In the AUSM project, URGE provided a 5-percent share of the project funding. The Chief, Procurement Branch, Contracts Management Division, EPA Research Triangle Park, North Carolina, told us that EPA does not have any written policy that dictates the type of procurement mechanism that should be used in dealing with private organizations. The EPA, he said, generally enters into cooperative agreements with non-profit organizations when the purpose is the transfer of money to accomplish a purpose authorized by federal statute.

The Federal Grant and Cooperative Agreement Act of 1977 specifies that a procurement contract is the correct legal instrument whenever the principal purpose is the acquisition of property or services for the direct benefit of the federal government.[6] If EPA's actual goal was to obtain a new model for its future use, rather than to stimulate development of a model, it should have awarded a contract.

EPA's New Agreement for Completion of AUSM

Because EPA could not require URGE to deliver a finished product, the agency issued a request for proposal on the job of completing AUSM. On August 21, 1985, EPA competitively awarded a contract to Science Applications International Corporation (SAIC) to complete and test AUSM. The contractor had been involved in the AUSM project earlier, in a short-term attempt to convert the model from a research tool to a working, validated analytical tool. The estimated cost to complete the model, including the first year and 2 option years on the contract, is approximately $1.5 million.

Science Applications International Corporation was one of four offerors on the project. Although its bid was not the lowest, an EPA official said that SAIC was awarded the contract because that corporation had the most expertise in the area and was rated technically superior to the other offerors In the case of AUSM completion, EPA considered technical merit to be more important than cost.

An EPA official said that SAIC may have had a slight competitive edge over the other offerors due to its involvement in AUSM development. However, the official thought it was appropriate for EPA to award the contract to SAIC, because (1) the award was conducted competitively; (2) the SAIC proposal was technically superior to the others; and (3) EPA followed appropriate federal procurement regulations including making all the necessary technical information available to all offerors. GAO found that the award was conducted competitively and that appropriate federal procurement regulations were followed including making all necessary technical information available to all offerors.

Conclusions

EPA has not been successful in developing a utility-sector analysis model, AUSM, to replace existing models, which do not fully meet all of the agency's needs. After 5 years of development and expenditures of $3 million, EPA still does not have a fully operational model. To develop the model, EPA chose a non-profit institution and provided it with federal

[6]The Federal Grant and Cooperative Agreement Act of 1977 was enacted to distinguish grants and cooperative agreements from procurement contracts The act applies to all executive agencies authorized by law to enter into contracts, grants, and cooperative agreements

assistance via a cooperative agreement. The EPA generally uses cooperative agreements when dealing with non-profit organizations, because the organization must provide a share of the project cost.

Although a contract may have been a more effective instrument to obtain a model, EPA elected to use a cooperative agreement. The EPA does not have written procurement guidelines for selecting the types of procurement mechanisms that should be used when dealing with various types of private organizations. Because EPA entered into a cooperative agreement with the initial developer of AUSM, it could not require the developer to finish the development of the model. Instead, the agency awarded a contract for about $1.5 million, including 2 option years, to another organization to get the model fully developed.

Recommendations

We recommend that the Administrator, Environmental Protection Agency, develop and implement a policy that provides guidance on what procurement mechanism should be used in various situations. The EPA's guidance should include the stipulation, to the extent possible, that contracts rather than cooperative agreements be used to obtain new computer models.

Models Tested by EPA

Air Pollution Research Advisory Committee-1A (APRAC-1A)
Buoyant Line and Point Source Dispersion Model (BLP)
California Line Source Dispersion Model-3 (CALINE-3)
Climatological Dispersion Model (CDM)
COMPLEX I
COMPLEX II
Single-Source Model (CRSTER)
Empirical Kinetic Modeling Approach (EKMA)
Industrial Source Complex Model-Short Term (ISCST)
HIWAY
HIWAY-2
Multiple-Point Gaussian Dispersion Algorithm with Terrain Adjustment (MPTER)
Point, Area, Line Source Algorithm (PAL)
PTMTP
Gaussian Plume Multiple Source Air Quality Algorithm (RAM)
Reactive Plume Model (RPM2)
Regional Transport Model-II (RPM-II)
SHORTZ
Urban Airshed Model (UAM)
VALLEY

Models Not Tested by EPA as of October 1985

AIRDOS - EPA
Air Pollution Research Advisory Committee-3 (APRAC-3)
Climatological Dispersion Model - Quality Control (CDMQC)
Industrial Fuel Choice Analysis Model (IFCAM)
Industrial Source Complex Model-Long Term (ISCLT)
LONGZ
Mesoscale Puff Model (MESOPUFF)
Mobile Source Emissions Model-3 (Mobile-3)
NAAQS Exposure Model (NEM)
PTDIS
PTMAX
PTPLU
RIVAD

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