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THE CLEAN AIR ACT SECTION 183(d) GUIDANCE ON COST-EFFECTIVENESS

Office of Air Quality Planning and Standards

<u>The Clean Air Act Section 183(d) Guidance
on Cost-Effectiveness, 1991</u>

OMISSION

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EPA has published the following guidance on the application of the Urban Airshed Model for SIP attainment demonstration:

Guideline for Regulatory Application of the Urban Airshed Model, EPA-450/4-91-013, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1991. Contact: Cindy Baines, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC. (919) 541-5690 or FTS 629-5690.

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THE CLEAN AIR ACT SECTION 183(d) GUIDANCE ON COST-EFFECTIVENESS

By

Ambient Standards Branch
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Office of Air and Radiation
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

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This report has been reviewed by the Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, and has been approved for publication. Any mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

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PREFACE

This guidance document was prepared by the Office of Air Quality Planning and Standards (OAQPS), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. The principal authors are Frank Bunyard and Allyson Siwik under the supervision of Allen Basala. In addition, the following individuals provided valuable technical assistance in preparing the final guidance:

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INTRODUCTION AND PURPOSE

On November 15, 1990, the President signed into law the new Clean Air Act (Act), which was passed by an overwhelming majority in the Congress, P.L.101-549, codified at 42 U.S.C. sections 7401-7671q (1991). The passage of the Act was in part an endorsement of market-based principles--innovative mechanisms through which cleaner air and better health for the Nation's citizens can be attained. One type of market-based principle is cost-effective, emission-reduction strategies. Cost-effectiveness is encouraged in Title I, Subpart 2, section 183(d) of the Act, which states "[w]ithin 1 year after the date of the enactment of the Clean Air Act Amendments of 1990, the Administrator shall provide guidance to the States to be used in evaluating the relative cost-effectiveness of various options for the control of emissions from existing stationary sources of air pollutants which contribute to nonattainment of the national ambient air quality standards for ozone."

In keeping with the Act's endorsement of market-based principles, this document is aimed at achieving, at lower cost, the compliance milestones for emission reductions to attain and maintain the national ambient air quality standard (NAAQS) for ozone. This document provides illustrative guidance on how to compare various types of control measures (i.e., process changes, add-on controls). In addition, it provides a list of references that can serve as cost-analysis guidance. The illustrative guidance and cross references are helpful in designing cost-effective strategies for State implementation plans written to fulfill section 110 and Title I, Part D requirements of the 1990 Act.

Furthermore, it should be made clear that this document focuses primarily on determining the cost-effectiveness of stationary source strategies. However, EPA recognizes that States will also need to consider mobile and area sources when designing their overall control strategies. Consequently, EPA has included some information on mobile sources, but this information is meant to be used only as an illustration and is not the focus of this document.

STATUS OF NONATTAINMENT OF OZONE AIR QUALITY

As of October 26, 1991, there were 98 areas in violation of the ozone ambient air quality standard.[1] Table 1 gives a listing of those nonattainment areas, their respective design values, and classifications. Except as noted in the table, the areas comprise consolidated metropolitan statistical areas (CMSA's) or metropolitan statistical areas (MSA's), as defined by the U. S. Department of Commerce. The areas are ranked according to ozone design values based on monitoring data over the 1988-1990 time period. In addition, the table lists the classification status of each area based on two factors--current design values and the area classifications referenced in Subpart 2, section 181(a) of the new Act. This table gives insight into the level of control for which individual States should strive in designing their State implementation plans. More specifically, classification indicates the need for emission reductions--i.e., in general, increased severity of nonattainment requires greater emission reductions.

TABLE 1. THE STATUS OF NONATTAINMENT OF OZONE AIR QUALITY

LOCATION	DESIGN VALUE	CLASS
Los Angeles-South Coast Basin	0.330	Extreme
Southeast Desert Modified CA	0.240	Severe-17
Houston-Galveston-Brazoria TX	0.220	Severe-17
New York NJ-NY-CT CSMA	0.201	Severe-17
Baltimore MD	0.194	Severe-15
San Diego CA	0.190	Severe-15
Chicago-Gary-Lake CO, IL-IN	0.190	Severe-17
Philadelphia-Wilm-Trenton PA-NJ-DE-MD	0.187	Severe-15
Milwaukee-Racine WI	0.183	Severe-17
Muskegon MI	0.181	Serious*
Sheboygan WI	0.176	Serious
Greater Connecticut	0.172	Serious
Ventura Co. CA	0.170	Severe-15*
San Joaquin Valley CA	0.170	Serious
El Paso TX	0.170	Serious
Manitowoc Co, WI**	0.167	Moderate*
Springfield (Western MA) MA	0.167	Serious
Boston-Lawrence-Worcester MA	0.165	Serious
Washington, DC-MD-VA	0.165	Serious
Portsmouth-Dover-Rochester NH	0.165	Serious
Huntington-Ashland WV-KY-OH	0.164	Moderate*
Baton Rouge LA	0.164	Serious
Providence RI (all RI)	0.162	Serious
Atlanta, GA	0.162	Serious
Beaumont-Port Arthur TX	0.160	Serious
Sacramento Metro CA	0.160	Serious
Charlotte-Gastonia NC	0.158	Moderate
Knox & Lincoln Cos. ME	0.158	Moderate*
Cleveland-Akron-Lorain OH	0.157	Moderate
Cincinnati-Hamilton OH	0.157	Moderate
St. Louis MO-IL	0.156	Moderate
Portland ME	0.156	Moderate
Parkersburg WV	0.152	Moderate
Greensboro-WS-H Point NC	0.151	Moderate
Pittsburgh-Beaver Valley PA	0.149	Moderate
Kewaunee Co. WI	0.147	Moderate
Louisville KY-IN	0.149	Moderate
Atlantic City NJ	0.145	Moderate
Detroit-Ann Arbor MI	0.144	Moderate

SOURCE: *Designation of Areas for Air Quality Planning Purposes*, 56 FR 56694, U.S. EPA, November 6, 1991.
* Indicates 5% classification change. ** Indicates an area not a CMSA/MSA.

TABLE 1. THE STATUS OF NONATTAINMENT OF OZONE AIR QUALITY (cont'd)

LOCATION	DESIGN VALUE	CLASS
Grand Rapids MI	0.143	Moderate
Salt Lake City UT	0.143	Moderate
Jefferson Co NY	0.143	Marginal*
Salt Lake City UT	0.143	Moderate
Dayton-Springfield OH	0.143	Moderate
Richmond-Petersburg VA	0.142	Moderate
Phoenix AZ	0.141	Moderate
Reading PA	0.141	Moderate
Raleigh-Durham NC	0.141	Moderate
San Francisco-Bay Area CA	0.140	Moderate
Dallas-Fort Worth TX	0.140	Moderate
Edmonson Co KY**	0.140	Marginal*
Santa Barbara-Santa Maria-Lompoc CA	0.140	Moderate
Memphis TN-AR-MS	0.140	Marginal*
Toledo OH	0.140	Moderate
Miami-Fort Lauderdale-W. Palm Beach FL	0.138	Moderate
Monterey Bay CA	0.138	Moderate
Charleston WV	0.138	Moderate
Nashville TN	0.138	Moderate
Lewiston-Auburn ME	0.137	Moderate
Allentown-Bethlehem-Easton PA-NJ	0.137	Marginal
Owensboro KY	0.137	Marginal
Harrisburg-Carlisle-Lebanon PA	0.136	Marginal
Canton OH	0.135	Marginal
Knoxville TN	0.135	Marginal
Poughkeepsie NY	0.134	Marginal
Youngstown-Warren-Sharon OH-PA	0.134	Marginal
Birmingham AL	0.133	Marginal
Hancock & Waldo Cos. ME**	0.133	Marginal
Johnstown PA	0.133	Marginal
Cherokee Co SC**	0.132	Marginal
Buffalo-Niagara Falls	0.131	Marginal
Columbus OH	0.131	Marginal
Kent & Queen Anne's Co MD**	0.131	Marginal
Lake Charles LA	0.131	Marginal
Reno NV	0.131	Marginal
Seattle-Tacoma WA	0.131	Marginal
Norfolk-Virg. Beach-Newport N VA	0.130	Marginal
Sussex Co DE**	0.130	Marginal

SOURCE: *Designation of Areas for Air Quality Planning Purposes*, 56 FR 56694, U.S. EPA, November 6, 1991.
* Indicates 5% classification change. ** Indicates an area not a CMSA/MSA.

TABLE 1. THE STATUS OF NONATTAINMENT OF OZONE AIR QUALITY (cont'd)

LOCATION	DESIGN VALUE	CLASS
York PA	0.129	Marginal
Tampa-St. Petersburg-Clear FL	0.129	Marginal
Walworth Co WI**	0.129	Marginal
Scranton-Wilkes-Barre PA	0.129	Marginal
Altoona, PA MSA	0.129	Marginal
Erie PA	0.129	Marginal
Portland-Vancouver OR-WA	0.128	Marginal
Manchester-Nashua NH	0.128	Marginal
Albany-Schenectady-Troy NY	0.128	Marginal
Jersey Co IL**	0.128	Marginal
Essex Co NY**	0.127	Marginal
Door Co WI**	0.126	Marginal
Lexington-Fayette KY	0.126	Marginal
Lancaster PA	0.125	Marginal
Smyth Co VA**	0.125	Marginal
Evansville IN	0.124	Marginal
Paducah CO KY**	0.124	Marginal
Indianapolis IN	0.121	Marginal
South Bend-Elkhart IN	0.121	Marginal
Kansas City MO-KA	0.120	Submarginal

SOURCE: *Designation of Areas for Air Quality Planning Purposes*, 56 FR 56694, U.S. EPA, November 6, 1991.
 * Indicates 5% classification change. ** Indicates an area not a CMSA/MSA.

FUNDAMENTALS OF COST-EFFECTIVENESS

Cost-effectiveness analysis is one of many tools available to analysts and decision makers involved in environmental quality management. In the broadest sense, cost-effectiveness analysis is used to rank a set of least-cost alternatives which achieve differing degrees of air quality improvement or health risk reductions. As used in this guidance, cost-effectiveness analysis is a procedure for evaluating alternatives to minimize the cost of attaining and maintaining the ozone NAAQS in accordance with Title I and other related Act requirements. These air quality or health risk reduction goals are pre-determined policy objectives. For more information on concepts and definitions of cost-effectiveness, refer to the paper by Walton and Basala, "Cost-Effectiveness Analysis and Environmental Quality Management," listed in the bibliography.

Ozone is a secondarily-generated air pollutant. It is the product of nitrogen oxides (NOx) and volatile organic compounds (VOC's) in the presence of sunlight. Consequently, this guidance illustrates the evaluation of measures to control these ozone precursors. Given the emission reductions required to attain and maintain the ozone NAAQS over some period, the costs of achieving these emission reductions are estimated and compared among alternative strategies.

Costs for alternative measures may not occur evenly across the time period of evaluation. For example, investment costs tend to occur prior to outlays for operation and maintenance. There are two common ways for the estimation and evaluation of costs over time: (1) the levelized method, and (2) the present value method. The levelized method adjusts investment and operation and maintenance costs so that they are equivalent to a yearly payment that remains the same over the analyzed time period. The present value method adjusts investment and operation and maintenance costs so that they are equivalent to a given sum expended today. The *California Clean Air Act Cost-Effectiveness Guidance* discusses both methods and is referenced in the bibliography. The *OAQPS Control Cost Manual* is also referenced in the bibliography and presents the levelized method, as well as engineering approaches to cost estimation.

Care should be taken in defining "cost." Cost is a measure of worth assigned to inputs (e.g., materials, fuel, ducting) and activities (e.g., design, fabrication, operation) used to provide emission reductions. Most of these costs are explicit or are costs for which one could produce an expense voucher. However, other costs are implicit. Although we cannot produce a voucher for these costs, they are not any less real. For example, if additional down time at a production facility is required to install a pollution control system, the foregone output should be valued and included as part of the cost of pollution control.

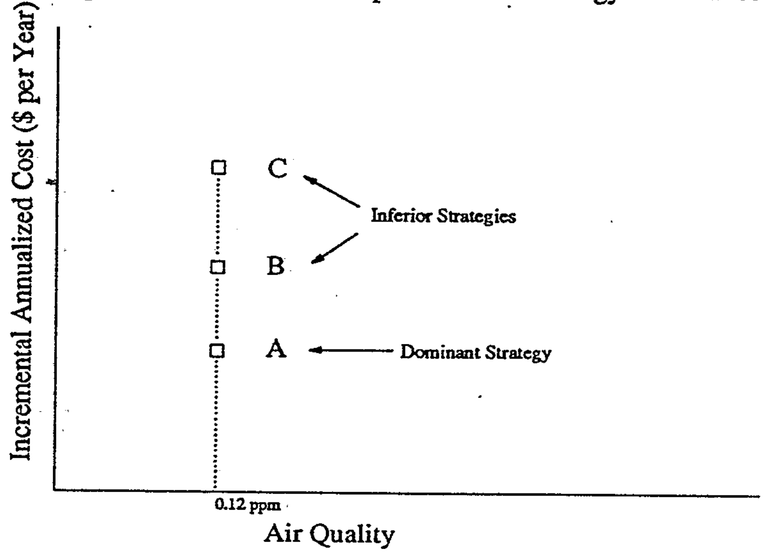
Cost may include purchase and installation of control equipment, as well as the annual cost of operating, maintaining, and insuring the equipment. In addition, there may be costs ancillary to the equipment or its operation such as operating permits, monitoring, and compliance certification. Under certain circumstances, control requirements may result in

higher product prices and concomitant reductions in output and employment. These output and employment adjustments may also be considered costs. Although such adjustments are not reflected in the cost-effectiveness calculations described in this document, in some instances, these costs may be important.

An important consideration in addressing the costs of control alternatives is the identification of the baseline. Within a given time frame, if certain pollution controls are already in place or already required under federally-enforceable provisions at the emission source, then the costs of these controls represent the baseline.* In such a situation, it is the incremental costs of installing and operating additional technologies--i.e., the difference in total control costs before and after a new technology is installed--that are relevant for cost-effectiveness analyses.

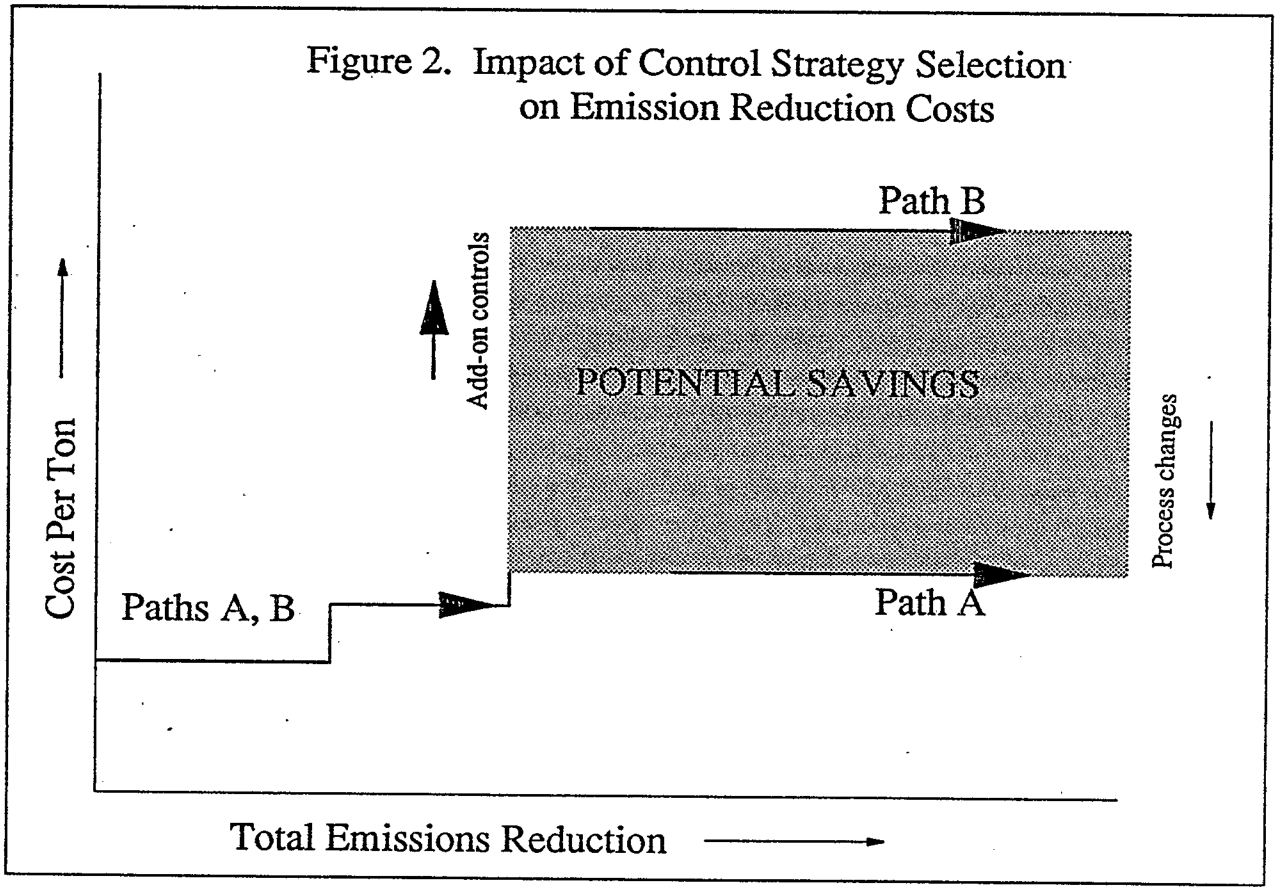
Application of cost-effectiveness analysis provides insight into the potential savings from lower-cost measures implemented to achieve the ozone NAAQS in accordance with Title I and related requirements. Figure 1 provides an illustration of strategies for achieving a desired level of air quality. Strategy A is the dominant control strategy because it represents the least-cost method of attaining the 0.12 ppm ozone NAAQS. A hypothetical dominant control strategy could be based on the following: (1) various lower-cost, add-on controls for stationary sources; (2) enhanced inspection and maintenance; or (3) economic incentive rules (outlined in section 183(g)(4) of the Act) such as marketable permits. In Figure 1, Strategies B and C are inferior strategies.

Figure 1. Illustrative Concept of Control Strategy Dominance



* In other words, if a source is required to comply with pre-existing (prior to Act Amendments) requirements--either adopted or not yet adopted by the State -- then the costs of those controls should be placed in the baseline, and not in the additional costs of control for the purpose of cost-effectiveness determination.

Figure 2 provides an illustration of two alternative strategies that might be implemented in a nonattainment area. Path A and Path B have overlapping, well-defined and low-cost control measures. When these control measures are implemented, divergence in costs occurs as Path A pursues process control opportunities (e.g., substitution of high solids or waterborne coatings for spray booths in specialty coating operations) and Path B pursues add-on controls for sources. Path A becomes the dominant strategy because it reduces emissions at less cost per ton than Path B. Path B therefore becomes the inferior strategy.



ROLE OF COST-EFFECTIVENESS IN STATE IMPLEMENTATION PLANS

After the EPA promulgates national ambient air quality standards, the Act requires States to develop and submit implementation plans for EPA approval. State implementation plans (SIP's) contain enforceable regulations that provide for attainment and maintenance of the NAAQS.

To select a control strategy, States must initially identify mandatory control measures that are required by the Act, such as the reasonable further progress requirements, reasonably available control technology (RACT) for stationary sources, volatility rules for fuels, and inspection and maintenance (I/M) for mobile sources. In addition, the amended Act requires that control measures adopted or required to be adopted under the pre-amended Act remain in effect [section 193]. Therefore, these mandatory control measures must be adopted and retained for certain nonattainment areas. Beyond these constraints, States may select cost-effective, discretionary measures to attain and maintain the ozone NAAQS.

Figure 3 illustrates the process of selecting a cost-effective control strategy. As the chart shows, the first step in the selection of discretionary control measures is the determination of required emission reductions. Two inputs for determining these reductions are the following:

- A well-defined emission inventory that includes (1) an understanding of the relationships between emission factors (e.g., amount or rate of emissions) and the parameters (i.e., inputs used in the production process such as labor and materials) affecting production of marketable goods and services in the economy, (2) speciation of VOC's in terms of photochemical reactivity, (3) the implications of economic growth on projection of quantities, and (4) the implications of geographical distribution of future emissions for a nonattainment area. For further information, see EPA's guidance, *Procedures for Preparing Emissions Projections*.

- Air quality modeling for the relevant emissions inventory. Modeling tropospheric ozone as a criteria pollutant involves a complex set of relationships. These relationships characterize the atmospheric chemical reactions that occur between those emissions that function as precursors, primarily VOC's and nitrogen oxides. When the linkage between the emissions inventory and air quality (design value) has been defined, the emission reductions required to meet attainment can be determined. The result is an environmental objective or target. The Urban Airshed Model is available to States to calculate the spatial and temporal concentrations of ground level ozone within urbanized areas or regional urbanized areas, such as the Northeastern United States (See Yocke, et. al., listed in the bibliography).

The second step in the process of selecting a cost-effective control strategy is to catalog all the control possibilities by some measure of cost versus environmental improvement. The proxy of cost-per-ton ratio is widely used in EPA analyses for developing regulations for individual source categories. The required inputs for this measurement call for the development of (1) a measurement that tracks control performance such as control efficiency or emission reductions per unit of time or production, and (2) cost (engineering cost) algorithms--mathematical expressions of the relationships between capital and operating

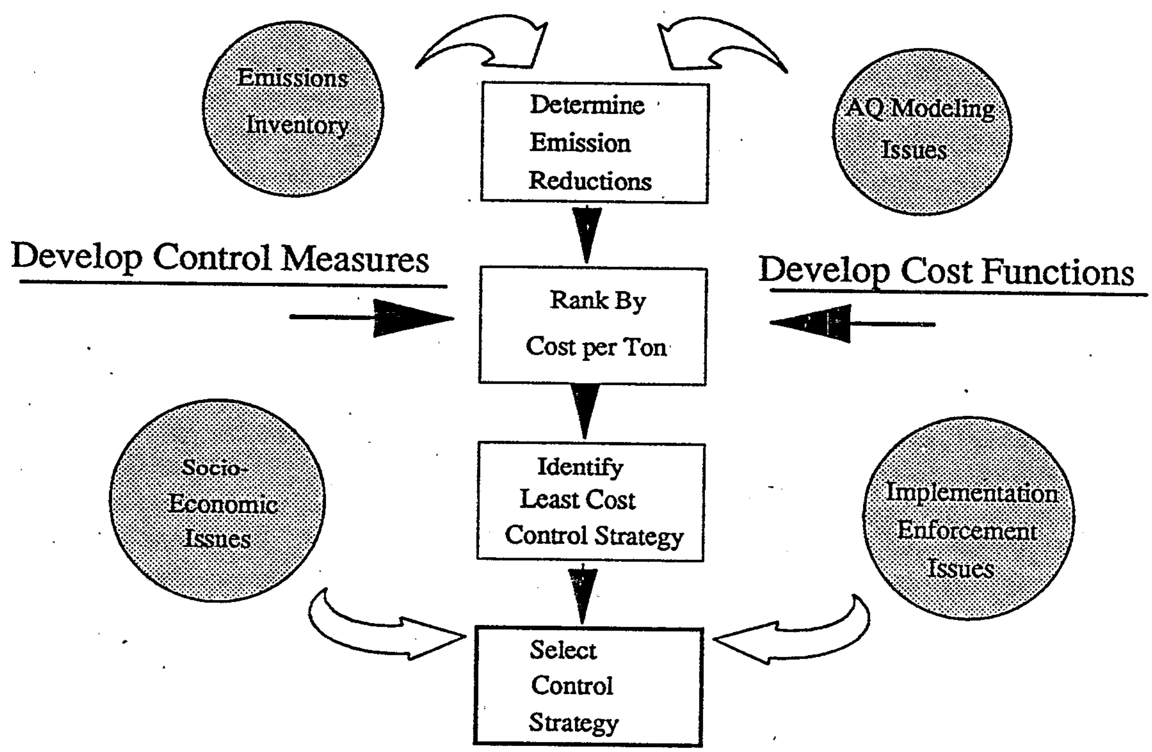
costs and engineering parameters, such as size and production rates. Based on a technical assessment of performance and costs, costs per ton of emissions reduction are calculated for each control measure.

The third step is to identify several control strategy options, including the least-cost control strategy for the target emission reductions. Identification of control strategy options is performed by combining various control measures and evaluating the emission reductions and incremental cost for each measure to derive a total incremental cost for implementation of the entire strategy. Different strategies are developed iteratively in this manner to ensure that the least-cost strategy is identified. Mathematical programming techniques are sometimes appropriate to make this determination. It is important to note that the cost-effectiveness of a given control strategy may be sensitive to the order in which individual control measures are applied. For example, if add-on control measures controlling 90 percent of emissions are applied to a stationary source before, after, or simultaneously with reformulated production inputs, the cost per ton of emissions reduced would vary between the three scenarios.

To this point, the process of identifying the least-cost control strategy is straightforward. However, there are policy (growth versus environmental tradeoffs) and socio-economic issues (employment dislocation and household sector impacts) that may not be quantifiable, or not readily quantifiable, in a least-cost mathematical programming structure. In addition, there may be implementation and enforcement issues, including the division of certain monitoring and certification responsibilities among various governmental entities and the regulated sources, that may not be quantifiable in this context. Control strategy selection is therefore a multi-attribute decision. In addition to costs, policy, socio-economic effects, and certain implementation and enforcement considerations may also factor into the decision.

As a further caveat, there are other issues affecting cost-effectiveness that have yet to be mentioned in this guidance. Baseline emission level, specification of emission reductions, rule effectiveness, and rule penetration are important factors that may influence the cost-effectiveness calculation and possibly the outcome of the control strategy selection. A discussion of these concepts is presented further in this document. Additionally, speciation may be important in the reactivity of various compounds and how those reactive compounds relate to ozone formation. The Agency position on reactivity is that all volatile organic compounds, except for those designated in the *Federal Register* as being negligibly reactive[2], are of equal importance insofar as the mandatory 15 percent reductions for all nonattainment areas classified as moderate or above. Reactivity, however, becomes important in modeling for demonstration of attainment and maintenance of the NAAQS. There is more discussion on reactivity and its impact on cost-effectiveness in the *California Clean Air Act Cost-Effectiveness Guidance* (See Bibliography at the end of this document.)

Figure 3. Process for Selection of Cost-Effective Control Strategy



IMPORTANT CONSIDERATIONS FOR COST-EFFECTIVENESS ANALYSIS

Estimation of Emission Reductions

The manner in which reduced emissions are derived can affect the cost-effectiveness value. To be consistent with EPA guidance for the development of emission inventories, projections of emissions, and other guidance related to tracking emission reductions[3], the estimation of emission reductions is based on the following:

- *determination of baseline emission level*

  Baseline emissions reflect actual emissions in the nonattainment area [sections 182(a)(1) and 182(b)(1)(B)]. Emissions are to be based on conditions that exist during the peak ozone season of the year of enactment of the Clean Air Act Amendments, i.e., 1990.[4] Reasonable further progress (RFP) requirements must use actual emissions, with certain exceptions as specified in the Act section 182(b)(1)(D). Refer to the upcoming guidance on estimation of emission reductions for RFP planning due out in the spring of 1992.

- *specification of emission reductions*

  Emission reductions are calculated using the baseline emission level as described above as the reference point from which expected emission reductions are derived. Emission reductions are either actual or allowable depending upon the methods used to determine post-control emissions within the attainment plan. If the post-control emissions are based on an enforceable emission rate, some allowable operating, capacity and an anticipated operating schedule, then the emission reductions are construed to be allowable emission reductions. Conversely, if post-control emissions are determined based on actual operating conditions (verified by compliance certification), then the emission reductions are considered actual emission reductions. According to the EPA guidance, *Procedures for Preparing Emissions Projections*, States must identify whether the emission projections are allowable or actual. For the purpose of identifying control strategy options, the emission reduction calculation should be modified for the following: (1) nondiscretionary emissions limitations that will apply in the future [e.g., maximum achievable control technology (MACT) regulations], (2) anticipated regulations that will provide sources with additional operational flexibility (e.g., marketable permits).

Rule Effectiveness

Expected costs and emission reductions for a given control strategy to attain and maintain the ozone NAAQS may not be the same as the realized costs and emission reductions. More often than not, when the expectations for a control strategy are not realized, the emission reductions are less than anticipated.

Rule effectiveness reflects the ability, or lack thereof, of a regulatory program to achieve all the emission reductions possible through full compliance by all sources all the time. For stationary sources, the EPA presumes a rule effectiveness of 80 percent for State implementation plan rules unless the State demonstrates a higher figure is appropriate for a source category.[5]

By calculating cost-effectiveness numbers assuming 100 percent rule effectiveness when rule effectiveness is less, the amount of emissions reduced will be overestimated, resulting in an underestimate of the cost per ton of emissions reduced. This potential effect is illustrated in Table 2.

As an example, suppose a control agency determines that a particular source category has uncontrolled emissions of 2500 tons per year. The agency believes that an objective of 90 percent emissions reduction is possible and specifies some allowable rate based on some output parameter, such as pounds of VOC emitted per pound of high solids coating applied. The source category installs control devices that are supposed to control at 95 percent control efficiency. With 100 percent rule effectiveness, emissions are reduced by 2375 tons per year (2500 tons/year x 0.95). However, rule effectiveness of less than 100 percent may result for a variety of reasons, including equipment leaks and failure to maintain specified operating conditions (e.g., flame temperature). Using EPA's default value of 80 percent rule effectiveness, the estimated emissions reductions are only 1900 tons per year (2500 tons/year x (0.95 x 0.80)). Improved monitoring and enforcement of presently regulated sources, more inspections, improved record keeping and reporting, and corrective actions should be examined for enhancement of rule effectiveness, emission reduction potential and cost-effectiveness.[6] This is not to say that rule effectiveness is the only way in which to achieve additional emission reductions. Enhanced rule effectiveness should be compared to other methods of achieving reductions.

TABLE 2. AN ILLUSTRATIVE SENSITIVITY ANALYSIS OF RULE EFFECTIVENESS

Control Efficiency (%)	Rule Effectiveness (%)	Emissions Reductions (tons/yr)	Post-Control Emissions (tons/yr)	Control Cost ($/ton/yr)
95	100	2375	125	632
95	90	2138	363	702
95	85	2019	481	743
95	80	1900	600	789

Basis for Analysis:
(1) Uncontrolled source category emits 2500 tons per year
(2) Control cost for source category is $1.5 million per year

Rule Penetration

Rule penetration is closely related to the rule effectiveness concept. The term is defined as the extent to which a regulation may cover emissions from a source category. For example, a rule promulgated for Stage I vapor recovery at gasoline stations and bulk terminals might exempt some sources from the vapor recovery requirement if the gasoline is delivered from out-of-state. In this case, the rule would not cover all emissions from this source category. Exemptions from a given rule may decrease the rule penetration and therefore result in less emission reductions from a source category. Authorities may therefore wish to regulate additional sources of emissions in an attempt to achieve emission reduction progress requirements. Cost-effectiveness considerations may be one of the factors decision makers must consider in determining the degree of penetration for a given rule.

Cost-Effectiveness Threshold Values and Geographical Variability

Cost-effectiveness should be used with caution in making decisions for implementing control strategies. Decisions based on one universally-applied ceiling value ($/ton) may leave some nonattainment areas short of target emission reduction requirements and cause other areas to overshoot their targets. For example, nonattainment areas classified as severe or extreme may need more expensive controls at the margin--for each additional unit of emission reduction--than marginal or moderate nonattainment areas. Similarly, variability in the average cost of control among nonattainment areas is likely to be the norm. Figure 4 presents the modeling results of a control strategy study of 81 nonattainment areas using 1987 to 1989 ozone monitoring data and illustrates this variability.[7] It is important to recognize that the incremental costs of control at the margin may not reflect the average cost-effectiveness across these areas.

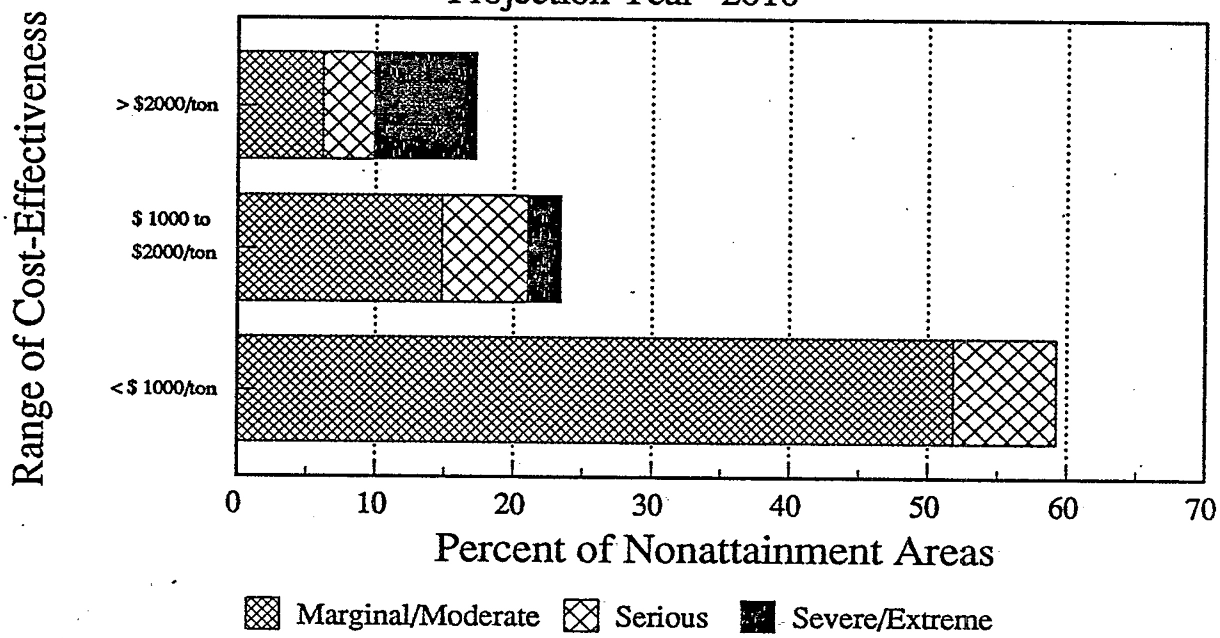
The marginal cost per ton of reduced emissions is likely to vary for the following reasons:

- *sources available and selected for control*

  The marginal cost of control for a nonattainment area depends upon the mix of sources available for control and the various control measures needed to reduce emissions within and across source categories. The potential variability in emission reductions from source categories across nonattainment areas is displayed in Figure 5. The graphic represents the lower cost measures available to the selected nonattainment areas for attainment and maintenance of the ozone NAAQS. Within a given nonattainment area, there may be more reductions available from mobile sources rather than large point sources.

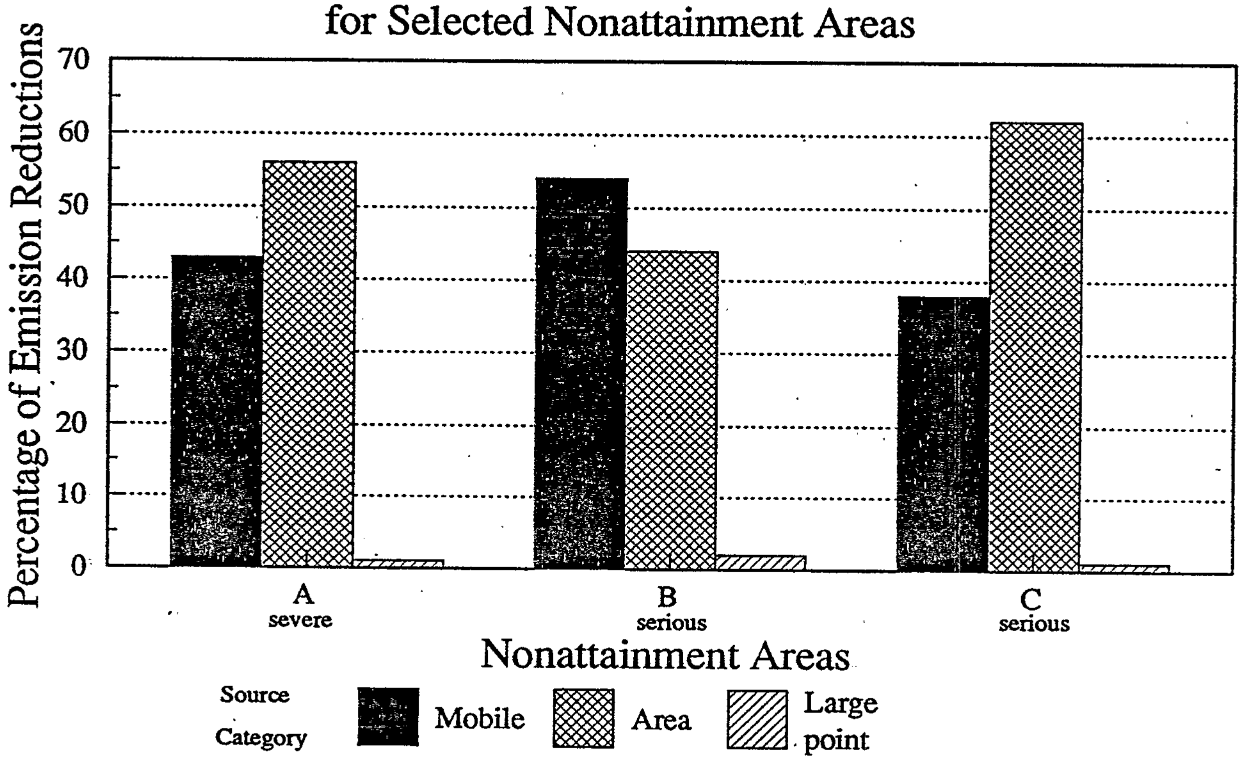
Figure 4. Cost-Effectiveness for Nonattainment Areas

A profile of CMSA's/MSA's by Avg. Cost per Ton
Projection Year--2010



SOURCE: "Ozone Nonattainment Analysis
Clean Air Act Amendments of 1990"
By E. H. Pechan, Inc. for US EPA, Sept. 1991

Figure 5. Percentage of Emission Reductions by Source Category for Selected Nonattainment Areas



SOURCE: "Ozone Nonattainment Analysis
Clean Air Act Amendments of 1990"
By E.H. Pechan, Inc. for US EPA, Sept. 1991.

Notes:

- o Large point sources are defined as those sources emitting greater than 100 tons per year for VOC.
- o Area sources are those emitting less than 100 tons per year.
- o The mobile source category does not include off-highway vehicles such as construction equipment, aircraft, agricultural and forestry equipment, locomotives, and vessels.
- o Projection Year--2010

- *baseline control levels*

  Some nonattainment areas may have already achieved the lower cost emission reductions available. Higher cost control measures might be required to reduce any additional units of emissions.

- *degree of control required*

  The amount of emissions reductions necessary to achieve attainment varies across nonattainment areas and therefore affects the relative marginal costs of control. These varying amounts of control are explained by differences in such factors as size and location of sources as well as daily and seasonal fluctuations in temperature, emission rates, and wind patterns.

- *control techniques*

  The marginal cost of control is dependent upon the control measure selected to achieve additional emission reductions. In some instances, process change may be less costly than add-on controls, or rule-effectiveness enhancement less costly than greater rule penetration.

Table 3 illustrates various VOC control measures and relative cost-effectiveness. These costs are national averages and represent current estimates.[8] Again, it should be noted that the marginal costs of VOC control measures for a given nonattainment area may differ from the national averages for these source categories. It should also be emphasized that some of these measures are mandatory while others may be discretionary in terms of combining various measures for an overall control strategy. In general, process changes are lower in cost than end-of-pipe incineration controls on small sources (including small marine vessels). Rule effectiveness has been added as a "source category" to the table because improving rule effectiveness may help to achieve emission reductions. More inspections, improved record keeping and reporting, and corrective actions represent some of the elements identified in the March 31 Rule Effectiveness Study Protocol.[9] It should be noted that emission reductions resulting from rule effectiveness improvements occurring before 1990 and that are built into the emission inventory baseline are not creditable to the 15 percent progress requirements. Additionally, rule effectiveness is not without costs. Greater enforcement and/or inspection and maintenance procedures cost resources. Finally, transportation control measures that achieve actual emission reductions are also available, such as employer-based, ride-sharing programs, mass public (rail or bus) transit, van pooling, and parking restriction ordinances in centralized business sections of metropolitan areas. A more comprehensive list is included in section 108(b) of the Act.

TABLE 3. ILLUSTRATIVE VOC CONTROL MEASURES AND COST-EFFECTIVENESS[a]

Source Category	Control Measure	Cost-Effectiveness ($ per ton)
Architectural Coatings	Application of High Solids Coating Technology	Savings
Stage II Refueling	Vapor Balance Fuel Recovery	770 to 1350
Treatment, Storage, and Disposal Facilities (RCRA) air emissions	Tank covers, controls on aerated treatment and storage tanks	190
Enhanced Inspection and Maintenance	Higher performance standards	1400 to 5300[b]
Volatility rules	Reid Vapor Pressure 7.8 psi	140
Marine Vessel Loading/Unloading	Ventilation System and Incineration	1000 to 50,000
Small Source Coating Operation	Ventilation System and Incineration	10,000 to 20,000
Rule Effectiveness	More inspections, Corrective Actions	May lower the cost of control[c]
Consumer Products	Substitute stick applicators for aerosol propellants	400 and higher

[a] E. H. Pechan and Associates, under contract with the U. S. Environmental Protection Agency,"Ozone Nonattainment Analysis Clean Air Amendments of 1990", September 1991.

[b] U. S. Environmental Protection Agency, Office of Mobile Sources, Enhanced Inspection & Maintenance Briefing, October 1991.

[c] Refer to Table 2.

The control measures listed for NOx emission reductions in Table 4 represent an illustration of various combustion sources to which process changes, such as low NOx burners, staged air combustion, and add-on controls, namely selective catalytic reduction, could apply. The range in costs per ton is due to factors such as flue gas flow rates, fuel, boiler configuration (tangential, wall), and application. More information on these types of controls can be found in the July 22, 1991 draft report entitled, "Cost Effectiveness of Stationary Sources for VOC and NOx Controls," prepared by E.H. Pechan and Associates for the U.S. Environmental Protection Agency.

As described above, control requirement needs and marginal costs and the anticipated environmental quality improvements vary across nonattainment areas; therefore, setting control limits based on single $/ton values may not be appropriate.

Multiple Pollutant Considerations and Assignment of Costs

In an unencumbered world, a control strategy would target a single pollutant for achieving an environmental objective. This eliminates problems of double counting--paying for the same controls twice for two separate environmental objectives. In addition, such an approach eliminates biases in the process of developing the least-cost envelope of dominant controls. Unfortunately, there are pragmatic problems with attempting to assign single pollutant ($/ton) values to control measures. Oftentimes, control measures being considered reduce several pollutants. An example is certain types of catalytic controls on combustion sources (e.g., mobile source tailpipe controls) that reduce carbon monoxide, nitrogen oxides, and VOC's. If the environmental objective in a State implementation plan is to reduce ozone, apportioning higher weights to nitrogen oxides and VOC's relative to carbon monoxide may be appropriate in transportation control measures, such as employee trip reductions. In another example, some controls (e.g., Stage II refueling) designed for a State implementation plan may reduce toxic pollutants that may be subject to Title III. The cost-effectiveness computation should include reductions in the ozone precursors. However, the incidental reduction in toxics may be considered as a secondary benefit and should be noted. Discussion on various ways to apportion weights per pollutant for assignment of cost-effectiveness is presented in the *California Clean Air Act Cost-Effectiveness Guidance*. The EPA has no preferred option for assigning costs for multiple pollutants, as the method used would vary with the control scenario.

TABLE 4. SAMPLE NOx CONTROL MEASURES AND COST-EFFECTIVENESS[a]

Source Type	Control Measure	NOx Emission Reduction (%)	Cost-Effectiveness ($ per ton)
Utility Wall or Tangential Coal-fired Boiler	Low NOx Burners	50	70 to 830
Utility Residual Oil-fired Boilers	Staged Combustion Air	42	310 to 920
Utility Tangential Natural Gas or Coal-fired Boiler	Selective Catalytic Reduction	80	3900 to 5300
Utility Natural-Gas Fired Boiler	Selective Catalytic Reduction	80	2200 to 2860
Industrial Coal-fired Boiler	Staged Combustion or Low Excess Air	36	Savings to 380
<100 MM Btu/Hr Natural Gas	Flue Gas Recirculation	31	4200 to 4700
>100 MM Btu/Hr Natural Gas	Flue Gas Recirculation	31	1000 to 1100
<100 MM Btu/Hr Natural Gas	Selective Catalytic Reduction	80	12,700 to 17,400
>100 MM Btu/Hr Natural Gas	Selective Catalytic Reduction	80	2100 to 3200
Gas Turbines	Water Injection	70	1000 to 1700
Gas Turbines	Selective Catalytic Reduction + Water Injection	70	2400 to 3900
Internal Combustion Engines	Change Air-Fuel Ratio	30	140 to 930
Internal Combustion Engines	Selective Catalytic Reduction	80	120 to 910
Process Heaters	Staged Combustion Air	45	Savings
Process Heaters (Oil Fired)	Selective Catalytic Reduction	90	200 to 4500

a SOURCE: E. H. Pechan and Associates, under contract with the U. S. Environmental Protection Agency, 1991.

APPLICATIONS OF COST-EFFECTIVENESS ANALYSIS

Modeling NO_X and VOC

Modeling of control strategies that combine NO_X and VOC controls to attain the ozone standard may be a difficult problem. As an example, a nonattainment area may employ the Urban Airshed Model (UAM) to estimate the spatial relationships of ozone concentration changes to determine optimal control strategies by applying a mix of NO_X and VOC controls. Such a model may produce several control strategies that are equivalent in terms of attaining and maintaining the ozone standard. For example, preliminary UAM modeling in the Ventura County portion of the South Central Coast Air Basin District has demonstrated that attainment can be achieved by reducing 55 percent of either VOC or NO_X, or a combined strategy of 40 percent emission reduction from both VOC and NO_X.[10] Cost-effectiveness analysis can play a useful role in the selection of the least-cost strategy from three equivalent strategies. The analysis involves a two-staged process with the following elements:

- to ensure efficiency, selection of the dominant controls across source categories (e.g., low NO_X burners on industrial boilers) in a cost per ton iterative process for each of the three strategies, and

- selection of the least-cost strategy from total annual costs perspective for the area.

ERCAM-PC Software Capability

Under a contract with E. H. Pechan and Associates, Inc., EPA developed a model to provide States and local agencies with the capability to analyze emission control strategies and costs of emission reductions needed to attain the ozone NAAQS. The model, known as the Emission Reduction and Cost Analysis Model (ERCAM), was developed from a national model used to analyze the various legislative initiatives during the debates over the 1990 Clean Air Act Amendments. The ERCAM was developed for a single State, but the model readily adapts to other States by inserting State-specific emission factors derived from mobile source emission factor models[11] and the Aerometric Information and Retrieval System (AIRS) for stationary sources. In addition, EPA has developed a cost-effectiveness model (CEM) for inspection and maintenance programs that can be used in conjunction with ERCAM. The model is programmed in dBASEIII Plus and operates on a PC.

CONCLUSION

Cost-effectiveness analysis is a tool designed to identify the least-cost means of achieving an environmental objective. However, other factors may warrant consideration prior to adoption of a control strategy. With respect to cost-effectiveness analysis, several considerations are important including rule effectiveness, rule penetration, threshold values, and multiple pollutants. A model, ERCAM, when used in conjunction with other models, does exist to enable States to consider cost-effectiveness. The application of ERCAM, although not mandated, should prove useful in designing lower-cost control strategies.

ENDNOTES

1 *Designation of Areas for Air Quality Planning Purposes*, 56 FR 56694, November 6, 1991, U.S. Environmental Protection Agency.

2 *Requirements For Preparation, Adoption, and Submittal of Implementation Plans*, 56 FR 11387, March 18, 1991, U.S. Environmental Protection Agency.

3 *Emission Inventory Requirements for Ozone State Implementation Plans*, EPA-450/4-91-010, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, March, 1991.
Procedures for Preparing Emissions Projections, EPA-450/4-91-019, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, July 1991.
Guidance on Reasonable Further Progress Requirements will be available in the spring of 1992.

4 *Emission Inventory Requirements for Ozone State Implementation Plans*, March 1991, pp. 10 and 13.
Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume I: General Guidance for Stationary Sources, EPA-450/4-91-016, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, May 1991.

5 Workshop for Implementation of Clean Air Act Provisions Relating to Ozone and Carbon Monoxide Emission Inventories, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, June 4-6, 1991.

6 Memorandum from John Seitz, Director of Stationary Source Compliance Division, Office of Air Quality Planning and Standards, to U.S. EPA Regional Directors, "Implementation of Rule-Effectiveness Studies," March 31, 1988.

7 *Ozone Nonattainment Analysis Clean Air Act Amendments of 1990*, Draft Report, E. H. Pechan and Associates, Inc., prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, September, 1991.

8 *Ozone Nonattainment Analysis Clean Air Act Amendments of 1990*, E. H. Pechan and Associates, Inc., September, 14991.

9 Memorandum from John Seitz, March 31, 1988.

10 *Modeling of Preliminary Emission Reduction Estimates for Attainment of the National Ambient Air Quality Standard for Ozone in Ventura County*, submitted as part of Docket No. 90-CA-VENT-1. Referenced in: *Federal Register*, Vol. 56, No. 12, January 17, 1991, Proposed Rules, p. 1754.

11 The EPA is presently completing MOBILE5, which should be available in the spring of 1992. The EPA recommends that States use this model if at all possible. In the mean time, however, MOBILE4.1 is available but does not include the effects of the Clean Fueled Fleets Programs, the Reformulated Gasoline Program, the On-board Diagnostics Program, and the Evaporative Test Procedure Changes.

A BIBLIOGRAPHY OF CROSS REFERENCES

California Clean Air Act Cost-Effectiveness Guidance, California Air Resources Board, Office of Air Quality Planning and Liaison, September 1990.
This document provides guidance to District agencies implementing the California Clean Air Act according to requirements for cost-effectiveness (i.e, least-cost envelope to select dominant control strategies) analysis prior to adoption of rules for attainment of air quality standards. Appendices provide insight into alternative methods of annualizing costs from a time value of money perspective.

E.H. Pechan and Associates, Inc., *Cost Effectiveness of Stationary Source VOC and NOx Controls*, Draft Report, prepared for the U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, July 1991.
This report is a compilation of cost-effectiveness values, including parameters for cost equations used in the ERCAM-VOC for all stationary source control measures to reduce VOC and NOx emissions. The report also contains references for sources of cost information used to develop cost equations. Contact: Frank Bunyard, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (919) 541-5297 or FTS 629-5297.

E. H. Pechan and Associates, Inc., *ERCAM-VOC: Description and Applications (Design Objectives, Structure and Use of the Emission Reduction and Cost Analysis Model for Volatile Organic Compounds)*, prepared for the U. S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, March 1989.
Although dated with respect to the enactment date of the new Clean Air Act, this paper provides a fairly comprehensive overview of the national ERCAM. The paper describes the model objectives and structure, including a description of files used to model controls and costs for analyzing impacts (i.e., emissions, emission reductions, costs) of base programs and mandatory measures of the new Clean Air Act for four projection years through 2010. Contact: Frank Bunyard, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (919) 541-5297 or FTS 629-5297.

E. H. Pechan and Associates, Inc., *User's Guide for the Prototype State Emission Reduction and Cost Analysis Model for Volatile Organic Compounds*, prepared for the U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, October 18, 1990.
This document provides information on the model structure, inputs, and outputs. State ERCAM is in the process of being modified and adapted for all States. A draft User's Guide of the present model is available. Contact: Frank Bunyard, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (919) 541-5297 or FTS 629-5297.

OAQPS Control Cost Manual, Fourth Edition, EPA 450/3-90-006, U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, January 1990.
Provides a standardized engineering approach to develop cost information for control systems for reducing gaseous and particulate emissions from stationary point sources. Provides a good tutorial on the description of types of cost estimates and annualization methods. The manual employs an engineering design and parameterization method, using plenty of example problems to developing capital costs. Contact: EPA Regional Offices or William Vatavuk, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (919) 541-5309 or FTS 629-5309.

Procedures for Preparing Emissions Projections, EPA-450/4-91-019, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, July 1991.
This document provides guidance for projecting emissions to future years focusing primarily on procedures for projecting how the combination of future emission controls and changes in source activity will influence future air pollution emission rates. Contact: EPA Regional Offices or Keith Baugues, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (919) 541-5366 or FTS 629-5366.

Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume I: General Guidance for Stationary Sources, EPA-450/4-91-016, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, May 1991.
This document discusses procedures for preparing inventories of VOC, NOx, and CO for the purposes of establishing baseline ozone levels in nonattainment areas. Contact: E.L Martinez, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (919) 541-5575 or FTS 629-5575.

Users Guide to MOBILE4.1 (Mobile Source Emission Factor Model), U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, MI, July 1991.
The users guides for MOBILE5 and CEM are presently unavailable, but should be available in the spring of 1992. Contact: Terry Newell, U.S. EPA, Office of Mobile Sources, Ann Arbor, MI, (313) 668-4462 or FTS 374-8462.

Walton, Thomas and Allen C. Basala, "Cost-Effectiveness Analysis and Environmental Quality Management," U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, June 1981.
A presentation at the 1981 national meeting of the Air Pollution Control Association. This paper presents an in-depth primer on definitions, selection of appropriate algorithms for a cost-effectiveness analysis, and identification of potential pitfalls in the use of cost-effectiveness analysis. Contact: Allen Basala, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (919) 541-5622 or FTS 629-5622.

Yocke, M. A., et al, "Methodologies for Applying the Urban Airshed Model to Determine the Effectiveness of Measures to Reduce Ozone Levels in the Los Angeles Air Basin," April 27, 1989.

A presentation at the 82nd Air and Waste Management Association Annual Meeting, June 1989. This paper summarizes UAM modeling results combining VOC and NO_X strategies for the South Coast Air Basin. An overall view of ozone reduction effectiveness as the criterion for comparison of alternative control strategies is presented. This paper provides an example of implementation of cost-effectiveness guidance. Contact: Frank Bunyard, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (919) 541-5297 or FTS 629-5297.