ACID RAIN AND ELECTRICITY CONSERVATION

by the American Council for an Energy-Efficient Economy

Howard S. Geller
Eric L. Miller
Marc R. Ledbetter
Peter M. Miller

Sponsored and published by:

American Council for an Energy-Efficient Economy
1001 Connecticut Ave., NW
Washington, DC 20036

and

Energy Conservation Coalition
(A Project of the Environmental Action Foundation)
1525 New Hampshire Ave., NW
Washington, DC 20036

June 1987

PREFACE

This study was conducted by the American Council for an Energy-Efficient Economy. Howard Geller coordinated the study and was involved in researching and writing all chapters. Eric Miller developed the utility simulation model, conducted the computer runs, and co-authored the modeling chapters. Marc Ledbetter was responsible for the legislative analysis and co-authored the chapter on conservation and acid rain legislation. Peter Miller conducted the electricity use and conservation analyses, and co-authored the electricity use and conservation potential chapters.

The study was jointly initiated and sponsored by the American Council for an Energy-Efficient Economy (ACEEE) and the Energy Conservation Coalition (ECC). Marc Ledbetter (with the ECC until June, 1986) and Paul Markowitz provided input from the ECC. ECC obtained funding for the study from the American Public Power Association, the Environmental Defense Fund, the New Land Foundation, and the Tennessee Valley Authority. ACEEE's work on the study was funded in part by a grant from the John D. and Catherine T. MacArthur Foundation.

A number of people reviewed working papers and a draft of this report. The authors thank Dick Ayres, Carl Blumstein, Steve Brick, Lars Brinck, Ralph Cavanagh, Paul Centolella, Mohamed El-Ashry, Arnold Fickett, Karl Gawell, Christopher Granda, Jerry Harper, David Hawkins, Ned Helme, Amory Lovins, Paul Markowitz, Jim MacKenzie, Chris Neme, Richard Richels, Marc Ross, and Randy Swisher for their helpful comments. Michael Shepard provided skillful editing.

Neither the individuals who provided comments nor the organizations that provided financial assistance necessarily endorse the conclusions of this report. The views expressed in the report are strictly those of the authors.

Cover drawing by Lucy Johnston

CONTENTS

OVERVIEW

This study documents ways in which electricity conservation can save consumers and utilities billions of dollars. It demonstrates that cost-effective, more efficient end-use technologies can reduce electricity consumption in the ECAR region -- a major acid rain-emitting area of the Midwest -- by 26% without lowering the level of energy services. Large economic savings accrue as conservation defers the need to construct new conventional power plants. Conservation can also reduce utility acid rain emissions and the costs of acid rain control by reducing the use of existing power plants and by deferring the purchase of emissions controls or cleaner, more costly fuels.

Analysis for the ECAR regions shows that it is possible to reduce utility SO2 emissions by 7-11% during the 1990s as a result of accelerated electricity conservation. The direct emissions reduction is likely to fall off after 2000 because it is more economical to use conservation for avoiding or deferring construction of new power plants rather than reducing operation of existing, dirty power plants. Thus, conservation cannot eliminate the need for pollution controls such as flue gas scrubbers or low-sulfur coal if a large reduction in acid rain emissions is mandated.

Electricity conservation can lower and offset the costs associated with emissions control legislation. A 55% reduction in SO2 emission in the ECAR region by 2000 is estimated to cost consumers $3.6-8.4 billion. An accelerated conservation program deployed in conjunction with conventional emissions control measures could reduce expenditures on scrubbers and low-sulfur coal by 25% or more. Furthermore, the economic savings from avoiding construction of new power plants more than compensate for the emissions control costs. Consumers in ECAR can save $3.7-7.7 billion when accelerated conservation and emissions control are simultaneously pursued.

Acid rain legislation should provide states and utilities with full credit for the emissions reductions they achieve through electricity conservation. The use of statewide emissions ceilings, i.e., "SO2 tonnage caps", does this. The use of emissions rate limits, i.e., limits on pounds of SO2 emitted per MMBtu of fuel burned, provides credit only in certain cases. Under a statewide average emissions rate limit, a state at best receives limited credit, and would actually be penalized when conservation leads to reduced use of cleaner-than-average power plants. Under a plant-by-plant emissions rate limit, a utility or state might not fully benefit from lower emissions due to reduced power plant use. However, if conservation leads to "mothballing" or early retirement of a dirty plant, states and utilities could benefit from deferring or avoiding pollution controls.

The various acid rain bills now being considered by Congress should be modified to ensure that states and utilities have an incentive to incorporate electricity conservation in their pollution control efforts. This can be done by establishing emissions ceilings for each state. Also, acid rain legislation should direct states to consider end-use efficiency improvements and to strive for least-cost energy services when they develop their acid rain compliance plans.

Requiring utilities or states to determine the electricity savings and corresponding emissions reductions resulting from their conservation programs is unnecessary and impractical. States should simply implement their conservation programs and monitor annual load growth and emissions in relation to a total emissions ceiling. If load growth and emissions exceed anticipated levels as a state approaches the date when emissions ceilings go into effect, a state should adopt additional pollution control measures.

A variety of policy and program options are available to stimulate greater adoption of electricity conservation measures. States or the federal government can adopt minimum efficiency requirements for new buildings and for lighting products to complement the national appliance efficiency standards promulgated in 1987. Utilities can offer rebate incentives or financing to stimulate the adoption of measures not covered by standards, or even directly install conservation measures in situations where financial incentives are not effective. Experience with these policies and programs has shown that they can substantially reduce electricity demand growth.

The acid rain issue provides the motivation and opportunity for states and utilities to aggressively pursue electricity conservation in regions where there is heavy reliance on high-sulfur coal. By planning and managing electricity demand, electricity supply, and emissions control in an integrated manner, states and utilities can both protect the environment and protect the economic interests of their consumers.

SUMMARY

I. INTRODUCTION

A number of acid rain control bills have been introduced in the U.S. Congress in recent years, but none have yet passed. Opponents of acid rain control have cited the cost of emissions control as a major reason for their opposition. An 8-12 million ton reduction in utility SO2 emissions as required in a number of bills is estimated to cost $2-6 billion per year assuming conventional control approaches such as flue gas scrubbers or switching to low-sulfur coal. Utilities have argued that costs of this magnitude are unacceptable, especially in Midwestern states that are very dependent on high-sulfur coal for generating electricity. Consequently, there is considerable interest in developing alternative emissions control strategies that are less expensive then conventional approaches.

Electricity conservation is one approach to emissions control that is receiving increased attention. Conservation involves increasing the efficiency of end-use equipment such as appliances, motors, lights and increasing the thermal integrity of buildings without lowering levels of comfort or economic activity. Because conservation reduces the amount of coal and other fuels that must be burned to provide the same level of services, it directly lowers emissions of SO2, NOx, and other pollutants. In addition, conservation usually reduces the net cost of energy services, which can offset the cost of further emissions reductions.

II. CONSERVATION, ELECTRICITY SUPPLY, AND EMISSIONS CONTROL

A main objective of this study is to analyze how electricity conservation can help a major SO2-emitting region comply with stringent emissions reduction requirements. The region selected for analysis is the East Central Area Reliability (ECAR) power pool as designated by the North American Electric Reliability Council. It includes Ohio, Michigan, Indiana, Kentucky, West Virginia, and small parts of Western Maryland and Pennsylvania. The ECAR region is very dependent on high-sulfur coal and is responsible for a disproportionate share of national SO2 emissions. While the region's electric utilities produce about 17% of the nation's electricity, they emit about 33% of utility-generated SO2.

The study first examines the end uses of electricity and the potential for electricity conservation in the ECAR region. The analysis includes approximately 65 conservation measures covering all major end-use categories in the industrial, commercial and residential sectors. Measures that exhibit a cost of saved electricity below average tariffs in each sector are considered cost effective for consumers. According to our analysis, the total cost-effective conservation potential in the region is 92,000 GWh/yr, 26% of regional electricity use in 1985.

The assessment of conservation potential is used as an input to a utility simulation model. The model first determines the penetration of energy conservation measures over time given electricity rates and assumptions about consumer behavior, incentive programs, lead times, etc. The model then simulates power plant operation, capacity additions and retirements, planning, financing and electric rates, and SO2 emissions in the region. To make the analysis manageable, the region is treated as one large utility with individual power plants exhibiting similar characteristics combined into blocks.

The utility simulation analysis examines key parameters such as SO2 emissions, electric rates, and overall costs to consumers for different load growth and emissions control scenarios. Two load growth scenarios are considered -- a base case close to the utility industry forecast for the region and an accelerated conservation case that involves a more rapid and intensified adoption of cost-effective efficiency measures over the next 15 years. Growth in electricity demand averages 0.9%/yr during 1985-2005 in the accelerated conservation case, compared to 1.7%/yr in the base case. In the accelerated conservation scenario, no new coal-fired power plants are needed prior to 2005.

Figure S-1 shows the total cost for electricity services, i.e., direct electricity costs plus investments in end-use efficiency, in the two scenarios during 1985-2005. While the goods and services provided by electricity are the same in both cases, the total cost to consumers is always lower with accelerated conservation. The cost advantage in the conservation case occurs in spite of the fact that electricity prices are higher between 1988 and 2001. The electricity price penalty is more than offset by reduced electricity consumption. After 2001, both electricity prices and total costs are lower in the conservation scenario. By 2005, the annual energy service cost is 26% lower in the accelerated conservation case compared to the base case without mandated emissions reductions. The large economic savings in the conservation scenario after 2000 are due to avoiding the construction of new coal-fired power plants.

A number of strategies for achieving mandated emissions reductions are also analyzed. It is assumed that utilities in the region reduce their SO2 emissions by at least 2.0 million tons in a first phase and at least an additional 1.1 million tons in a second phase. The deadlines for the two phases are assumed to be 1995 and 2000. With reductions of this magnitude, ECAR's utilities would emit about 55% less SO2 in 2000 compared to emissions in 1980. Such a reduction is of intermediate stringency in light of recent legislative proposals.

FIGURE S.1

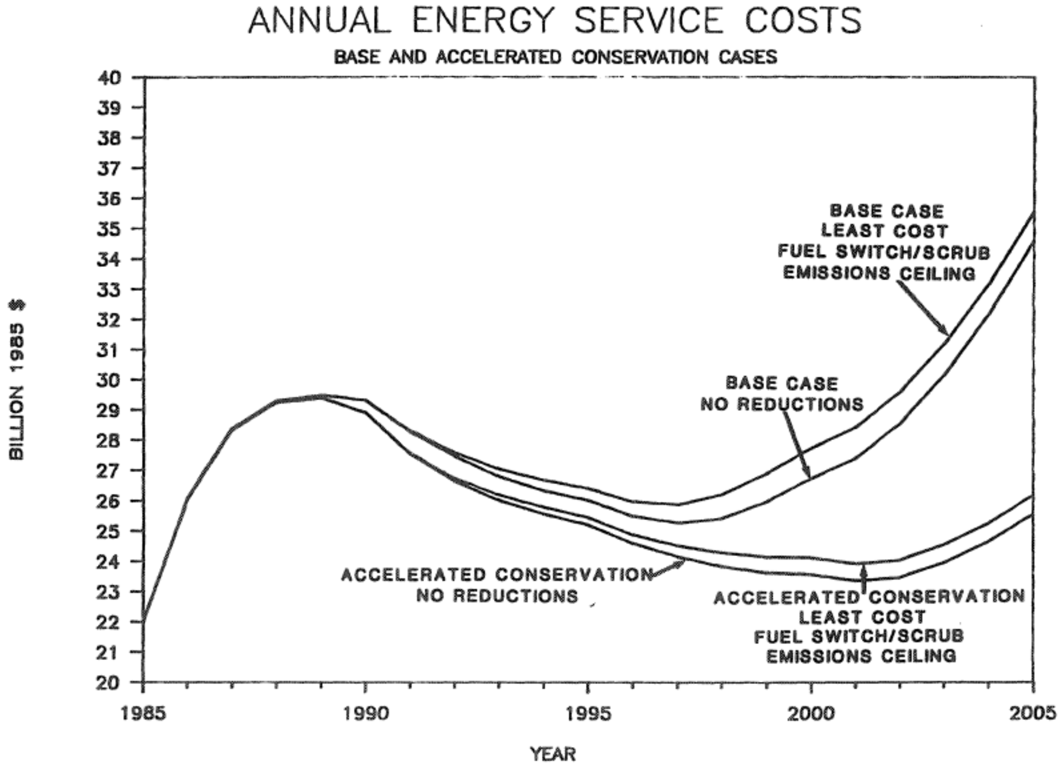
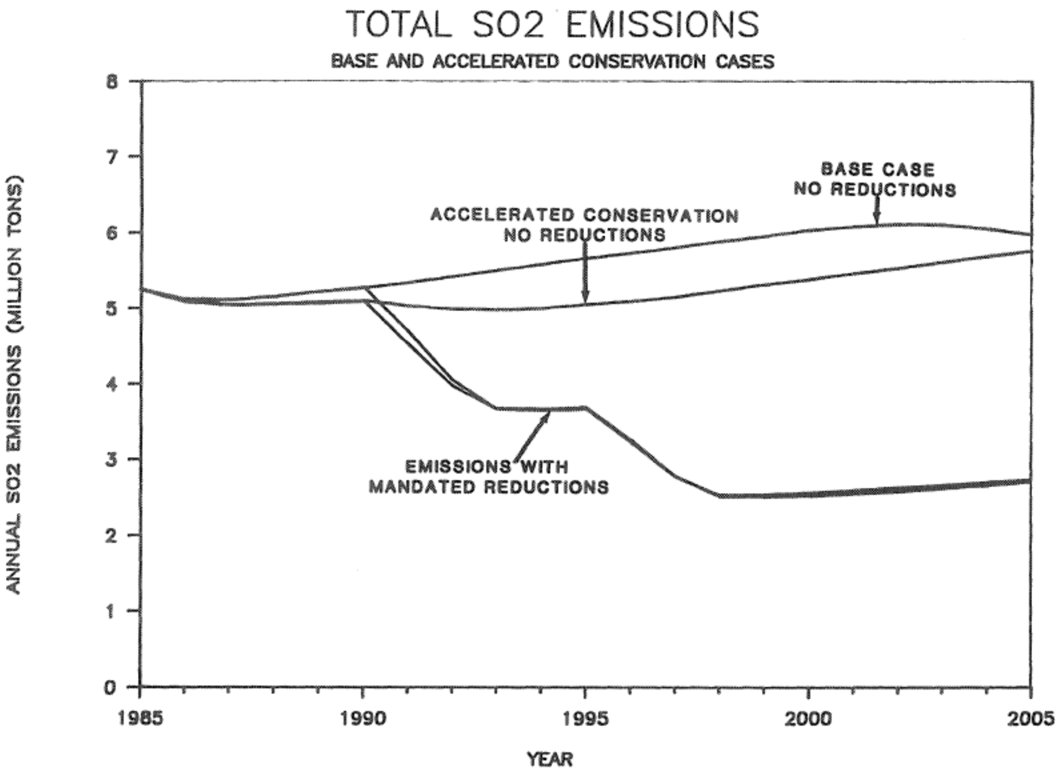


FIGURE S.2



One strategy for complying with the emissions targets involves installing enough scrubbers to provide the necessary emissions reductions without discriminating between high- or low-cost applications in the region -- the "across-the-board" case. Second, interstate and intrastate emissions trading is assumed, enabling states and utilities to retrofit scrubbers where most economical -- the "least-cost first" case. Third, coal-fired generating capacity is dispatched on the basis of lowest sulfur emissions rather than lowest cost -- the "environmental dispatch" case. Finally, a combination of about 15-25% scrubbers in the least costly applications and about 75-85% fuel switching is considered. These strategies are combined with either statewide average emissions rate limits (i.e., constraints on lbs of SO2 emitted per MMBTU of heat input) or emissions ceilings (i.e., constraints on total tons of SO2 emitted), and either base case load growth or accelerated conservation.

Figure S-2 shows the estimated annual SO2 emissions in the region over time, both with and without the emissions reduction targets. The accelerated conservation scenario by itself leads to an emissions reduction of 7-11% during 1992-2002. The direct emissions reduction falls off after 2000 because conservation is used to defer addition of new generating capacity rather than to cut back on the operation of existing, dirty power plants.

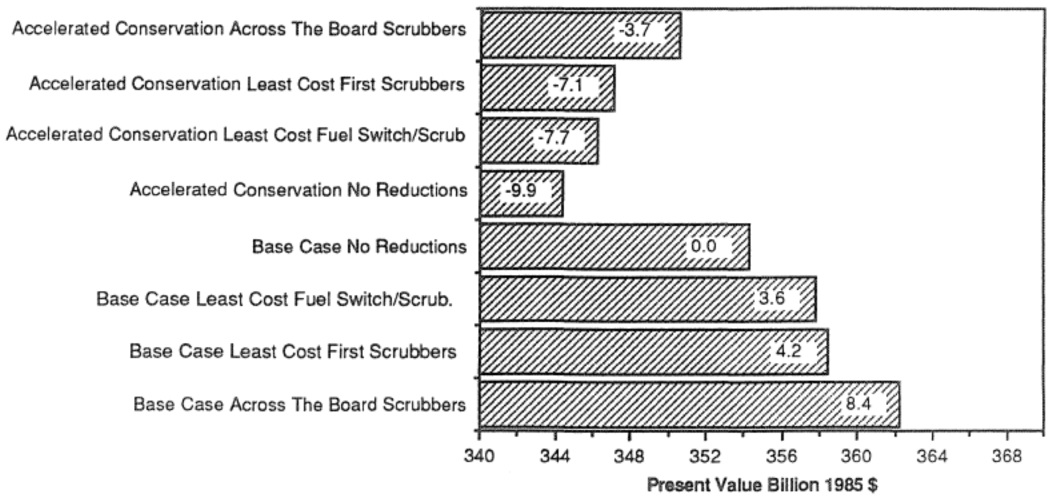
Figure S-1 includes the annual energy service cost for consumers when the least-cost combination of fuel switching and scrubbers are used to meet the emissions targets. If accelerated conservation is pursued along with emissions control, the overall cost of energy services is less than the cost if neither conservation nor emissions control occur. In other words, the economic savings due to conservation more than compensate for the cost of complying with the emissions control requirements.

Figure S-3 shows the present value of energy service costs during 1985-2000 for a variety of emissions control and load growth cases. This figure also provides the change in cost relative to the base case without emissions control. Consumers in ECAR can save $3.7-7.7 billion when accelerated conservation and emissions control are simultaneously pursued. Fuel switching and/or applying scrubbers on a least-cost first basis would minimize the cost of emissions control, saving nearly half the cost relative to the across-the-board scrubber case. Although environmental dispatch can minimize the amount of capacity that must be scrubbed, it does not reduce regional costs as much because of the greater reliance on power plants with higher fuel costs.

As shown in Figure S-4, accelerated conservation also leads to reduced expenditures on pollution control measures. With the least-cost approach, the cumulative cost for fuel switching and scrubbers is 42% lower in 2005 in the accelerated conservation scenario. This is a

FIGURE S.3

Present Value of Energy Service Costs During 1985-2000

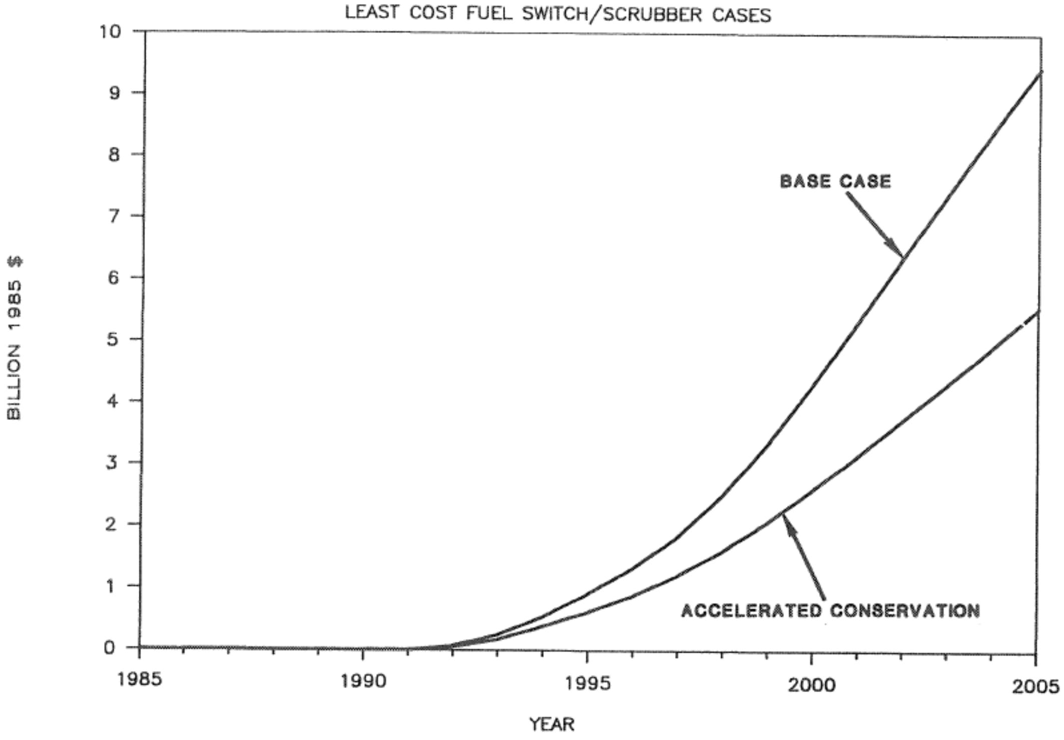


1) The length of each bar equals the total present value of the scenario.
2) The number within each bar equals the difference between the scenario and the base case with no emission reductions.

FIGURE S.4

CUMULATIVE EMISSION CONTROL COSTS

LEAST COST FUEL SWITCH/SCRUBBER CASES



consequence of obtaining some reduced emissions due to lower electricity demand, from avoiding controls in relatively expensive applications, and from delaying purchase of scrubbers and/or low-sulfur coal.

III. CONSERVATION AND ACID RAIN LEGISLATION

This section of the study examines the various regulatory approaches to achieving substantial emissions reductions from the perspective of receiving credit for and encouraging electricity conservation. Of course, other factors such as cost, equity, and certainty of emissions reductions need to be considered when deciding which regulatory approach to adopt.

The regional analysis shows that aggressive electricity conservation can provide economic benefits that can totally offset the cost of substantial SO2 emissions reductions. Any conservation used to defer the construction of new conventional power plants benefits consumers regardless of the legislative approach to controlling emissions.

Conservation is also likely to lead to reduced use of existing power plants. Whether or not states and utilities receive credit towards meeting their emissions reduction requirements depends on the legislative approach. One approach imposes ceilings on total emissions on a state-by-state basis. This approach provides states with full credit for emissions reductions due to conservation. An emissions ceiling is one option in bills proposed in 1987 by Sen. Mitchell (S. 321) and Sen. Proxmire (S.316).

A second legislative approach imposes a limit on the statewide average emissions rate. This approach is one option in the 1987 Mitchell and Proxmire bills and is used in the 1986 bill sponsored by Rep. Waxman (H.R. 4567). Credit may or may not be given for conservation-induced emissions reductions under this approach. If lower electricity demand results in reduced utilization or early retirement of plants with above average emissions rates, then conservation could help a state move towards its reduction goal. On the other hand, reduced utilization or early retirement of plants with below average emissions will penalize a state in terms of its average emissions rate, even though the action is reducing the absolute amount of emissions. This situation is likely to occur in practice since cleaner plants are often more expensive to run and are the first to be cut back under normal economic dispatch. Even when use of plants with above average emissions rates is reduced, the credit will be less with a statewide average emissions rate limit than with an emissions ceiling.

A third legislative approach places emissions rate limits on individual power plants. This approach is used in the bill introduced by Sen. Stafford in 1987 (S. 300). An emissions rate limit enforced on a source-by-source basis may not provide full credit for lower emissions when conservation leads to reduced power plant operation. A plant's emissions rate is not affected by the amount of operation, a retrofit scrubber is still needed if the emissions rate limit is sufficiently stringent. Conservation could be used to "mothball" dirty power plants or even retire functioning units, thereby deferring or avoiding purchase of scrubbers or low-sulfur coal. Utilities might benefit from mothballing dirty generating units during years when they have excess capacity, but utilities are not likely to prematurely retire existing power plants if it accelerates construction of expensive new capacity.

Both the Proxmire and Mitchell bills attempt to encourage states to incorporate conservation into their acid rain control strategies. In the Proxmire bill, a state can choose to comply with an emissions ceiling if its governor certifies that conservation program(s) have been undertaken and are reducing emissions. Otherwise, states must comply with a statewide average emissions rate limit. The Mitchell bill directs states to make electricity conservation their top priority for achieving emissions reductions. The Mitchell bill also allows a state to adjust its statewide average emissions rate limit according to the amount of emissions reduction directly attributable to conservation.

Conservation program certification and determining the amount of emissions reduction directly resulting from conservation programs, while well-meaning provisions, are unnecessary and impractical. As the Proxmire bill is now written, states are likely to select the ceiling or rate limit based on which approach requires the least reduction in total emissions. If a state chooses the emissions ceiling, it may simply go through the motions of adopting a conservation program without necessarily taking end-use efficiency seriously.

Further, it is very difficult to accurately determine how much electricity savings results from utility or statewide conservation programs, let alone the impact on SO2 emissions. Consumers are influenced by many factors, e.g., prices, regulations, advertising, and utility programs. If conservation programs are implemented, states and utilities can only estimate what would occur without such programs. The problem of calculating electricity savings and emissions reductions resulting from conservation efforts can be avoided by simply requiring states to comply with an emissions ceiling.

The emissions ceiling for each state could be set assuming a fixed emissions rate for all coal-burning plants in some reference year. For example, the ceilings could be calculated based on the emissions that would have occurred in 1986 had all utility plants operated at 0.9 lbs. of SO2 per MMBtu of coal input. Electricity conservation would be one option states have to move towards their ceiling and to hold down the overall cost of energy services over the long run.

Efforts to achieve some emissions reductions through end-use efficiency improvements would have to begin years before limitations on emissions take effect in order to have a large impact. Progress could be tracked through annual electricity sales and emissions. If a state is not moving towards its emissions ceiling as planned, e.g., if consumers don't respond to financial incentives or if economic growth is greater than anticipated, short lead-time measures such as switching to low-sulfur coal or scrubber retrofits could be implemented. Since there is always uncertainty about load growth and the amount of electricity use in the future, states need to make contingency plans for meeting emissions reduction goals regardless of how aggressively they pursue conservation.

Acid rain legislation should direct states to consider end-use efficiency improvements and to strive for least-cost energy services when they develop their acid rain compliance plans. By planning and managing electricity demand, electricity supply, and emissions control in an integrated manner, states and utilities can both protect the environment and protect the economic interests of their consumers.

IV. MAXIMIZING CONSERVATION ADOPTION

For certain end-uses such as residential appliances and fluorescent lighting, a clear shift towards greater efficiency is underway. In other areas, adoption of more efficient technologies is still limited.

A variety of policy and program options are available to stimulate greater adoption of electricity conservation measures. States or the federal government can adopt minimum efficiency requirements for new buildings and for lighting products to complement the national appliance efficiency standards promulgated in 1987. Utilities can offer rebate incentives or financing to stimulate the adoption of measures not covered by standards. In addition, a utility or energy agency can sponsor direct installation of conservation measures in markets where financial incentives are not effective.

Experience with these policies and programs has shown that they can substantially reduce electricity demand growth. California's appliance efficiency standards have been the most effective conservation program in that state, having already cut electricity use by over 3000 GWh/yr and lowered peak demand by about 1750 MW. It is estimated that the federal appliance standards adopted in 1987 will lower national electricity demand in 2000 by 22,000 MW. A number of utilities with comprehensive efficiency rebate programs claim that they are reducing their peak demand by 0.5%/yr or more. Finally, utility-sponsored direct installation programs have demonstrated that it is possible to implement conservation measures in a large fraction of potential applications.

V. CONCLUSIONS AND RECOMMENDATIONS

1. It is cost effective to reduce total electricity demand in the ECAR region by 26%. Such savings can be obtained with end-use efficiency improvements exhibiting a cost of saved energy below average electricity prices in each sector. Over half the identified savings potential is in the residential sector.

2. By aggressively pursuing end-use efficiency, average growth in electricity demand in the region can be limited to 0.9%/yr during 1985-2005, compared to average growth of 1.7%/yr in a "base case" scenario. In our accelerated conservation scenario, no new base load capacity beyond what is already under construction is needed in the region before 2005.

3. Energy services are always provided at a lower cost when conservation is aggressively pursued. By 2005, the annual energy service cost, i.e., the cost for electricity as well as efficiency improvements, is 26% lower in the accelerated conservation scenario compared to the base case scenario.

4. The accelerated conservation scenario leads to a direct reduction in regional SO2 emissions of 7-11% during 1992-2002. The direct emissions reduction declines after 2000 as conservation is used to displace new conventional generating capacity.

5. Assuming that acid rain legislation is adopted which requires a 55% reduction in regional utility SO2 emissions by 2000, the economic benefits provided by aggressive end-use efficiency improvements can more than offset the cost of SO2 emissions controls. This is true even if flue gas scrubbers are widely implemented. Accelerated conservation, switching to low-sulfur coal, and installing a small number of scrubbers appear to be the least costly approach to emissions control and energy services in the ECAR region.

6. Conservation, when used to defer the construction of conventional power plants, benefits consumers regardless of which legislative approach to emissions control is adopted. Whether or not states and utilities receive credit for using conservation to reduce the use of existing power plants depends on the legislative approach.

7. From the perspective of receiving credit for emissions reductions due to conservation, statewide emissions ceilings are preferable as the policy approach to emissions control. An emissions rate limit imposed on a state-by-state basis may penalize states that aggressively pursue conservation and at best provides partial credit for reductions due to conservation. Legislation that imposes

emissions rate limits on individual power plants allows utilities to defer or avoid pollution controls by mothballing or prematurely retiring dirty power plants. But utilities might not fully benefit from emissions reductions due to reduced operation of existing power plants.

8. Some legislative proposals call for states to certify that conservation programs have been undertaken or to determine the actual amount of emissions reductions from conservation programs. These requirements are unnecessary and impractical particularly if statewide emissions ceilings are adopted. Under an emissions ceiling approach, states should submit acid rain control plans and monitor annual load growth and emissions. If load growth is greater than anticipated, a state should adjust its plan and adopt additional control measures.

9. Acid rain legislation should require states to consider end-use efficiency improvements and to strive for least-cost energy services when they develop their acid rain compliance plans. Consumers can benefit if states and utilities integrate their planning and management of electricity supply, electricity demand, and emissions control.

10. States and utilities interested in stimulating a high degree of electricity conservation could adopt a complementary set of programs including minimum efficiency standards for new buildings and lighting equipment, utility rebates for other electricity conservation measures, and direct installation programs in markets that do not respond to incentives.

CHAPTER 1

INTRODUCTION

I. BACKGROUND

Numerous studies conclude that acid deposition (commonly referred to as acid rain) is adversely affecting aquatic ecosystems, forests, croplands, materials, and even human health [1]. Analyses have shown that the damage is costing the U.S. at least $10 billion per year [2]. Sulfur dioxide (SO2) is the primary acid rain precursor in most regions, and electric utilities generate approximately 65% of total SO2 emissions in the U.S. Therefore, large reductions in electric utility SO2 emissions have been called for.

Certain nations and states are already making large reductions in SO2 emissions. West Germany is committed to a 50% reduction in SO2 emissions while the province of Ontario, Canada is committed to a two-thirds reduction. In the U.S., Massachusetts, Minnesota, New Hampshire, New York, and Wisconsin have adopted legislation requiring a 25-50% reduction in statewide SO2 emissions [3]. However, efforts to curb acid rain emissions at the national level are deadlocked. A number of acid rain control bills have been introduced in the U.S. Congress in recent years, but the Reagan Administration has opposed them and the Congress has failed to pass any such legislation.

The cost of emissions control is a major obstacle to passage of acid rain legislation in the U.S. An 8-12 million ton reduction in annual SO2 emissions as required in a number of bills would cost an estimated $2-6 billion per year assuming use of conventional control approaches such as flue gas scrubbers or switching to low-sulfur coal [1, 4]. The proposed reductions represent 45-70% of utility SO2 emissions in 1985.

Utilities have argued that costs of this magnitude are unacceptable, especially in states such as Ohio and West Virginia that are very dependent on high-sulfur coal for generating electricity. Electricity rates could climb by 10% or more in these states under some of the acid rain control proposals [1]. Consequently, there is considerable interest in developing alternative emissions control strategies that are less expensive then conventional approaches.

Electricity conservation is one alternative approach to emissions control that is receiving increased attention. Conservation, as considered here, involves raising the efficiency of end-use equipment such as appliances, motors, and lighting or increasing the thermal integrity of buildings, without cutting back on levels of comfort or economic activity. Because conservation leads to less combustion of coal and other fuels, it directly lowers pollutant emissions. In addition, conservation usually reduces the cost of providing energy services, thereby making the cost for further emissions reductions more acceptable. Because of these benefits, two acid rain control bills recently introduced in Congress attempt to encourage use of conservation as an emissions control method.

The discussion and analysis of acid rain emissions in this study is limited to SO2 emissions. Although other pollutants contribute to acid rain, SO2 is considered the main source of acidity in most regions and is the primary focus of acid rain control legislation [1]. However, it is important to remember that while most pollution control methods effectively reduce emissions of only a single pollutant, electricity conservation reduces the whole range of emissions from fossil-fueled power plants, including nitrogen oxides, hydrocarbons, particulates, and trace metals.

II. OTHER STUDIES OF ACID RAIN AND ELECTRICITY CONSERVATION

A few other studies consider conservation as an emissions control option. An earlier version of the utility simulation model used in this study was previously used to evaluate the implications of reduced load growth on emissions control costs in the Midwest [5]. This study showed that conservation could reduce emissions directly and reduce overall energy service costs for consumers. However, this study did not contain a detailed analysis of electricity conservation options and savings potential.

A study was completed in Wisconsin showing that the cost of a 30-70% reduction in statewide SO2 emissions could be substantially reduced if load growth is 0.5%/yr rather than the 2.0%/yr forecast by Wisconsin's utilities [6]. The Wisconsin study only considered the costs for conventional emissions reduction techniques, i.e., scrubbers or low-sulfur coal. The study did not specifically examine how to achieve this degree of conservation or how much the conservation would cost.

Another study analyzed the short-term impacts that electricity conservation could have on SO2 emissions by Northern States Power Co. in Minnesota. Conservation occurring in the marketplace as well as savings resulting from utility programs were considered. According to this study, conservation could cut total electricity use by 0.5-1.7% by 1989, thereby lowering the utility's SO2 emissions by 1.0-3.5% [7]. This degree of SO2 reduction is small relative to state requirements, and reflects the limited amount of electricity savings envisioned over the short run.

Although other studies have considered electricity conservation as an emissions control option, they did not develop a comprehensive, integrated analysis of electricity conservation opportunities, electricity supply, and acid rain abatement. An integrated analysis is necessary to explore how conservation can lower SO2 and the extent to which conservation can reduce the overall cost of compliance with acid rain legislation. Moreover, an integrated analysis makes it possible to assess alternative strategies for acid rain control in terms of the total cost to society for providing electrically-driven services. Narrower indices, such as the cost of pollution control equipment or changes in electricity rates, do not provide a satisfactory basis for choosing among the alternatives.

A main objective of this study is to analyze how electricity conservation can help a major SO2-emitting region comply with stringent emissions reduction requirements. The area selected for analysis is the East Central Area Reliability Council (ECAR) region as designated by the National Electric Reliability Council. It includes Ohio, Michigan, Indiana, Kentucky, West Virginia, and small parts of Maryland and Pennsylvania. The ECAR region is very dependent on high-sulfur coal. The region's electric utilities produce about 17% of the nation's electricity while they emit about 33% of utility-generated SO2.

III. REPORT OUTLINE

Chapter 2 examines the potential for electricity conservation in the ECAR region. Approximately 65 types of conservation measures are considered covering all major end-use categories in the industrial, commercial and residential sectors. For each measure, cost, electricity savings, cost effectiveness, and aggregate savings potential are estimated. The analysis is based on electricity use as of 1985.

The assessment of electricity conservation potential is used as an input to a utility simulation model, described briefly in Chapter 3 and in greater detail in Appendix B. The model determines the penetration of energy conservation measures over time given electricity rates and assumptions about consumer behavior, incentive programs, lead times, and other factors. The model also simulates power plant operation, capacity additions and retirements, planning, financing and electric rates, and SO2 emissions in the region. To make the analysis manageable, the region is treated as one large utility with individual power plants exhibiting similar characteristics combined into blocks.

The utility simulation analysis examines key parameters such as SO2 emissions, electric rates, and overall costs to consumers for different load growth and emissions control scenarios. Two load growth scenarios are considered -- a base case close to the official utility industry forecast for the region and an accelerated conservation case that involves a more rapid and intensified adoption of cost-effective efficiency measures over the next 15 years (Chapter 3). While a wide range of policy options are available for accelerating conservation, rebate incentives are used for stimulating efficiency improvements in the low growth scenario.

Simulations involving the two load growth scenarios and a variety of emissions reduction strategies are presented in Chapter 4. Most of the simulations assume states and utilities cut SO2 emissions from existing power plants approximately 35% by 1995 and 55% by 2000. Such reductions are of intermediate stringency compared to the various legislative proposals. Flue gas scrubbers and fuel switching are considered as emissions control techniques, in addition to electricity conservation.

Chapter 5 examines the different legislative approaches to acid rain control and their compatibility with electricity conservation. The chapter suggests how the bills could be modified so that states and utilities have incentives to pursue end-use efficiency as one element in their acid rain abatement programs.

The final chapter of the study, Chapter 6, examines the issue of how to maximize investment in end-use efficiency through a combination of regulations, utility incentive programs, and direct installation. This issue is relevant because of the concern that while there is a large potential for cost-effective electricity conservation, only a limited amount of this potential can be realized.

IV. NOTES AND REFERENCES

1. Acid Rain and Transported Air Pollutants, OTA-O-204, Office of Technology Assessment, U.S. Congress, Washington, DC, June 1984.

2. "Materials Effects - 1985 Assessment of Acid Deposition", draft report prepared for the Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, July 1985. Also, "Visibility and Other Air Quality Benefits of Sulfur Dioxide Emissions Controls in the Eastern U.S.", draft report prepared by Systems Applications Inc. for the Office of Policy, Planning, and Evaluation, U.S. Environmental Protection Agency, Washington, DC, Sept. 1984.

3. Personal communication with Michael Oppenheimer, Environmental Defense Fund, New York, NY, April 1987.

4. "Curbing Acid Rain: Cost, Budget, and Coal-Market Effects", Congressional Budget Office, U.S. Congress, Washington, DC, June 1986.

5. E.L. Miller, "The Impacts of Conservation on Electric Utility Pollution Control Strategies", Masters thesis, Thayer School of Engineering, Dartmouth College, June 1985.

6. "Utility Sulfur Dioxide Cleanup - Cost and Capability", Systems Planning, Environmental Review, and Consumer Analysis Division, Wisconsin Public Service Commission, Madison, WI, Nov. 1985.

7. A.L. Adiarte, "Sulfur Dioxide Emissions Reduction Through Energy Efficiency Programs in the NSP System", Minnesota Department of Energy and Economic Development, St. Paul, MN, March 1986.

CHAPTER 2

THE POTENTIAL FOR ELECTRICITY CONSERVATION IN THE ECAR REGION

I. INTRODUCTION

This chapter analyzes the potential for electricity conservation in the ECAR region. Separate assessments are developed for each of the major electricity end-use categories (industrial motors, commercial buildings, residential refrigerators, etc.). These assessments consist of a base case and a series of increasingly efficient options that result from the implementation of conservation measures. For each of the options, annual energy consumption, incremental cost, energy savings, and potential saturation are presented [1]. The primary objective is to define the cost and electricity savings potential for the different conservation measures.

A. WHAT ELECTRICITY IS USED FOR

Assessing the potential for electricity conservation requires an understanding of how electricity demand is apportioned among the major end uses. Our analysis of current electricity use is summarized here and presented in detail in Appendix A.

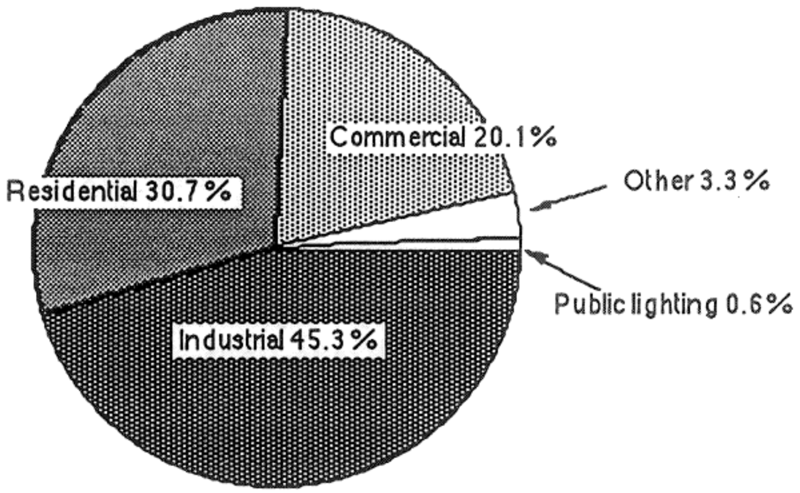
As Figure 2.1 illustrates, nearly half of ECAR's electricity use goes to the industrial sector, about 30% goes to the residential sector, and 20% is consumed in the commercial sector. Regarding industrial electricity use, motors consume just over three-quarters (77%) and lighting consumes about 4%. Electrolysis and process heat account for much of the remaining demand; however, they are not included in the conservation analysis because of their application-specific nature.

The largest end use in the residential sector is refrigerators (18.3%), followed by electric water heaters (14.5%), space heating (12.8%), and lighting (11.9%). The remaining end uses each account for less than 7% of residential electricity demand. As the later analysis will show, most of the residential conservation potential lies in improving end-use efficiency in the four major end uses.

In the commercial sector, lighting accounts for approximately 42% and cooling approximately 29% of electricity use. The remainder is used for heating, ventilation, and other purposes.

FIGURE 2.1

SECTORAL ELECTRICITY USE IN THE ECAR REGION
TOTAL ELECTRICITY SALES, 1984



Source: EEI Statistical Yearbook, 1984

B. METHODOLOGY FOR CONSERVATION ANALYSIS

The conservation analysis begins by defining a "base technology" for each end use or building type considered. The base technology is assumed to have the technical characteristics and corresponding electricity consumption typical of the 1985 equipment stock in the region. Since the base technology is estimated to be typical of the existing stock, more efficient refrigerators, lighting products, motors, etc. will already be in use to some extent. These more efficient technologies are included in the assessments.

The conservation analysis indicates which measures are cost effective for consumers as well as the maximum potential reduction in electricity consumption their implementation could bring. The analysis in this chapter is based on building and equipment stocks and electricity use in 1985. In the utility simulation analysis presented in Chapters 3-4, the conservation measures will be considered for both existing consumers and new consumers added during 1985-2005.

Conservation measures that cost less than the average electricity price are considered to be cost-effective for consumers. In 1985, electricity in the ECAR region typically cost 7.1 cents/kWh for residential consumers, 6.7 cents/kWh for commercial consumers and 4.7 cents/kWh for industrial consumers. These prices are based on weighting electricity prices in each complete state in the region by the population in the state [2].

The cost-effectiveness of conservation measures is based on the calculation of the marginal cost of saved energy (CSE). The marginal CSE is calculated by multiplying the cost for the efficiency measure by the appropriate capital recovery factor and dividing by the incremental annual electricity savings [3]. For conservation measures such as more efficient appliances, lamps, and motors where there is an improvement in efficiency compared to an ordinary model, the extra cost for the efficiency improvement is used. For stand-alone conservation measures such as home weatherization and variable speed motor controls, the full cost is used. The term "marginal CSE" is used because the CSE is based on the cost and savings from each particular conservation measure, rather than combining measures cumulatively as they are applied.

The capital recovery factor, a function of the discount rate and assumed measure lifetime, is needed to define the effective annual cost for a particular conservation measure. The capital recovery factor is based on a real discount rate of 6%, i.e., 6% above inflation. This rate was chosen because it is a reasonable estimate of the opportunity cost based on investments such as savings certificates, money market funds, etc. and because a discount rate at or close to 6% is used by other organizations including the California Energy Commission [4]. It is appropriate to use a social discount rate rather than a so-called implicit discount rate because we are estimating the cost-effective conservation potential in this chapter. Implicit discount rates are empirical estimates characterizing actual consumer purchasing behavior in the context of available efficiency options and their costs. Implicit discount rates generally are well above social discount rates and in some cases are as high as 200% [5].

All conservation measures considered in this assessment meet two basic criteria. First, they require no significant decrease in performance or in the number of features available to consumers -- some measures actually provide better performance. Second, they require no more than moderate technological advance -- the application of commercially available technologies or prototypes not yet in mass production. Prototype technologies are included in the analysis as long as actual performance data are available and the lead time required for commercial production is approximately three years or less.

Since the interest is in displacing baseload coal use, only annual kWh savings are considered. Potential reductions in peak demand are not accounted for. Thus, load management technologies such as thermal storage systems for commercial buildings are not considered because they reduce peak demand but not total electricity use.

Likewise, neither the conservation analysis nor the simulation model will address the issue of the potential for greater electrification through technologies such as heat pumps or induction heating. It is reasonable to avoid this issue since the objective is not to forecast the actual demand for electricity in the future. Rather, this study focuses on the potential impacts on emissions and the costs for energy services when electricity conservation occurs at an accelerated pace.

II. INDUSTRIAL SECTOR

A. INDUSTRIAL MOTORS

Motors consume the largest share of electricity in the industrial sector in the ECAR region. Because the industrial sector accounts for about 45% of total electricity use in the region, industrial motors are also the largest end-use overall, accounting for about 35% of total electricity consumption. Table 2.1 lists the assumptions regarding the base case characteristics of the motor stock, which is divided into six categories according to size. The characteristics for the six motor categories are based primarily on a major national study of electricity consumption by motors [6]. The efficiency assumptions are based on a more recent motor technology review [7]. Table 2.1 shows that while small motors dominate in terms of numbers, larger motors account for the majority of electricity use

Table 2.1

BASE CASE INDUSTRIAL MOTOR ASSUMPTIONS (1)

Size range (HP)	Average size (HP)	Number (1000)	Average usage (hrs/yr)	Average cost (1985$)	Average demand (kWh/yr)	Total demand (GWh/yr)	Avg. eff. (%)	Avg. life (yrs)	Fraction rebuilt (%)
< 1	0.28	905	400	40 (2)	84	76	70.0	20	0
1-5	1.34	895	921	160 (2)	926	828	80.5	20	0
5-20	8.61	971	2050	640	13,238	12,854	85.0	30	35
21-50	25.86	323	3139	1,430	60,881	19,636	89.0	17	74
51-125	80.55	170	3656	4,860	220,868	37,481	90.5	12	94
>125	195.00	92	3913	11,860	572,276	52,415	93.5	11	95
Total	--	3354	--	--	--	123,290 (3)	--	--	--

Notes:

1. Average usage, cost, and efficiency apply to the average size unit in any particular size range.

2. The cost values for motors < 5 HP are estimates.

3. The total electricity demand of 123,290 GWh/yr is equal to 77.1% of industrial electricity demand in 1985.

Sources: "Classification and Evaluation of Electric Motors and Pumps", DOE/CS-0147, U.S. Dept. of Energy, Feb. 1980.

W.J. McDonald and H.N. Hickok, "Energy Losses in Electric Power Systems", *IEEE Transactions on Industry Applications*, Vol. IA-21, No. 4, pp. 803-819, May/June 1985.

by industrial motors.

Rather than develop individual conservation assessments for each size category, we present one analysis for all industrial motors. We begin with a "typical" motor with a base consumption equal to the average for the size range. The full set of measures are then applied to this typical motor with the cost and impact of each measure weighted in accordance with the fraction of the overall stock to which it would be applied.

Two conservation measures -- replacement with a higher efficiency motor and installation of a variable frequency drive -- are applied independently to each of the six size categories. Both of these measures are widely available and are being implemented to some degree today. One technology review estimates that high efficiency motors and/or variable speed drives were used in 1-5% of motor applications greater then 50 HP in 1985 [8].

The first measure entails the replacement of a motor of average efficiency with a motor of higher efficiency. Costs and efficiencies for both standard and high efficiency motors are listed in Tables 2.1 and 2.2. The replacement is assumed to occur only when the motor needs to be either replaced or rebuilt. Rebuilding a motor (essentially rewinding the iron core) is assumed to cost 30% as much as a new motor. Because the cost effectiveness differs significantly depending upon whether a motor is replaced or rebuilt, the assessment includes separate measures -- weighted by the appropriate fractions -- for each possibility.

It should be noted that the efficiency of a motor can decline due to rebuilding. If so, there would be even greater savings by purchasing a new energy-efficient motor rather than rebuilding an existing motor. However, the magnitude of additional savings that is possible is highly uncertain and depends on factors such as quality control during rebuilding. Therefore, this effect is not included in the savings evaluation.

The second measure involves the installation of an adjustable speed drive (ASD), an electronic device which increases or decreases motor speed to meet changing process requirements. ASDs save energy by providing a better match of drive output to load compared to conventional clutches, valves and vanes. Additional benefits include the ability to start and stop a motor gradually, which extends the life of the motor and associated machinery, and precise speed control, which can enhance product quality. The current generation of energy-efficient ASDs employ a rectifier and an inverter. The rectifier converts alternating current to direct current and the inverter converts the direct current back to alternating current at the desired frequency, which determines the speed. Equipment and installation costs for the current generation of ASDs are listed in Table 2.2.

Table 2.2

INDUSTRIAL MOTOR CONSERVATION OPTIONS

Size range (HP)	Avg. size (HP)	HIGH EFFICIENCY MOTOR Eff. (%)	HIGH EFFICIENCY MOTOR Incr. cost (1) (1985 $)	ADJUSTABLE SPEED DRIVE Cost (1985 $/HP) Equip.	ADJUSTABLE SPEED DRIVE Cost (1985 $/HP) Install.	ADJUSTABLE SPEED DRIVE Cost (1985 $/HP) Total
<1	0.28	74.5	10	--	--	--
1-5	1.34	85.5	30	500	300	800
5-20	8.61	90.5	110	400	250	650
21-50	25.86	91.0	200	300	200	500
51-125	80.55	94.0	390	150	150	300
>125	195.00	95.0	990	125	125	250

Notes:

1. The incremental cost for a high efficiency motor is in addition to the cost for an average motor as shown in Table 2.1. Cost values for motors < 5 HP are estimates.

Sources: "Classification and Evaluation of Electric Motors and Pumps", DOE/CS-0147, U.S. Dept. of Energy, Feb. 1980.

W.J. McDonald and H.N. Hickok, "Energy Losses in Electric Power Systems", *IEEE Transactions on Industry Applications*, Vol. IA-21, No. 4, pp. 803-819, May/June 1985.

"Adjustable Speed Drives Directory", Electric Power Research Institute, Palo Alto, CA, 1985.

It is assumed that an ASD typically reduces electricity use by 22.5%, based on a detailed review which concluded that ASDs will save 20-30% of electricity use in a wide range of applications such as industrial pumps and compressors, blowers and refrigeration equipment [9]. Although other studies have estimated even greater savings potential with ASDs [8, 10], an average savings of 22.5% is conservative but reasonable given the uncertainties regarding ASD performance. In practice, electricity savings is very application specific and depends on the amount of variation in the load, the relative sizing of the motor to load, and the amount of part load operation.

Table 2.3 presents the overall conservation analysis for industrial motors. It is estimated that all of the identified measures could have reduced 1985 electricity consumption by nearly 25%. The four measures with the lowest CSE involve the replacement of standard efficiency motors with high-efficiency units. These four measures reduce demand by 0.6% from the base case with a marginal CSE of 1.4 cents/kWh or less. The next two measures consist of the installation of ASDS for the >125 HP and 51-125 HP classes. These two measures are estimated to cut overall consumption by industrial motors by 9.4% and 6.9% of the base case, respectively, with a marginal CSE of 3.3 cents/kWh and 4.2 cents/kWh.

Overall, motor efficiency measures with a marginal CSE less than the current average industrial price in the region could reduce motor electricity use by 16.9%. This level of savings is very similar to that identified in a study of electricity savings potential in the service area of General Public Utilities (located in Pennsylvania and New Jersey) [11]. Our findings that high efficiency motors are cost effective if a replacement is needed and that ASDs are cost effective in applications over 50 HP also are in agreement with other studies [8]. Of course, some applications in the real world, e.g., those with higher than average usage and/or higher potential savings, will be even more cost effective for conservation projects than indicated here, while other applications will not be feasible.

B. INDUSTRIAL LIGHTING

We estimate that lighting accounts for approximately 4% of industrial electricity use in the ECAR region. Lighting electricity demand can be reduced through the application of a number of high-efficiency alternatives which are available for upgrading typical light bulbs and fixtures. The conservation assessment for this end use is based on the installation of increasingly efficient luminaires for two of the bulb types included in our base case.

The base case scenario assumes 60% of electricity use for industrial lighting goes to 8 foot, 75 watt, standard fluorescent lamps in 2-lamp shielded fixtures with standard ballasts; 30% goes to

Table 2.3

INDUSTRIAL MOTORS CONSERVATION ASSESSMENT

Option (1)	Number (2) (1000)	Measure savings (kWh/yr)	First cost (1985 $)	Marginal CSE ($/kWh)	Net savings (%)	Potential regional savings (3) (GWh/yr)
51-125 HP, HEM @ retire	10	8,180	390	0.006	0.07	83
5-20 HP, HEM @ retire	631	800	110	0.010	0.48	505
21-50 HP, HEM @ retire	84	1,330	200	0.014	0.57	112
>125 HP, HEM @ retire	5	8,990	990	0.014	0.60	41
>125 HP, ASD	92	128,760	48,750	0.033	10.01	11,659
51-125 HP, ASD	170	49,690	24,160	0.042	16.91	8,491
1-5 HP, HEM @ retire	895	50	30	0.048	16.95	48
5-20 HP, HEM @ rebuild	340	800	560	0.051	17.23	272
51-125 HP, HEM @ rebuild	160	8,180	3790	0.055	18.29	1,307
21-50 HP, HEM @ rebuild	239	1,330	1200	0.085	18.55	318
21-50 HP, ASD	323	13,700	12,930	0.086	21.98	4,222
>125 HP, HEM @ rebuild	87	8,990	9,290	0.131	22.62	786
<1 HP, HEM @ retire	905	5	10	0.172	22.62	5
5-20 HP, ASD	971	2,980	5,600	0.176	24.80	2,682
1-5 HP, ASD	895	210	1,070	0.500	24.94	167

Notes:

1. HEM is a high efficiency motor installed either at the time of replacement or rebuilding. ASD is a variable speed drive.

2. Number refers to the motors eligible for a particular measure.

3. The estimated electricity consumption by industrial motors in 1985 is 123,100 GWh.

400 watt, phosphor-coated mercury lamps in shielded fixtures; and 10% goes to 400 watt, high-pressure sodium lamps [12]. The base case is based on a survey of industrial lighting and other industrial electricity uses in Arkansas [13]. This survey includes data on the total number of bulbs by type and SIC sector. These totals are weighted by the SIC electricity use fractions in the ECAR region to obtain the base case lighting assumptions.

The conservation options for the fluorescent luminaire first consists of replacing a standard lamp with a high-efficiency fluorescent lamp. Second, the ballast is upgraded to a high efficiency, core/coil ballast. The analysis for the mercury vapor lamp also consists of two measures. First, the mercury vapor bulb is replaced with a high efficiency, high-output, multi-vapor bulb. Second, the bulb is upgraded to a 400-watt, high-pressure sodium luminaire. No measures are considered for the lighting fraction already assumed to be high-pressure sodium because this lighting type is already very efficient.

For both the fluorescent and mercury vapor lamps, the same environmental and usage values are assumed: 4,000 hours/year of use, 10 hours per start, large room and average fixture conditions. Cost and savings data are drawn from a General Electric handbook prepared for the purpose of estimating lighting energy use and material and labor costs [14].

The lighting analysis, presented in Table 2.4, shows that three of the four measures are cost-effective (i.e., with a CSE under the 1985 average tariff of 4.7 cents/kWh). Implementation of these measures would save 1,595 GWh/yr regionwide, or 25% of the estimated electricity use for industrial lighting in 1985.

The installation of the high efficiency fluorescent lamp saves 92 kWh/yr per equivalent output at an incremental cost of $3 and a CSE of 0.8 cents/kWh. The high efficiency ballast saves an additional 33 kWh/yr at a cost of $10 and a marginal CSE of 4.3 cents/kWh. Together the two measures reduce the base case consumption of the fluorescent luminaire by 19%. For the mercury vapor luminaire, the installation of the multi-vapor lamp -- which requires no change in ballast or fixture, though fewer are required -- saves 854 kWh/yr per equivalent output at an incremental cost of $20 and a CSE of 0.6 cents/kWh. The high-pressure sodium luminaire saves 431 kWh/yr per equivalent output at an incremental cost of $124 and a CSE of 5.2 cents/kWh.

III. RESIDENTIAL SECTOR

Eight separate conservation assessments are presented in the residential sector, one for each of the major end-uses. The assessments are independent of one another; no attempt is made to account for interactions between end-uses (e.g., increased refrigerator efficiency will decrease cooling load and increase

Table 2.4

INDUSTRIAL LIGHTING CONSERVATION ASSESSMENT (1)

Option	Demand (kWh/yr)	Marginal savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (years)	CSE ($/kWh)	Regional savings potential (GWh/yr)
FLUORESCENT						
Base case (2)	688			4.5		
Watt-miser lamp	596	92	3	4.5	0.008	513
High-eff. ballast	563	33	10	10.0	0.043	182
MERCURY VAPOR						
Base case (3)	1820					
Multi-vapor lamp	966	854	20	5.0	0.006	900
High-pres. sodium	536	431	124	7.0	0.052	454

Notes:

1. The analysis is done on the basis of an equivalent light output when considering different options. It is assumed the overall composition of industrial lighting is: 60% fluorescent, 30% mercury vapor, 10% high-pressure sodium, and <1% incandescent and that total electricity demand for industrial lighting was 6,396 GWh in 1985.

2. Fluorescent base case: Standard 96" lamps, 60 watt bulbs, 2-lamp shielded fixture, 4000 hrs/yr usage, lifetime of 18,000 hrs.

3. Mercury-vapor base case: 400 W phosphor-coated bulbs, 22,500 lumens, 4000 hrs/yr usage, lifetime of 28,000 hrs.

heating load). These interactions are not very significant and are often neglected in residential conservation assessments [3]. Interactions within a particular end-use are accounted for, however. For example, mutual interactions between conservation measures that reduce hot water use and measures that increase water heater efficiency are included in the water heating analysis.

A. REFRIGERATORS

Table 2.5 presents the analysis for refrigerators (both single-door and two-door refrigerators are included in this category). The costs and savings were developed through the use of a computer model which simulates the impact of various conservation options on the electricity consumption of a refrigerator [15]. The analysis begins with a refrigerator model whose assumed unit energy consumption (UEC), 1400 kWh/yr, is considered typical of the stock in use in 1985.

The first set of measures reduces the UEC to 1166 kWh/yr, approximately typical of current sales [16]. These measures include the installation of an anti-sweat switch and the replacement of fiberglass insulation in the doors with polyurethane foam. The anti-sweat switch allows the user to turn off case heaters when surface condensation is not a problem. The polyurethane foam is a better insulator than fiberglass. The marginal CSE for this set of measures is 0.6 cents/kWh.

The second set of measures, entitled "Best current," reduces consumption to 750 kWh/yr, the level of the most efficient two-door, automatic defrost model produced in the U.S. in 1986 [17]. This package includes an upgrade in the efficiency of the compressor to 4.5 EER, an upgrade in the efficiency of the fan and fan motor and, an increase in insulation thickness. With an estimated incremental cost of $55, this package has a marginal CSE of 1.2 cents/kWh.

The third set of measures, entitled "Advanced", includes measures that are not commercially available in the United States, but that have been demonstrated in prototypes or in foreign products. The measures employed and electricity consumption of this option are similar to the characteristics and performance of a prototype refrigerator/freezer constructed in Denmark and now undergoing field testing in the U.S. [18]. This package reduces consumption to 480 kWh/yr through use of 2.5-3.35 inches of insulation and a separate motor/compressor for the refrigerator and freezer compartments. The estimated incremental cost for this package is $85; the marginal CSE is 2.7 cents/kWh.

B. FREEZERS

The conservation analysis for freezers is based on the same computer model and data sources as the refrigerator analysis [11]. The analysis, presented in Table 2.6, begins with a base case

Table 2.5

REFRIGERATOR CONSERVATION ASSESSMENT (1)

Option	UEC (kWh/yr)	Savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (yrs)	Marginal CSE ($/kWh)	Net percent savings	Total savings potential per house (kWh/yr)	Total savings potential Regional (GWh/yr)
1985 stock average	1400			20				
Current sales (2)	1166	234	15	20	0.006	16.7%	257	3313
Best current (3)	750	416	55	20	0.012	46.4%	458	5889
Advanced (4)	480	270	85	20	0.027	65.7%	297	3822

Notes:

1. Base model is 17 cubic foot, top-mount freezer, automatic defrost. Regional saturation of refrigerators is 110%.

2. Current sales average includes foam doors and anti-sweat switch.

3. Best current includes 4.5 EER compressor, additional insulation and more efficient fan and fan motor.

4. Advanced includes dual refrigeration systems with 5.0 EER compressors and additional insulation.

Table 2.6

FREEZER CONSERVATION ASSESSMENT (1)

Option	UEC (kWh/yr)	Savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (yrs)	Marginal CSE ($/kWh)	Net percent savings	Total savings potential Per house (kWh/yr)	Total savings potential Regional (GWh/yr)
1985 stock average	1100			20				
Current sales (2)	820	280	40	20	0.012	25.5%	134	1730
Best current (3)	534	286	40	20	0.012	51.5%	137	1767
Advanced (4)	385	149	70	20	0.041	65.0%	72	920

Notes:

1. The base model is a 15 cubic foot, manual defrost unit with an assumed electricity use that is an average between upright and chest freezers. The regional freezer saturation is 48%.

2. Current sales model includes additional insulation.

3. Best current model includes a more efficient fan/motor and a 4.5 EER compressor.

4. The advanced model includes 5.0 EER compressor and a double gasket.

consumption of 1100 kWh/yr. This is considered typical of the stock of manual defrost freezers of either the upright or chest style.

The first option reduces consumption to 820 kWh/yr, approximately the current sales average for manual defrost freezers [19]. The option involves increasing insulation thickness to 3.5 inches at a marginal CSE of 1.2 cents/kWh. The second option reduces consumption to 534 kWh/yr, close to the level of the most efficient 18-20 cubic foot freezer available in 1986 [20]. This option includes the addition of a 4.5 EER compressor and a more efficient fan/motor assembly. The marginal CSE for this package is also 1.2 cents/kWh. The third option, titled "Advanced", reduces consumption to 385 kWh/yr at a marginal CSE of 4.1 cents/kWh. This package includes a 5.0 EER compressor, a second door gasket and the removal of the fan motor from conditioned space. Such measures also appear to be cost effective based on the estimated CSE of 4.1 cents/kWh.

C. WATER HEATING

The water heating analysis, shown in Table 2.7, includes all measures that reduce consumption of hot water as well as those that improve the efficiency of heating and storing water. The base case option consists of a standard electric water heater with an energy factor rating of 0.82 [21], standard showerheads, and a top-loading clothes washer. Base case energy use is 3,800 kWh/yr, appropriate for an average three-person family.

The first conservation measure is the installation of a low-flow showerhead (flow rate of 2-3 gpm,) which is assumed to have an installed cost of $10 and to reduce electricity consumption by 10% [3]. This measure has a CSE of 0.3 cents/kWh. The second measure is the installation of an insulating blanket and heat traps. The latter prevents convective heat flow to the water pipes during standby periods. At a combined cost of $35, they reduce consumption by an additional 10% [22], leading to a marginal CSE of 1.2 cents/kWh. The third measure is the purchase of a front-loading clothes washer in place of the standard top-loading model. By using less hot water to wash the same amount of clothes, this measure saves 480 kWh/yr (for a water heater with an energy factor rating of 0.90) and has an incremental cost of $150 [22]. The marginal CSE for this measure is 3.5 cents/kWh.

The final two conservation measures involve the replacement of the standard water heater with a heat pump water heater (HPWH). A HPWH is similar in principle to a refrigerator or room air conditioner; it transfers heat from the surrounding air to the water in a tank. Because a HPWH delivers more heat than the electrical energy it consumes, its energy factor is greater than 1 -- typically in the range of 1.6 to 2.2. The first HPWH measure is based on an ordinary model with an energy factor of 1.6. This measure cuts electricity consumption by 1137 kWh/yr relative to the previous

Table 2.7

ELECTRIC WATER HEATER CONSERVATION ASSESSMENT (1)

Option	UEC (kWh/yr)	Savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (yrs)	Marginal CSE ($/kWh)	Net percent savings	Total savings potential Per house (kWh/yr)	Total savings potential Regional (GWh/yr)
1985 stock avg.	3800							
Low-flow showerhead (2)	3420	380	10	13	0.003	10.0%	122	1565
Traps & blanket (3)	3078	342	35	13	0.012	19.0%	109	1408
Front loading C/W (4)	2598	480	150	13	0.035	31.6%	154	1977
Average HPWH (5)	1461	1137	715	13	0.071	61.5%	364	4681
Best HPWH (6)	1063	399	300	13	0.085	72.0%	128	1641

Notes:

1. The 1985 stock average model has an energy factor efficiency rating of 0.82. The regional saturation of electric water heaters is 32%.

2. Low-flow showerhead reduces hot water use by 10%.

3. Thermal traps and an insulation jacket increase the energy factor to 0.90.

4. Front loading clothes washer reduces electricity demand by 480 kWh/yr.

5. The average heat pump water heater (HPWH) has an energy factor rating of 1.6.

6. The best heat pump water heater (HPWH) has an energy factor rating of 2.2.

option at an estimated incremental cost of $715 [22]. The corresponding marginal CSE is 7.1 cents/kWh. The second HPWH measure is based on the most efficient domestic HPWH available in 1986 with an energy factor of 2.2 [22]. This measure reduces consumption by an additional 400 kWh/yr with an additional cost of $300, leading to a marginal CSE of 8.5 cents/kWh.

D. LIGHTING

Our conservation analysis for residential lighting is based on the following typical lighting use pattern: three 75-watt bulbs used for 1240 hrs/yr, five 75-watt bulbs used for 620 hrs/yr, and twenty-seven 60-watt bulbs each used an average of 300 hrs/yr [22]. Total electricity use based on this lighting pattern is 1000 kWh/yr. The conservation analysis for residential lighting is presented in Table 2.8. The analysis consists of two efficiency measures, each evaluated at the three different usage levels. The measures involve the replacement of the standard incandescent bulbs with more efficient bulbs.

The first measure is the replacement of standard bulbs with "Watt-miser" or "Supersaver" type bulbs. These incandescent bulbs are filled with Krypton and have improved filaments. They cost slightly more than standard incandescents but use about 6% less electricity per unit of light output. The bulbs require no changes in socket or fixture. At an extra first cost of 10 cents per bulb, they can save 60 kWh/yr per household at a marginal CSE of 3.1-3.3 cents/kWh.

The second lighting measure is a further upgrade in efficiency from Watt-miser bulbs to compact fluorescents. Fluorescent lamps are up to five times more efficient than standard incandescents with efficacies (light output per unit of power consumed) of 40-60 lumens/watt, as compared to 11-18 lumens/watt for incandescents. They also last 5-10 times longer than incandescent bulbs and are available in a wide range of wattages either as an integral bulb-ballast unit, or as a conversion base containing the ballast with a separate bulb that plugs into the base. In the U.S., compact fluorescent lamps are still primarily used in commercial buildings. However, compact fluorescent lamps are starting to be used in European and Japanese homes.

Our analysis assumes a cost of $18 for a 20W compact fluorescent (replacing a 75W incandescent) and $15 for a 18W bulb (replacing a 60W incandescent). These costs are typical of current market prices and are conservative in that they are based on small purchase quantities [22]. The replacement of Watt-miser bulbs with the appropriate compact fluorescent results in a marginal CSE of 3.2-4.8 cents/kWh.

An alternative to the compact fluorescent measure is the replacement of the Watt-miser bulbs with coated incandescents or

Table 2.8

LIGHTING CONSERVATION ASSESSMENT (1)

Option (2, 3)	Usage level (hrs/yr)	UEC (kWh/yr)	Savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (yrs)	Marginal CSE ($/kWh)	Net percent savings	Regional savings potential (GWh/yr)
Watt-miser/supersaver	1240	983	17	0.30	0.6	0.031	1.7%	215
Watt-miser/supersaver	620	969	14	0.50	1.2	0.032	3.1%	180
Compact fluorescents	1240	781	188	30.00	6.0	0.032	21.9%	2418
Watt-miser/supersaver	300	752	29	2.70	2.5	0.041	24.8%	375
Compact fluorescents	620	596	157	50.00	12.1	0.038	40.4%	2015
Compact fluorescents	300	285	311	189.00	25.0	0.048	71.5%	4003

Notes:

1. Base case usage: 3 bulbs @ 75 W &1240 hrs/yr; 5 bulbs @ 75W & 620 hrs/yr; 27 bulbs @ 60 W & 300 hrs/yr; standard bulbs are assumed to cost $0.70 and last 750 hrs. Bulb costs are undiscounted.

2. Watt-miser/Supersaver: saves 6% at $0.80/bulb, lifetime of 750 hrs.

3. Compact fluorescents: 20W bulb replaces a 75W incandescent and costs $18, 18W replaces a 60W incandescent and costs $15, lifetime of 7500 hrs.

or "heat mirror" bulbs. These bulbs have a heat-reflective coating on their inside surface and are spherically shaped so that the coating reflects infrared radiation back onto an improved filament. A heat mirror bulb (called the MI-T-Wattsaver) is now being marketed on a limited basis by the Duro-Test Corporation. It uses about 35% less electricity per unit of light output compared to an ordinary incandescent and costs $6-9 depending on the purchase quantity [23]. However, the Duro-Test heat mirror bulb is neither as efficient or cost effective as a compact fluorescent bulb.

E. SPACE HEATING

The housing stock is made up of a variety of building types, including single family homes, multi-family apartment buildings and mobile homes. Our residential space heating evaluation consists of two separate analyses, one for single family homes and one for multi-family and mobile homes. The housing stock is divided this way because single family homes account for a large majority of space heating energy consumption and consume significantly more energy per home than the other housing types.

Table 2.9 includes the assumptions regarding the fraction of the two housing types in the ECAR region, the housing characteristics, and the average heating energy demand in the base case. As discussed in Appendix A, it is estimated that only 10% of the households in the region have electric space heating as of 1985. Based on a number of residential surveys, we estimate that as of 1985, electrically-heated single family (SF) homes typically had insulation levels of R-19 to R-25 in the ceiling, R-11 in the walls, R-7 to R-11 in the floor, and two window glazings [24, 25, 26]. These thermal integrity values are consistent with the base case electricity consumption of 12,100 kWh/yr.

The first efficiency measure applied to SF homes is "house doctoring." This measure consists of an instrumented audit and relatively quick, low-cost measures directed at reducing infiltration and eliminating thermal bypasses. The audit includes a blower-door pressurization test to detect major air leakage sites and infrared scanning to detect cold spots. Caulking, gaskets and spot insulation are applied where necessary. Instrumented audits of this type are now widely available and their application is growing [27].

The costs and savings for house doctor audits are drawn from a study involving 138 single family houses in New Jersey and New York [28]. These homes received house doctoring by trained utility auditors. The average cost of a house doctor audit is estimated to be about $325 with a space heating savings of 15%. This corresponds to 1,815 kWh/yr given our base consumption level. The CSE associated with these assumptions is 1.6 cents/kWh.

Table 2.9

ELECTRIC SPACE HEATING CONSERVATION ASSESSMENT (1)

Option	UEC (kWh/yr)	Savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (yrs)	Marginal CSE ($/kWh)	Net percent savings	Total savings potential Per house (kWh/yr)	Total savings potential Regional (GWh/yr)
SINGLE FAMILY (2)								
1985 stock average	12100							
House doctor (3)	10285	1815	325	15	0.018	15.0%	129	1658
Level II (4)	6962	3323	1740	20	0.046	42.5%	236	3036
Level III (5)	5917	1045	1452	20	0.121	51.1%	74	955
MULTI-FAMILY/MOBILE HOME (2)								
1985 stock average	6400							
Level II (3)	5305	1095	726	20	0.058	17.1%	32	409
Level III (4)	4972	334	639	20	0.167	22.3%	10	124

Notes:

1. Housing stock fractions: Single family (SF) - 71%, Multi-family/Mobile home (MF/MH) - 29%. The regional saturation of electric space heating is 10%.

2. Reference housing types: SF - R-19 ceiling, R-11 walls, R-7 floors, 2 glazings.
MF-Low Density - 900 sq.ft./unit; 3-story, 24-unit structure; wood frame construction.
MF-High density - 900 sq.ft./unit; 10-story, 60-unit structure; masonry construction.

3. House doctor measure: instrumented audit and measures to reduce infiltration and eliminate thermal bypasses. See Reference 28.

4. Level II measures: SF - Storm door attachments, dual-set thermostat, pipe and duct insulation, insulating drapes, 1" basement insulation. MF - Dual-set thermostat, pipe and duct insulation, insulating drapes, storm windows and doors, add ceiling insulation.

5. Level III measures: SF - Loose fill wall insulation, clock thermostat, 2" basement insulation. MF - Air lock entrances, add basement insulation, combustion air preheat.

The second conservation option is titled "Level II" and is derived from a study which evaluates housing retrofits [29]. The measures included are storm attachments for doors, a dual-set thermostat, pipe and duct insulation, insulating drapes, and 1 inch of insulation applied to unfinished basement walls. The Level II measures further reduce SF space heating consumption by 3323 kWh/yr at an incremental cost of $1,740. The corresponding marginal CSE is 4.6 cents/kWh assuming the measures have a lifetime of 20 years.

The third option for SF homes also is based on the same study [29]. These measures include a clock thermostat, loose fill insulation in the walls, and an additional inch of insulation for unfinished basement walls. Application of these measures reduces consumption to 49% of the base case level at a marginal cost of $1,452. The marginal CSE for this option is 12.1 cents/kWh.

Our finding of 42% cost-effective savings potential in single family housing is consistent with other recent studies. In particular, an analysis of the conservation potential in electrically-heated homes in Michigan found that it should be possible to cut electricity use for space heating by 43% through measures exhibiting a marginal CSE of less than 6.5 cents/kWh assuming a 6% real discount rate [30]. Baseline electricity use for heating in this assessment was 12,600 kWh/yr, similar to the value assumed for SF housing in ECAR.

The supply curve for multi-family (MF) and mobile homes, constituting 29% of the building stock, contains only the Level II and III measures since house doctor audits are generally not applied in these housing types. Baseline space heating consumption is 6,400 kWh/yr per household. The Level II measures include storm attachments for windows and external doors, a dual-set thermostat, pipe and duct insulation, insulating drapes and an increase in insulation for MF buildings. With an estimated cost of $726 per housing unit and estimated savings of 1,095 kWh/yr, the CSE is 5.8 cents/kWh.

The Level III option includes a clock thermostat for both MF and mobile homes. For low-density MF homes, additional basement insulation and a combustion air preheat system are also part of this package. For mobile homes, this option includes storm attachments for doors and rigid insulation for the sheathing around the crawl space beneath the home. The marginal cost and savings per housing unit are $639 and 334 kWh/yr, respectively. Consequently, the CSE for this option is 16.7 cents/kWh.

F. CLOTHES DRYERS

The clothes dryer analysis, shown in Table 2.10, begins with a base UEC of 880 kWh/yr. This value is derived from the utility surveys and other studies cited in Appendix A. The first

Table 2.10

ELECTRIC CLOTHES DRYER CONSERVATION ASSESSMENT (1)

Option	UEC (kWh/yr)	Savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (yrs)	Marginal CSE ($/kWh)	Net percent savings	Total savings potential Per house (kWh/yr)	Total savings potential Regional (GWh/yr)
1985 Stock average	880			18				
Moisture sensor	763	117	60	18	0.047	13.3%	61	783
Heat pump cl. dryer	345	418	300	18	0.066	60.8%	218	2800

Notes:

1. The regional saturation of electric clothes dryers is 52%.

conservation measure is the addition of a moisture sensor which automatically shuts off the dryer when clothes are dry. Tests show that this feature typically saves 10-15% relative to the use of an ordinary timer [22]. The cost estimate of $60 is derived from prices in the 1986 Sears catalog. With an estimated savings of 117 kWh/yr and a first cost of $60, the moisture sensor option has a CSE of 4.7 cents/kWh.

The second conservation measure is the replacement of the standard resistance heating coil with a heat pump. A heat pump clothes dryer (HPCD) works like a dehumidifier by removing moisture from the dryer air in a closed cycle. Moisture in the air coming from the dryer condenses out on the evaporator coil of a refrigeration system. The dried and cooled air is recycled to the dryer rather than exhausted outdoors as in a conventional dryer. Prototype HPCDs have been built and tested, and one company intends to introduce them in the marketplace in 1987 or 1988 [31].

Tests of the prototype HPCD show electricity savings of 50-60% relative to a standard clothes dryer, and about the same drying time [32]. A further advantage is the replacement of the exhaust vent with a drain pipe, convenient for apartment buildings where exhaust vents are difficult to install. With an estimated savings of 55% or 418 kWh/yr over the moisture sensor model and an extra first cost of $300 [31], the marginal CSE is 6.6 cents/kWh.

G. CENTRAL AIR CONDITIONING

Approximately 17% of the households in the ECAR region had central air conditioners (CACs) as of 1985. The base option assumes an average CAC with an efficiency rating of 7.5 SEER and electricity use of 2500 kWh/yr [33]. These estimates imply 625 hours of operation per year for a typical CAC system with a capacity of 30,000 Btu/hr (2.5 tons).

The central air conditioner analysis, shown in Table 2.11, includes three measures related to improvements in air conditioner efficiency and one measure which saves energy by reducing the cooling load. The most cost-effective measure is an upgrade in air conditioner efficiency to an SEER of 10.0. This measure reduces consumption by 625 kWh/yr at an estimated incremental first cost of $200 [22]. The marginal CSE for this measure is 3.8 cents/kWh.

The second measure is the application of a self-adhesive reflective window film to south-facing windows in order to reduce heat gain in the summer months. For this measure, we assume the film has 80% reflectance (which reduces heat gain by 0.075 MBtu/sq.ft./yr), a cost of $2/sq.ft., a five year lifetime, and is applied to 30 square feet of windows [22]. The resulting electricity savings is 225 kWh/yr and the marginal CSE is 6.3 cents/kWh.

Table 2.11

CENTRAL AIR CONDITIONING CONSERVATION ASSESSMENT (1)

Option (2)	UEC (kWh/yr)	Savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (yrs)	Marginal CSE ($/kWh)	Net percent savings	Total savings potential Per house (kWh/yr)	Total savings potential Regional (GWh/yr)
1985 Stock avg.	2500			12				
10.0 SEER	1875	625	200	12	0.038	25.0%	106	1367
Window film (3)	1650	225	60	5	0.063	34.0%	38	492
12.0 SEER	1375	275	440	12	0.191	45.0%	47	602
15.0 SEER	1100	275	660	12	0.286	56.0%	47	602

Notes:

1. The regional saturation of central air conditioning is 17%.

2. SEER is the seasonal energy efficiency ratio defined as the Btu output per Wh consumed on a seasonal basis. The 1985 stock average SEER is assumed to be 7.5.

3. Window film assumes shading installed on five 2'x3' windows at $2/sq.ft. with a reduction in cooling load of 0.075 MBtu/sq.ft./yr.

The final two measures involve further upgrades in the efficiency of the CAC system, first to an SEER of 12.0 and then to an SEER of 15.0. The latter is close to the efficiency of the top-rated CAC system available in the U.S. in 1986 [34]. Efficiency improvements are assumed to cost $220 per unit of SEER in this range [22]. The marginal CSE for these measures is 19.1 cents/kWh and 28.6 cents/kWh, respectively. Thus, these options do not appear to be cost-effective for consumers in the ECAR region when compared to a residential electric rate of 7.1 cents/kWh. However, the first cost premium is expected to drop as the market for highly efficient CAC systems expands.

H. COOKING RANGES

Our conservation analysis for cooking ranges, presented in Table 2.12, begins with a base electricity consumption of 700 kWh/yr. The first conservation option, entitled "Simple measures," is composed of a set of relatively minor changes, all commercially available. For the oven, the changes include increased insulation, improved door seals, reduced thermal mass and a change in heating element configuration for improved heat transfer. For the surface elements, the measures include reduced contact resistance and an improvement in the reflectance of the pans underneath the heating elements. Estimates of the cost of these measures are $30 or less, with savings of about 130 kWh/yr [22]. Given these assumptions, the CSE for this option is 2.1 cents/kWh.

The second measure is the replacement of the standard oven with a "Bi-radiant" oven which maximizes the heat transfer between the heating coil and the food. The oven walls are highly reflective to infrared radiation so that, rather than absorbing energy, they reflect it back to the food and baking pan. Dark-colored cooking pans are used to increase energy absorbtion by the pan. The oven is called bi-radiant because heating coils are provided both below and above the food. Although the bi-radiant oven is not commercially available, prototypes were constructed and tested. Tests show that food quality is equal to that provided by a conventional oven while cooking time is reduced [35].

Electricity savings with the bi-radiant oven vary depending on the particular food being cooked but are typically at least 60% [22]. Since the oven itself is estimated to consume 225 kWh/yr following the application of the "Simple measures," a 60% reduction in oven electricity use leads to 135 kWh/yr of savings. A researcher familiar with the technology estimates an extra first cost of $100 for the bi-radiant oven [36]. At this cost, the marginal CSE for the bi-radiant oven is 6.8 cents/kWh.

The final measure for cooking ranges is an induction cooktop. An induction cooktop uses magnetic coils which are located underneath a smooth cooking surface through which a high frequency (20-40 kHz)

Table 2.12

ELECTRIC COOKING RANGE CONSERVATION ASSESSMENT (1)

Option	UEC (kWh/yr)	Savings (kWh/yr)	Extra first cost (1985 $)	Lifetime (yrs)	Marginal CSE ($/kWh)	Net percent savings	Total savings potential Per house (kWh/yr)	Total savings potential Regional (GWh/yr)
1985 stock average (2)	700							
Simple measures (3)	570	130	30	18	0.021	18.6%	75	970
Bi-radiant oven	435	135	100	18	0.068	37.9%	78	1008
Induction cooktop	387	48	360	18	0.688	44.8%	28	361

Notes:

1. The regional saturation of electric ranges is 58%.

2. 1985 stock average UEC is based on 325 kWh/yr for the oven, 375 kWh/yr for the cooktop.

3. Simple measures include increased oven insulation, improved door seals, improved reflectance of burner pans and reduced burner contact resistance. Simple measures save 100 kWh/yr from the oven and 30 kWh/yr from the cooktop.

current is run. The current creates an alternating magnetic field which induces a secondary current in an iron or steel pan. Because of the high resistance in the pan, the current is converted to heat. Induction cooktops are marketed by a number of firms, including General Electric, Sears, and several Japanese companies.

Induction cooktops save energy by heating the pan directly rather than through an electric resistance coil. Additional benefits include a cool cooktop -- reducing the possibility of burns -- and vastly improved temperature control. The induction unit provides continuous heat variability and "instant heat" much like a gas burner. Indeed, the induction cooktop is primarily marketed on the basis of these features.

Tests of induction cooktops have show efficiency gains of 20-40% over conventional ranges [22]. In this analysis, a savings of 30% relative to the base case is assumed. This corresponds to a savings of 48 kWh/yr compared to the previous option. The incremental first cost for the induction cooktop, $360, is based on prices in the 1986 Sears catalog. Consequently, the CSE for this option is 68 cents/kWh. While mass production and wider marketing should lead to price reductions and an improved CSE for this option, it is unlikely that the induction cooktop will ever be justifiable on the basis of energy savings alone.

IV. COMMERCIAL SECTOR

The commercial sector accounts for 20% of electricity use in the ECAR region. Because of the wide range of building types and the complex interactions between the various end-uses, it is difficult to develop independent supply curves for each of the end-uses. Instead, we rely on a computer model which simulates overall building energy demand in response to various energy-conserving measures. The simulation takes into account end-use interactions as well as usage patterns and climate in calculating energy use. The simulation model, known as DOE-2, was developed at Lawrence Berkeley Laboratory for the Department of Energy and is widely used for evaluating energy savings potential in buildings [37].

For our simulations, we chose the two commercial building types which account for the largest fractions of commercial energy demand -- office and retail/sales buildings. The base case building prototypes are drawn from a Pacific Northwest Laboratory study [38] and are chosen to match the stock average electricity consumption values (see Appendix A). Electricity savings resulting from the application of various conservation measures are derived from computer simulations using weather data from Detroit, MI. This city is typical of the ECAR region at least in terms of cooling degree-days. The installed costs for the conservation measures are derived from a study of conservation potential in buildings in Texas [39], and from a survey of commercial sector conservation technologies [40].

As usual, the various conservation measures are listed in tables in order of increasing CSE. However, in the simulation analysis, the measures were applied in a logical sequence which varies somewhat from our least-cost ordering. Analysis according to our least-cost ranking would lead to slightly different results because savings depend on the order in which the measures are applied. However, this would not fundamentally change the results.

Ideally, separate analyses would be conducted for all major building types because of the wide variety of building types, load patterns, operating schedules, etc. in the commercial sector. However, the time and cost involved in modeling ten or more building types precludes this possibility. Instead, it is assumed that the conservation analysis for retail sales buildings applies to 40% of the commercial building stock and that the analysis for offices applies to 40% of the building stock. The remaining 20% of the building stock is excluded from the savings evaluation to account for buildings that are not eligible for conservation retrofits due to technical or other reasons. Extrapolating the results for offices and retail stores to other commercial building types is consistent with the findings in other conservation studies [39, 41].

A. OFFICE BUILDINGS

The hypothetical office building is a 48,600 sq.ft., 3-floor building with glazing on 36% of the wall area. Operating hours are 8 AM to 6 PM weekdays with 30% occupancy on Saturdays. Thermostat settings are 78°F for cooling and 72°F for heating with night and weekend setback to 55°F during the heating season. The internal loads in the base case are 3.0 W/sq.ft. for lighting and 1.0 W/sq.ft. for other equipment. The base HVAC system is a dual-duct, constant volume system without an economizer. Heat is supplied by a gas-fired hydronic system and cooling by an air-cooled reciprocating chiller with a coefficient of performance (COP) of 2.4. The analysis begins with a base electricity consumption of 1417 MWh/yr, equal to 29.2 kWh/sq.ft./yr.

The conservation analysis, shown in Table 2.13, consists of eight conservation measures. Five are directed at the HVAC system and the remaining three at reducing electricity use for lighting and thermal loads. Since the hypothetical office building is assumed to use natural gas for heating, many of the measures affect natural gas consumption. Most measures lead to a decrease in natural gas consumption while a few lead to an increase. Overall, the measures reduce gas consumption by more than 80%. However, we do not include changes in gas consumption in our analysis; only changes in electricity consumption are presented.

Together, the seven cost-effective conservation measures for the office building (i.e., those with a CSE less than 6.7 cents/kWh)

Table 2.13

OFFICE BUILDING CONSERVATION ASSESSMENT (1)

Option	UEC (MWh/yr)	Savings (MWh/yr)	Extra first cost (1985 $)	Life (yrs)	Marginal CSE ($/kWh)	Net percent savings	Potential regional savings (GWh/yr)
1985 stock average	1417						
Reduce air flow (2)	1229	188	1,700	20	0.001	13.3%	3765
Reset supply air temp.(3)	1088	141	2,300	20	0.001	23.2%	2825
Lighting delamp (4)	1014	74	1,000	14	0.001	28.4%	1482
Economizer	884	130	6,695	20	0.004	37.6%	2599
Increase motor eff. (5)	867	17	4,000	10	0.032	38.8%	340
Window films (6)	843	24	12,733	20	0.046	40.5%	481
High eff. lighting (7)	729	114	57,518	14	0.054	48.5%	2283
Re-size chillers (8)	670	59	49,500	20	0.073	52.7%	1182

Notes:

1. It is assumed that these measures apply to 40% of the commercial building stock. Commercial building electricity consumption is 70,950 GWh/yr in 1985.

2. Reduce air flow: A 32% decrease in ventilation rates.

3. Reset supply air temperature: Continuous reset based on need of "worst" room; install sensors and processor.

4. Lighting delamp: Remove 17% of lamps, reduce consumption from 3.0 to 2.5 W/sq.ft.

5. Increase motor efficiency: 5% increase in 38 HP fan motor.

6. Window films: Install reflective film, shading coefficient = 0.47; $2.25/sq.ft.

7. High efficiency lighting: Install high-efficiency lamps and ballasts; $3.25/lamp plus $0.82/lamp-yr, $13.40/ballast; reduce consumption from 2.5 to 1.7 W/sq.ft.

8. Re-size chillers: Install 1.1 MBtu/hr, 4.55 COP centrifugal, water-cooled chiller; $550/ton installed.

reduce electricity consumption by 48.5% compared to the base level. Given the assumption that this conservation analysis is applicable to 40% of the commercial building stock in the region, the total cost-effective savings potential is 13,775 GWh/yr.

The first measure is a reduction in the air flow rate to the minimum amount necessary to meet the peak cooling load. Significant savings are possible because the air flow rate is often larger than needed due to oversizing. This measure involves determining the minimum possible flow rate, changing the motor sheave for belt-driven fans, using a lower motor speed for direct-driven fans, or duty-cycling the fan at the original flow rate. The estimated cost of this measure for the medium-size office building is $1,700 with a measure lifetime of 20 years [39]. Forecast savings from this measure are 188 MWh/yr, about 13% of the base case level. The resulting CSE is less than 0.1 cents/kWh.

The second measure is a shift from constant supply air temperature to a variable temperature based on the needs of the "worst" room. This measure involves the installation of temperature sensors in a number of rooms and a central processor which monitors temperatures and adjusts the supply air temperature. The installed cost is estimated to be $2,300, the savings is 141 MWh/yr, and the measure lifetime is 20 years. The CSE for this measure is approximately 0.1 cents/kWh. This measure also leads to a large reduction in gas consumption for space heating.

The third measure is a decrease in lighting intensity from 3.0 W/sq.ft. to 2.5 W/sq.ft., accomplished by removing 17% of the fluorescent bulbs from their fixtures. Delamping is a widely employed lighting conservation strategy because many commercial buildings constructed prior to 1980 included excessive lighting levels [40]. Though we estimate a first cost of $1000, the real cost may be much less as the delamping can be carried out as part of normal maintenance procedures. This measure saves 74 MWh/yr and, at a first cost of $1000, has a marginal CSE of 0.1 cents/kWh.

The fourth conservation measure is the installation of an economizer control on the HVAC system. An economizer brings in outdoor air when it is cool enough, thereby reducing the use of the mechanical chillers. An economizer consists of indoor and outdoor temperature sensors, dampers, motors, and motor controls. While smaller economizer systems can be purchased off-the-shelf, they are custom designed for larger buildings. The estimated installed cost of an economizer for the hypothetical office building is $6,695 and the estimated lifetime is 20 years [39]. The computer simulation predicts a savings of 130 MWh/yr, leading to a CSE of 0.4 cents/kWh.

The fifth measure is an increase in the efficiency of the fan motor, similar to that described earlier for industrial motors. A 5% increase in the efficiency of the 38 HP fan motor is assumed. It is estimated that the installed cost for replacing the fan motor would be $4,000 with a savings of 17 MWh/yr. This results in a CSE of 3.2 cents/kWh.

The sixth measure is the application of reflective window film. By reducing heat gain through the windows, the film saves energy by decreasing the internal load. It is assumed that the window film has a shading coefficient of 0.47 and an estimated installed cost of $2.25/sq.ft. [39]. With a glazing area of 5,560 sq.ft. in our hypothetical office building, the total cost is $12,733. Savings of 24 MWh/yr are expected at a CSE of 4.6 cents/kWh.

The seventh measure is an upgrade in the fluorescent lighting to high-efficiency lamps and ballasts. This retrofit involves switching from 40W to 34W lamps and from ordinary to energy-efficient core/coil ballasts. The new luminaires use 77% as much electricity as those in the base case while providing 12% more light. The installed cost is $13.40 per ballast and $3.25 per lamp, with an incremental cost of $0.82/lamp-yr for continued replacement with the high-efficiency lamps [14]. If energy-efficient lamps and ballasts are installed as part of normal lamp replacement, then the incremental costs will be lower. The installation of the new lamps and ballasts saves 114 MWh/yr and costs $57,518 for the hypothetical office building. The resulting marginal CSE for this conservation measure is 5.4 cents/kWh.

The eighth measure involves replacing the air-cooled reciprocating chiller with a smaller and more efficient unit. The new chiller is assumed to be a 1.1 MBtu/hr (90 ton) centrifugal, water-cooled chiller with a COP of 4.55. Assuming an installed cost of $550/ton [40], the new chiller would cost $49,500. It is important to note that this is the full cost of the new chiller. In practice, a new chiller would most likely be installed when old equipment fails, in which case it would be appropriate to use a much lower incremental first cost. At the full cost of $49,500 and with a lifetime of 20 years, this measure saves 59 MWh/yr and has a CSE of 7.3 cents/kWh.

Even greater electricity savings are possible through use of electronic lamp ballasts, reflective light fixtures, or daylighting sensors and controls [40]. However, the performance of these conservation technologies is somewhat uncertain. Therefore, they were not included in the analysis.

B. RETAIL BUILDINGS

The hypothetical retail building is an 11,760 sq.ft. strip store, composed of two single-story units. The construction is wood frame with glazing on 35% of the southern and western exposures, and no glazing on either the northern or eastern exposures. Operating hours are 10 AM to 10 PM Mondays through Saturdays and 10 AM to 8 PM on Sundays and holidays. The thermostat settings are identical to the office buildings -- 78°F during the cooling season and 72°F when heating. Internal loads in the base case are 2.5 W/sq.ft. for lighting and 0.5 W/sq.ft. for other equipment. The HVAC system consists of two package units (single-zone, variable temperature, constant volume, direct expansion units without economizers). Heating is supplied through electric resistance baseboard units and cooling through reciprocating compressors with air-cooled condensers. A base cooling COP of 2.4 is assumed. Total electricity consumption is 292 MWh/yr, equivalent to 24.8 kWh/sq.ft.

The conservation analysis, shown in Table 2.14, consists of eight measures, six of which are identical to measures applied in the office building (although downsized to account for the smaller building). Five of the measures are directed at the HVAC system, two are improvements in lighting efficiency, and one involves increasing building shell insulation. Together, the four conservation measures for the retail store with a CSE below 6.7 cents/kWh reduce electricity consumption by 14.1% from the base level. Given our assumption that this analysis is applicable to 40% of the commercial building stock, the aggregate savings potential is 4,000 GWh/yr.

The first measure is a reduction in lighting load through delamping, as described previously for the office building. With an estimated savings of 9 MWh/yr and a cost of $150, the CSE for this measure is 0.2 cents/kWh.

The second measure is a reduction in air flow as described in the previous section. The installed cost for this measure when applied to the hypothetical retail store is $620 and the electricity savings as estimated by the simulation model are 13 MWh/yr. With a lifetime of 20 years, the CSE is 0.4 cents/kWh.

The third measure, also described in the previous section, is a 5% increase in fan motor efficiency. With a first cost of $750, this measure saves 13 MWh/yr at a CSE of 0.5 cents/kWh.

The fourth measure for the hypothetical retail store is the installation of smaller, more efficient chillers. Chiller efficiency is increased from a COP of 2.4 to 3.2. Our cost estimate for this measure is $7,300 [40]. With savings of 12 MWh/yr, the CSE for this measure is 5.3 cents/kWh.

The fifth measure is the replacement of the standard fluorescent bulbs and ballasts with high-efficiency bulbs and ballasts as described in the office building analysis. The installed cost for this measure is $9,501, predicted savings are 21 MWh/yr, and the CSE is 6.1 cents/kWh.

The sixth measure involves increasing heating efficiency along with cooling efficiency. Rather than install more efficient chillers alone, it is possible to install a heat pump with a COP equal

Table 2.14

RETAIL STORE CONSERVATION ASSESSMENT (1)

Option	UEC (MWh/yr)	Savings (MWh/yr)	Extra first cost (1985 $)	Life (yrs)	Marginal CSE ($/kWh)	Net percent savings	Potential regional savings (GWh/yr)
1985 stock average	342						
Lighting delamp (2)	333	9	150	10	0.002	2.7%	774
Reduce air flow (3)	320	13	620	20	0.004	6.6%	1112
Increase motor eff. (4)	306	13	750	20	0.005	10.6%	1112
Re-size chillers (5)	294	12	7,300	20	0.053	14.1%	1002
High eff. lighting (6)	273	21	9,500	10	0.061	20.3%	1756
Heat pump conversion (7)	269	4	3,650	20	0.076	21.5%	349
Insulation (8)	224	45	51,477	20	0.100	34.6%	3705
Economizer	222	2	2,237	20	0.106	35.1%	152

Notes:

1. It is assumed that these measures apply to 40% of the commercial building stock. Commercial building electricity consumption is 70,950 GWh/yr in 1985.

2. Lighting delamp: Remove 17% of lamps, reduce consumption from 2.5 to 2.2 W/sq.ft.

3. Reduce air flow: Decrease ventilation rates by 18%.

4. Increase motor efficiency: 5% increase in 6.3 HP fan motor, $750 first cost.

5. Re-size chillers: Install new chillers: 76 kBtu/hr and 343 kBtu/hr, 3.2 COP.

6. Heat pump conversion: Install air-to-air heat pump, 3.2 COP.

7. High efficiency lighting: Install high-efficiency lamps and ballasts; $2.11/lamp plus $0.78/lamp-yr, $13.40/ballast; reduce consumption from 2.2 to 1.42 W/sq.ft.

8. Economizer: Install economizer control system; 58°F dry-bulb limit.

to that of high-efficiency chillers. The heat pump reduces the use of electricity for both heating and cooling. With an incremental cost for upgrading to a heat pump of $3650 (50% of the cost for the chiller alone) and a savings of 4 MWh/yr, this measure has a marginal CSE of 7.6 cents/kWh.

The seventh measure is the addition of fiberglass insulation to the walls and ceiling. Three inches are added to both the walls and ceiling, increasing the insulation levels to R-7 in the walls and R-19 in the ceiling. The installed cost is estimated to be $51,500, or $4.40 per sq.ft. of floor area. Electricity savings are predicted to be 45 MWh/yr. With a 20 year assumed lifetime, the CSE is 10.0 cents/kWh. The cost for this measure and the resulting CSE would be much lower if the insulation is added during construction of a new building.

The final measure for the retail store is the installation of an economizer control as described in the office building analysis. The savings from this measure are estimated to be 1 Mwh/yr, resulting in a CSE of 19.5 cents/kWh. This measure is much less cost effective when applied to the retail store compared to the office building because a lower outdoor temperature limit is assumed. Also, single zone HVAC systems are less energy intensive than the multi-zone systems used in larger buildings.

V. CONCLUSION

The overall results of the conservation assessments for the industrial residential, and commercial sectors are presented in Tables 2.15, 2.16, and 2.17, respectively. All the measures are ranked according to their cost effectiveness, with regional savings and percent cumulative savings in the sector presented as well. Some measures are listed twice in Table 2.17 because they were considered for both the hypothetical office and retail buildings.

Figures 2.2, 2.3, and 2.4 display the results as "conservation supply curves". The curves indicate the amount of savings potential available up to any particular cost of saved energy in each sector.

In order to develop estimates of the overall cost-effective conservation potential, the savings is summed for measures whose CSE is lower than the average electricity price for the appropriate sector. Table 2.18 shows the total cost-effective conservation potential for each sector and for the region as a whole. The residential sector offers the largest amount of cost-effective conservation potential in the region -- nearly 49,000 GWh. This equals 45% of residential electricity use in 1985. The industrial sector presents a cost-effective conservation potential of 22,500 GWh, about 14% of 1985 industrial electricity use, while the commercial sector presents about 19,500 GWh, 27.5% of commercial electricity use in 1985. The total cost-effective conservation

Table 2.15

OVERALL CONSERVATION ASSESSMENT FOR THE INDUSTRIAL SECTOR (1)

Area and option (2)		Marginal CSE ($/kWh)	Potential regional savings (GWh/yr)	Cumulative savings (%)
LTG	Multi-vapor bulb	0.006	900	0.56
MOT	51-125 HP, HEM @ retire	0.006	83	0.61
LTG	Watt-miser fl. bulb	0.008	513	0.94
MOT	5-20 HP, HEM @ retire	0.010	505	1.25
MOT	21-50 HP, HEM @ retire	0.014	112	1.32
MOT	>125 HP, HEM @ retire	0.014	41	1.35
MOT	>125 HP, ASD	0.033	11,659	8.64
MOT	51-125 HP, ASD	0.042	8,491	13.95
LTG	High-eff. ballast	0.043	182	14.06
MOT	1-5 HP, HEM @ retire	0.048	48	14.09
MOT	5-20 HP, HEM @ rebuild	0.051	272	14.26
LTG	High-press. sodium bulb	0.052	454	14.54
MOT	51-125 HP, HEM @ rebuild	0.055	1,307	15.36
MOT	21-50 HP, HEM @ rebuild	0.085	318	15.56
MOT	21-50 HP, ASD	0.086	4,222	18.20
MOT	>125 HP, HEM @ rebuild	0.131	786	18.69
MOT	<1 HP, HEM @ retire	0.172	5	18.69
MOT	5-20 HP, ASD	0.176	2,682	20.37
MOT	1-5 HP, ASD	0.500	167	20.48
TOTAL		---	32,747	20.48

Notes:

1. The estimated regional electricity consumption in the industrial sector in 1985 is 159,910 GWh.

2. MOT: motor; LTG: lighting; HEM: high efficiency motor; ASD: adjustable speed drive.

Table 2.16

OVERALL CONSERVATION ASSESSMENT FOR THE RESIDENTIAL SECTOR (1)

Appliance and option (2)		Marginal CSE ($/kWh)	Savings per house (kWh/yr)	Potential regional savings (GWh/yr)	Cumulative savings (%)
EWH	Low-flow showerhead	0.003	122	1565	1.4
REF	Current sales avg.	0.006	257	3313	4.5
REF	Best current	0.012	458	5889	9.9
EWH	Traps and blanket	0.012	109	1408	11.2
FRE	Best current	0.012	137	1767	12.9
FRE	Current sales avg.	0.012	134	1730	14.5
SH1	House doctor	0.018	129	1658	16.0
RAN	Simple measures	0.021	75	970	16.9
REF	Advanced	0.027	297	3822	20.4
LTG	Watt-miser 1	0.031	17	215	20.6
LTG	Watt-miser 2	0.032	14	180	20.8
LTG	Compact fl. 1	0.032	188	2418	23.0
EWH	Front-loading CW	0.035	154	1977	24.8
LTG	Compact fl. 2	0.038	157	2015	26.7
CAC	SEER = 10.0	0.038	106	1367	28.0
FRE	Advanced	0.041	72	920	28.8
LTG	Watt-miser 3	0.041	29	375	29.2
SH1	Level II	0.046	236	3036	32.0
CLD	Moisture sensor	0.047	61	783	32.7
LTG	Compact fl. 3	0.048	311	4003	36.4
SH2	Level II	0.058	32	409	36.7
CAC	Window film	0.063	38	492	37.2
CLD	Heat pump	0.066	218	2880	39.8
RAN	Bi-radiant oven	0.068	78	1008	40.7
EWH	Avg. HPWH	0.071	364	4681	45.0
EWH	Best HPWH	0.085	128	1641	46.6
SH1	Level III	0.121	74	955	47.4
SH2	Level III	0.167	10	124	47.5
CAC	SEER = 12.0	0.191	47	602	48.1
CAC	SEER = 15.0	0.286	47	602	48.7
RAN	Induction cooktop	0.688	28	361	49.0
TOTAL		---	--	53,165	49.0

Notes:

1. The estimated regional electricity consumption in the residential sector in 1985 is 108,370 GWh.

2. EWH: electric water heater; REF: refrigerator/freezer; FRE: freezer; SH1: single family space heating; SH2: multi-family and mobile home space heating; RAN: cooking range; LTG: lighting; CAC: central air conditioning; CLD: clothes drying.

Table 2.17

OVERALL CONSERVATION ASSESSMENT FOR THE COMMERCIAL SECTOR (1)

Option (2)	Marginal CSE ($/kWh)	Potential regional savings (GWh/yr)	Cumulative savings (%)
Reduce air flow 1	0.001	3765	5.3
Reset supply air temp.	0.001	2825	9.3
Lighting delamp 1	0.001	1482	11.4
Lighting delamp 2	0.002	774	12.5
Economizer 1	0.004	2599	16.1
Reduce air flow 2	0.004	1112	17.7
Increase motor eff. 1	0.005	1112	19.3
Increase motor eff. 2	0.032	340	19.7
Window films	0.046	481	20.4
Upgrade chillers 1	0.053	1002	21.8
High eff. lighting 1	0.054	2283	25.1
High eff. lighting 2	0.061	1756	27.5
Upgrade chillers 2	0.073	1182	29.2
Heat pump conversion	0.076	349	29.7
Insulation	0.100	3705	34.9
Economizer 2	0.106	152	35.1
TOTAL	---	24,919	35.1

Notes:

1. The estimated regional electricity consumption in the commercial sector in 1985 is 70,950 GWh/yr.

2. Some measures are listed twice because they were analyzed for both the hypothetical office building and retail store.

FIGURE 2.2

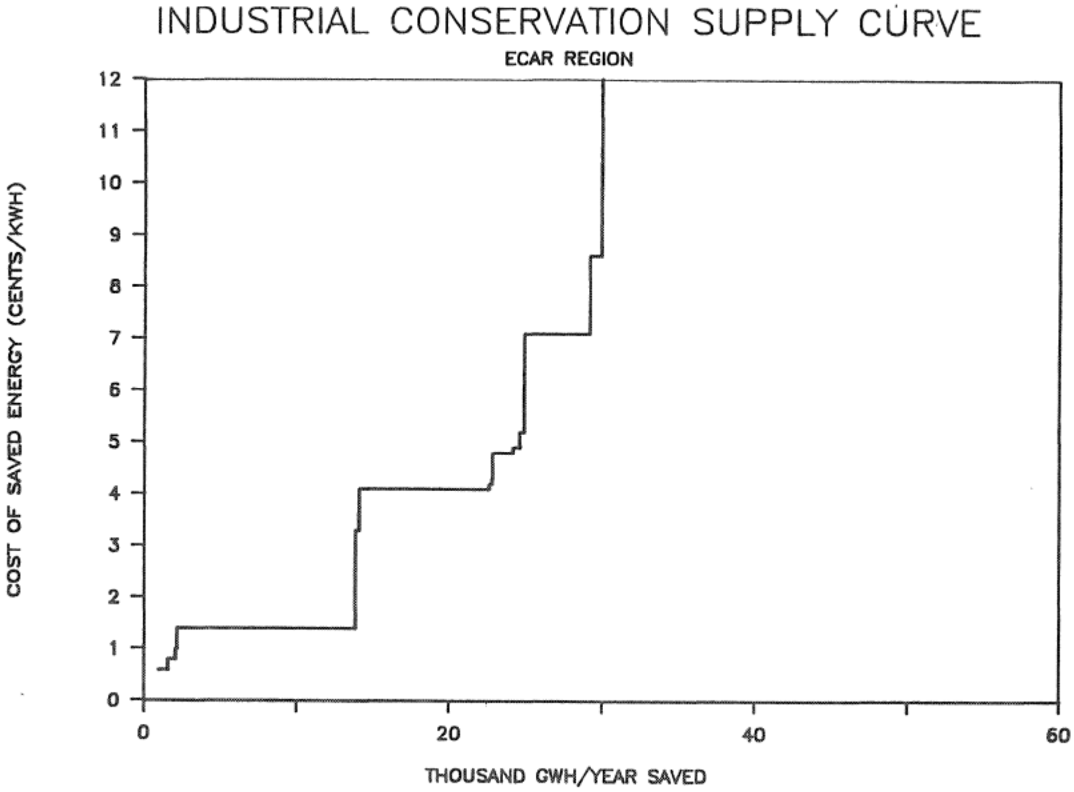


FIGURE 2.3

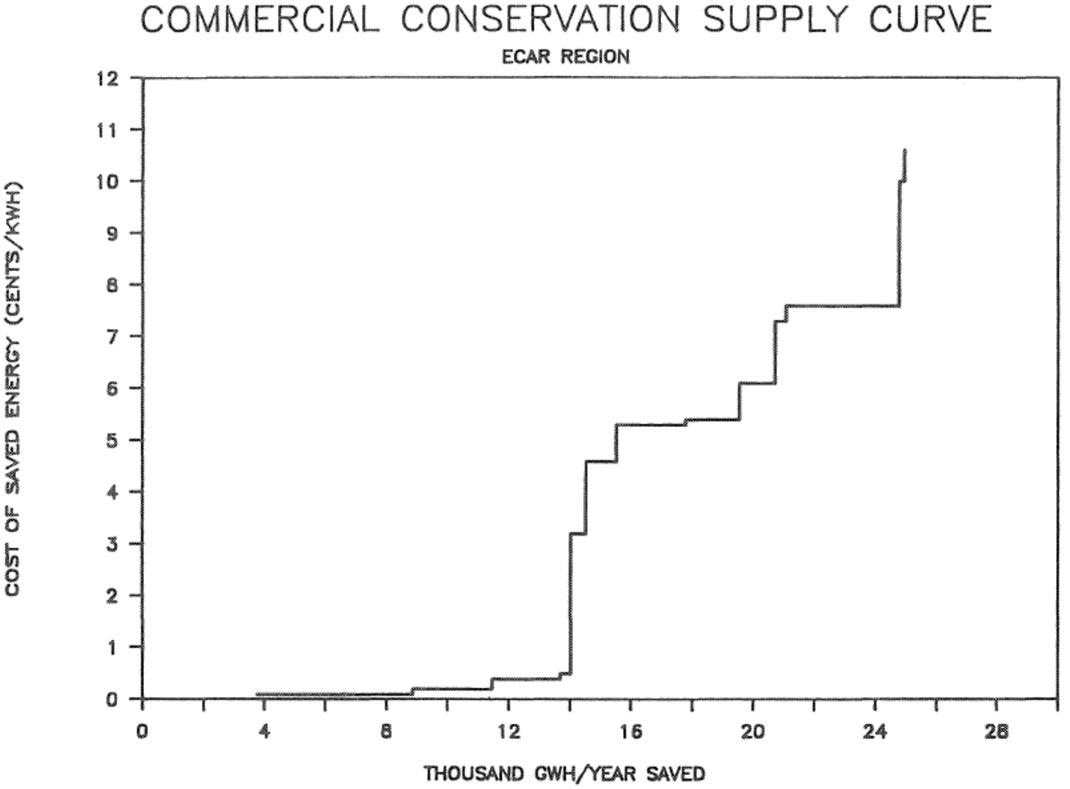
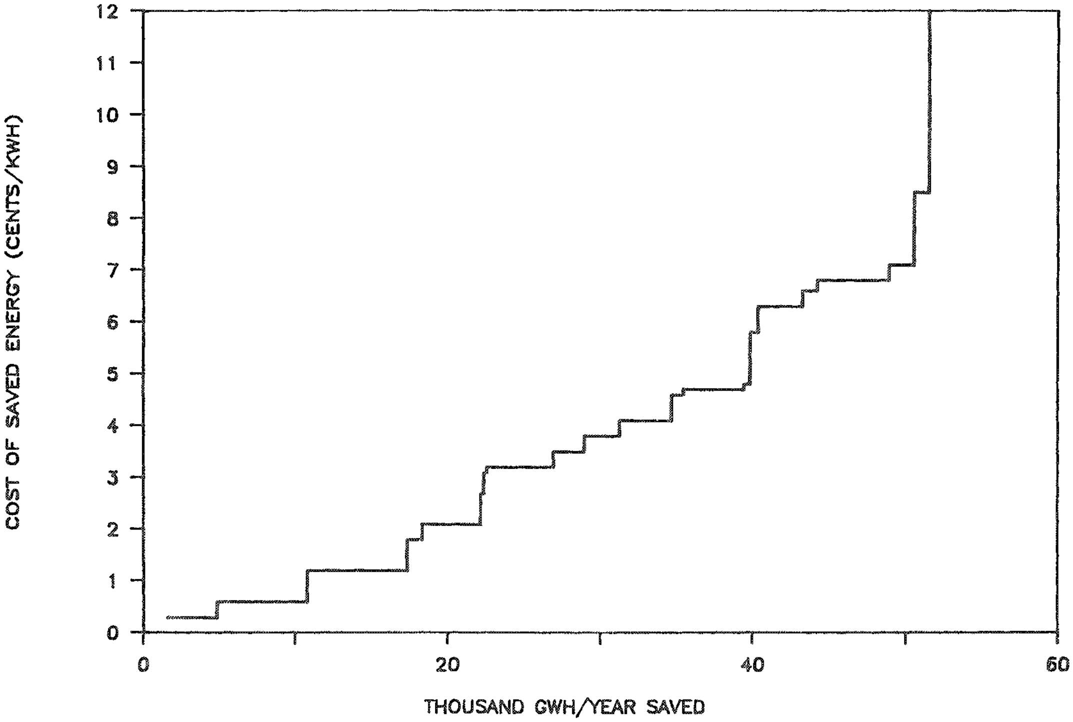


FIGURE 2.4



RESIDENTIAL CONSERVATION SUPPLY CURVE

ECAR REGION

Table 2.18

OVERALL COST-EFFECTIVE ELECTRICITY CONSERVATION POTENTIAL IN THE ECAR REGION (1)

Sector	1985 elect. use (GWH)	Cost-effective savings potential (GWh)	(%)
Industrial	159,910	22,490	14.1
Residential	108,370	48,880	45.1
Commercial	70,950	19,510	27.5
Other	13,770	--	--
Total	353,000	90,880	25.7

Notes:

1. Cost-effective conservation potential is determined from the perspective of the consumer. All conservation measures with a CSE below average electricity prices are included. The average electricity prices in 1985 are: industrial - 4.7 cents/kWh, residential - 7.1 cents/kWh, commercial - 6.7 cents/kWh.

potential for the region is approximately 90,900 GWh -- nearly 26% of regional electricity use in 1985.

As previously noted, these estimates of overall sectoral and regional conservation potential are conservative because they are not based on analyses of all end uses. For example, our estimate of conservation potential in the industrial sector only covers motors and lighting. Together, these two end uses account for 81% of industrial electricity demand according to our assessment. Additional savings which are likely to be available from other end uses (e.g., electrolytic processes) are not included because of uncertainties regarding electricity use and cost-effective savings potential. In sum, we have examined savings measures that are applicable to 80% of all electricity demand in the region.

Another reason our analysis is conservative is because it judges cost effectiveness on the basis of average electricity prices in ECAR in 1985. However, as will be shown in Chapter 4, electricity prices are expected to rise significantly by 1990 as expensive new power plants begin operating. Additional conservation measures will become cost effective for consumers as electricity prices rise.

It is also important to note that the estimates of total cost-effective conservation potential are not highly sensitive to small errors in estimating either the first cost or energy savings for particular measures. If, for example, the first cost for all conservation measures is increased by 20% or electricity savings are reduced by 20%, the total cost-effective conservation potential for the region in 1985 would equal 70,980 GWh. This is still 20% of total electricity consumption in the region in 1985, compared to about 26% total savings reached in our analysis.

VI. NOTES AND REFERENCES

1. Potential saturation refers to the technical potential and assumes no increase in appliance saturations; i.e., it refers to all homes with the particular appliance, heating system, etc.

2. "1985 Statistical Yearbook of the Electric Utility Industry", Edison Electric Institute, Washington, DC, 1986.

3. A. Meier, J. Wright, and A.H. Rosenfeld, Supplying Energy Through Greater Efficiency, University of California Press, 1983.

4. A 6% real discount rate is used by the California Energy Commission in their assessment of the cost-effectiveness of more efficient equipment from the perspective of consumers. See, for example, M. Martin, et al., "Staff Report on Proposed Revision of Appliance Efficiency Standards for Central Air Conditioning Heat Pumps", California Energy Commission, Sacramento, CA, April 1985.

5. H. Ruderman, M. Levine, and J. McMahon, "Energy-Efficiency Choice in the Purchase of Residential Appliances", in Energy Efficiency: Perspectives on Individual Behavior, American Council for an Energy-Efficient Economy, Washington, DC, 1986.

6. "Classification and Evaluation of Electric Motors and Pumps", DOE/CS-0147, U.S. Dept. of Energy, Washington, DC, Feb. 1985.

7. W.J. McDonald and H.N. Hickok, "Energy Losses in Electric Power Systems", IEEE Transactions on Industry Applications, Vol. IA-21, No. 4, May/June 1985, pp. 803-819.

8. R.J. Moe, et al., "The Electric Energy Savings from New Technologies", PNL-5665 Rev. 1, Pacific Northwest Laboratory, Richland, WA, Sept. 1986.

9. Estimate based on data provided in "Impact of Advanced Semiconductor Systems on Utilities and Industry", EPRI EM-2112, Electric Power Research Institute, Palo Alto, CA, Nov. 1981.

10. A. Lovins, "Least-cost Electrical Services as an Alternative to the Big A Dam", testimony before the Maine Land Use Regulation Commission, Rocky Mountain Institute Publication 85-4, Old Snowmass, CO, May 7, 1985.

11. "The GPU Project: Findings and Implications", Alliance to Save Energy, Washington, DC, 1987.

12. The industrial lighting assumptions involve considerable simplification, as there is a wide variety of wattages and fixtures for these lamp types as well as other lamp types including metal-halide lamps, high-pressure sodium lamps, etc. However, this degree of simplification was necessary to make the conservation analysis manageable.

13. Personal communication with Doug Norland, Alliance to Save Energy, Washington, DC, 1986.

14. "General Lighting Cost Analysis: Industrial and Commercial 1985/86", Lighting Division, General Electric Company, Cleveland, OH.

15. D.B. Goldstein and P. Miller, "Developing Cost Curves for Conserved Energy in New Refrigerators and Freezers", Proceedings of the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy, Washington, DC, Aug. 1986.

16. The sales-weighted average electricity use of new refrigerators in 1984 was 1141 kWh/yr. Personal communication with the Association of Home Appliance Manufacturers, Chicago, IL, 1986.

17. The most efficient refrigerator in the top-mounted freezer, automatic defrost, 16.5-18.4 cubic feet class as of mid-1986 was the Whirlpool ET17HK1M, rated at 744 kWh/yr. See "The Most Energy-Efficient Appliances", American Council for an Energy-Efficient Economy, Washington, DC, Fall 1986.

18. P.H. Pedersen, et al., "Reducing Electricity Consumption in American Type Combined Refrigerator/Freezer", paper presented at the 37th Annual International Appliance Technical Conference, Purdue University, May 1986. The prototype refrigerator built in Denmark is being field tested by the Southern California Edison Co. in 1987.

19. The sales-weighted average electricity use of new freezers in 1984 was 800 KWh/yr. Personal communication from the Association of Home Appliance Manufacturers, Chicago, IL, 1986.

20. The most efficient freezer in the manual defrost chest freezer, 17.5-21 cubic feet class as of mid-1986 was the Wood's OC50, rated at 512 KWh/yr. See "The Most Energy-Efficient Appliances", American Council for an Energy-Efficient Economy, Washington, DC, Fall 1986.

21. Energy factor is given by the ratio of the useful heat provided to the net energy consumed.

22. H.S. Geller, et.al., "Residential Conservation Power Plant Study", American Council for an Energy-Efficient Economy, Washington, DC, Feb. 1986.

23. Duro-Test Corporation, "Energy-Efficient Incandescent Lamp", LBL-14546, Lawrence Berkeley Laboratory, Berkeley, CA, April 1982. Also, personal communication with Mr. J. Wiers, Duro-Test Corp., North Bergen, NJ, July 1986.

24. 1984 Residential Survey, Consumers Power Company, Jackson, MI, May 1985.

25. 1985 Residential Appliance Survey, West Penn Power, Greensburg, PA.

26. Survey data summarized in "Power Planning in Kentucky: Assessing Issues and Choices", Energy Systems Research Group, Boston, MA, Jan. 1984.

27. *Energy Auditor and Retrofitter 3*, No. 3, May/June, 1986, pp. 6-12.

28. G.S. Dutt, et al., "The Modular Retrofit Experiment: Exploring the House Doctor Concept", in *What Works: Documenting Conservation in Buildings*, American Council for an Energy-Efficient Economy, Washington, DC, 1984.

29. S. Carhart, et al., *The Least-Cost Energy Strategy: Technical Appendix*, The Energy Productivity Center, Mellon Institute, Arlington, VA, 1979.

30. F. Krause, et al., "Analysis of Michigan's Demand-Side Electricity Resources in the Residential Sector", LBL-23025, Lawrence Berkeley Laboratory, Berkeley, CA, 1987.

31. Personal communication with Mr. D. Lewis, Nyle Corporation, Bangor, ME, Feb. 1987.

32. D.C. Lewis, "Final Technical Report - Closed Cycle Clothes Dryer", DOE/CE/15100-T1, U.S. Dept. of Energy, Washington, DC, June 1983.

33. The seasonal energy efficiency ratio (SEER) of central air conditioners and heat pumps is calculated by dividing the cooling rate (in terms of Btus/hr) by the electrical power consumed (in terms of watts).

34. The most efficient central air conditioner produced in 1986 is a Lennox Power Saver unit with a capacity of 40,000 Btu/hr and an SEER of 15.0. See "The Most Energy-Efficient Appliances", American Council for an Energy-Efficient Economy, Washington, DC, Fall 1986.

35. V. Peart, et al., "Energy Saving Domestic Oven", DOE/CONF-780238, Proceedings of the Conference on Major Home Appliance Technology for Energy Conservation, U.S. Dept. of Energy, Washington, DC, Feb. 1978.

36. Personal communication with Ed Vineyard, Oak Ridge National Laboratory, Oak Ridge, TN, Sept. 1985.

37. "Overview of the DOE-2 Building Energy Analysis Program", LBL-19735, Building Energy Simulation Group, Lawrence Berkeley Laboratory, Berkeley, CA, June 1985.

38. "Recommendations for Energy Conservation Standards and Guidelines for New Commercial Buildings", DOE/NBB-0051, U.S. Dept. of Energy, Washington, DC, Oct. 1983.

39. B. Hunn, et al., "Technical Potential for Electrical Energy Conservation and Peak Demand Reduction in Texas Buildings", Center for Energy Studies, University of Texas, Austin, TX, Feb. 1986.

40. A. Usibelli, et al., "Commercial Sector Conservation Technologies", LBL-18543, report prepared for Pacific Gas and Electric Company and Southern California Edison Company by the Buildings Energy Data Group, Lawrence Berkeley Laboratory, Berkeley, CA, Oct. 1984.

41. B.L. Gardiner, et al., "Measured Results of Energy Conservation Retrofits in Non-residential Buildings", Proceedings of the ACEEE 1984 Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy, Washington, DC, Aug. 1984.

CHAPTER 3

OVERVIEW OF THE INTEGRATED ELECTRIC UTILITY PLANNING MODEL AND ELECTRICITY DEMAND SCENARIOS FOR THE ECAR REGION

The Integrated Electric Utility Planning Model (IEUPM) is used to assess electricity prices, energy service costs, and SO2 emissions in the ECAR region through 2005. Different scenarios for load growth and emissions control are considered. This chapter presents a brief overview of the analytical model along with two contrasting electricity demand scenarios and their implications. The IEUPM is described in greater detail in Appendix B.

I. OVERVIEW OF THE MODEL

Figure 3.1 illustrates the overall structure of the IEUPM. The model, described in detail in Appendix B, simulates the key activities undertaken by consumers and utilities. The demand portion of the model simulates the electricity conservation investments made by consumers on a sector and end-use specific basis. The supply portion of the model simulates the routine operations, capacity additions and retirements, finance, regulation, and SO2 emissions for all utilities in the region.

The demand sub-model is based on the concept that consumers want the services provided by electricity and not electricity itself. The model tries to meet consumers' needs in a cost-effective manner given assumptions of how they will behave when making capital investments in energy efficiency. It is not assumed that conservation measures are fully adopted solely because they were determined to be cost effective for consumers on a life-cycle cost basis in Chapter 2.

The demand sub-model determines which conservation measures will be adopted by comparing the extra cost of installing the conservation device with the discounted savings from reduced electricity purchases over the life of the device. So-called "implicit discount rates" are used to discount future savings.

Utility incentive programs which offer to pay some or all of the cost of conservation measures can stimulate adoption by lowering the effective price to consumers and gaining the attention of dealers and purchasers. The IEUPM has the capability to include utility rebate incentives at some percentage of the cost for conservation measures or minimum efficiency requirements. The demand sub-model also contains implementation-period assumptions for conservation measures deemed cost effective in each end-use category.

In this study, the IEUPM is calibrated to the demand and generating mix of the ECAR region. The model treats ECAR as if it were

FIGURE 3.1

INTEGRATED ELECTRIC UTILITY PLANNING MODEL STRUCTURE

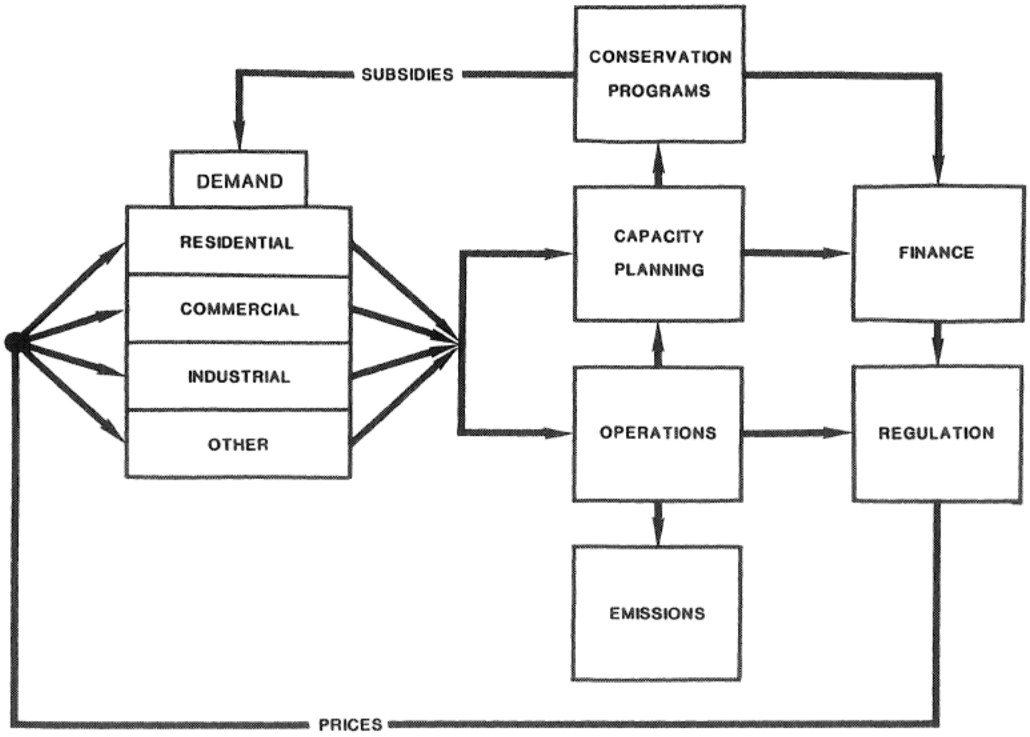
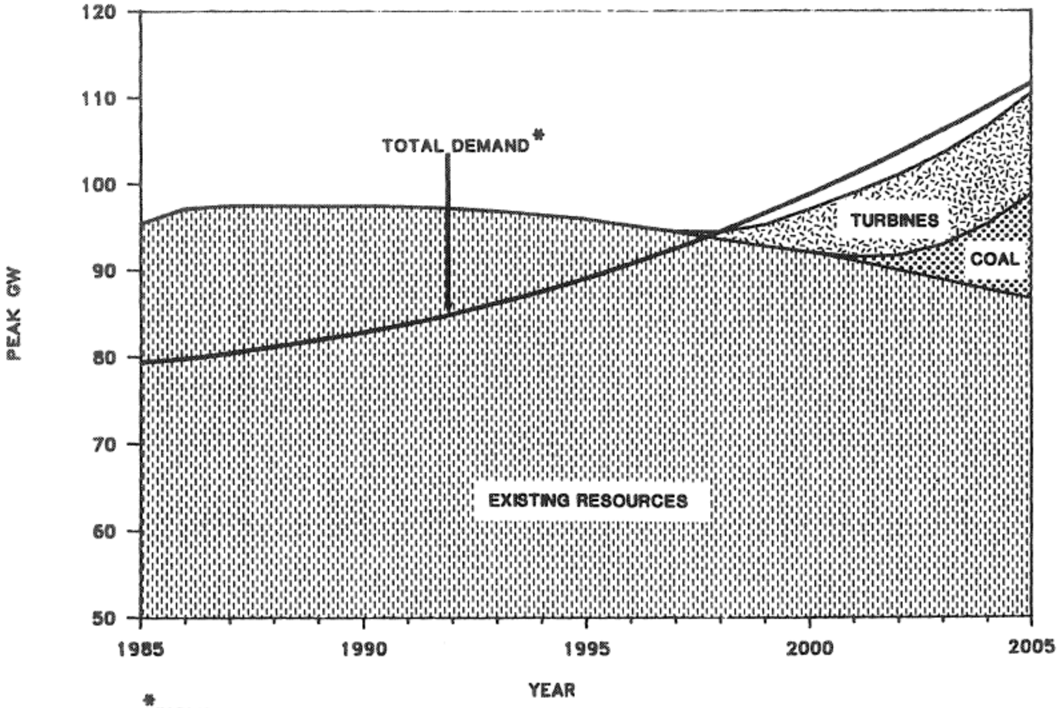


FIGURE 3.2

LOAD–RESOURCE BALANCE

BASE CASE W/O EMISSION CONTROL



*INCLUDES 20% RESERVE MARGIN

a single utility, dispatching generating capacity to meet regional electricity demand year-by-year. The power plants in the region are aggregated into groups exhibiting similar characteristics for dispatching and accounting purposes.

Regarding capacity planning, the IEUPM initiates construction of new power plants when they are judged to be necessary. As part of this analysis, it is assumed that the life of most existing coal-fired plants is extended due to the high cost of new generating capacity. This limits but does not entirely eliminate new plant construction over the period of analysis (1985-2005).

Regarding emissions control options, both retrofit flue gas scrubbers and switching to low-sulfur coal are possible. The user inputs the extent to which emissions control measures are adopted over time in any particular simulation run. Scenarios involving both no mandated emissions reductions and substantial required reductions are presented in Chapter 4.

As indicated in Fig. 3.1, the IEUPM determines electricity prices each year based on current electricity demand, routine utility operations, new capacity planning, emissions control activities, conservation programs, and financial factors. Electricity prices in turn influence future conservation investments and electricity demand, creating a feedback loop between the demand and supply sections of the model.

II. BASE CASE ELECTRICITY DEMAND SCENARIO

The base case scenario does not include utility conservation programs beyond those currently underway. The major assumptions concerning demographics, economic growth, capital and fuel costs, power plant performance, and other factors for both load growth scenarios are contained in Appendix B.

Figure 3.2 shows the projected load-resource balance for the region under the base case. Electricity demand and supply are presented in terms of peak gigawatts (GW). The peak demand values can be converted to annual electricity use by dividing by 1.506 (the peak-to-average demand ratio) and multiplying by 8760 hours per year.

The total demand in Figure 3.2 includes a 20% reserve margin as is considered desirable for coal-based utilities in the Midwest [1]. The base case forecast has power demand in the region growing at about 1.7% per year on the average during 1985-2005. Meanwhile, economic output is growing at an average rate of approximately 2.0% per year (see Appendix B). The difference between growth in electricity demand and growth in economic output is due to conservation induced by market forces.

The North American Electric Reliability Council (NERC) forecasts that summer peak demand in the ECAR region will grow at 1.9% per year on the average between 1985 and 1994 [2]. This is reasonably close to our base case growth rate. Our base case scenario is intended to serve as a reasonable reference from which to analyze the implications of alternative load growth and SO2 control strategies. It should not be interpreted as the most likely or most desirable future.

The area labeled "existing resources" in Fig. 3.2 includes all existing power plants, plants under construction as of 1985, and a modest amount of new cogeneration. We assume in both load growth scenarios that 3 GW of cogeneration capacity is added in the region by 2005 [3]. In the base case, the surplus of existing resources ends in 1998, indicating the year in which other new capacity is needed unless further electricity conservation occurs. The turbine and coal areas indicate the new capacity initiated by the model to meet the shortfall after 1998.

When new capacity is needed, the model first calls for turbine peaking units. These are the lowest capital cost resources, and are considered to be underrepresented in the current generating mix. Once a desirable level of peaking capacity has been reached (15% of total resources in this analysis), the model calls for new base and intermediate load coal-fired units. The model adds about 11 GW of new turbine capacity and about 12 GW of new coal-fired power plants by 2005 in the base case.

III. ACCELERATED ELECTRICITY CONSERVATION SCENARIO

The accelerated conservation scenario involves the more rapid and intensified adoption of cost-effective conservation measures. In terms of the integrated planning model, this accelerated adoption is achieved by: 1) lowering the implicit discount rates that consumers use when trading off the higher first cost of a conservation device versus the savings from lower energy use over the life of the unit; 2) assuming that utilities will subsidize consumers' investments in efficiency measures through rebate payments; and 3) shortening the time required for cost-effective conservation measures to penetrate a large fraction of the eligible market. As discussed in more detail later, these changes lead to an average growth in electricity demand of 0.1% per year between 1985 and 1995, and 0.9% per year over the 1985 to 2005 forecast period.

The principal demand-side input assumptions that change between the base and accelerated conservation cases are listed in Table 3.1. The lower implicit discount rates in the conservation case imply that consumers become more aware and take greater advantage of economical conservation options. Lowering the rates in the accelerated conservation case is consistent with strong utility promotion of efficiency measures. The lower rates are still above the cost of

Table 3.1

COMPARISON OF ASSUMPTIONS BETWEEN THE BASE AND ACCELERATED CONSERVATION CASES

INPUT	BASE CASE	ACCELERATED CONSERVATION CASE
Implicit discount rates: (Real values)		
Residential space heat	35%	15%
Residential water heat	50%	20%
Residential appliances	75%	20%
Commercial	35%	15%
Industrial	25%	10%
Fraction of conservation measure cost paid by the utility:		
Residential space heat	0%	90%
Residential water heat	0%	90%
Residential appliances	0%	90%
Commercial	0%	90%
Industrial	0%	90%
Conservation measure implementation period: (Years)		
Residential space heat	20	7
Residential water heat	13	9
Residential appliances	20	11
Commercial	20	7
Industrial	20	7

capital and the opportunity costs in each end-use sector.

In order to run the simulation model, a detailed "conservation program" has to be specified. Designing a sound electricity conservation program requires balancing several factors to achieve competing goals. An energy conservation program must encourage significant improvements in energy efficiency. The program must do this on a timely basis, with reasonable certainty of success, yet be cost effective and accessible to most consumers in the region.

The first step in designing a program is to choose which measures will be eligible for rebate incentives. This is done by specifying the maximum cost of saved energy that utilities will pay subsidies for. This level is set at the average price of electricity in 1985. For the ECAR region, the average price is about 6 cents per kWh in 1985 dollars. This also turns out to be the average price of electricity during the late 1990s in the base case. Conservation measures described in Chapter 2 with a cost of saved energy at or below this value can cut electricity use in the region by approximately 26%.

The second step is to choose the timing of the program. The region is projected to require new generating capacity around 1994 in the base case, so a conservation program must begin well before 1994 or it will not yield enough savings in time to avoid new generating capacity. We chose 1990 as a start date for the full scale utility conservation subsidies. This provides enough lead time for developing capability and operating pilot programs during the late 1980s, while maximizing conservation implementation during the period when it is most needed (the 1990s).

The next feature of the program is the subsidy level paid by the utilities. The larger the fraction paid by the utility, the more certain the savings, and the more rapidly they will occur. The disadvantage of large subsidies, however, is that they increase the overhead costs from program implementation and transfer a larger portion of the cost for efficient equipment from the consumer to all ratepayers. For this analysis, we assume that utilities pay 90% of the initial cost for all conservation measures.

The 90% rebate payment assumed in the accelerated conservation scenario is higher than the incentive level used in most utility rebate programs. But some utilities are paying for all or nearly all the cost of certain conservation measures (see Chapter 6), so a 90% rebate level is not unreasonable. Furthermore, the intention here is to maximize investment in cost-effective conservation measures. The subsidy is paid to all consumers investing in conservation whether or not they would otherwise make the investment. Thus, there is a broad transfer of economic burden from the individual beneficiaries (including "free riders" who would invest in conservation without the subsidy) to society as a whole, just as there is when power plants are constructed.

The subsidy level also can affect the supply of conservation equipment from manufacturers and dealers, and consumers' attitudes concerning energy efficiency. Large rebate incentives along with an information campaign and contacts with equipment vendors can increase the availability of energy-efficient equipment and reduce consumers' aversion to making capital investments [5]. We assume that the incentive program will result in discount rates falling from historical levels of 35% or more down to 15-25%.

The primary objective of this portion of the study is to produce a credible low demand growth scenario for comparison to the base case scenario when emission reductions are considered. The conservation program consists of a plausible and consistent set of assumptions that lead to such an outcome. Of course, there are other policy options, e.g., high reliance on minimum efficiency regulations, that could lead to a similar outcome with respect to demand growth (see Chapter 6). Our program and assumptions are not presented as the optimal means for stimulating much greater end-use efficiencies, rather they are a reasonable example of how this might be achieved.

Figure 3.3 compares the forecasts for electricity demand in the base and accelerated conservation scenarios. In both cases, the demand for electric services, e.g., light, space conditioning, and motive power, grows by 2%/yr. As mentioned in the previous section, electricity demand grows at an average rate of 1.7%/yr during 1985-2005 in the base case scenario. This leads to a 6% reduction in electricity demand in 2005 compared to what would occur without any investment in more efficient equipment.

The accelerated conservation program achieves substantially more savings than the base case. Electricity demand grows at an average rate of only 0.9%/yr during 1985-2005. By 2005, total electricity demand in the ECAR region is 15% lower than in the base case. The reduction in electricity demand in 2005 compared to what would occur without any investment in more efficient equipment is 19.5%. This is about 75% of the total cost-effective savings potential identified in Chapter 2. It should be made clear that there is no double-counting of savings in the accelerated conservation scenario, i.e., conservation investments included in the base case are not included a second time in the accelerated conservation scenario. Each simulation is independent from the other and generates its own absolute level of electricity demand.

The accelerated conservation program is able to hold electricity demand close to the 1985 level until 1995, with average growth in demand of only 0.1%/yr during 1985-95. After 1995, economic growth and other factors increase demand, but more slowly than without the conservation program. The conservation measures and program actually saturate the equipment stock to a large extent by 2000, resulting in renewed growth in electricity demand after 2000 in the

FIGURE 3.3

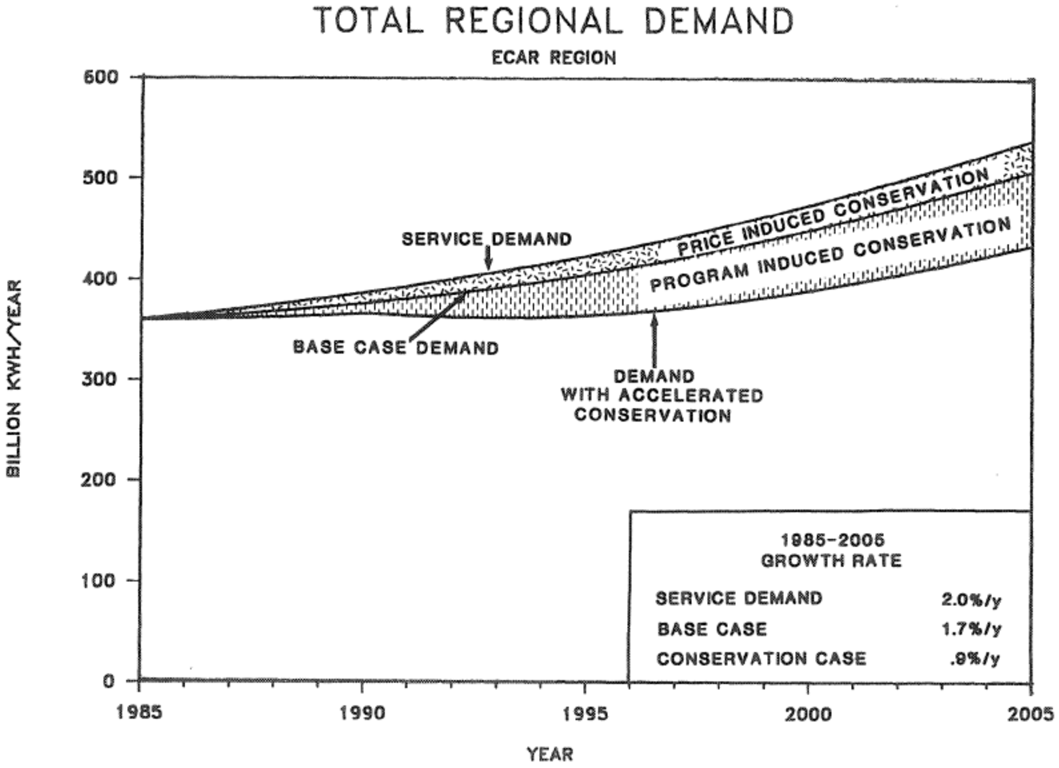
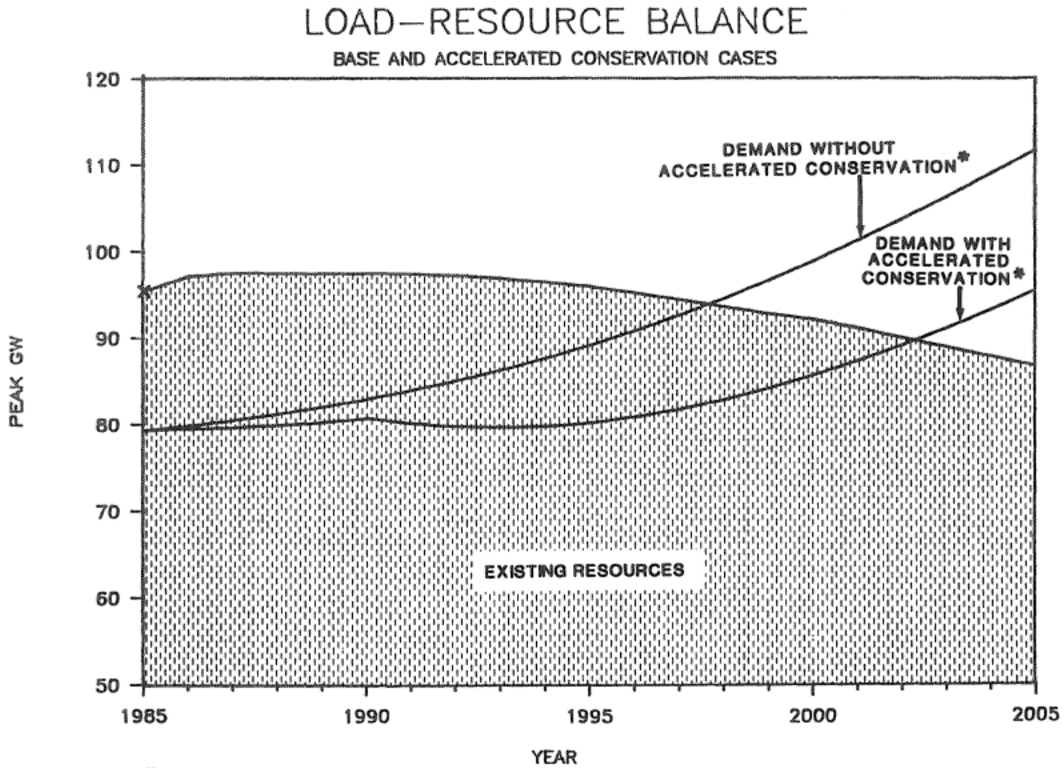


FIGURE 3.4



*INCLUDES 20% RESERVE MARGIN

accelerated conservation case. It is highly likely, however, that new technologies will be available for further cost-effective electricity savings by then. If so, it may be possible to avoid any significant upturn in electricity demand in the ECAR region during the next 20 years.

The magnitude of savings in the accelerated conservation case has a significant impact on the resource balance for the region and the timing of new capacity needs. Figure 3.4 compares the requirements for generating capacity in the two cases. Once again, "existing resources" refers to capacity both installed and under construction in 1985. With accelerated conservation, the first year in which the region needs to add generating capacity is pushed back from about 1998 to about 2002.

Under the accelerated conservation scenario, the model adds only 5.2 GW of new gas turbine capacity prior to 2005 and no new coal-fired capacity. Thus, the total amount of new capacity is reduced from 23 GW to just 5 GW. Of course, some of the reduction in load growth could be used to accelerate the retirement of existing power plants burning high-sulfur coal, in which case the need for new generating capacity in the region would increase.

IV. COMPARISON OF COSTS FOR THE TWO SCENARIOS

Table 3.2 summarizes the costs and savings in the conservation case on a sector-specific level. Residential appliances provide the largest share of the savings in the region, while the least expensive savings are available in the commercial sector. In total, over 70 billion kWh of net savings are induced by the conservation program by 2005 at an average cost of about 2.7 cents per kWh. These results are based on the conservation technologies and characteristics described in Chapter 2 and the incentive program designed to increase conservation adoption.

Table 3.3 shows the actual costs paid by the region's consumers and utilities for efficiency improvements under the accelerated conservation scenario. The region's utilities would spend a total of $1.5 billion per year during 1985-2005 on efficiency investments. During the course of the program, utilities would typically spend about $100 per year on an electrically-heated household and about $26 for a nonelectrically-heated household. This is about three times the level of conservation investment by utilities who are conducting relatively ambitious conservation incentive programs today [6].

Although the conservation investments are highly cost effective, utility-sponsored conservation programs in a time of surplus are likely to raise electricity rates temporarily. When demand goes down, unchanged fixed costs must be spread over fewer sales, thus rates go up. This is usually unavoidable, even when conservation costs less than the average cost for existing plants.

Table 3.2

ELECTRICITY SAVINGS AND COST EFFECTIVENESS OF THE ACCELERATED CONSERVATION SCENARIO

Sector	Net savings in 2005 (Billion kWh)	Average cost of saved energy (1) (Cents/kWh)
Residential		
Space heat	5.3	3.9
Water heat	5.6	3.1
Appliances	31.4	2.7
Commercial	11.2	0.8
Industrial	19.9	3.4
TOTAL	73.4	2.7

Notes:

(1) Computed based on a 20 year conservation measure life and a 6% discount rate.

Table 3.3

COST FOR CONSERVATION INVESTMENTS BY CUSTOMER CLASS (1)

Customer class	Average annual cost		1985-2005 total cost	
	consumer	utility	consumer	utility
Residential cost per house				
Space heat	$7	$62	$133	$933
Water heat	$2	$16	$29	$243
Appliances	$3	$26	$57	$384
Commercial cost per building (3)				
Commercial	$52	$700	$1,047	$10,477
Total cost for industrial customers (million 1985 $)				
Industrial	$80	$525	$1,590	$7,880
Total cost in all sectors (million 1985 $)				
All Sectors	$186	$1,538	$3,720	$23,080

Notes:

1. All costs are in 1985 dollars.

2. Assuming an average commercial building of 30,000 square feet.

If conservation costs considerably less than the operating cost of existing plants, the savings could offset the fixed cost rate increase, but savings at this level are well below the economically optimum level for the region as a whole. The rate penalty is exacerbated when utilities take responsibility for paying a large fraction of the cost for more efficient equipment.

Figure 3.5 shows the projected average electricity prices for all customer classes in the two load growth scenarios. In both cases, the high cost for coal and nuclear plants added in the late 1980s causes large real price increases between 1985 and 1989. The average electricity price increases from about six cents/kWh in 1985 to just under eight cents/kWh in 1989. These increases are due largely to the Perry 1 and Beaver Valley 2 nuclear stations, and the Zimmer nuclear-to-coal plant conversion. After 1990, the real value of fixed assets declines as existing plants depreciate. Electricity rates decline in real terms until new capacity added after 1995 increases them once again.

The mid-term electricity price penalty in the accelerated conservation case is apparent in Fig. 3.5. The price penalty reaches a peak around 1997 at about 0.5 cents per kWh. However, the average electricity price still falls throughout the 1990s in the accelerated conservation scenario. As the conservation savings displace new capacity which otherwise would be needed, the price penalty diminishes, and by 2000 it has been completely eliminated. After 2000, the accelerated conservation scenario leads to lower electricity prices for all consumers.

More important than electricity prices are the overall energy service costs for consumers. The energy service cost is the combination of electricity expenditures and conservation costs paid by consumers. Electricity price penalties do not necessarily mean higher overall energy service costs. Conservation-induced price increases only produce higher electricity bills for consumers who do not reduce their electricity use. For most consumers, the reduction in demand from conservation more than offsets the mid-term electricity price penalties.

Figure 3.6 shows the overall energy service costs in ECAR for the two scenarios. Even during 1992-2000, when electricity price penalties are greatest, the annual cost of energy services in the region are lower with the accelerated conservation program. In the later years, as new baseload capacity is avoided, the conservation program yields substantially lower annual costs to the region. The cost savings are about $9.0 billion per year by 2005 (1985 dollars). It is important to remember that the level of energy services (light, motive power, refrigeration, etc.) is identical in the two cases.

Table 3.4 summarizes the regional cost impacts from the two load growth scenarios. Estimated costs in 2005 are presented along with

Table 3.4

OVERALL ECONOMIC IMPACTS IN THE TWO LOAD GROWTH SCENARIOS

Indicator	Base case	Accelerated conservation case	Net savings with conservation
Average electricity price in 2005 (1985 mills/kWh)	68.0	58.6	9.4 (14%)
Annual energy service cost in 2005 (billion 1985 $)	34.6	25.6	9.0 (26%)
Total energy service cost during 1985-2005 (billion 1985 $)	552	512	40 (7%)
Present value of energy service cost 1985-2005 (billion 1985 $)	476	432	44 (9%)

FIGURE 3.5

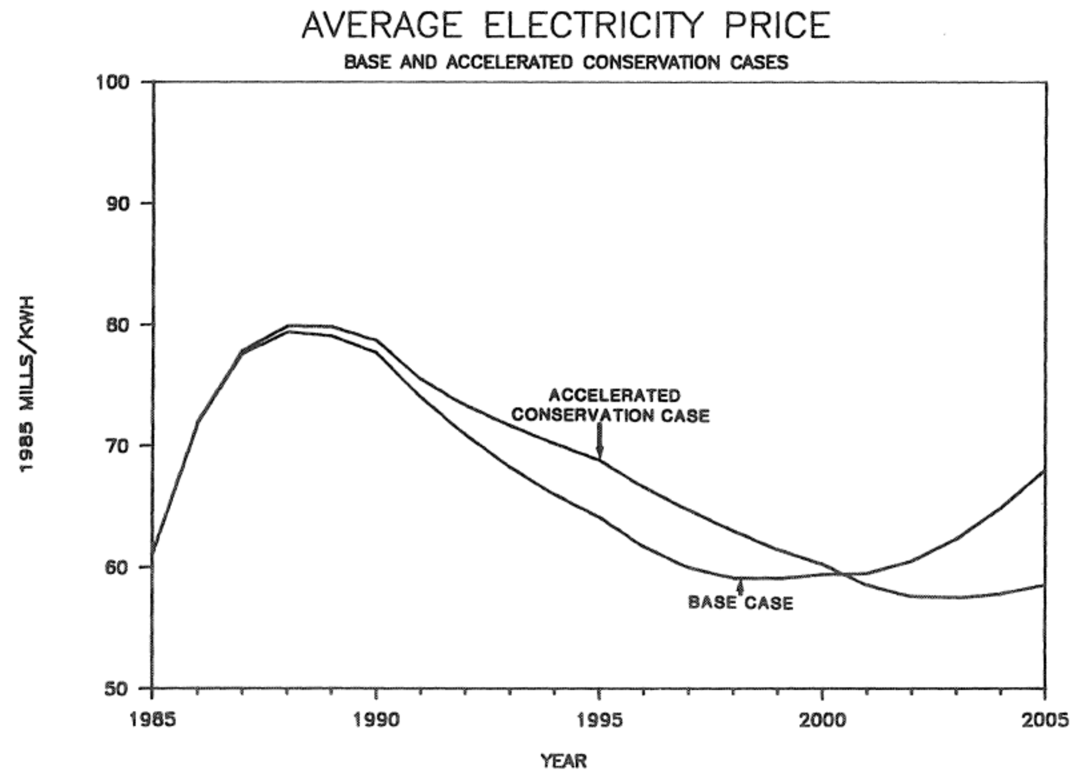
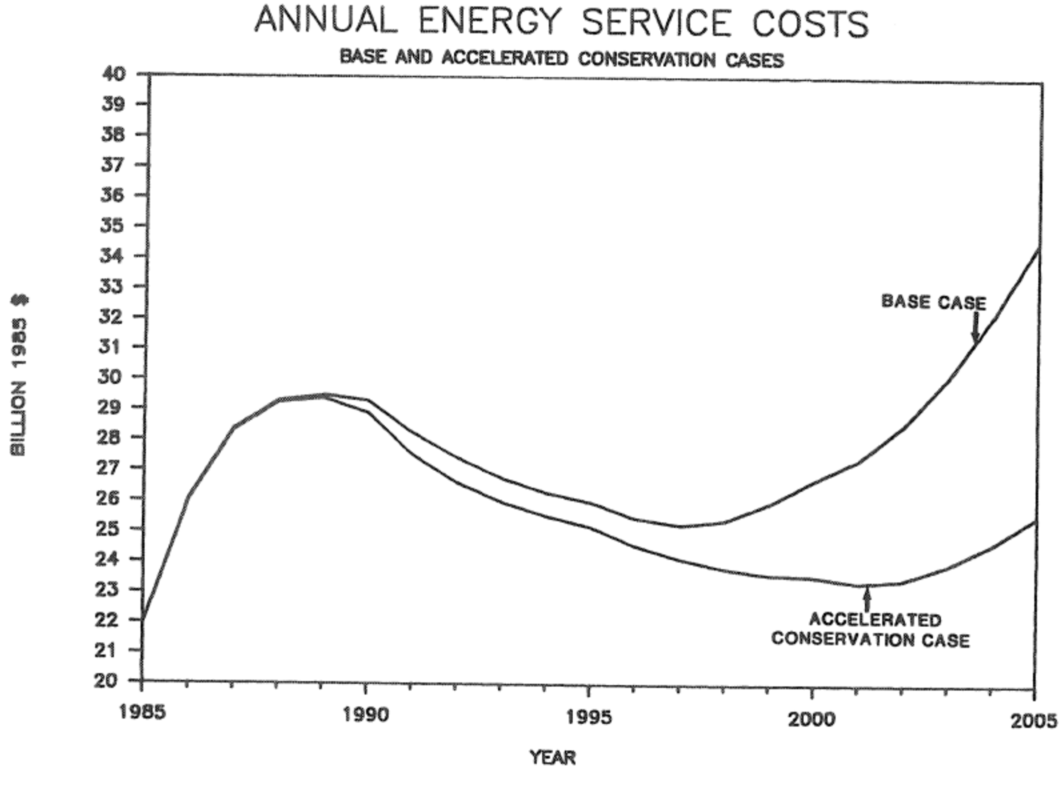


FIGURE 3.6



cumulative costs during 1985-2005. The latter is presented in terms of simple total and net present value with future expenditures discounted at 6% per year above inflation. All costs and prices are in 1985 dollars.

During 1985-2005, accelerated conservation lowers the energy service cost in the region by 9% on a present value basis and by 26% annually in the end year. The electricity rate benefit is significant in the long-term, and the mid-term penalty will not create hardship if the conservation program is designed to benefit consumers on a broad scale.

In summary, accelerated electricity conservation offers significant potential benefits to the region, with minimal negative impacts. Naturally, the investments must be made in technologies that offer the most cost-effective savings and the investments must be done in a timely manner. Accelerated conservation can benefit the region regardless of whether SO2 emissions are further controlled. The next chapter examines the implications of pursuing aggressive electricity conservation along with emissions control.

V. NOTES AND REFERENCES

1. A 20% reserve margin is used by the Ohio Public Utility Commission, for example. Personal communication with the Ohio Consumers Council, Columbus, OH, 1986.

2. Electric Power Supply and Demand 1984-1993, North American Electric Reliability Council, Princeton, NJ, 1984, p. 8.

3. Cogeneration forecast developed by Applied Energy Services, Inc, Arlington, VA, 1986.

4. "A Compendium of Utility-Sponsored Energy Efficiency Rebate Programs", American Council for an Energy-Efficient Economy and Consumer Energy Council of America, Washington, DC, 1987.

5. R. Gunn, et al., " NSP's Appliance Rebate Program: Overall Impacts and Market Acceptance Results", in C.B. Smith, T. Davis, and P.W. Turnbull, eds., *Meeting Energy Challenges*, Vol. II, Pergamon Press, New York, NY, 1985.

6. "A Compendium of Utility-Sponsored Energy Efficiency Rebate Programs", American Council for an Energy-Efficient Economy and Consumer Energy Council of America, Washington, DC, 1987.

CHAPTER 4

EMISSIONS REDUCTIONS WITH AND WITHOUT ACCELERATED ELECTRICITY CONSERVATION

I. OVERVIEW

In this chapter, a variety of SO2 emissions reductions strategies are considered with each of the load growth scenarios in the ECAR region. The strategies rely on retrofitting flue gas scrubbers or switching to low-sulfur coal to achieve most of the emissions reductions that we assume are required. Here we examine SO2 emissions and average emissions rates along with average electricity prices and energy service costs in the region.

The results presented below show that an accelerated electricity conservation effort can have very positive impacts on emissions control. Compared to the base case scenario, emissions drop by about 10% during the 1990s due to accelerated conservation alone. Avoiding new power plant construction provides more than enough economic savings to completely offset the cost of even a relatively expensive emissions control program. Reduced electricity demand also cuts the direct cost for emissions controls by 26-44%, if legislation is flexible and it allows states and utilities to take credit for emissions reductions caused by reduced power plant use.

II. EMISSIONS REDUCTION TARGETS

Congress is considering a number of legislative proposals for reducing SO2 emissions. In general, the proposals require an 8-14 million ton reduction in nationwide SO2 emissions by utilities. For comparison, utility emissions were about 17 million tons in 1980 and are expected to grow to nearly 20 million tons by 2000 if no acid rain legislation is enacted [1]. Both the magnitude of reductions and flexibility in meeting reduction requirements vary among proposals.

The bill introduced by Sen. Stafford (S. 300) in the 100th Congress requires each plant not already covered by the New Source Performance Standard to meet certain emissions rate limits in order to remain in operation beyond a certain number of hours. The bill is expected to eventually produce a 13-14 million ton reduction in SO2 emissions relative to projected emissions in 2000 without acid rain legislation. This approach does not allow any emissions trading within utilities, states, or regions.

The bill introduced in the House by Reps. Waxman and Sikorski (H.R. 4567) in the 99th Congress is more moderate. It requires that the annual statewide emissions from all fossil-fueled utility plants be limited to 2.0 pounds per million Btu (Lbs/MMBtu) by 1993 and

1.2 Lbs/MMBtu by 1997. This approach allows considerably more flexibility in meeting the emissions target. It would only result, however, in about an eight million ton reduction in SO2 emissions.

A third proposal introduced by Senator Proxmire (S. 316 in the 100th Congress) also includes statewide average emissions rate limits. This approach requires all existing, pre-NSPS fossil-fueled facilities to meet a 2.0 Lbs/MMBtu rate limit by 1993 and a 1.2 Lbs/MMBtu limit by 1998. The bill allows interstate and intrastate trading and is expected to achieve a 9-10 million ton reduction in emissions relative to projected emissions in 2000. Also, if the governor of a state certifies that energy conservation is part of the control program, the state can elect to meet a ceiling on total SO2 emissions. This latter approach provides full credit for emissions reductions caused by reduced load growth. (See Chapter 5 for further discussion of how conservation is treated in the different legislative proposals.)

In this analysis, we examine a scenario that would require states to reduce their SO2 emissions to an average of 2.0 Lbs/MMBtu of fuel input by 1995, and then to 1.2 Lbs/MMBtu by 2000, or meet a total emissions ceiling which would yield an equivalent reduction under base case load growth. The limits apply to units not considered new sources under the NSPS regulations. Thus new, cleaner plants cannot be included when computing the SO2 emission rates. The requirements would generate a 5 million ton reduction nationwide in the first phase and about a 10 million ton reduction in the second phase.

In 1980, utilities in the ECAR region produced about 5.7 million tons of SO2 emissions, about 33% of nationwide SO2 emissions by utilities [2]. If all existing, pre-NSPS facilities have an average emission rate of 2.0 lbs/MMBtu at the end of the first stage and 1.2 lbs/MMBtu at the end of the second stage, the maximum allowable emissions would be 3.7 million tons per year in phase one and 2.6 million tons per year in phase two, assuming base case load growth. These values are used as the equivalent emissions ceilings when evaluating control strategies based on total emissions limits.

We consider emissions control programs which rely either exclusively on flue gas scrubbers, or a combination of scrubbers and switching to low-sulfur coal. Scrubbers directly remove the SO2 emissions from the exhaust gases from the boiler. They can achieve very high (over 90%) SO2 removal. Other emission reduction options including limestone injection multistage burners (LIMB) and a range of "clean coal" technologies hold the potential to significantly reduce the cost of emissions control, but are still in the development stage.

There is still some uncertainty regarding what retrofit scrubbers or fuel switching on a large scale will cost. For fuel switching, we assume a cost premium for low-sulfur coal of approximately $10 per ton (a 25% penalty on the base fuel price of about $40 per ton). Our value is close to the base case low-sulfur coal premium in a recent study of emissions control costs for the American Electric Power system (the largest utility in ECAR) [3].

For retrofit scrubbers, the EPA estimates average capital costs of $200-$250/kW [4]. EPRI estimates scrubber capital costs of $145-200/kW, but this cost range refers to new power plants [5]. Assuming scrubber retrofits cost 30% more than new plant applications, the EPRI retrofit cost is in the range of $188-256/kW. In this study, we assume an intermediate value of $220/kW for a typical retrofit scrubber application. Other assumptions regarding the emissions control options are included in Appendix B.

III. EMISSIONS CONTROL STRATEGIES

We test four compliance strategies under emission rate limits and emissions ceilings. The first strategy is a simple across-the-board retrofit scrubber program, with enough scrubbers installed to provide the expected emissions reductions. This case assumes that limited interstate and intrastate emissions trading would occur. Consequently, scrubbers are not retrofitted in the most cost-effective manner in the region. In the across-the-board case we assume an average retrofit scrubber cost of $220 per KW.

The second strategy assumes full interstate and intrastate trading but with all reductions still met by scrubbers. The increased flexibility allows the region to retrofit emissions control in a least-cost first order based on cost per ton of SO2 removed. This lowers the average cost of the emissions control to $184/KW in phase one and $191/KW in phase two under the rate limits and $184/KW for both phases with the emissions ceilings.

The third strategy is called "environmental dispatch." This case assumes that the generating capacity would be dispatched based on lowest SO2 emissions rather than lowest cost. This results in lower emissions, but increased operating and maintenance costs. We test a moderate environmental dispatch case, assuming that coal-fired capacity is run on a least-emissions first basis, but that oil- and gas-fired capacity is still run only for intermediate and peak duty. Strict environmental dispatch would base-load these peaking plants because of their low emissions, which would increase costs and possibly reduce system reliability. We assume that any scrubber retrofits which occur in conjunction with environmental dispatch are of average cost ($220/kW).

The final strategy combines fuel switching with scrubber retrofits in least-cost first order. This case is intended to test the implications of a least-cost combination of fuel switching and scrubbing. The model cannot explicitly determine the least-cost mix, but can test the impacts of any desired combination. We have chosen a mix of approximately 75-85% fuel switching and 15-25% scrubbing, depending on the simulation run. This is within the range of 60-90% fuel switching suggested as the lowest cost combination in recent studies conducted for the EPA [6].

Table 4.1 presents the major results for all of the emissions control strategies with each load growth scenario. The values displayed in Table 4.1 show the results in both 1995 and 2000. The 1995 demand growth rate represents the 1985-1995 average, and the 2000 rate represents the 1985 to 2000 average. The average SO2 emissions rates listed in Table 4.1 are the average rates for existing (pre-NSPS) fossil-fired plants. The data displayed in Table 4.1 are discussed and highlighted in the sections below.

The annual energy service cost represents the yearly expenditures by consumers on electricity plus conservation investments paid by consumers. The total energy service cost is simply the sum of these annual costs starting in 1985. For instance, the 1995 total energy service cost is the sum of costs during 1985-1995. The present value of energy service costs are similar to the total cost, but future expenditures have been discounted at 6% per year above inflation. All costs and prices are in 1985 dollars. The annual cost per ton removed is calculated by taking the difference between the annual energy service cost with and without emissions control and dividing it by the emissions reduction.

Since our analysis assumes that the emissions rate limit and emissions ceiling yield the same emissions reduction under base case load growth, the rate limit and emissions ceiling runs are identical with base case load growth. The data displayed in Table 4.1 are discussed in the sections below, first for the emissions control programs along with base case load growth, then for the same programs under the accelerated conservation scenario, and then comparing selected cases from each growth scenario.

IV. EMISSIONS REDUCTIONS WITH BASE CASE LOAD GROWTH

Figure 4.1 shows our projections of the average SO2 emission rate through the year 2005 with base case load growth and three emissions control strategies. Without required emissions reductions, the existing plants continue producing emissions at the rate of about 3 Lbs/MMBtu throughout the forecast period. Switching to environmental dispatch in the early 1990s without further controls would reduce the average emission rate to 2.7 Lbs/MMBtu by 1995. Thus, environmental dispatch alone is not sufficient to meet the mandated reductions. After 2002, the average emissions rate increases as high-sulfur coal plants must run more to meet the increased demand for electricity.

In the cases with mandated emissions reductions, it is assumed that scrubbers or fuel switching are phased in a few years before the

Table 4.1

SUMMARY OF EMISSIONS CONTROL IMPACTS WITH BASE CASE GROWTH AND ACCELERATED CONSERVATION

	DEMAND GROWTH RATE (%/YR) 1995/2000	ANNUAL SULFUR EMISSIONS (MILLION TONS/YEAR) 1995/2000	AVERAGE SULFUR EMISSION RATE (LBS/MMBTU) 1995/2000	FRACTION OF EXISTING PLANTS SCRUBBED 1995/2000	FRACTION OF EXISTING PLANTS FUEL SWITCHED 1995/2000	AVERAGE ELECTRICITY PRICE (MILLS/KWH) 1995/2000	ANNUAL ENERGY SERVICE COST* (BILLION $) 1995/2000	TOTAL ENERGY SERVICE COST* (BILLION $) 1995/2000	PRESENT VALUE ENERGY SERVICE COST* (BILLION $) 1995/2000	ANNUAL COST PER TON ($/TON) 1995/2000
BASE CASE LOAD GROWTH SCENARIOS										
NO REDUCTIONS	1.2%/1.5%	5.7/6.0	3.1/3.0	0%/0%	0%/0%	64.2/59.5	$26.0/$26.7	$275.6/$404.0	$246.4/$354.3	$0/$0
ENVIRONMENTAL DISPATCH NO REDUCTIONS	1.2%/1.5%	5.2/5.1	2.7/2.4	0%/0%	0%/0%	64.8/63.9	$26.3/$28.7	$276.3/$408.8	$246.9/$358.1	$587/$2118
ACROSS THE BOARD--RATE CAP/EMISSION CEILING	1.2%/1.5%	3.7/2.6	2.0/1.2	42%/70%	0%/0%	67.1/64.1	$27.2/$28.8	$278.0/$414.2	$248.2/$362.6	$610/$587
LEAST COST FIRST--RATE CAP/EMISSION CEILING	1.2%/1.5%	3.8/2.6	2.0/1.2	23%/43%	0%/0%	65.5/62.1	$26.6/$27.9	$276.7/$409.2	$247.2/$358.5	$296/$334
ENVIRONMENTAL DISPATCH-RATE CAP/EMISSION CEIL.	1.2%/1.5%	4.0/2.6	2.0/1.2	21%/45%	0%/0%	66.2/67.4	$26.8/$30.3	$277.4/$415.1	$247.8/$363.2	$509/$1038
FUEL SWITCH AND SCRUBBERS, LEAST COST --RATE CAP/EMISSION CEILING	1.2%/1.5%	3.7/2.5	2.0/1.2	5%/14%	20%/38%	65.2/61.7	$26.4/$27.7	$276.6/$408.4	$247.1/$357.8	$203/$285
ACCELERATED CONSERVATION SCENARIOS										
NO REDUCTIONS	0.1%/0.5%	5.1/5.4	3.2/3.1	0%/0%	0%/0%	68.8/60.3	$25.2/$23.6	$271.6/$392.3	$242.9/$344.3	$0/$0
ENVIRONMENTAL DISPATCH NO REDUCTIONS	0.1%/0.5%	4.3/4.9	2.5/2.6	0%/0%	0%/0%	69.5/61.1	$25.4/$23.9	$271.9/$394.6	$243.1/$346.0	$329/$600
ACROSS THE BOARD--RATE CAP	0.1%/0.5%	3.3/2.3	2.0/1.2	42%/71%	0%/0%	71.9/65.1	$26.3/$25.4	$273.8/$401.6	$244.7/$352.1	$645/$601
ACROSS THE BOARD--EMISSION CEILING	0.1%/0.5%	3.7/2.6	2.3/1.4	33%/64%	0%/0%	71.2/64.6	$26.1/$25.2	$273.3/$399.9	$244.2/$350.6	$639/$600
LEAST COST FIRST--RATE CAP	0.1%/0.5%	3.4/2.2	2.0/1.2	23%/48%	0%/0%	70.2/63.3	$25.7/$24.7	$272.6/$397.0	$243.7/$348.2	$282/$364
LEAST COST FIRST--EMISSION CEILING	0.1%/0.5%	3.7/2.6	2.3/1.4	18%/36%	0%/0%	69.9/62.3	$25.6/$24.4	$272.4/$395.7	$243.5/$347.1	$273/$280
ENVIRONMENTAL DISPATCH-RATE CAP	0.1%/0.5%	3.5/2.4	2.0/1.2	20%/49%	0%/0%	70.9/64.0	$25.9/$25.0	$272.9/$399.2	$243.9/$350.0	$463/$477
ENVIRONMENTAL DISPATCH-EMISSION CEILING	0.1%/0.5%	3.7/2.6	2.1/1.4	15%/44%	0%/0%	70.5/63.7	$25.8/$24.9	$272.6/$398.3	$243.7/$349.3	$439/$476
FUEL SWITCH AND SCRUBBERS LEAST COST--RATE CAP	0.1%/0.5%	3.3/2.2	2.0/1.2	5%/15%	20%/41%	69.8/62.7	$25.5/$24.5	$272.5/$396.2	$243.6/$347.5	$191/$299
FUEL SWITCH AND SCRUBBERS LEAST COST --EMISSION CEILING	0.1%/0.5%	3.7/2.6	2.3/1.4	3%/5%	17%/33%	69.6/61.7	$25.5/$24.1	$272.3/$394.9	$243.4/$346.5	$181/$195

*Defined in the text.

FIGURE 4.1

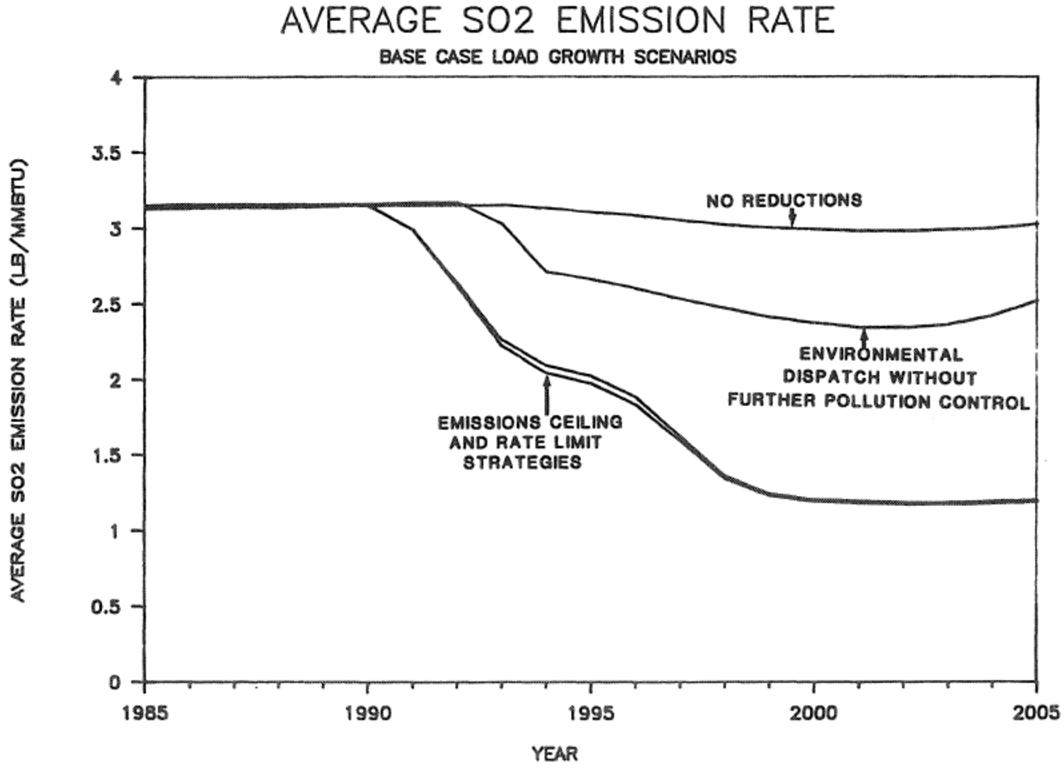
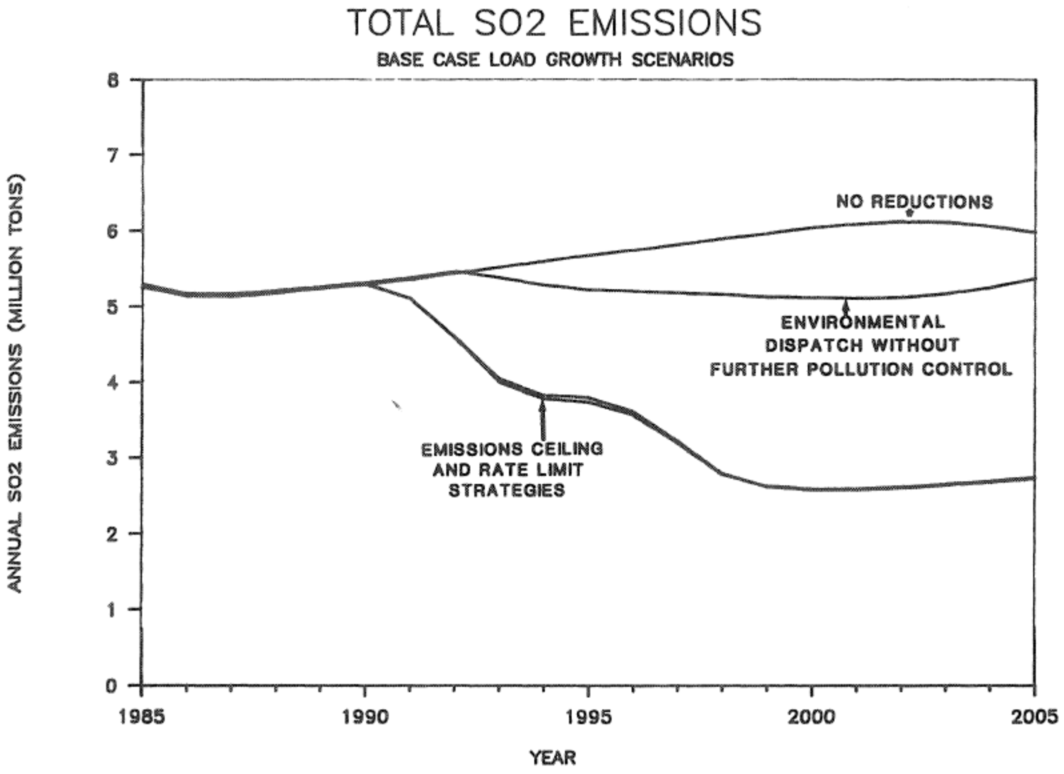


FIGURE 4.2



rate limits or ceilings take effect. Therefore, the average emissions rate begins to fall soon after 1990. The rate drops to the required 2.0 Lbs/MMBtu by 1995, and to 1.2 Lbs/MMBtu by 2000.

Figure 4.2 shows the annual SO2 emissions under base case load growth. Emissions follow a similar path as the emission rates. Without planned reductions, emissions increase slowly through 2002 as load growth increases the use of existing plants. After that point, new plants with low emissions replace older, dirty plants in a manner that leads to slight reductions in total emissions. Switching to environmental dispatch in the early 1990s would reduce SO2 emissions to about 5.2 million tons per year through 2002. After that point, total emissions rise as operation of high-sulfur plants increases to meet growing electricity demand. With the addition of retrofit scrubbers or fuel switching in order to meet the requirements assumed here, annual SO2 emissions drop to about 3.7 million tons by 1995, and 2.6 million tons by 2000.

Figure 4.3 shows the projected electric prices under base case load growth without emissions control, with an across-the-board rate limit strategy, and a least-cost fuel-switch/scrubber program under an emission ceiling. The large price increase in the late 1980s is due to expensive new nuclear and coal-fired capacity now under construction in the region. It is seen in Fig. 4.3 that the "rate shock" resulting from these projects is much greater then the rate impacts expected from any emissions control strategy.

The across-the-board scrubber strategy depicted in Fig. 4.3 is the most expensive reduction alternative. This strategy requires 42% of the existing coal capacity to be retrofit by 1995, and 70% by 2000 (see Table 4.1). This costs consumers an additional $8.4 billion by 2000 in discounted 1985 dollars. These costs raise average electricity rates in the region by about 8% in the year 2000. The least-cost fuel-switch/scrubber program requires 14% of plants to be scrubbed and 38% of plants to be fuel switched by 2000. This costs consumers about $3.6 billion by 2000, and increases average electricity rates by about 4%. Thus, allowing fuel switching and interstate emissions trading could cut the control cost approximately in half.

Our projections of electricity price increases are in line with the price penalties estimated in other studies. EPA and the Office of Technology Assessment estimate that a 50% reduction in SO2 emissions in a region similar to ECAR will increase electricity prices by 4% to 12% [7]. Likewise, our total cost estimates are similar to EPA's assessment of the costs associated with the Proxmire bill [8].

The strategy combining environmental dispatch and scrubbers does not look particularly attractive under base case load growth. It raises rates by 13% in phase two and would cost consumers in ECAR about $9.0 billion by 2000 (relative to the no-reductions case).

FIGURE 4.3

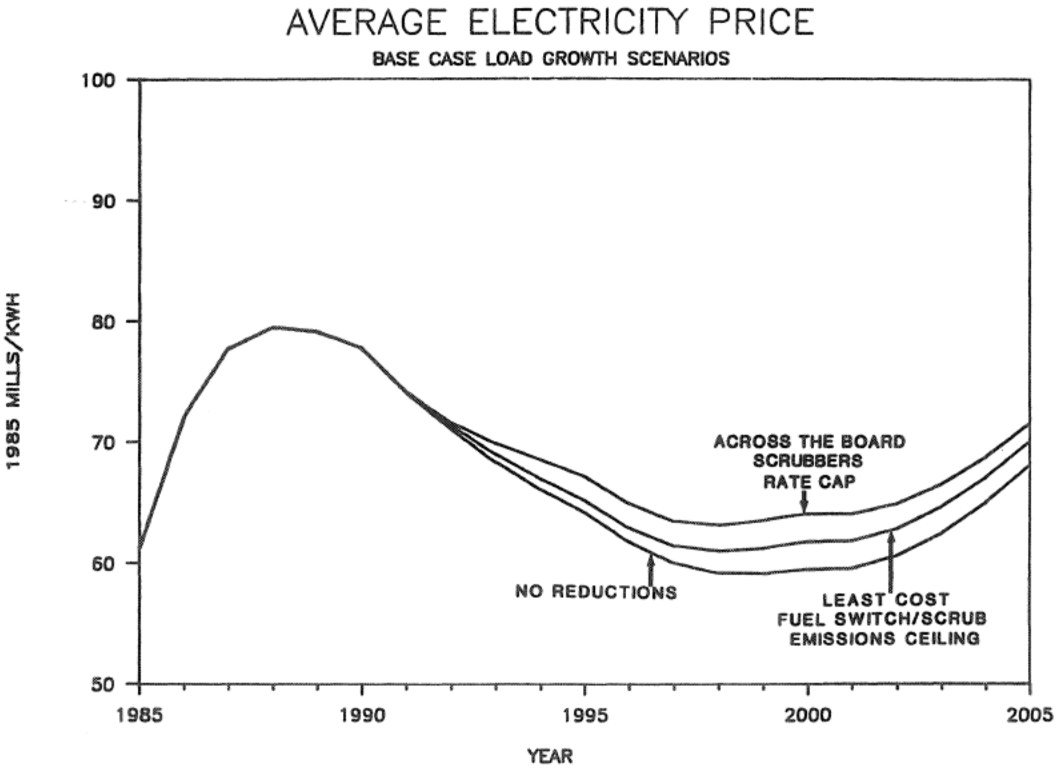
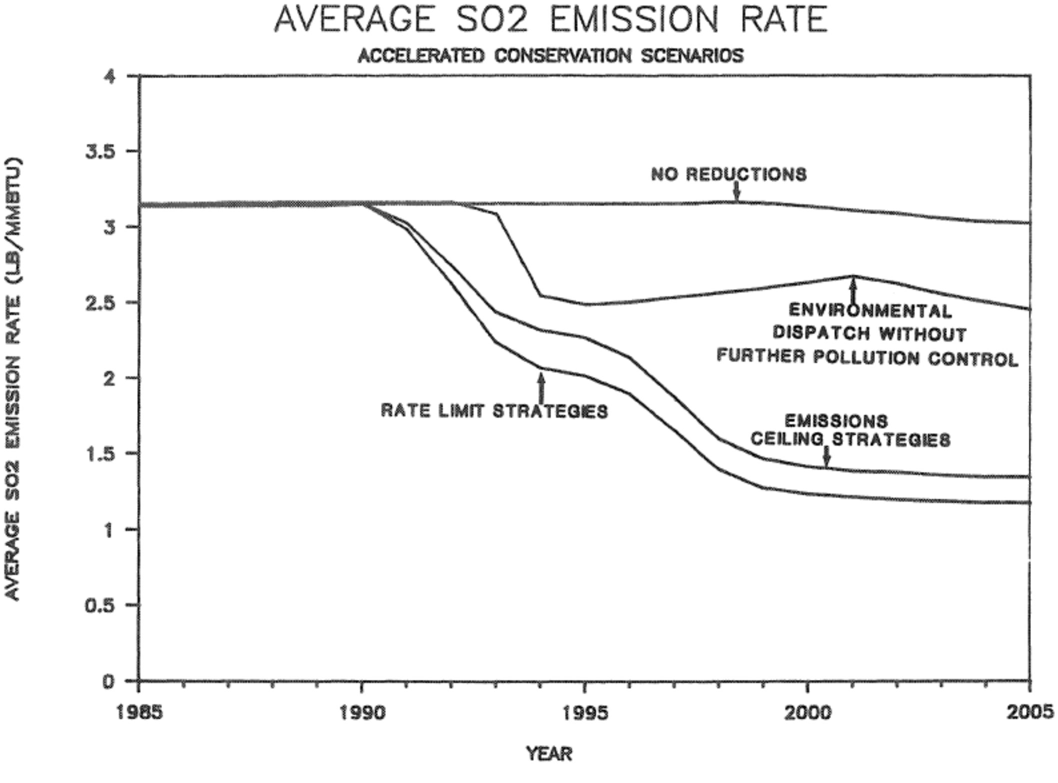


FIGURE 4.4



This is due to the fact that by the late 1990s, the reserve margin drops to 20% and further environmental dispatch leads to higher costs.

On purely economic grounds, the least-cost fuel-switch/scrubber strategy with economic dispatch seems the best choice. States or localities that decide to maintain employment in nearby high-sulfur coal mines rather than switch to low-sulfur coal will pay an economic penalty. However, if fuel switching is avoided, the least-cost-first scrubbing strategy is most economical, producing about a 5% electricity price increase in the region.

Further research on the utility and state level is required to identify the advantages and disadvantages of particular strategies on a smaller scale. In some cases, the ranking of strategies according to cost may be different from that in the entire ECAR region. For example, Ohio is projected to have a higher reserve margin than the region during 1990-2000. Thus, the environmental dispatch strategy may be more economical there.

V. EMISSIONS REDUCTIONS WITH ACCELERATED ELECTRICITY CONSERVATION

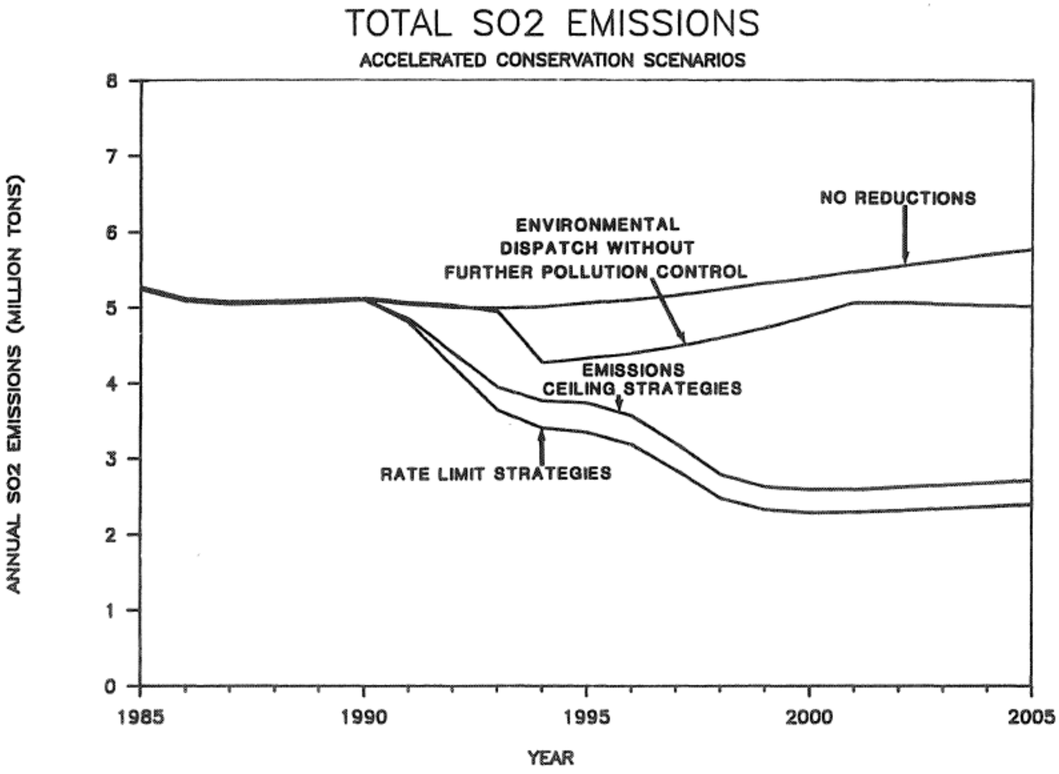
The second set of simulations combined the various emissions control strategies with the accelerated electricity conservation scenario. Table 4.1 includes the complete results of the eight cases tested under low load growth. The accelerated conservation cases do not assume any early retirement of existing plants. Although lower electricity demand might allow utilities to retire plants earlier and avoid some scrubber retrofits, it is generally less expensive to extend the lifetime of these plants and control emissions in order to avoid new plant construction [9].

Figure 4.4 shows the SO2 emissions rates for various strategies with accelerated conservation. The average emissions rate is higher with the emissions ceiling strategies compared to rate limit strategies because conservation provides some direct emissions reductions which can be taken credit for with the ceiling. This in effect leads to less required fuel switching or scrubbing with an emissions ceiling than with a rate limit.

With accelerated conservation, meeting the 1.2 Lbs/MMBtu phase two rate limit requires retrofitting 71% of the capacity with an across-the-board strategy. The least-cost fuel-switch/scrubber strategy requires retrofitting 15% of the capacity with scrubbers and shifting 41% of the capacity to low-sulfur coal. Environmental dispatch coupled with scrubber retrofits also can limit the number of existing power plants affected by emissions controls. In this case, 49% of the capacity must be retrofit to meet the phase two rate limit.

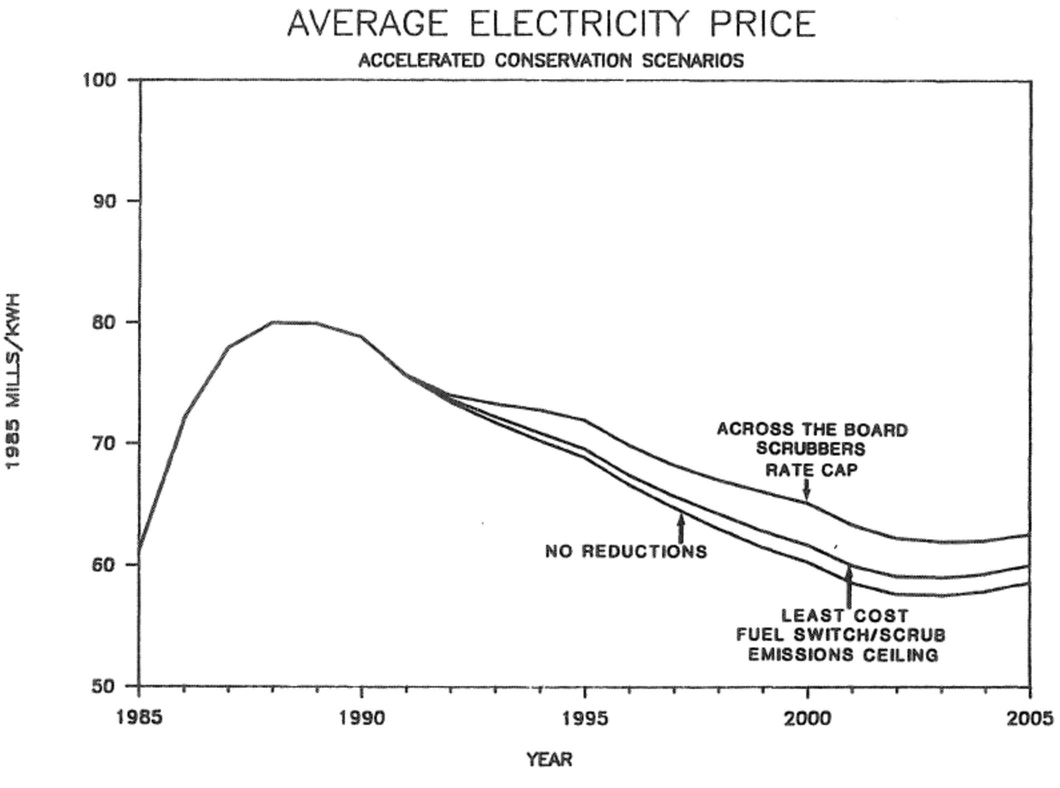
Figure 4.5 shows total SO2 emissions with accelerated conservation for several control strategies. The annual SO2

FIGURE 4.5


TOTAL SO2 EMISSIONS

ACCELERATED CONSERVATION SCENARIOS

FIGURE 4.6


AVERAGE ELECTRICITY PRICE

ACCELERATED CONSERVATION SCENARIOS

emissions without emissions control fall slightly in the mid 1990s, and rebound slowly thereafter. The aggressive energy conservation program reduces the amount of coal burned and so reduces emissions. Compared to base case load growth, emissions during the 1990s drop by over one half million tons per year, a 10% reduction.

Regarding the number of scrubbers required, the emissions ceilings could be met by retrofitting only 33% of the capacity in phase one, and 64% in phase two under an across-the-board scrubber strategy. This compares to 42% and 70% with a rate limit. The least-cost fuel-switch/scrubber strategy under an emissions ceiling is able to make even better use of the emissions reduction from low load growth. The phase two ceiling of 2.6 million tons could be reached by retrofitting only 5% of the total capacity with scrubbers and switching 33% of the capacity to low-sulfur coal, as compared to 15% scrubbed and 41% switched with an emissions rate limit.

Figure 4.6 shows annual electricity prices for selected strategies with accelerated conservation. The advantages of the emissions ceiling and the fuel switching and scrubbing strategy are apparent. The least-cost control approach only causes a 2.3% increase in electricity price in the year 2000 relative to no reductions. With across-the-board scrubbers and the rate cap, on the other hand, the electricity price increases by 8.0%.

The relative attractiveness of the different emissions control strategies is similar with either base case load growth or accelerated conservation. The least-cost fuel-switch/scrubber strategy still achieves the lowest cost reductions, and is best able to capture the benefits of an emissions ceiling. The next best strategy is least-cost-first scrubbing only, followed by the environmental dispatch or the across-the-board scrubbers depending on the load growth scenario. Switching to an emissions ceiling permits a 5% to 11% increase in emission rates, without exceeding the total emissions ceiling. This can save $100-400 million per year and reduce the total control cost by 13-33% in 2000.

VI. COMPARISON OF EMISSIONS CONTROL COSTS IN DIFFERENT LOAD GROWTH SCENARIOS

Figure 4.7 shows that if the conservation and emissions control programs are both in full swing during the 1990s, consumers will temporarily pay higher electricity prices compared to scenarios without accelerated conservation. This happens because the region is still in surplus, and the cost savings from avoided new power plant construction have not yet been realized. As Figure 4.7 indicates, combining aggressive energy conservation and emissions control will lead to higher electricity prices until about 2000. After that point the full benefits of the conservation begin to be realized and conservation leads to lower electricity prices.

FIGURE 4.7

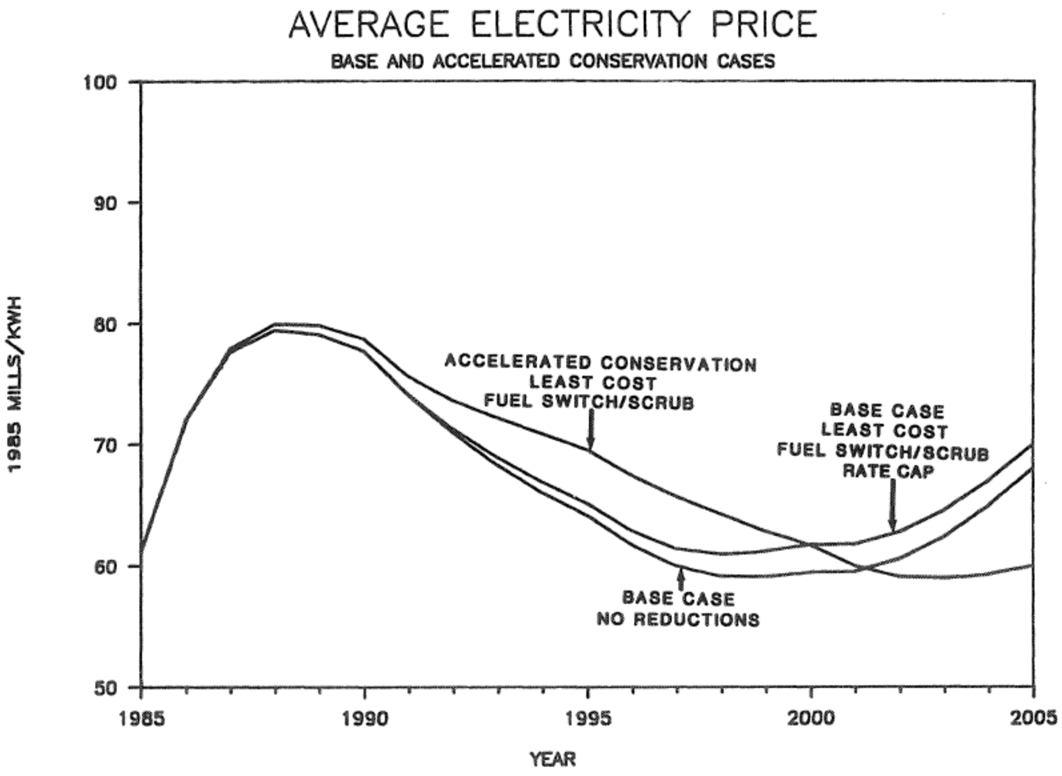
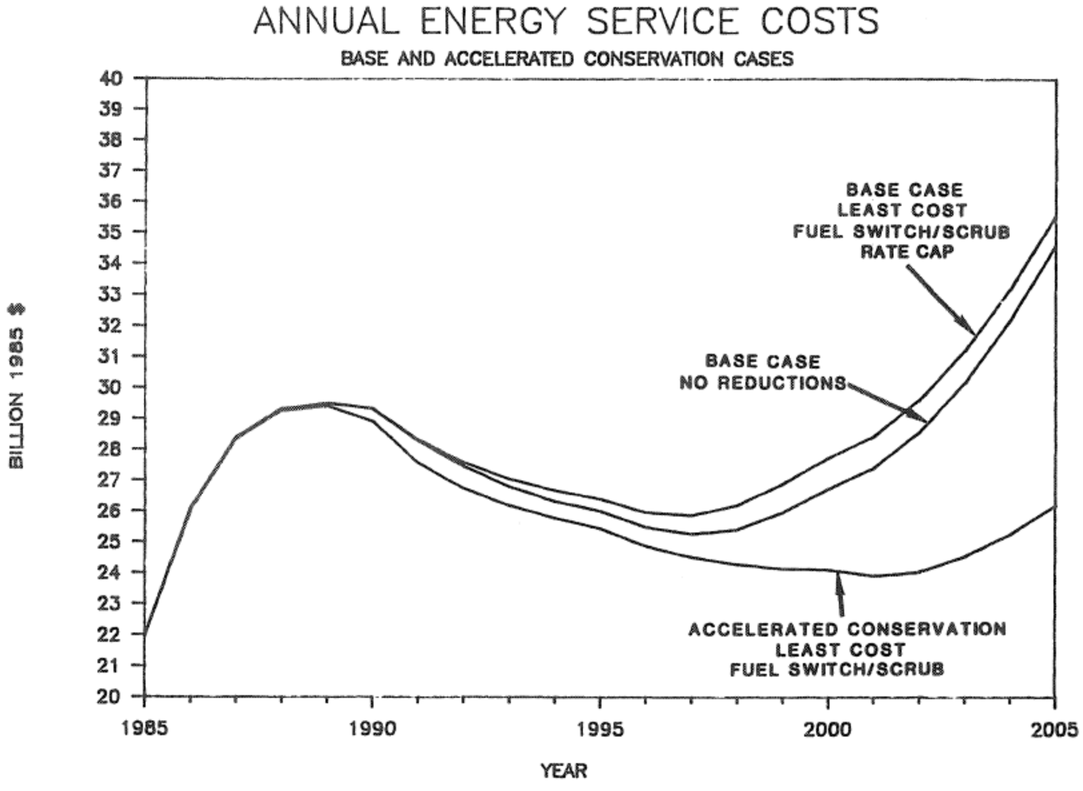


FIGURE 4.8



It is important to emphasize that higher electricity prices do not necessarily mean higher overall costs for consumers. Consumers who participate in the conservation program will find their decreased use of electricity more than compensating for the higher electricity price, as well as their investment in conservation. Figure 4.8 shows that consumers overall will always pay less for their energy services if accelerated conservation and emissions control are both implemented compared to base case load growth and no emissions reductions. Although Fig. 4.8 shows the most cost-effective emissions control strategy, this general result is true no matter which emissions control strategy is followed.

Figure 4.9 shows the total present value of energy service costs during 1985-2000 for a variety of emissions control and load growth cases. This chart also presents the change in cost relative to the base case without emissions control. With no direct emissions controls, accelerated conservation alone saves consumers $9.9 billion. This is enough to pay for any of the emissions control programs. The net savings to consumers ranges from $3.7-7.7 billion when accelerated conservation and emissions control are jointly pursued (relative to doing neither).

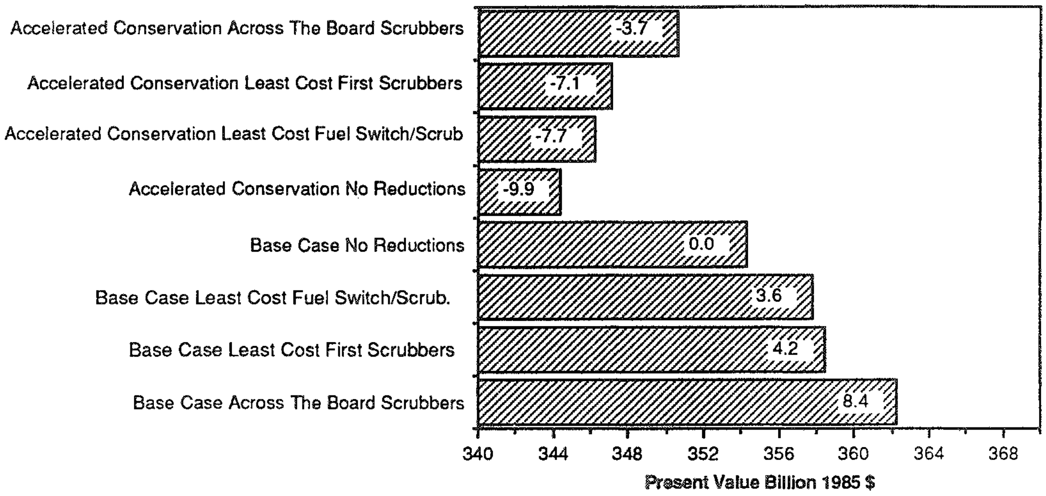
The least-cost fuel-switch/scrubber strategy leads to the lowest overall energy service cost under the assumed emissions reduction requirements. The present value of energy service costs during 1985-2000 increases only $2.2 billion with accelerated conservation and $3.6 billion with base case load growth. Thus, accelerated conservation can provide substantial reductions in the direct cost of emissions control.

Figure 4.10 clearly illustrates this point by showing the cumulative direct control costs, i.e., costs for fuel switching and scrubbers only, over time using the least-cost approach in both load growth scenarios. By 2005, the cumulative cost for fuel switching and scrubbers is 42% lower if accelerated conservation is pursued. This result is a consequence of a number of factors. First, lower electricity demand leads to a direct reduction in emissions, meaning fewer scrubbers or less low-sulfur coal are required and pollution controls can be avoided in relatively expensive applications. Second, purchase of some scrubbers and/or low-sulfur coal can be delayed with accelerated conservation. This results from the region maintaining excess capacity for a longer period, i.e., present coal-burning capacity is not fully utilized as soon.

Similar results occur for the other emissions control strategies. With the least-cost-first scrubbing-only strategy and accelerated conservation, the present value of energy service costs during 1985-2000 increases by $2.8 billion due to the emissions controls. However, with base case load growth, the emissions controls cost consumers $4.2 billion during the same period. The environmental dispatch strategy along with scrubbers also has a lower

FIGURE 4.9

Present Value of Energy Service Costs During 1985-2000

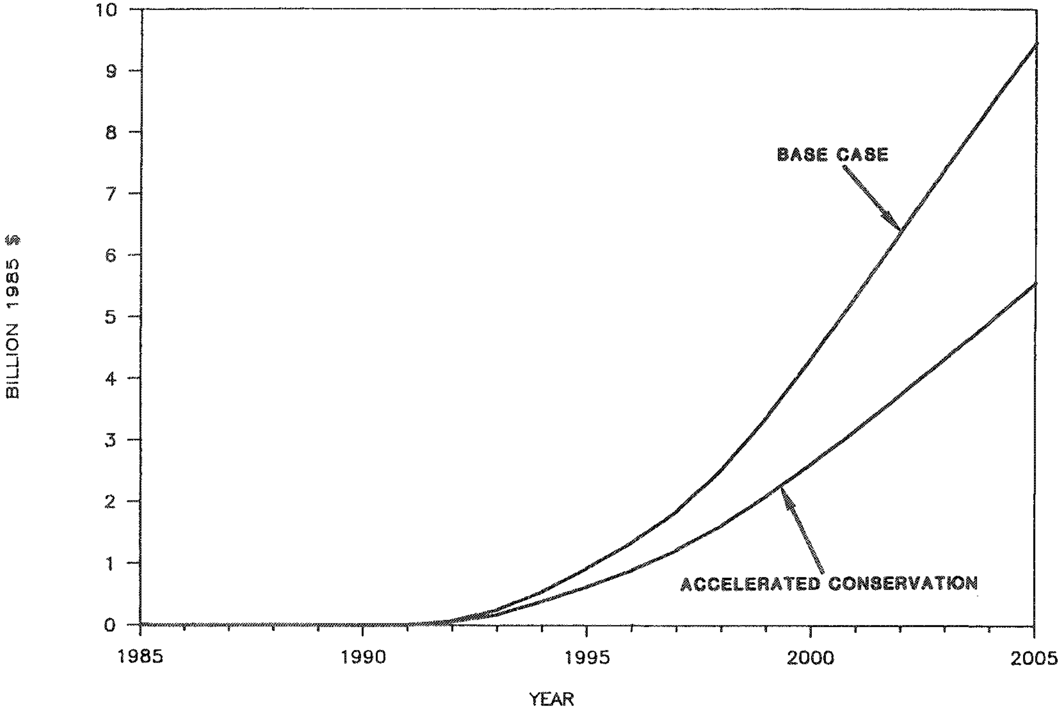


1) The length of each bar equals the total present value of the scenario.
2) The number within each bar equals the difference between the scenario and the base case with no emission reductions.

FIGURE 4.10

CUMULATIVE EMISSION CONTROL COSTS

LEAST COST FUEL SWITCH/SCRUBBER CASES



compliance cost if accelerated conservation is pursued.

The next chapter discusses the pros and cons of different emissions control policies in relation to electricity conservation and suggests ways in which legislation can best encourage conservation.

VII. NOTES AND REFERENCES

1. Acid Rain and Transported Air Pollutants, OTA-O-204, Office of Technology Assessment, Washington, DC, June 1984. p. 172.

2. "Estimates of Sulfur Oxide Emissions From the Electric Utility Industry", report prepared by E.H. Pechan and Associates, Inc. for the U.S. Environmental Protection Agency, 1983.

3. "Impacts of Selected Acid Rain Policy Options on the AEP System", draft analysis prepared by ICF Inc. for the Acid Rain Policy Options Dialogue, Washington, DC, Jan. 1987.

4. "An Economic Analysis of HR-4567: The Acid Deposition Control Act of 1986", report prepared by ICF Inc. for the U.S. Environmental Protection Agency, Washington, DC, Aug. 1986.

5. Economic Evaluation of FGD Systems, EPRI CS-3342, Electric Power Research Institute, Palo Alto, CA, 5 volumes, Oct. 1986.

6. "An Economic Analysis of HR-4567: The Acid Deposition Control Act of 1986", report prepared by ICF Inc. for the U.S. Environmental Protection Agency, Washington, DC, Aug. 1986 and "Preliminary Forecasts: Proxmire Bill", draft report prepared by ICF Inc. for the U.S. Environmental Protection Agency, Washington, DC, Oct. 1986.

7. Acid Rain and Transported Air Pollutants, OTA-O-204, Office of Technology Assessment, Washington, DC, June 1984. p. 172.

8. "Preliminary Forecasts: Proxmire Bill", draft report prepared by ICF Inc. for the U.S. Environmental Protection Agency, Washington, DC, Oct. 1986.

9. Lifetime extension of older coal-fired plants generally costs $200-400/kW and retrofit scrubbers cost $200-250/kW, compared to at least $1200/kW for new coal-fired capacity. See New Electric Power Technologies: Problems and Prospects for the 1990s, OTA-E-246, U.S. Office of Technology Assessment, July, 1985.

CHAPTER 5

ELECTRICITY CONSERVATION AND FEDERAL ACID RAIN LEGISLATION

I. INTRODUCTION

The acid rain control bills introduced in the U.S. Congress in recent years contain various regulatory approaches for achieving substantial SO2 emissions reductions (see Table 5.1). Some of them give credit toward emissions reduction goals for conservation-induced emission reductions. Others only give partial or no credit.

As discussed previously, electricity conservation can be used to defer construction of new power plants, to reduce or slow the increase in use of existing power plants, and to retire power plants ahead of schedule. The analysis in Chapter 4 showed that using conservation to defer construction of new power plants is highly beneficial to utility ratepayers, regardless of the regulatory approach used for acid rain control. In some instances, however, acid rain legislation could discourage pursuit of conservation to defer construction of new power plants. The reason for this will be explained below.

Two recent acid rain control bills attempt to encourage use of conservation as an emissions control method. Moreover, virtually every proposed acid rain bill requires that states submit emissions control plans, explaining how they plan to meet emissions reduction goals expressed in terms of source-by-source or statewide average emissions rates, reductions below certain levels of total emissions, or simple ceilings on total emissions. In developing their plans, states will have to estimate electric utility load growth, or, if complying with an emissions rate limit, states will have to estimate how much they expect to operate certain power plants in future years. Thus, states and utilities will need to assess factors such as demand growth and the impact of conservation efforts when developing their emissions control plans.

It is not our intent to advocate a single approach to acid rain control. However, because conservation has enormous potential for reducing costs, it is important that legislation being considered by Congress not prevent or discourage states from using conservation to help meet their emissions reduction goals. Therefore, this chapter examines how various legislative approaches encourage or discourage use of conservation to reduce emissions, and the extent to which conservation-caused emission reductions are credited toward emission reduction goals. Also, we recommend legislative modifications that will encourage electricity conservation in conjunction with emissions control. Of course, other factors such as cost, equity, and certainty of emissions reductions need to be considered when deciding which regulatory approach to adopt.

II. LEGISLATIVE FEATURES THAT AFFECT USE OF CONSERVATION

Each acid rain control bill has several features that will affect a state's willingness and ability to incorporate conservation in their emission reduction plans. Some of these features will have an important effect, others won't. This section reviews the most important features in the major acid rain control bills recently considered by Congress.

Most bills use one or both of two mechanisms for obtaining emissions reductions from power plants. The first is an emissions rate limit, expressed as a unit of pollutant emissions per unit of heat input to a combustion chamber, e.g., Lbs. of SO2 per MMBtu of heat input. The second is an emissions ceiling, often expressed as an amount of reduction below a given level of emissions, e.g., 10 million tons below the 1980 SO2 emissions level.

These two fundamental approaches and variations of them are discussed below. Central to this discussion is how these approaches account for and credit emissions reductions resulting from conservation. Credit is used here to mean progress toward an emissions reduction goal.

A. STATEWIDE AVERAGE EMISSIONS RATE LIMITS

Statewide average SO2 emissions rate limits are one of the most popular legislative approaches (see Table 5.1). Representative Waxman's proposal in 1985-86 (H.R. 4567 in the 99th Congress) contained statewide average emissions rate limits that would have become effective in 1993 and 1997. Other bills, including Senator Mitchell's (S. 321 in the 100th Congress) and Senator Proxmire's (S. 316 in the 100th Congress) use statewide average emissions rate limits as one means for obtaining emissions reductions.

Statewide average SO2 emissions rates are determined by summing SO2 emissions in an entire state for a class of sources (fossil fuel-fired power plants, for example) and then dividing by the sum of the total heat input for those plants. In effect, this procedure weights each power plant's emissions rate according to plant size and usage. The statewide average emissions rate is then a sum of weighted individual emissions rates. The larger a plant and the more it is used, the greater effect its emissions rate will have on the statewide average.

Electricity conservation that results in reduced utilization or early retirement of power plants with emissions rates <u>below</u> a state's average emissions rate, while lowering absolute emissions, will cause the state's average emissions rate to rise. On the other hand, electricity conservation that results in reduced utilization or early retirement of power plants with emissions rates <u>above</u> a state's

Table 5.1 (cont.)

SIDE-BY-SIDE COMPARISON OF ACID RAIN CONTROL BILLS

	S. 300 (Stafford)	H.R. 4567 (Waxman)	S. 316 (Proxmire)	S. 321 (Mitchell)	S. 95 (Kerry)
Credit for Conservation Used to Reduce Operation of Power Plants:	No	Partial, if state reduces operation of plants with emission rates above statewide average. Negative credit if state reduces operation of plants with emission rates below statewide average.	Same as for H.R. 4567 if state chooses to comply with statewide average emission rate. Full credit if state chooses to comply with emissions ceiling. No credit under either choice for conservation used to reduce operation of existing, new source plants.	1996 Requirements: Same as for H.R. 4567 if state is constrained by .9 lbs/MMBTU statewide average emission rate limit. Full credit if state is constrained by share of 12 million ton emissons reduction requirement. Post-1996 Requirements: No credit if state chooses to comply with plant-by-plant emission rate limit. Full credit if state chooses to comply with statewide emissions ceiling.	Full credit.

* All bills from 100th Congress, except H.R. 4567, which is from th 98th Congress.

Table 5.1

SIDE-BY-SIDE COMPARISON OF ACID RAIN CONTROL BILLS*

	S. 300 (Stafford)	H.R. 4567 (Waxman)	S. 316 (Proxmire)	S. 321 (Mitchell)	S. 95 (Kerry)
Effective Date	1991	1993, 1997	1993, 1997	1996	1989, 1992, 1994
Effective Region	Entire U.S.	Entire U.S.	31 Eastern States	Entire U.S.	48 Contiguous States
Approaches to Limiting Utility SO2 Emissions	No limit on plants that operate no more than 10,000 hours after effective date. 1.5 lbs/MMBTU for plants that operate up to 30,000 hours. 0.9 lbs/MMBTU for plants that operate more than 30,000 hours. NSPS for plants that are at least 30 years of age.	2.0 lbs/MMBTU statewide average emission rate limit for fossil-fueled plants, effective 1993; 1.2 lbs/MMBTU statewide average emission rate limit for fossil-fuel plants, effective 1997.	2.0 lbs/MMBTU statewide average emission rate limit for fossil-fueled plants, effective 1993; 1.2 lbs/MMBTU statewide average emission rate limit for fossil-fueled plants, effective 1998. If Governor certifies conservation program, state can choose to comply with emission ceiling set at level of emissions that would have occurred in 1980 had statewide average emission rate been 2.0 (effective 1993) or 1.2 (effective 1998).	0.9 lbs/MMBTU statewide average emission rate limit, effective 1996. Total emissions reduction equal to state's share of 12 million tons, effective 1996. Share based on state's excess utility emissions over 0.9 lbs/MMBTU relative to other states excess utility emissions over 0.9. After 1996, 0.9 lbs/MMBTU for 30 year old plants, or emissions ceiling equal to 1980 emissions minus share of 12 million tons. Share determined as above.	Coal for utility plants with more than 2% sulfur content must be cleaned, effective 1989. States must reduce emissions by their share of 12 million tons. Shares to be determined by EPA on the basis of excess utility and non-utility emissions above specified levels. 7/12 of share shall be reduced by 1992; remainder by 1994. Interim emissions ceiling equal to 1985 emissions, effective until above reductions achieved. 2 for 1 NOx/SO2 substitution allowed to meet reductions.
State Implementation	No state role.	Free choice of strategies.	Free choice of strategies.	Free choice of strategies.	Free choice of strategies, except requirements for 2% sulfur coal cleaning and use of adiptic acid in all scrubbers.

average will cause the state's average emissions rate to fall. Thus, the question of whether a state benefits from conservation-induced emissions reductions depends on whether the state uses conservation to reduce utilization of plants with emissions rates above or below the state's average.

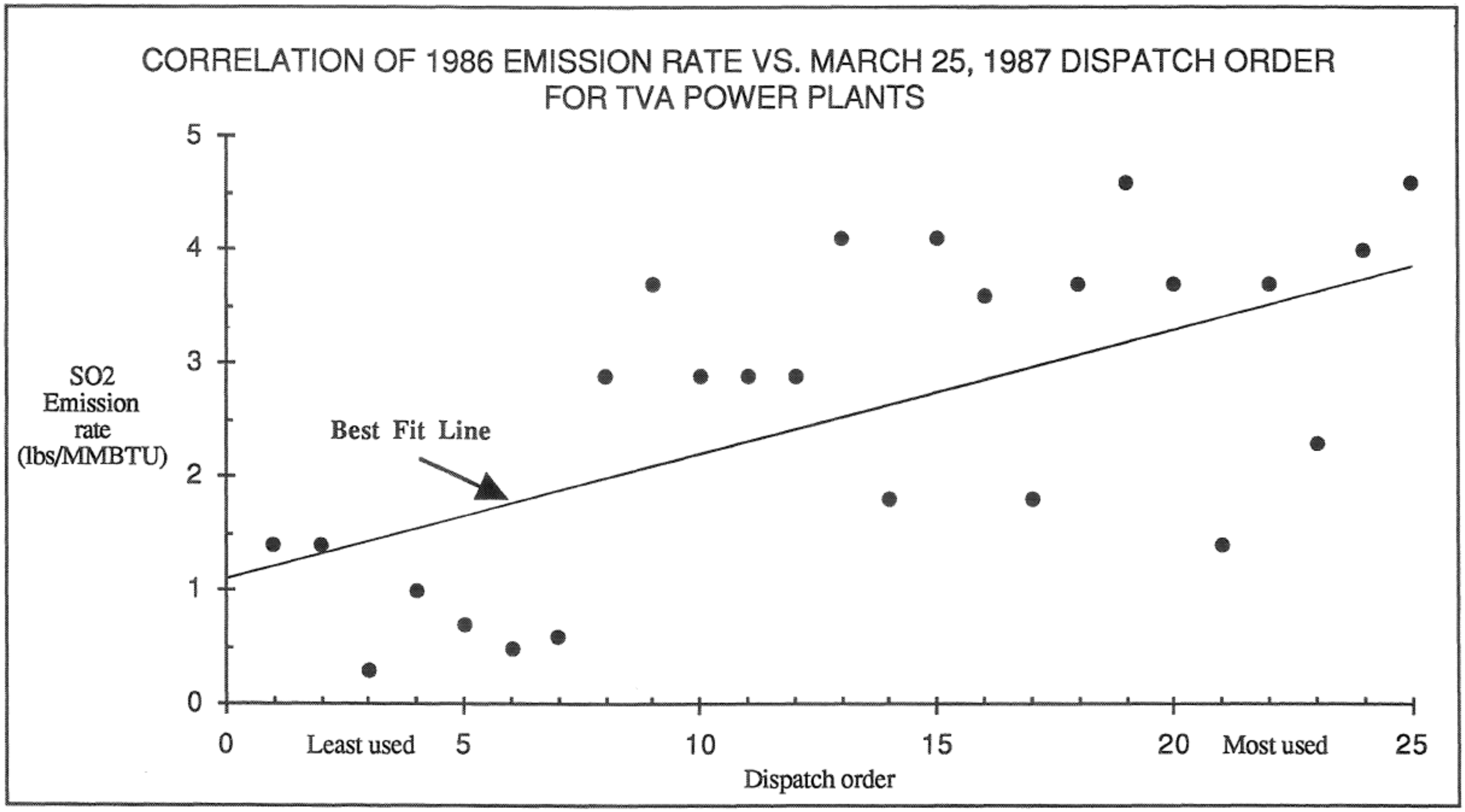
Under normal economic dispatch, electricity conservation will cause a utility (or power pool) to reduce operation of plants that are the most expensive to operate. For most utilities or power pools, plants that burn low-sulfur coal are typically more expensive to operate than plants that burn higher-sulfur coal because of the differential in coal prices. (In our ECAR analysis, we assumed a 25% price premium for low-sulfur coal.) Thus, electricity conservation will tend to move states and utilities away from pollution reduction targets based on statewide average emissions rates.

An example of this phenomenon is provided by considering the dispatch order and SO2 emissions rates of the coal-fired power plants operated by the Tennessee Valley Authority. The emissions rates are plotted according to each plant's rank in the dispatch order Figure 5.1. There is a strong correlation between emissions rate and dispatch order rank, with dirtier plants generally used before cleaner plants. The cleaner, less frequently used plants burn low-sulfur coal or include a flue gas scrubber. Under normal operations, TVA would tend to reduce operation of these plants first in response to lower electricity demand, thereby raising its average emissions rate while lowering overall emissions.

The question of how a statewide average emissions rate limit affects the use of conservation to defer construction of new power plants is more complicated. The answer depends upon whether the limit applies to both existing and future plants, or just existing plants. If the limit applies to existing and future plants, a state will be discouraged from implementing electricity conservation because slowed electric load growth will reduce the need for new, low-emissions rate power plants. Such plants, if built, would lower a state's average emissions rate. Building new plants that increase a state's total emissions has the perverse result of moving a state closer to its emissions reduction goal. However, if electricity generated by a new power plant is partially substituted for electricity generated from an existing, high emissions rate plant, total emissions may be reduced, depending on the extent of the substitution.

Despite the incentives a statewide average emissions rate limit may create for building new power plants, there are still sizable economic penalties associated with building new power plants in areas where electricity rates are now relatively low. For example, substantial rate hikes are expected in the next five years in the ECAR region as a consequence of ongoing power plant construction (see Chapter 3). Therefore, the economic penalty associated with

FIGURE 5.1


CORRELATION OF 1986 EMISSION RATE VS. MARCH 25, 1987 DISPATCH ORDER FOR TVA POWER PLANTS
SO2 Emission rate (lbs/MMBTU)
5
4
3
2
1
0
Best Fit Line
0
Least used
5
10
15
20
Most used
25
Dispatch order

building new plants may in practice outweigh any advantage in terms of emissions rate reductions.

A statewide average emissions rate limit that applies only to existing plants does not encourage construction of new power plants. Of the bills featuring a statewide average emissions rate limit, the old Waxman bill applies the rate limit to all plants, the current Proxmire bill applies the rate limit only to plants not defined as "new sources" in the Clean Air Act, and the current Mitchell bill applies the limit to plants that operated at any time during 1980. Thus, the Waxman bill creates the incentive for building new power plants described above, while the Proxmire and Mitchell bills do not.

B. SOURCE-BY-SOURCE EMISSIONS RATE LIMITS

An emissions rate limit enforced on a source-by-source basis may not provide full credit for emissions reductions resulting from cutbacks in power plant use. As defined in acid rain legislation, an emissions rate measures the amount of emissions per unit of heat input. Changes in usage of a particular power plant in response to electricity conservation won't affect the emissions rate. For example, a plant that emits 5 Lbs/MMBtu of heat input and consumes one trillion Btu per month emits 2,500 tons of SO2 per month. Cutting usage and thus the heat input in half would reduce emissions by half, but would not effect the emissions rate. A retrofit scrubber is still needed if the emissions rate limit is sufficiently stringent. However, the operating cost associated with the scrubber will decline since it is proportional to the amount of fuel input.

Senator Stafford's bill (S. 300 in the 100th Congress) sets a maximum SO2 emission rate of 0.9 Lbs/MMBtu for each power plant that is going to operate for more than 30,000 hours after January 1, 1991. For plants that are going to operate for more than 10,000 hours but less than 30,000 hours after that date, an emissions rate limit of 1.5 Lbs/MMBtu must be met. A power plant could emit in excess of 1.5 Lbs/MMBtu as long as it is operated no more than 10,000 hours after 1990. In addition, the Stafford bill requires all plants to meet New Source Performance Standards, which include a more stringent SO2 standard (generally 0.6 Lbs/MMBtu), once they reach 30 years of age. To comply with this provision, such power plants would have to be retrofitted with a scrubber or shut down.

The Stafford bill could encourage conservation by providing utilities an incentive to reduce operation of existing plants in order to avoid the tougher rate limits, and to "mothball" old plants when they reach 30 years of age in order to avoid the NSPS provision [2]. It is possible that by reducing utilization of existing plants (say from 5000 hours/yr to 2500 hours/yr), it would become more feasible to operate the plant(s) at higher emissions rates in order to avoid more costly pollution control measures. For example, a power plant cut back to 2500 hours/yr could continue operating for 12 years beyond

1990 if it emits no more than 1.5 Lbs/MMBtu. Such a plant could operate using low-sulfur coal rather than a more costly scrubber retrofit necessitated by the 0.9 Lbs/MMBtu rate limit.

Regarding the stringent emissions rate limit in the Stafford Bill for plants operating after they reach 30 years of age, it may be feasible to "mothball", i.e., temporarily shut down plants as long as there is excess capacity in a utility system or power pool. This would enable the utility to defer installation of flue gas scrubbers (as long as scrubbers weren't already installed at this plant) and thereby lower pollution control costs. Thus, states and utilities would have an additional incentive to reduce electricity demand growth in order to maintain excess capacity and keep older plants out of operation for as long as possible.

However, it is likely that states and utilities will eventually want to resume operation of mothballed plants rather than prematurely retire them. Once excess capacity is exhausted, either a new plant will need to be brought on line or a mothballed plant restarted. Early plant retirement is cost-effective only when the cost of extending the life of the plant and bringing it into compliance with emissions limitations is more expensive than adding new generating capacity at this time. As discussed in Appendix B, life-extension plus a retrofit scrubber cost on the order of $450-650/kW, much less than the cost of new coal-fired capacity (about $1200/kW as of 1985). Unless new generating technologies are developed that are both clean and inexpensive, early retirement of existing power plants is not likely to be economical.

The application of conservation to defer new plant construction is neither encouraged nor discouraged by the Stafford bill. Emissions rates are considered on a source-by-source basis and the requirements are neither increased or decreased as a consequence of new plant construction. However, as discussed above, if conservation is used to cut back on the operation of existing plants or retire them ahead of schedule, the date when new capacity is required may be pushed up.

C. STATEWIDE EMISSIONS CEILINGS

Statewide emissions ceilings simply limit total SO2 emissions in states. Under a statewide emissions ceiling, conservation used to reduce operation of existing power plants will lower states' total emissions and move the states closer to their emissions reduction goals, independent of emissions rates.

The effect of a statewide emissions ceiling on decisions to defer new power plant construction is minor. As pointed out several times before, deferring construction of new power plants yields large benefits to electric utilities, regardless of the regulatory approach used for acid rain control. Nonetheless, if an emissions ceiling applies only to existing plants, states that defer construction of new power plants will not receive credit for the emissions thus avoided, nor will they be penalized for emissions increases caused by building new power plants. If an emissions ceiling applies to all plants, both existing and new, states will benefit from avoiding emissions by deferring construction of new plants.

The Proxmire bill and the Mitchell bill reduce emissions ceilings over time as older power plants are retired. The statewide emissions ceiling is reduced by an amount equal to the average annual SO2 emissions of the retired power plant in the five years preceding its retirement. This kind of ratchet mechanism will deprive states of credit for emissions reductions provided through plant retirement. But, as discussed previously, utilities already have an economic incentive to keep existing plants operating as long as possible. Reducing emissions ceilings would tend to reinforce their desire to continue operating existing plants.

D. COMBINATION EMISSIONS CEILING/EMISSIONS RATE LIMIT APPROACHES

A fourth regulatory approach contained in the Proxmire bill is a hybrid of the statewide emissions rate limit and statewide emissions ceiling. The bill establishes a statewide average emission rate limit of 2.0 Lbs/MMBtu that must be met in 1993, and a limit of 1.2 Lbs/MMBtu that must be met in 1998. The bill also gives states the option of complying with emissions ceilings instead of the emissions rate limits, if the governor of a state certifies to the EPA Administrator that a program encouraging conservation of electricity will be implemented, and that the program will result in a reduction in emissions of sulfur dioxide. The emissions ceilings under this option assume that the state's fossil-fuel-fired utility boilers operating in 1980 (not including those defined as new sources by the Clean Air Act) emitted SO2 at the rate of 2.0 Lbs/MMBtu for phase one and 1.2 Lbs/MMBtu for phase two. These equivalent rate limits and ceilings were used in the ECAR analysis presented in previous chapters.

The Proxmire approach is meant to encourage the pursuit of electricity conservation in acid rain control strategies. If a state wants to incorporate conservation in its control effort, it would seemingly choose to comply with the emissions ceilings because, as discussed above, emissions ceilings more fully account for the emissions reductions resulting from electricity conservation. Unfortunately, the choice for a state is not that simple. There probably will be cases in which states interested in implementing conservation programs still choose to comply with average emissions rate limits.

To understand why this is so, consider a state that has substantially increased operation of its non new-source plants since

1980. Total emissions from these relatively high-emissions rate plants will also have grown substantially, but barring unusual circumstances, the average emissions rates of these plants are likely to be similar or the same as in 1980. Consequently, the level of effort or amount of emissions reduction required to meet the statewide average emission rate limits in 1993 or 1998 won't have increased as a result of the increased use of existing power plants. However, this is not true if a state were to opt to be regulated by statewide emissions ceilings. In this case, the state's growth in total emissions will have moved it further away from its emissions reduction goals, thus greater emissions reductions are necessary in order to meet the emissions ceilings.

If, as is less likely, a state has reduced operation of non new-source plants since 1980, and thereby reduced total emissions from these plants, the opposite of the above would be true. A state choosing to be regulated by statewide average emissions rate limits will find that emissions reductions at its non new-source plants won't have moved it any closer to its emissions reduction goals. But, if the state were to choose to be regulated by statewide emissions ceilings, the reduction in non new-source plant emissions since 1980 will have moved the state closer to its emissions goals. Most likely, a state will decide on whether to be regulated by statewide average emissions rate limits or statewide emissions ceilings based on which of the two regulatory approaches requires the least emissions reductions.

The Mitchell bill also uses a combination of emissions rate limits and emissions ceilings to regulate emissions. However, the bill as drafted is quite complicated. The Mitchell bill requires that all major stationary sources (utility and non-utility steam generators) of SO2 meet two requirements by January 1, 1996:

1) A statewide average emissions rate limit of 0.9 Lbs/MMBtu.

2) A total reduction in SO2 equal to the state's share of 12 million tons, whereby the state's share is its fraction of nationwide utility SO2 emissions in excess of 0.9 Lbs/MMBtu. This requirement appears to result in an emissions ceiling.

In addition, after January 1, 1996, major utility and non-utility steam generators must comply with one of the following requirements:

3) Upon reaching 30 years of age, each source must meet an emissions rate limit of 0.9 Lbs/MMBtu.

4) An emissions ceiling, equal to the total 1980 SO2 emissions in a state, minus the fraction of 12 million tons of SO2 determined in 2) above. This ceiling is reduced -- each

time a covered source is retired -- by an amount equal to the average annual SO2 emissions from the source in the five years preceding retirement.

For the first two provisions listed above, some states are going to be more constrained by the statewide average emissions rate limit, and others are going to be more constrained by the emissions ceiling. High-emissions states with most emissions coming from utility sources are likely to be constrained by the emissions ceiling. These states will receive credit for their conservation-induced emissions reductions. Other states will be constrained by the statewide emissions rate limit and may receive credit for their conservation-induced emissions reductions because a special provision in the bill allows states to estimate the effect its conservation programs will have on emissions, and then adjust its statewide average emissions rate limit (0.9 Lbs/MMBtu) upward an equivalent amount. As in the Proxmire bill, Governors must certify plans to implement such conservation programs.

Adjustment of the rate limit presents serious problems and opportunities for abuse. The task of estimating electricity savings from conservation programs and resulting emissions reductions is very difficult. Electricity savings due to conservation programs can be estimated, but without much accuracy because of the range of factors influencing electricity demand. Dispute is sure to arise over what demand would have been without the conservation programs. As a way to ease their statewide average emission rate limit, some states could claim an unrealistically high level of savings from their conservation programs. There would be no way to prove or disprove their claims. In addition, even if total electricity savings could be established, estimating the corresponding emissions reductions is a formidable task.

By way of contrast, if states were simply required to comply with an emissions ceiling, estimating the effect of conservation programs on load growth would be less of an analytical problem and less controversial. States could opt to use accelerated conservation to move towards the emissions ceiling, but if its estimates of conservation-induced electric load and emissions reductions were inaccurate, it would still be obligated to meet the same emissions ceiling as it would if it chose not to pursue conservation. On the other hand, conservation efforts may turn out to be more effective than anticipated, in which case a state would need fewer scrubbers and/or less low-sulfur coal. Compliance strategies may need to be adjusted periodically in response to unanticipated changes in electricity demand regardless of whether or not conservation is aggressively pursued.

III. COMPARISON OF STATEWIDE AVERAGE EMISSIONS RATE LIMIT AND STATEWIDE EMISSIONS CEILING IN TERMS OF CREDIT FOR EMISSIONS REDUCTIONS DUE TO CONSERVATION

The preceding section described the circumstances under which states and utilities would receive credit for and thereby have an incentive to pursue conservation-induced emissions reductions. An important conclusion was that a state is penalized in terms of its average emissions rate if conservation is used to reduce the operation of power plants with emission rates below the statewide average. However, a state benefits if it reduces the operation of power plants with emissions rates above the statewide average. But the extent of the credit under an emissions rate limit is less than that under a statewide emissions ceiling. An example illustrates this point.

Assume that a state has 20 power plants, each with a monthly heat input of one trillion Btu, and that the state's average emission rate for all plants is 3.0 Lbs/MMBtu. Assume also that one plant, call it plant T, has an emission rate of 5.0 Lbs/MMBtu, and that conservation efforts enable a 50% reduction in the operation (and heat input) of plant T. Thus, emissions are reduced by 1,250 tons per month.

The calculation of the state's average emission rate and the effect of a 50% reduction in the use of plant T are shown in Table 5.2. A 50% reduction in the heat input to plant T decreases the statewide average emissions rate to 2.95 Lbs/MMBTU. If the state in the example is required to comply with a statewide average emissions rate limit of 2.0 Lbs/MMBtu, the reduction in the use of plant T will have moved the state 5% of the way to its goal.

The calculation of the effect of reducing the use of plant T on total emissions is shown in Table 5.3. A 50% reduction in the use of plant T would result in lowering the state's monthly emissions from 30,000 to 27,500 tons. If the state were required to comply with an emissions ceiling of 20,000 tons per month (equivalent to a 2 Lbs/MMBtu statewide average emissions rate limit), the reduction in the use of plant T will have moved the state 12.5% of the way to its goal.

The example shows that when conservation is used to reduce the use of a power plant with an emissions rate above the statewide average, an emissions ceiling gives more credit for the resulting emissions reductions than a statewide average emissions rate limit. In this example, application of the statewide emissions rate limit gave less than half the credit compared to the application of the ceiling. Therefore, states and utilities have more incentive to incorporate electricity conservation in their emissions reduction strategies if required to comply with an emissions ceiling.

If for some reason the statewide average emissions rate approach is followed, the total heat input to all major utility boilers in a

Table 5.2

HYPOTHETICAL EXAMPLE
EFFECT OF CONSERVATION ON STATEWIDE AVERAGE EMISSIONS RATE

Power plants	(A) Emissions rate (Lbs/MMBtu)	(B) Weighting factor	AxB
Before conservation:			
A-S	2.895 (1)	19.0/20.0	2.75
T	5.00	1.0/20.0	0.25
	Statewide average emissions rate -		3.00 (2)
After conservation:			
A-S	2.895	19.0/19.5 (3)	2.82
T	5.00	0.5/19.5	0.13
	Statewide average emissions rate -		2.95

Notes:

(1) Knowing that the state's average emission rate is 3.0, and that each plant is weighted according to its heat input when calculating the statewide average emission rate, the average emission rate (X) of plants A-S is given by: 19/20 X + 1/20 (5.0) = 3.0. X = 2.895.

(2) The state's average emissions rate is the sum of the weighted emissions rates for all plants (2.75 + 0.25).

(3) Conservation has cut heat input at plant T from 1 trillion Btu to 0.5 trillion Btu, which has reduced total heat input for all plants from 20 to 19.5 trillion Btu.

Table 5.3

HYPOTHETICAL EXAMPLE
EFFECT OF CONSERVATION ON STATEWIDE EMISSIONS

Power plants	Total emissions (tons/month)
Before conservation:	
A-S	27,500 (1)
T	2,500
Monthly total emissions -	30,000
After conservation:	
A-S	27,500
T	1,250
Monthly total emissions -	28,750

Notes:

(1) Nineteen plants each burning 1 trillion Btu per month with an average SO2 emissions rate of 2.895 Lbs/MMBtu.

Table 5.4

HYPOTHETICAL EXAMPLE
EFFECT OF CONSERVATION ON STATEWIDE AVERAGE EMISSIONS RATE WHEN HEAT INPUT IS HELD CONSTANT

Power plants	(A) Emissions rate (Lbs/MMBtu)	(B) Weighting factor	AxB
Before conservation:			
A-S	2.895	19.0/20.0	2.75
T	5.00	1.0/20.0	0.25
	Statewide average emissions rate -		3.00
After conservation:			
A-S	2.895	19.0/20.0	2.75
T	5.00	0.5/20.0	0.125
	Statewide average emissions rate -		2.875

state could be frozen at a certain level. For example, the heat input could be fixed at the level experienced in states in 1987. Of course, the actual heat input could continue to grow as demand for power dictates. Freezing the heat input for the purpose of calculating average emissions rate would ensure that states and utilities receive full credit for conservation-induced emissions reductions.

To illustrate the effect of freezing total heat input in a state, refer back to the example presented in Table 5.2. If the heat input is frozen at the pre-conservation level, the average emissions rate following conservation is recalculated in Table 5.4. The 50% reduction in the use of plant T then results in an average emissions rate of 2.875 Lbs/MMBtu rather than the 2.95 Lbs/MMBtu previously calculated. Thus, the state moves 12.5% closer to the assumed emissions goal of 2.00 Lbs/MMBtu. This is identical to the movement calculated by using the emissions ceiling (see Table 5.3).

Holding the heat input constant when calculating a statewide average emissions rate in effect converts the rate into an emissions ceiling. Why then propose modifying the rate limit approach instead of directly adopting the more straightforward emissions ceiling? The modified rate limit at least partly accommodates those that prefer emission rate limits to emissions ceilings on the basis that rate limits more fairly allocate emissions reductions among states. The modified rate limit is identical to an ordinary rate limit for the year in which the heat input is fixed. As time passes and use of existing plants changes, the two rate limit approaches will diverge in terms of their emissions reduction requirements. Likewise, the allocation of emissions reductions among states will change to a limited degree as power demand grows at different rates among states.

IV. INTEGRATED UTILITY PLANNING

A relatively new approach to electric utility planning has emerged in recent years. The approach, called least-cost utility planning, integrates "demand-side" and "supply-side" planning into a comprehensive evaluation framework that seeks to provide energy services (heat, light, motive power, etc.) at the lowest possible cost [3]. Demand-side planning refers to the evaluation of the options utilities have to influence the way their customers use energy, i.e., conservation and load management programs. Supply-side planning refers to the evaluation of options utilities have for generating or purchasing power. All feasible demand-side and supply-side options can then be ranked according to cost effectiveness, and implemented as needs dictate. Also, factors such as reliability, safety, environmental impacts, and social concerns can be taken into account in the ranking.

Least-cost utility planning is steadily gaining acceptance among energy planners. The concept was adopted in 1980 as part of the Northwest Electric Power Planning and Conservation Act, which requires periodic preparation of least-cost plans for the Pacific Northwest region served by the Bonneville Power Administration. The Northwest Power Planning Council developed major least-cost plans for the region in 1983 and 1985 [4].

Nevada has a law that requires least-cost utility planning [5]; Michigan is currently studying its electricity supply and demand options under a least-cost approach; and the Wisconsin Public Service Commission issued an order requiring utilities to prepare least-cost plans [6]. In addition, the U.S. Congress adopted a Least-Cost Utility Planning Initiative in 1985. It requires the Department of Energy to provide information that will help utilities and utility commissions prepare least-cost plans [7].

Any state or utility confronted with substantial emissions reduction requirements could greatly benefit from adopting least-cost planning. This can lead to systematic and integrated evaluation of electricity supply, electricity conservation, and even emissions control options. A state could use the impetus provided by mandated emissions reductions (and the associated costs) to adopt a least-cost planning approach. This will help to minimize the cost of emissions reductions and, as demonstrated in this study, could lead to an overall reduction in the cost of energy services.

An integrated approach to environmental and utility planning is needed to take full advantage of the opportunities presented by end-use electricity conservation. For example, if accelerated conservation is incorporated into a state's emissions reduction strategy, it may be necessary for utilities to offer financial incentives and take other actions to stimulate conservation. This in turn may require direction and oversight from a regulatory commission. In addition, statewide minimum efficiency standards may be needed. (See Chapter 6 regarding ways for maximizing the adoption of conservation measures.) Therefore, close cooperation between state energy authorities, utility commissions, and environmental departments is called for.

In most states, however, the functions of planning and managing energy conservation programs, power generation, and environmental protection are housed in separate divisions and agencies. More often than not, these divisions and agencies do not engage in integrated planning. The result is that the agency responsible for environmental planning and regulation ends up responding to each electric generating plant on an ad hoc basis. The agency probably has the authority to regulate emissions from a new power plant, but is not involved in decisions regarding whether that plant is needed and whether or not there are more cost-effective alternatives to the new power plant.

Better integration of utility and environmental planning should lead to improved strategies for addressing issues such as acid rain abatement. Some states recognize this and are taking steps to bring together energy and environmental planners. For example, subsequent to completing a study on how energy conservation can lower the cost of an acid rain control program, a special committee in Wisconsin recommended that the Governor establish an Acid Rain Research Advisory Council made up of state government officials from the State's Departments of Administration and Natural Resources and the Public Service Commission [8]. Massachusetts is in the early stages of forming an interagency working group to address joint energy-environmental issues like acid rain. As planned, the group will include representatives from the state energy agencies, utility commission, and environmental agency [9].

As shown in this study, the rewards for simultaneously considering the potential for electricity conservation, needs for power capacity expansion, and emissions reductions can be large. An integrated planning approach that combines demand-side and supply-side electricity planning along with environmental planning increases the likelihood of realizing these rewards.

V. RECOMMENDATIONS FOR LEGISLATION

1. Statewide emissions ceilings are preferable to statewide average or source-by-source emissions rate limits for mandating emissions reductions.

A statewide emissions ceiling is the most flexible legislative approach. It gives full credit for emissions reductions induced by electricity conservation. Under a statewide average emissions rate limit, a state at best receives partial credit, and would actually be penalized when conservation leads to reduced use of cleaner-than-average power plants. Under a plant-by-plant emissions rate limit, a utility or state may not receive full credit for emissions reductions due to cutbacks in power plant use. Conservation must be used to "mothball" or prematurely retire dirty power plants in order for states and utilities to defer or avoid certain pollution controls.

2. Change the method of calculating compliance with a statewide average emissions rate limit.

Some observers argue that a statewide average emissions rate limit is an inherently fair way to allocate emissions reductions among states. If a statewide average emissions rate limit is preferred over statewide emissions ceilings, the total heat input to all major utility boilers in a state should be frozen (for purposes of the emissions rate calculation) at the level in a particular year. This will ensure that full credit is received for emissions reductions due to electricity conservation.

3. Exclude unbuilt power plants from those plants covered by a statewide average emissions rate limit, but include all existing plants.

As discussed earlier, the 1985-86 Waxman bill creates an incentive for construction of new power plants by including them in the calculation of average emissions rate. Since new plants are required to be relatively clean, they help a state lower its average emissions rate. We recommend including only existing power plants in the calculation of the statewide average emissions rate limit. If this is done, states would not be penalized for conserving electricity and deferring construction of new power plants.

The Proxmire bill does not include new power plants among those included in the statewide average emissions rate, but the rate limit in this bill only applies to those sources not defined as "new sources" in the Clean Air Act. Since there are numerous existing power plants that are defined as new sources, the bill subjects only part of all existing power plants to a statewide average emission rate limit. The effect of this is to not give credit for conservation that is used to reduce the operation of existing, "new source" power plants.

4. Do not require certification of conservation programs as a precondition for certain emissions control options.

The Proxmire bill requires that states undertake conservation programs in order to use an emissions ceiling rather than a rate limit. But a state's preference for an emissions ceiling or an emissions rate limit will depend largely on the amount of emissions reduction required under each approach. In cases where a state prefers the ceiling solely because it requires less emissions reductions than the rate limit, requiring initiation of conservation programs could result in poorly designed and managed programs that are not effective. This would be a waste of money and a deterrent to subsequent, more serious conservation efforts.

5. Do not require that states determine the electricity savings and emissions reductions directly attributable to conservation programs.

Electricity conservation can provide enormous benefits through lower emissions and reduced energy service costs, and should be legitimately encouraged. Furthermore, evaluating alternative load growth scenarios along the lines done in this study is important for understanding potential economic and environmental benefits. However, it is difficult to accurately determine the amount of energy savings resulting from particular conservation programs. Estimating the associated emissions reductions is even more difficult. Such requirements could discourage states from aggressively pursuing conservation, and are unnecessary if statewide emissions ceilings are mandated.

6. Require states to submit annual load growth and emissions reports, along with revised compliance plans as necessary.

When filing an emissions control plan that specifies how a state intends to comply with federal acid rain legislation, a state will need to estimate electric load growth between the date the compliance plan is filed and the time when the emissions reduction requirements take effect. Underestimating electric load growth could lead to increased operation of dirty power plants and failure to meet the emissions requirements by the mandated deadline, if appropriate steps such as adopting additional control measures are not taken. Conversely, if electricity demand grows less rapidly than projected, fewer emissions controls may be needed.

States should be required to file annual emissions and electric load growth reports with the EPA. If the reports indicate that the emissions and load projections contained in the original plan are reasonably accurate and that the state is proceeding towards timely compliance, the plan could remain unchanged. On the other hand, if the annual reports indicate that conditions have deviated significantly from the original plan, a state should be obligated to modify its original emissions control plan to ensure timely compliance.

7. Require states to consider end-use efficiency improvements and least-cost utility planning in conjunction with emissions reduction planning.

Federal acid rain legislation should require states to consider end-use efficiency improvements and to strive for least-cost energy services when they develop their emissions reduction plans. Least-cost utility planning can ensure that both end-use efficiency improvements and supply-side investments are systematically evaluated and implemented in the most cost-effective manner. This can help to minimize the overall cost of complying with federal acid rain control legislation.

VI. NOTES AND REFERENCES

1. Acid Rain and Transported Air Pollutants, OTA-O-204, Office of Technology Assessment, U.S. Congress, Washington, DC, June 1984.

2. Personal communication with Ralph Cavanagh and David Hawkins, Natural Resources Defense Council, San Francisco, CA and Washington, DC, 1987.

3. "Least-Cost Electrical Strategies: An Information Packet", Energy Conservation Coalition, Washington, DC, Jan. 1987.

4. See, for example, Northwest Conservation and Electric Power Plan, Northwest Power Planning Council, Portland, OR, 1985.

5. J. Wellinghoff and C. Mitchell, "A Model for Statewide Integrated Utility Resource Planning", Public Utilities Fortnightly, Aug. 8, 1985.

6. "Findings of Fact, Conclusions of Law, and Order for Advance Plans for Construction of Facilities", Docket No. 05-EP-4, Wisconsin Public Service Commission, Madison, WI, Aug. 1986.

7. Hearing Report on Least Cost Utility Planning Initiative, Report No. 53, Committee on Science and Technology, U.S. House of Representatives, Washington, DC, Sept. 26, 1985.

8. "A Course of Action to Reduce Acid Rain in Wisconsin", Wisconsin Acid Deposition Review Committee Final Report, Madison, WI, Jan. 1986.

9. Personal communication with Steve Kaufman, Division of Air Quality Control, Massachusetts Department of Environmental Engineering, Boston, MA, March 1987.

Chapter 6

MAXIMIZING THE ADOPTION OF MORE EFFICIENT EQUIPMENT

The analysis of conservation potential (Chapter 2) showed that it is cost-effective to reduce electricity consumption by 26% in the ECAR region through the adoption of more energy-efficient end-use technologies. The vast majority of these technologies are proven and commercially available; a few are prototypes that are expected to become available in the near future.

The utility simulation analysis (Chapter 4) showed that realizing a large fraction of this potential can totally offset the cost of substantial emissions reductions. This leads to a variety of questions about adoption of more energy-efficient technologies. For example, how much of the savings potential can be obtained "in the real world"? And, how can energy planners and policy makers maximize adoption? In this chapter, we examine strategies for maximizing cost-effective efficiency improvements.

I. MARKETPLACE TRENDS AND EXPECTATIONS

The overall energy efficiency of the U.S. economy has dramatically improved during the past 15 years. Overall energy consumption per unit of GNP fell 24% between 1973 and 1985 [1]. Regarding electricity, total consumption has continued to rise in recent years, although at much lower rates than prior to 1975. During 1976-85, total electricity use grew at an average rate of 2.5%/yr, while electricity use per unit of GNP fell at an average rate of 0.5%/yr.

For certain electrical end-uses, there is a clear shift towards greater efficiency. For example, the average refrigerator sold in 1985 consumed 36% less electricity than the average model sold in 1972 [2]. During the same period, the average refrigerator size increased by 13%. Likewise, the efficiency of new air conditioners increased 25-32% on average between 1972 and 1985 [3].

Regarding commercial buildings, electricity use per square foot of floor area in 1983 was 18% lower in buildings constructed during 1980-83 compared to buildings constructed during 1974-79 [4]. Total energy use per unit of floor area dropped even more when comparing post-1980 buildings with late-1970s vintage. Lighting technology is one area where overall efficiency is improving. A recent review of the U.S. lighting market indicated that the market share for energy-efficient fluorescent lamps is growing and now accounts for about 20-30% of all sales of standard 48" lamps [5].

In other end-use areas, however, adoption of electricity-conserving end-use technologies has been limited. For example, there has been minimal improvement in the average efficiency of new residential electric water heaters during the past 15 years [6]. Sales of heat pump water heaters are still very low even though this technology has been available for over five years. In the industrial sector, it is estimated that less than 5% of motors in use in 1985 were of the energy-efficient type [7]. Likewise, the adoption of electronic adjustable speed drives for industrial motors is proceeding slowly and is far from the cost-effective potential [7, 8]. Regarding lighting products, electronic ballasts and optical reflectors are just beginning to be adopted on a significant scale [5].

The acceptance and market penetration of energy-efficient technologies is a consequence of a complicated mix of factors, including manufacturing decisions, consumer behavior, institutional considerations, regulations, and conservation programs. Numerous studies and reviews have shown that there is widespread underinvestment in end-use efficiency among consumers in all sectors [9, 10, 11]. The factors and barriers inhibiting greater purchase and use of energy-efficient equipment include:

- many technologies were recently commercialized and are still undergoing improvement,
- lack of awareness among consumers,
- uncertainty regarding savings and payback,
- lack of capital and resistance to buying equipment with a greater first cost,
- energy conservation investments are required to show a rapid payback and high rate of return,
- separation of responsibilities for making capital investments and paying operating costs.

Although there are numerous obstacles to the widespread implementation of more energy-efficient end-use technologies, a number of market forecasts indicate that implementation and adoption of efficiency improvements will greatly expand during the next 15 years. For example, an EPRI study projects that industrial motors with adjustable speed drives will be responsible for about 45% of electricity use by motors in 2000, up from around 4% in 1980 [8]. In the area of lighting, manufacturers indicate that electronic lamp ballasts could account for as much as 50% of ballast sales by 1995 [5]. In the area of residential appliances, minimum efficiency standards and other factors are expected to lead to an additional 40% reduction in the average electricity use of new refrigerators and freezers between 1986 and 2000 [12].

Various initiatives can help to overcome the barriers to conservation and hasten the implementation of more efficient technologies, including:

- o manufacturers offering and promoting efficient products,
- o governments adopting minimum efficiency standards for equipment and buildings,
- o utilities offering financial incentives such as rebates or subsidized loans to stimulate consumer adoption,
- o utilities organizing and paying for direct installation of conservation measures,
- o policy makers and consumers taking greater interest in least-cost energy services.

The remainder of the chapter focuses on minimum efficiency standards, financial incentives, and direct installation as ways of accelerating and maximizing the adoption of electricity-conserving technologies.

II. MINIMUM EFFICIENCY STANDARDS

Minimum efficiency regulations adopted at the federal or state level can be one of the most effective means for stimulating the purchase and use of more energy-efficient equipment. Such regulations either bar the sale of products that fail to achieve some minimum level of efficiency, or force products or buildings to meet specific performance requirements.

Efficiency standards provide "assured savings" by eliminating inefficient products or buildings. Consequently, standards reduce the uncertainty associated with forecasting future energy demand in an unregulated marketplace. One concern with efficiency standards is that the requirements can become outdated. Therefore, it is important to review and update standards regularly.

Minimum efficiency standards have been or could be applied to appliances, residential and commercial buildings, lighting products, and motors. The following sections review the experience with and savings potential from standards on appliances, buildings, and lighting products.

A. APPLIANCE STANDARDS

Several states including California, Massachusetts, and New York have enacted minimum efficiency standards for appliances sold within their borders. California set the precedent, having adopted comprehensive standards during the mid-1970s that have been updated periodically. It is estimated that California's appliance efficiency standards will reduce electricity use by over 3300 GWh/yr, reduce peak power needs by 1750 MW, and save consumers in California more than $600 million by 1987 [13]. This makes appliance standards the most effective conservation program in California.

After many years of delay, national residential appliance standards were adopted into law in March, 1987. The standards take effect in 1990 for refrigerators, freezers, water heaters, and room air conditioners. For central heating and cooling equipment, the standards mainly take effect in 1992. The standards are relatively stringent -- in most cases, 70-90% of the models produced in 1986 won't be permitted once the standards take effect. In addition, the Department of Energy is required to review and possibly tighten the standards throughout the 1990s, and may continue to do so thereafter. The national standards will be easier to enforce than state standards and will benefit manufacturers who dislike varying state regulations.

An analysis of the savings resulting from the national appliance standards shows that peak electricity demand would be reduced by 22,000 MW and that total residential energy consumption would drop by 1 Quad or about 6% in 2000 [12]. These savings estimates are in addition to moderate gains in efficiency expected in an unregulated marketplace. The analysis also shows that the standards are very cost-effective for consumers with an overall benefit-cost ratio of 3.0 [12]. In addition, the national appliance standards should stimulate innovation and help U.S. manufacturers compete with foreign producers.

Table 6.1 shows the estimated electricity and gas savings in the ECAR region by 2000 from the national standards. These values are estimates based on the fraction of products assumed to be sold in the region. It is seen that the standards alone are estimated to cut electricity use by nearly 5000 GWh and lower peak demand by nearly 1900 MW by 2000. The electricity savings represent nearly 4% of residential electricity use in the region in 2000 in our base case scenario. Once again, the savings estimates in Table 6.1 are in addition to moderate efficiency improvements expected in the unregulated marketplace [12].

B. BUILDING STANDARDS

Many states have adopted thermal efficiency standards for new building construction, usually based on the model standards developed by ASHRAE. Residential standards usually address building thermal integrity as well as the efficiency of space conditioning equipment. Commercial standards address both fuel use for heating and electricity use for air conditioning, ventilation, and lighting. Because of the limited use of electricity use for home heating and cooling in ECAR, commercial building standards offer the greatest potential for electricity savings from building codes.

California is in the process of adopting new commercial building standards that may be the toughest in the nation. The standards are designed to achieve a high level of energy efficiency through both prescriptive and performance-based requirements. In office

Table 6.1

Savings Potential in the ECAR Region in 2000 from Appliance Efficiency Standards

Product	Electricity savings (GWh/yr)	Peak capacity savings (MW)	Total energy savings (1) (TBtu/yr)	Lifetime economic savings (2) (million $)
Refrigerators	1390	185	16	570
Freezers	330	44	4	174
El. water heaters	1920	237	22	809
Room AC	470	504	5	85
Central AC	840	892	10	60
Gas furnace	--	--	22	548
Gas water heaters	--	--	32	1074
Gas range	--	--	4	183
TOTAL	4950	1862	115	3503

Notes:

1. A TBtu is one trillion Btus; electricity is valued in this case on a primary basis (11,500 Btu per kWh).

2. Lifetime economic savings are the net savings for consumers over the lifetime of products sold between now and 2000. The savings are based on an electricity price of 7.8 cents/kWh and a natural gas price of $0.60/therm. The savings are in terms of constant 1985 dollars using a 5% real discount rate. See Reference 12.

buildings, for example, the standards are expected to cut electricity use for cooling by 16-63%, electricity use for ventilation by 0-24%, and electricity use for lighting by 32% relative to California's previous standards for new office buildings [14]. It is estimated that commercial building standards in effect in California since 1978 will cut statewide electricity use in 1989 by 3000 GWh and save 870 MW of peak demand by 1989 [15]. These values are equivalent to 1.5% of the state's expected electricity sales and 2.1% of expected peak demand in 1989.

Building standards could have a significant impact on electricity use in the ECAR region in the time frame of interest. Based on the assumptions in Appendix B, an estimated one third of housing and commercial floor space that will be in place in 2005 is still unbuilt. By adopting stringent commercial building standards, for example, it should be possible to lower total commercial sector electricity use in 2005 by 5-10%. This represents approximately 4700-9400 GWh/yr based on the projected electricity demand in 2005 in our base case scenario.

Effective implementation of buildings standards requires both enforcement and education. Enforcement can be difficult because the standards are inherently complex, code officials must be well-trained, and on-site inspections are necessary. In California, for example, substantial resources are devoted to training, design manuals, calculation techniques, and evaluation of compliance [15].

C. LIGHTING STANDARDS

We estimate that lighting accounts for 40-50% of commercial building electricity use, 12% of residential use, and 4% of industrial electricity use in the ECAR region. Overall, lighting accounts for about 15% of regionwide electricity use, and over half of this is thought to be fluorescent lighting.

A number of states including California, New York, and Massachusetts have adopted minimum efficiency standards for fluorescent lamp ballasts. The standards require the sale and use of energy efficient core-coil ballasts, which consume about half as much electricity as standard ballasts [5]. Energy-efficient ballasts reduce the total electricity use in fluorescent lamp fixtures by about 10%. Massachusetts's fluorescent ballast standard is projected to reduce peak summer demand in 2000 by 240 MW [16]. This is equal to 5% of the projected statewide peak demand in commercial buildings in 2000 [19].

It is feasible to consider adopting minimum efficiency standards for fluorescent lamps as well as ballasts, although no states have adopted lamp standards so far. In recent years, a wide variety of energy saving lamps have become available for the full range lighting applications. A standard could be expressed in terms of a minimum lumen per watt rating for different size lamps e.g., at least 85 lumens per watt for 48" lamps, in effect requiring the use of "supersaver" or "watt-miser" lamps. This would reduce electricity use by 15-20% compared to standard fluorescent lamps [5]. Moreover, the full impact from adopting such a standard would occur within a few years due to the frequent replacement of fluorescent lamps.

Adopting fluorescent lamp and ballast standards could lower electricity consumption in the ECAR region by about 9000 GWh in the year 2005. This is equal to about 10% of projected commercial electricity use in the region in our base case scenario. Such standards should have an even greater impact on peak demand because of the high degree of fluorescent lighting use during peak periods.

III. UTILITY INCENTIVE PROGRAMS

In order to produce a plausible accelerated conservation scenario using the IEUPM, we assumed that utilities heavily invest in end-use efficiency through comprehensive rebate incentives. It is becoming increasingly common for utilities to provide financial incentives to stimulate efficiency improvements on the part of their customers. A survey completed in 1986 found that more than half the households in the nation are served by utilities that offer rebates or low-interest loans for certain efficiency measures [17].

This section reviews how electric utilities can use rebates and subsidized loans to increase investment in end-use efficiency. In addition, important nonfinancial aspects of incentive programs are discussed.

A. REBATE PROGRAMS

A survey of utility rebate programs conducted by the American Council for an Energy-Efficient Economy and the Consumer Energy Council of America in 1986-87 (hereafter called the ACEEE survey) found 59 utilities offering rebates to purchasers or sellers of energy-efficient equipment [18]. Most of these programs are offered by electric utilities and/or apply to electrical equipment. Rebate programs are underway throughout the country, although the ACEEE survey shows the largest concentration of programs in the South, Mid-Atlantic, and Pacific regions. Three utility rebate programs were found in the ECAR region, but all three are pilot and/or small-scale efforts.

Reducing peak demand, which in turn reduces the need for new generating capacity, is the primary reason given for offering rebates. It is not surprising, therefore, that air conditioners and heat pumps are the most common products for which incentives are offered. Nearly 60% of the utilities with residential programs include heat pumps and 39% include central air conditioners. A large majority of utilities are satisfied with their rebate programs.

While rebates for residential equipment are more common than rebates in other sectors, commercial and industrial (C&I) programs are gaining in popularity due to the large amount of electricity use in these sectors (C&I users account for 65% of electricity consumption in ECAR). The ACEEE survey found 24 C&I rebate programs with emphasis on energy-efficient lighting and air conditioning equipment.

Qualification levels and rebate amounts vary from program to program. In some cases, fixed rebates are given; in other cases, the rebate amount increases with efficiency. The sliding scale approach encourages the purchase of highly efficient models and product innovation. Over 90% of the utilities provide rebates to the purchaser; about 24% offer rebates to the seller.

Regarding program scale, rebate programs vary from pilot programs with funding of under $100,000 per year to full-scale savings acquisition programs. The ACEEE survey found five residential and two commercial programs with budgets over $5 million per year. Approximately half the utilities include their rebate programs in the rate base and about half treat them as an operating expense.

Table 6.2 presents the budgets and other characteristics for six of the largest and most effective utility rebate programs now underway. All of these utilities are offering rebates to both residential and commercial-industrial customers. For the six utilities listed in the table, the average peak demand savings is 62 MW per year. Comparing the savings estimates to actual peak demand for each of the utilities, these six programs are cutting peak demand by 0.35-1.38% per year, with an average reduction of 0.69%/yr. The program operated by the Austin, TX municipal utility is having an especially large impact because large incentives are offered, the program is heavily promoted, both dealers and purchasers are eligible for rebates and have responded to the program, and because economic growth and equipment sales have been relatively high in Austin.

The experiences of the six utilities listed in Table 6.2 confirm that rebate programs can have a significant impact on electricity use. While the savings that result in our accelerated conservation scenario for the ECAR region (0.8%/yr average reduction in electricity demand relative to the base case during 1985-2005) is greater than what most of the utilities listed in Table 6.2 have achieved, the utilities generally have a budget constraint and are offering rebates on a limited number of products. The utilities should be able to obtain even greater savings given higher funding, greater promotion, and expanded coverage.

B. LOAN PROGRAMS

Some utilities are providing low- or no-interest loans to encourage customers to purchase energy-efficient equipment or to

Table 6.2

CHARACTERISTICS OF SELECTED MAJOR UTILITY REBATE PROGRAMS (1)

Utility	Products (2)	Annual budget (million $)	Peak demand savings (MW/yr)	Fraction of peak saved (%/yr)
Austin, TX Elect. Dept.	Res: AC, HP C&I: LT, HVAC, MO	5.9	19.3	1.38
Florida P&L	Res: CAC, HP, WH C&I: LT	23.7	59.3	0.57
Northern States Power Co.	Res: RF, FR, AC, HP, WH; C&I: LT, HVAC, MO	3.8	18.8	0.35
Pacific Gas and El. Co.	Res: RF; C&I: HVAC, LT, MO, EMS	24.9	56.2	0.40
Southern Cal. Edison Co.	Res: RF, AC, HP, WH C&I: HVAC, LT, MO	22.0	81.1	0.55
Texas Ut. Co.	Res: AC, HP, WH C&I: HVAC, LT	17.0	140.0	0.88

Notes:

1. The annual budget and peak demand savings figures apply to both the residential and commercial-industrial programs in the most recent year for which data are available. The fraction of peak demand saved by the rebate program is presented in terms of the percentage of total summer peak demand. See Ref. 18.

2. Product codes: RF - refrigerator, FR - freezer, AC - air conditioners, HP - heat pumps, WH - water heaters, HVAC - commercial heating, ventilating, and air conditioning systems, LT - lighting, MO - motors, EMS - energy management systems

weatherize their buildings. The objective is to reduce the first-cost barrier to investing in conservation and sometimes to offer a loan repayment plan in which energy bill savings exceed monthly loan payments.

Offering low-interest loans can improve both the degree of participation and the resulting energy savings in residential conservation programs. Comparison of utility programs throughout the country shows that combined audit-loan programs have participation rates six times greater than audit-only programs on the average [21]. Utilities such as the Bonneville Power Administration and Northern States Power Co. have found that consumers who receive a loan as well as an audit save much more energy than consumers who only receive an audit [9, 21].

TVA has offered zero-interest and low-interest loans for home weatherization and heat pumps since 1977. By the end of 1984, over 500,000 loans had been made with an estimated reduction in winter peak demand of more than 600 MW, about 3% of peak demand [20]. Although TVA has emphasized the residential sector in its electricity conservation programs so far, the utility plans to greatly expand its C&I audit and low-interest loan programs in the future.

Experience shows that loan programs can result in high administrative costs and debt-service expenses for utilities [9]. Also, when customers are given a choice of a rebate or low-interest loan, they tend to prefer the rebate. Southern California Edison Co., for example, found that only 2% of the participants in their residential conservation incentive program preferred a loan over a rebate [18]. Puget Sound Power and Light had similar results when it offered commercial customers either a cash grant or a zero-interest loan [21]. For these reasons, some utilities have phased out their loan programs.

C. NONFINANCIAL ASPECTS

Availability and amount of financial incentive is one of many factors influencing whether or not consumers invest in energy efficiency. Maximizing the success of a conservation incentive program also depends on the ability to get the attention of the consumer, communicate to the consumer in an understandable and credible manner, and minimize the effort and risk associated with investing in energy efficiency [22]. Thus, the ways in which conservation programs are organized, marketed, and implemented are extremely important.

The effect of nonfinancial factors is evident when considering the responses to different programs that contain identical financial incentives. For example, nine utilities in New York offered low-interest loans for home weatherization during 1978-84. There was a 50-fold variation in program participation rate between the highest and lowest utility [23]. Likewise, the Bonneville Power Administration offered financial incentives for home weatherization through local utilities in the Pacific Northwest. There the most successful utility weatherized eligible homes at 13 times the rate of the least successful utility [23].

Involving local community groups has proven to be one program element that can greatly increase the effectiveness of residential conservation programs. Experience with residential audits in Minnesota showed that community groups provided four times the response rate and delivered better quality audits then utility-performed audits [23]. Involving community groups in promotion, audits, and retrofit work is also used by many utilities to increase participation and adoption rates among low-income households [23, 24].

Marketing and outreach are important factors affecting the impact of incentive and other conservation programs. Studies of commercial customer behavior suggest the following strategies for maximizing adoption and program effectiveness in this sector [25, 26]:

1. Direct programs to those responsible for investment decisions with an understanding of the decision criteria and process utilized as well as the barriers that inhibit investment.

2. Tailor program design and marketing strategy to different market segments, based on building type, ownership and organizational type, company size, degree of technical sophistication, etc.

3. Directly contact owners and decision makers to solicit program participation.

4. Demonstrate the non-energy advantages of energy-efficient equipment or services such as increased comfort, productivity, flexibility, or reliability.

5. Reduce the uncertainty associated with conservation investments through demonstrations, guarantees, etc.

Working with "trade allies" is another important aspect of maximizing conservation adoption. For example, appliance and equipment dealers and contractors need to stock and encourage the purchase of efficient products in order for a rebate program to be successful. Many utilities involve vendors in the design and implementation of their incentive programs, some even pay dealers or contractors when they sell or install qualifying products [18].

IV. DIRECT INSTALLATION PROGRAMS

Direct installation involves a utility or contractor hired by a utility installing conservation measures in eligible homes or commercial-industrial facilities at no cost to the owner. Consequently, a high level of participation and adoption can be obtained. The utility benefits by avoiding new energy supplies and the associated capital investment and operating costs.

Direct installation programs are often adopted in "hard to reach" markets that don't respond well to information and incentive programs, such as low-income and rental housing. Although direct installation programs have been implemented predominantly in the residential sector, there is no reason why they could not be applied in other areas.

Free installation is employed in a number of utility-sponsored low-income weatherization programs [24]. Pacific Gas and Electric Co., for example, greatly increased the participation of low-income households when it switched from a zero-interest loan to free installation [27]. In addition, the cost per household turned out to be about the same for the utility because of the high debt-service, outreach, and overhead costs with the loan program.

Utilities in California sponsored an innovative direct installation and audit program in Santa Monica, a city with 78% rental housing. The Santa Monica Energy Fitness program involved door-to-door canvassing of every household, streamlined audits, and free installation of up to three low-cost conservation measures oriented primarily towards natural gas and water savings [28]. During the one year program, about 35% of the households in the city participated. The program cost only $87 per participant and resulted in 5.4% natural gas savings in participating households, yielding a 3.5 year payback based on the value of the actual energy and water savings [28]. Expanding the list of conservation measures might have increased energy savings and program effectiveness.

General Public Utilities has contracted with private companies to provide lower-cost conservation retrofits in selected electrically-heated households at no cost to the consumer. The utility pays the contractor based on actual electricity savings. This program, known as RECAP, was tested in four communities in Pennsylvania and New Jersey in 1983-85.

Table 6.3 lists the results in the four communities. The participation rates are much greater than is customary in financial incentive programs [29]. However, the RECAP program resulted in only moderate electricity savings (7.6% on average), in part because some contractors limited their work to the most cost-effective conservation measures, i.e., measures with the highest electricity savings per dollar installed, to maximize their profit. With an

Table 6.3

RESULTS FROM GENERAL PUBLIC UTILITIES'S RECAP PROGRAM

Community	Number of participants	Participation rate (1) (%)	Total electricity savings (2) (%/yr)	Average retrofit cost (3) ($)
Covered Bridge, NJ	320	43	8.9	270
Leisure Village, NJ	3000	>90	4.8	480
York, PA	368	16 (4)	9.7	1340
Reading, PA	1500	25	6.9	595
TOTAL	5188	36	7.6	670

Notes:

1. Fraction of eligible households in which retrofits were performed.

2. Fraction of pre-retrofit electricity saved due to participation in RECAP, based on actual performance and statistical analysis.

3. Total retrofit cost per household including marketing, materials, and labor.

4. Low market penetration was due primarily to early withdrawal of the contractor.

Source: Reference 29.

average cost of $670 and average savings of 1560 KWh/yr in retrofit households, the RECAP pilot program was reasonably cost effective [29]. Also, the program was profitable for three of the four contractors.

The last example of direct installation is the Hood River Conservation Project (HRCP). The demonstration project sought to install as many cost-effective conservation measures in electrically-heated homes in Hood River, Oregon as possible during 1983-86. The Bonneville Power Administration paid for both audits and the installation of conservation measures.

Of the 3500 eligible households in Hood River, about 91% received an energy audit and 85% had one or more major retrofit measures installed [30]. The enormous success of the HRCP in achieving participation was due to utility funding, community-based marketing approaches, extensive word-of-mouth communication among residents, and determination on the part of HRCP staff to reach every household.

Eighty-three percent of the conservation measures recommended in the energy audits were actually installed [31]. The measures include low-cost items such as low-flow showerheads and water heater wraps as well as major measures such as ceiling, wall, and floor insulation. Conservation cost effectiveness was viewed from the societal perspective, thereby permitting homes to be retrofitted to a high degree of thermal integrity.

Analysis of pre- and post-retrofit electricity consumption data found a typical savings of 2600 kWh/yr (14%) in homes retrofit in Hood River [32]. Savings in single family homes that used electricity as their primary heating fuel were 4000 kWh/yr (16%). Although substantially greater savings were predicted based on energy audits, actual savings are usually less than predicted savings in home retrofit programs. Changes in energy-related behavior such as higher indoor temperatures and less use of wood fuel accounted for part of the discrepancy in Hood River [32].

V. CONCLUSION

A variety of policy and program options are available to stimulate greater adoption of energy-efficient end-use technologies. Government authorities can adopt minimum efficiency standards affecting appliances, buildings, and lighting products. Utilities can offer financial incentives or engage in the direct installation of conservation measures.

A state or region interested in stimulating a high degree of electricity conservation could put together a complementary package of programs and policies to achieve this objective. For example, stringent appliance standards have been adopted at the federal level, but states can go ahead with building standards tailored to the local climate and conditions. Lighting standards could be implemented at either the national or state level. Utilities could offer substantial rebates to stimulate the adoption of measures not covered by the standards, and even provide rebates when there is still a range of efficiency levels in the marketplace after standards have been adopted [33]. Finally, utilities could engage in direct installation in areas where standards or more limited incentives are not effective.

At present, it appears that such policies and programs are lacking to a great extent in the ECAR region. While the national appliance standards will have an impact in the region, none of the states appear to have or are considering adopting stringent standards in other areas. Furthermore, utilities in ECAR generally are not among the growing number of utilities that are pursuing and bringing on line cost-effective "conservation resources" through rebates, direct installation, and other financial incentive programs.

The acid rain issue provides the opportunity and motivation for energy authorities and utilities in the region to move to the forefront in end-use electricity conservation. The economic benefits from greater end-use efficiency can more than compensate for the cost of large emissions reductions. Our accelerated conservation scenario involves a reduction in regional electricity consumption of about 73,000 GWh (15.4%) in 2005 relative to the base case scenario. This is an ambitious but achievable target if utilities and energy officials make the commitment to providing least-cost energy services while they are reducing acid rain emissions.

VI. NOTES AND REFERENCES

1. "Monthly Energy Review", DOE/EIA-0035(86/09), Energy Information Administration, U.S. Dept. of Energy, Washington, DC, Dec. 1986.

2. Personal communication with the Association of Home Appliance Manufacturers, Chicago, IL, 1986.

3. Personal communication with the Air-Conditioning and Refrigeration Institute, Arlington, VA, 1986.

4. "Commercial Buildings Consumption and Expenditures 1983", DOE/EIA-0318(83), Energy Information Administration, U.S. Dept. of Energy, Washington, DC, Sept. 1986.

5. Marbek Resource Consultants Ltd., "Energy Efficient Fluorescent Lighting in Canadian Office Buildings: Technologies, Market Factors, and Penetration Rates" report prepared for the Energy Conservation Branch, Dept. of Energy, Mines and Resources, Government of Canada, Ottawa, July, 1986.

6. H.S. Geller, "Energy Efficient Appliances: 1986 Update", Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy, Washington, DC, Aug., 1986.

7. R.J. Moe, et al., "The Electric Energy Savings from New Technologies", PNL-5665 Rev. 1, Pacific Northwest Laboratory, Richland, WA, Sept. 1986.

8. Resource Dynamics Corp., "Electrotechnology Reference Guide", EPRI EM-4527, Electric Power Research Institute, Palo Alto, CA, April, 1986.

9. E. Hirst, et al., *Energy Efficiency in Buildings: Progress and Promise*, American Council for an Energy-Efficient Economy, Washington, DC, 1986.

10. H. Ruderman, et al., "Energy-Efficiency Choice in the Purchase of Residential Appliances", in W. Kempton and M. Neiman, eds., *Energy Efficiency: Perspectives on Individual Behavior*, American Council for an Energy-Efficient Economy, Washington, DC, 1987.

11. *Industrial Investment in Energy Efficiency: Opportunities, Management Practices, and Tax Incentives*, Alliance to Save Energy, Washington, DC, July, 1983.

12. H.S. Geller, "Energy and Economic Savings from the National Appliance Efficiency Standards", American Council for an Energy-Efficient Economy, Washington, DC, March 1987.

13. "California's Appliance Standards: An Historical Review, Analysis, and Recommendations", P400-83-020, California Energy Commission, Sacramento, CA, 1983.

14. "A Compendium of Major California Conservation Programs", P300-84-017, California Energy Commission, Sacramento, CA, May, 1984.

15. J.A. Wilson, "Efficiency Standards in California's Energy Policy", in S. Sawyer and J. Armstrong, eds., *State Energy Policy: Current Issues, Future Directions*, Westview Press, Boulder, CO, 1985.

16. S. Nadel, et al., "The Case for Home Appliance Efficiency Standards in Massachusetts", Massachusetts Audubon Society, Lincoln, MA, Feb. 1986.

17. D. Dickey, et al., "Effects of Utility Incentive Programs on the Average Efficiency of New Residential Appliances", LBL-18339, Lawrence Berkeley Laboratory, Berkeley, CA, Aug. 1986.

18. "A Compendium of Utility-Sponsored Energy Efficiency Rebate Programs", American Council for an Energy-Efficient Economy and Consumer Energy Council of America, Washington, DC, 1987.

19. Personal communication with Ann Bachman, Office of Energy Resources, Commonwealth of Massachusetts, Boston, MA, 1987.

20. "Energy Conservation Program", Division of Conservation and Energy Management, Tennessee Valley Authority, Knoxville, TN, May 1984.

21. G.W. Lehenbauer, "Marketing Energy Management to Commercial Facilities: Utility Program Field Experience", in *Meeting Energy Challenges*, Proceedings of the Second Great PG&E Energy Expo - 1985, Pergamon Press, New York, NY, May 1985.

22. P.C. Stern and E. Aronson, eds., Energy Use - The Human Dimension, W.H. Freeman and Co., New York, NY, 1984.

23. P.C. Stern, et al., "The Effectiveness of Incentives for Residential Energy Conservation", *Evaluation Review 10*, No. 2, April 1986, pp. 147-176.

24. L. Berry, M. Hubbard, and D. White, "A Review of Financial Incentive, Low-Income, Elderly and Multifamily Residential Conservation Programs", ORNL/CON-206, Oak Ridge National Laboratory, Oak Ridge, TN, Sept. 1986.

25. S.S. George, "Commercial Customer Acceptance of Demand-Side Management: Conservation Programs", in *Productivity Through Energy Innovation*, Proceedings of the Third Great PG&E Energy Expo - 1986, Pacific Gas and Electric Co., San Francisco, CA, 1986.

26. T.M. Dinan, "Understanding the Market for Conservation Technologies in the Commercial Sector", *Proceedings of the ACEEE 1986 Summer Study on Energy Efficiency in Buildings*, Vol 5, American Council for an Energy-Efficient Economy, Washington, DC, Aug. 1986, pp. 5.37-5.49.

27. D.H. Moulton, "The Impact of Utility-Sponsored Conservation Loan Programs on Low-Income Households", *Proceedings of the ACEEE 1984 Summer Study on Energy Efficiency in Buildings*, Vol H, American Council for an Energy-Efficient Economy, Washington, DC, Aug. 1984, pp. 104-116.

28. K. Egel, "Final Evaluation of an RCS Program Alternative: The Santa Monica Energy Fitness Program", *Proceedings of the ACEEE 1986 Summer Study on Energy Efficiency in Buildings*, Vol 10, American Council for an Energy-Efficient Economy, Washington, DC, Aug. 1986, pp. 10.42-10.54.

29. M.A. Brown and D.L. White, "Impact Analysis of a Residential Energy Conservation Shared Savings Program: The General Public Utilities Experience", ORNL/CON-217, Oak Ridge National Laboratory, Oak Ridge, TN, Feb. 1987.

30. E. Hirst and R. Goeltz, "Dynamics of Participation and Supply of Services in the Hood River Conservation Project", ORNL/CON-210, Oak Ridge National Laboratory, Oak Ridge, TN, July 1986.

31. R. Goeltz and E. Hirst, "Residential Retrofit Measures in the Hood River Conservation Project: Recommendations, Installations, and Barriers", ORNL/CON-208, Oak Ridge National Laboratory, Oak Ridge, TN, June 1986.

32. E. Hirst, R. Goeltz, and D. Trumble, "Electricity Use and Savings in the Hood River Conservation Project", ORNL/CON-231, Oak Ridge National Laboratory, Oak Ridge, TN, April 1987.

33. Minimum efficiency standards and financial incentives can be complementary since standards eliminate the least-efficient products from the market and incentives can stimulate consumers to purchase the very best products. For example, state ballast efficiency standards generally ban the sale of conventional magnetic ballasts (requiring more efficient magnetic ballasts or very efficient electronic ballasts). Thus, utilities could still offer rebates to stimulate the purchase of the top-rated electronic ballasts.

APPENDIX A

ELECTRICITY END-USE BREAKDOWN FOR THE ECAR REGION

I. INTRODUCTION

This appendix describes in detail how electricity is used within the ECAR region. It begins with a breakdown among the three major end-use sectors -- residential, commercial and industrial. It then presents the intrasectoral breakdowns for each of the sectors. The analysis applies to electricity use in 1985.

Figure A.1 presents the fraction of electricity going to each of the three major sectors, to street lighting, and to other end uses. The industrial sector is clearly dominant, accounting for almost half of all electricity sales. The residential sector is second largest with 30.5% of all sales and the commercial sector is third with 20.1%. Total electricity use in the ECAR region in 1985 was 353,000 GWh [1].

II. The Industrial Sector

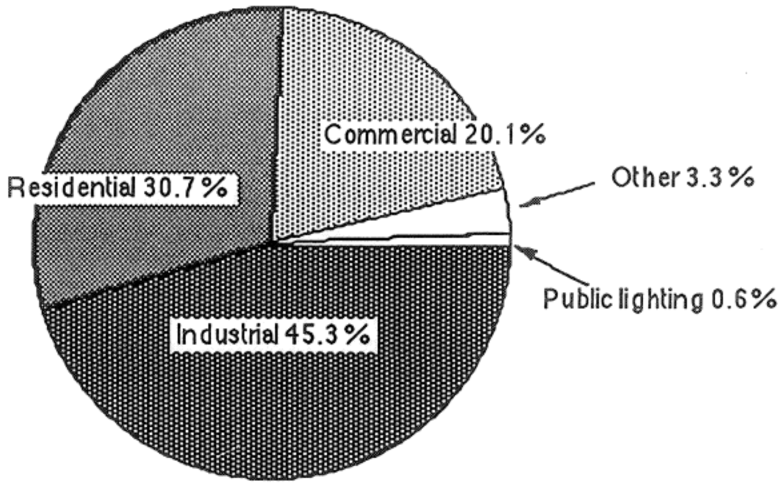
As shown in Table A.1, about two-thirds of the industrial electricity consumption in ECAR occurs in the areas of primary metals (40.1%), chemicals and allied products (14.2%), and transportation equipment (10.3%). Fourteen other industry groups together make up the remaining 35.4% of industrial demand in the region [2]. The data were obtained from the survey of manufacturers completed in 1980 [2].

Table A.1 also shows electricity consumption by specific industries for the top three industry groups. Blast furnaces and basic steel production is the largest single consumer, accounting for 69% of the primary metal group's electricity use and over 27% of total industrial use in the region. Motor vehicles and equipment is second with 92% of the transportation group's electricity demand, and 9.5% of total demand. Industrial inorganic chemicals follows at 52% of the chemicals group and 7.4% of overall industrial electricity use.

We did not locate any data on specific electricity end uses within the ECAR region, but national studies indicate that about 75% of total industrial electricity use is by motors that drive pumps, fans, compressors, conveyors, and related equipment [3, 4, 5]. We estimate that motors account for 77.1% of industrial electricity use in the ECAR region, slightly higher than the national average. This estimate is derived by taking the percentage of electricity used by motors in each SIC industrial class as estimated nationally [6], and multiplying by the amount of industrial electricity use in each class in the region (see Table A.2).

FIGURE A.1

SECTORAL ELECTRICITY USE IN THE ECAR REGION
TOTAL ELECTRICITY SALES, 1984



Source: EEI Statistical Yearbook, 1984

Table A.1

INDUSTRIAL ELECTRICITY USE IN THE ECAR REGION, 1980 (1)

SIC group	Industry	Total elect. use (GWh/yr)	Fraction of SIC group (%)	Fraction of total (%)
33	Primary metal industries	47,157	100	40.1
331	Blast furnace, basic steel	32,539	69	(27.6)
332	Iron and steel foundries	7,828	17	(6.7)
335	Nonferrous rolling/drawing	4,621	10	(3.9)
33-	Other primary metals	2,169	5	(2.0)
28	Chemicals and allied products	16,742	100	14.2
281	Industrial inorganic chemicals	8,706	52	(7.4)
282	Plastics, synthetics	1,490	9	(1.3)
286	Industrial organic chemicals	5,157	31	(4.4)
28-	Other chemicals	1,390	8	(1.1)
37	Transportation equipment	12,151	100	10.3
371	Motor vehicles and equip.	11,227	92	(9.5)
372	Aircraft and parts	693	6	(0.6)
37-	Other transportation	231	2	(0.2)
34	Fabricated metal products	6,835	100	5.8
35	Machinery, except electrical	6,409	100	5.4
32	Stone, clay and glass products	5,148	100	4.4
--	Other industries	23,252	--	19.8
--	All industries	117,694	--	100.0

Notes:

1. Data from Indiana, Kentucky, Michigan, Ohio, and West Virginia; does not include portions of western Pennsylvania and Maryland within ECAR, nor electricity use for uranium enrichment.

Source: *1980 Annual Survey of Manufactures*, Bureau of the Census, U.S. Dept. of Commerce, Washington, DC.

Table A.2

INDUSTRIAL ELECTRICITY USE BY MOTORS IN THE ECAR REGION IN 1980

SIC group	Industry group	Total elect. use (1) (GWh/yr)	Fraction by motors (%)	Motor elect. use (GWh/yr)
20	Food and kindred products	4,508	81	3,651
21	Tobacco products	178	73	130
22	Textile mill products	223	79	176
23	Apparel and other textiles	292	73	213
24	Lumber and wood products	866	74	641
25	Furniture and fixtures	653	74	483
26	Paper and allied products	3,293	81	2,667
27	Printing and publishing	1,426	73	1,041
28	Chemicals and allied prod.	16,742	63	10,547
29	Petroleum and coal products	2,218	83	1,841
30	Rubber and misc. plastics	4,222	87	3,673
31	Leather and leather prod.	30	73	22
32	Stone, clay and glass prod.	5,148	92	4,736
33	Primary metal industries	47,157	77	36,311
34	Fabricated metal products	6,835	85	5,810
35	Machinery, except electrical	6,409	81	5,191
36	Electric and elect. equip.	4,501	83	3,736
37	Transportation equipment	12,151	76	9,235
38	Instruments and related prod.	447	70	313
39	Misc. manufacturing	395	70	276
--	TOTAL	117,694	77.1	90,742

Notes:

1. Data from IN, KY, MI, OH, and WV; does not include portions of western PA and MD within ECAR, nor electricity use for uranium enrichment.

Sources: *1980 Annual Survey of Manufactures*, Bureau of the Census, U.S. Dept. of Commerce, Washington, DC.

Classification and Evaluation of Electric Motors and Pumps, DOE/CS-0147, U.S. Dept. of Energy, Feb. 1980.

The three other large industrial electricity uses are electrolytic processing, process heat, and lighting [7]. Because of the application-specific nature of process uses, lighting is the only other area in which we analyze conservation potential. We estimate that lighting accounts for about 4% of industrial electricity use in the ECAR region.

III. RESIDENTIAL SECTOR

Electricity use in the residential sector was analyzed in a three-step process. First, estimates of unit energy consumption (UEC) for the major residential end uses were collected and compared in order to develop a regional "average" (see Figure A.2). Then, estimates of appliance saturations were collected and regional values were developed (see Figure A.3). Finally, the regional UEC's were multiplied by the regional saturations to get average demand values across all residential electric customers (see Table A.3).

The regional UEC value for space heating is equal to the population-weighted average degree-days for the region [8] multiplied by an estimate of kWh per degree-day [9]. All other regional UEC values are simple averages of utility UEC estimates [10]. The regional saturation values are all population-weighted averages of estimates from four utilities in the region [11].

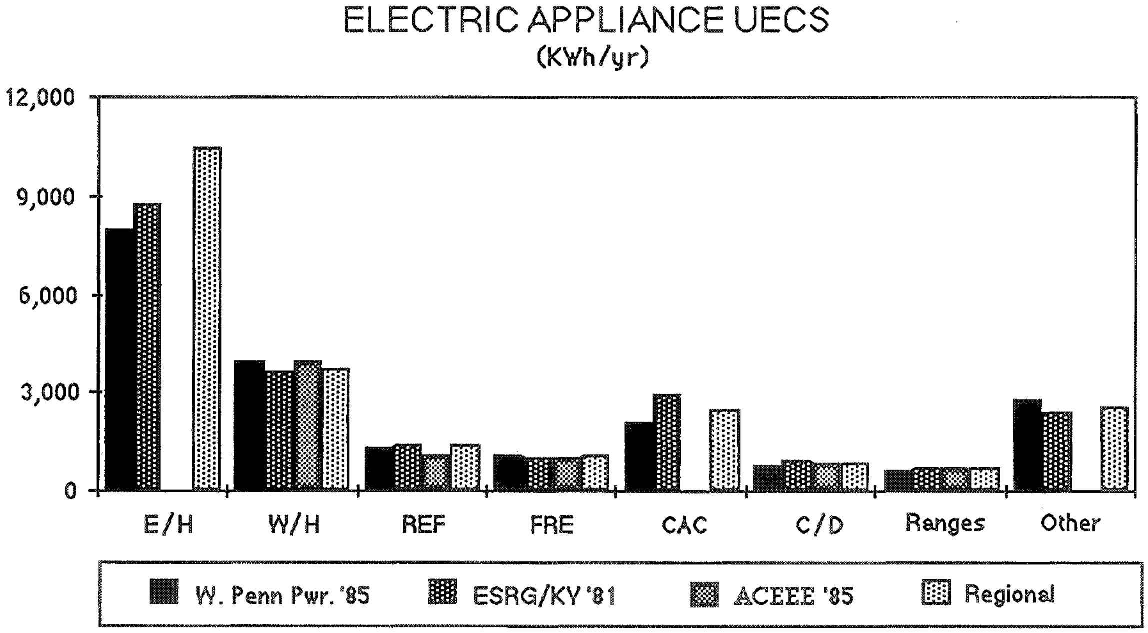
As Figure A.4 indicates, the largest single end use in ECAR's residential sector is refrigerators, which account for 18.3% of demand, or 1540 kWh/yr for the average household. Electric water heaters are the second largest end use (14.5%), space heating is the third largest (12.8%), and lighting (11.9%) is fourth. The remaining end uses each account for less than 7% of total residential electricity demand.

IV. THE COMMERCIAL SECTOR

A study published in 1986 estimates end-use electricity consumption in commercial buildings on a regional basis [12]. The overall end-use shares for the DOE region most closely overlapping with ECAR (including Ohio, Michigan and Indiana) are as follows: lighting (42.5%), cooling (29.1%), ventilation and other (18.1%), and heating (10.3%). These values are based on the national survey of energy use in commercial buildings conducted by the Energy Information Administration in 1979 [13].

These regional values are compared to estimates for Kentucky and the nation as a whole in Table A.4. The variations between studies are due in part to the use of different end-use categorizations. For example, HVAC system fans and motors are included as "ventilation and other" in the regional and Kentucky studies, but as heating and cooling in the national breakdown. It is apparent, however, that lighting is the dominant electricity end use in commercial buildings.

FIGURE A.2

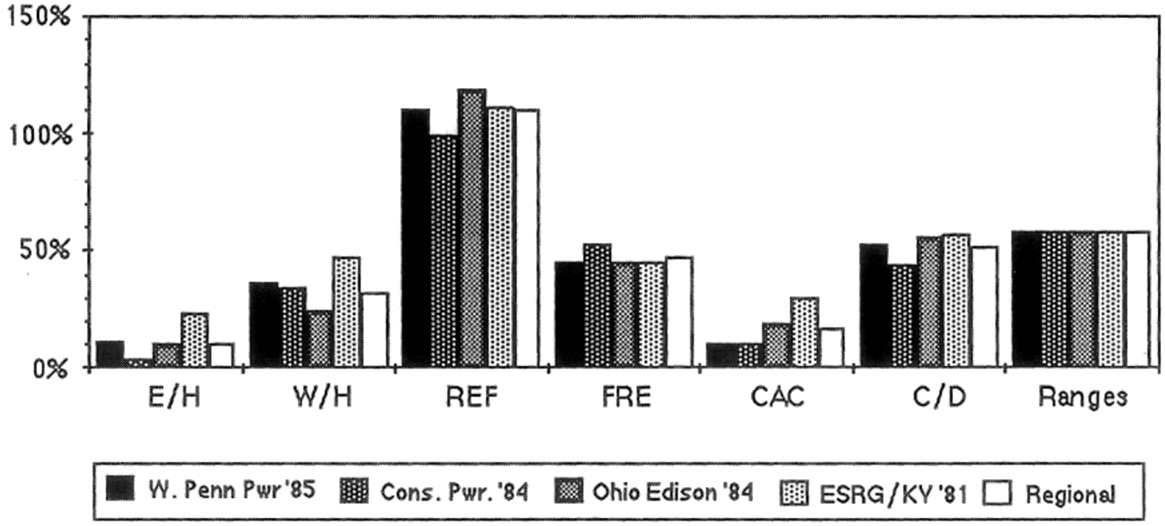


Sources:

1. 1985 Residential Appliance Survey; West Penn Power; Greensburg, PA
2. Power Planning in Kentucky: Assessing Issues and Choices; Energy Systems Research Group; Boston, MA; Jan. 1984
3. Geller, H. et.al; Residential Conservation Power Plant Study; ACEEE; Washington, D.C; Feb. 1986

FIGURE A.3

ELECTRIC APPLIANCE SATURATIONS



Sources:

1. 1985 Residential Appliance Survey; West Penn Power; Greensburg, PA
2. 1984 Residential Survey; Consumers Power Co.; Jackson, MI; May 1985
3. 1982 Appliance Saturation Survey; Ohio Edison Co.; Akron, OH; April 1983
4. Power Planning in Kentucky: Assessing Issues and Choices; Energy Systems Research Group; Boston, MA; Jan. 1984

Table A.3

RESIDENTIAL ELECTRICITY USE IN THE ECAR REGION (1)

End use	UEC per appliance (kWh/yr)	Saturation (%)	UEC per customer (kWh/yr)
Space heating	10,500	10	1,081
Water heating	3,800	32	1,221
Refrigerators	1,400	110	1,543
Freezers	1,100	48	530
Central AC	2,500	17	430
Clothes dryers	880	52	456
Ranges	700	58	408
Lighting	700	100	1,000
Other (2)	--	--	1,750
TOTAL	--	--	8,420

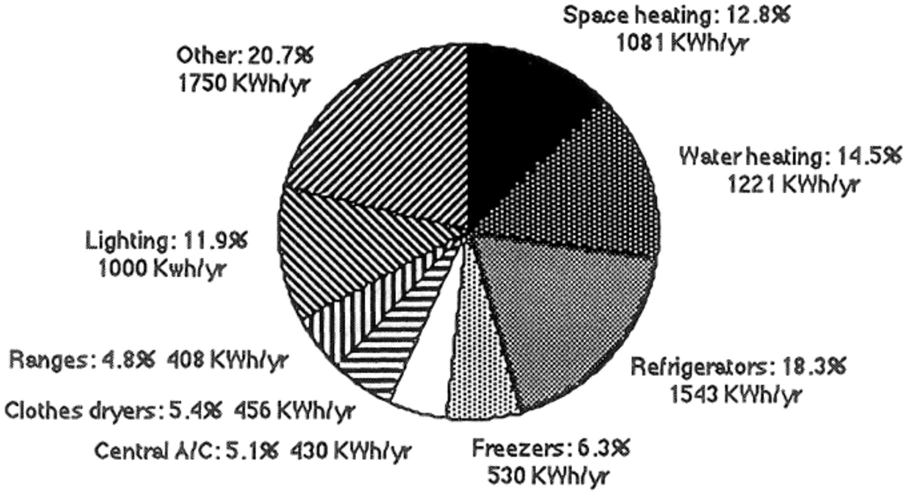
Notes:

1. UEC stands for unit energy consumption.

2. Other includes room air conditioners, clothes washers, dishwashers. televisions, and all small appliances.

FIGURE A.4

ELECTRICITY USE IN ECAR'S RESIDENTIAL SECTOR



Average Annual Residential Electricity Use in ECAR is 8,420 KWh/yr

Table A.4

COMMERCIAL SECTOR ELECTRICITY END USES

End use	DOE Region 5 (1) (%)	Kentucky (2) (%)	National (3) (%)
Lighting	42.5	48.5	39.7
Cooling	29.1	17.5	36.1
Ventilation and other	18.1	30.8	15.8 (4)
Heating	10.3	3.2	6.6

Notes:

1. DOE region 5 contains OH, IN, MI, IL, and WI. Georgia Institute of Technology, "The COMMEND Planning System: National and Regional Data and Analysis", EPRI EM-4486, Electric Power Research Institute, Palo Alto, CA, March 1986.

2. "Power Planning in Kentucky: Assessing Issues and Choices", Energy Systems Research Group, Boston, MA, Jan. 1984.

3. J.L. Blue, et al., "Buildings Energy Use Data Book: Edition 2", ORNL-5552-Ed-2, Oak Ridge National Laboratory, Oak Ridge, TN, Dec. 1979.

4. In this breakdown, electricity use by ventilation motors and fans is included in cooling or heating.

V. NOTES AND REFERENCES

1. *Electric Power Monthly*, DOE/EIA-0226(84/12), Energy Information Administration, U.S. Dept. of Energy, Washington, DC, March 1985.

2. The estimates of industrial electricity use in Table 2.1 are based on the five full states in the ECAR region. The portions of western Pennsylvania and Maryland in ECAR are not accounted for. Also, these estimates exclude electricity use by the uranium enrichment plants in Paducah, Kentucky and Portsmouth, Ohio.

3. "Classification and Evaluation of Electric Motors and Pumps", DOE/CS-0147, U.S. Dept. of Energy, Washington, D.C., Feb. 1980, p. 3-65.

4. *Industrial Energy Use*, OTA-E-198, Office of Technology Assessment, U.S. Congress, Washington, D.C., June 1983, p. 50.

5. M. Ross, "Trends in the Use of Electricity in Manufacturing", *IEEE Technology and Society Magazine* 5:1, March 1986, p. 21.

6. See Reference 3, p. 3-64.

7. See reference 5.

8. Average degree-day data were taken from *1979 Systems Handbook*, ASHRAE, Atlanta, GA, 1979.

9. Estimates of space heating electricity use per degree-day were obtained by dividing UEC estimates by number of degree-days. UEC estimates were obtained from "1985 Residential Appliance Survey", West Penn Power, Greensburg, PA, 1985; and "Power Planning in Kentucky: Assessing Issues and Choices", Energy Systems Research Group, Boston, MA, Jan. 1984, p. 37.

10. UEC estimates were from West Penn Power and ESRG (previous reference) and H. Geller, et.al., "Residential Conservation Power Plant Study", American Council for an Energy-Efficient Economy, Washington, D.C., Feb. 1986.

11. Saturation estimates from: "1985 Residential Appliance Survey", West Penn Power; "1984 Appliance Saturation Survey", Ohio Edison Co.; "1984 Residential Survey", Consumers Power; and "Power Planning in Kentucky: Assessing Issues and Choices", Energy Systems Research Group.

12. Georgia Institute of Technology, "The COMMEND Planning System: National and Regional Data and Analysis", EPRI EM-4486, Electric Power Research Institute, Palo Alto, CA, March 1986.

13. "Nonresidential Buildings Energy Consumption Survey: Characteristics of Commercial Buildings 1983", DOE/EIA-0246(83), Energy Information Administration, U.S. Dept. of Energy, Washington, D.C., July 1985.

APPENDIX B

INTEGRATED ELECTRIC UTILITY PLANNING MODEL

I. OVERVIEW

The Integrated Electric Utility Planning Model (IEUPM) is used to assess energy service costs and acid rain emissions in the ECAR region, particularly in response to accelerated electricity conservation. The IEUPM is written in DYNAMO, a computer language designed for models using the System Dynamics methodology. The technique was originally developed to study the feedbacks between elements of a system. The approach is best used for generating insights about policy design, but can also be used for system planning at a strategic level.

Fig. B.1 illustrates the overall structure of the IEUPM. The model simulates the key activities undertaken by consumers and utilities. The demand sub-model simulates the electricity demand and conservation investments made by consumers on an end-use specific level. The model forecasts these conservation investment decisions with and without incentive programs. The supply sectors of the model simulate the routine operations, capacity additions and retirements, finance, regulation, and SO2 emissions for all the utilities in the region. The IEUPM is described in greater detail in a previous report [1].

The IEUPM independently determines the penetration of energy-efficient measures based on the conservation assessment and other assumptions. It is not assumed that conservation measures are fully adopted solely because they were determined to be cost effective for consumers on a life-cycle cost basis in Chapter 2. Likewise, the utility simulation model will spread out adoption of the conservation measures over an extended period of time (e.g., 10-20 years). Different scenarios for conservation penetration and adoption will be considered.

II. ECAR REGION

The model as used in this study is calibrated to the demand and generating mix of the ECAR region. The model treats ECAR as if it were a single utility, dispatching and planning generating capacity to meet the regional demand. The region's utilities do not fully dispatch their plants on a regional basis (as is the case in other parts of the country) but they are well-connected by high-voltage interties and many jointly plan and share generating resources. Also, American Electric Power, a very large interstate utility in ECAR (with 23.4 GW of installed capacity in 1985), dispatches its plants regionally.

Table B.1 summarizes the generating capacity in operation or under construction in the ECAR region as of 1985; nearly 80% of the capacity in the region is coal-fired [2]. In 1985, the region's 98.8 GW of generating capacity produced about 425 billion kWh at an average capacity factor of 49%.

Much of the coal-fired capacity in the region was constructed before the EPA's New Source Performance Standards (NSPS) required all new power plants to meet stringent SO2 emissions rate limits. These older coal units generally burn high-sulfur coal because it is inexpensive and plentiful within the ECAR region. As a result, most of the coal-fired capacity in the ECAR region has SO2 emission rates which exceed the levels required for new plants. Of the 50 dirtiest (i.e., highest sulfur emitting) power plants in the country, 23 are located in the ECAR region.

As Figure B.2 demonstrates, over 70% of the existing coal-fired capacity in the ECAR region exceeds the new source performance standards limits. In 1980, the region emitted over five million tons of sulfur and sulfur oxides, about 33% of total electric utility emissions in the U.S. [3]. The region's heavy dependence on high sulfur coal makes it a good choice for evaluating the alternative emission control strategies along with different load growth scenarios.

III. DEMAND SUB-MODEL

The demand sub-model is based on the concept that consumers want the services provided by electricity and not the electricity itself. The model tries to meet consumers' needs in a cost-effective manner given assumptions of how they will behave when making capital investments in energy efficiency. Minimizing the cost of energy services involves choosing the right mix of energy saving devices described in Chapter 2, and ordinary electricity purchases.

The demand sub-model explicitly simulates changes in electricity use due to efficiency improvements. It does not rely on price elasticities to forecast changes in demand. Rather, it specifies the physical mechanisms through which demand changes, i.e., through the purchase of more efficient equipment, and includes the resulting effects on electricity prices. This approach permits modeling of how different program actions can influence the adoption of efficiency measures and hence electricity demand.

The demand sub-model simulates the growth in demand for electricity, the rate and extent to which the conservation options identified in Chapter 2 are adopted by consumers with or without incentive programs, and constructs summer peak, annual average and minimum regional demands for electricity. The model separates electric customers into the six categories listed in Table B.2.

FIGURE B.1

INTEGRATED ELECTRIC UTILITY PLANNING MODEL STRUCTURE

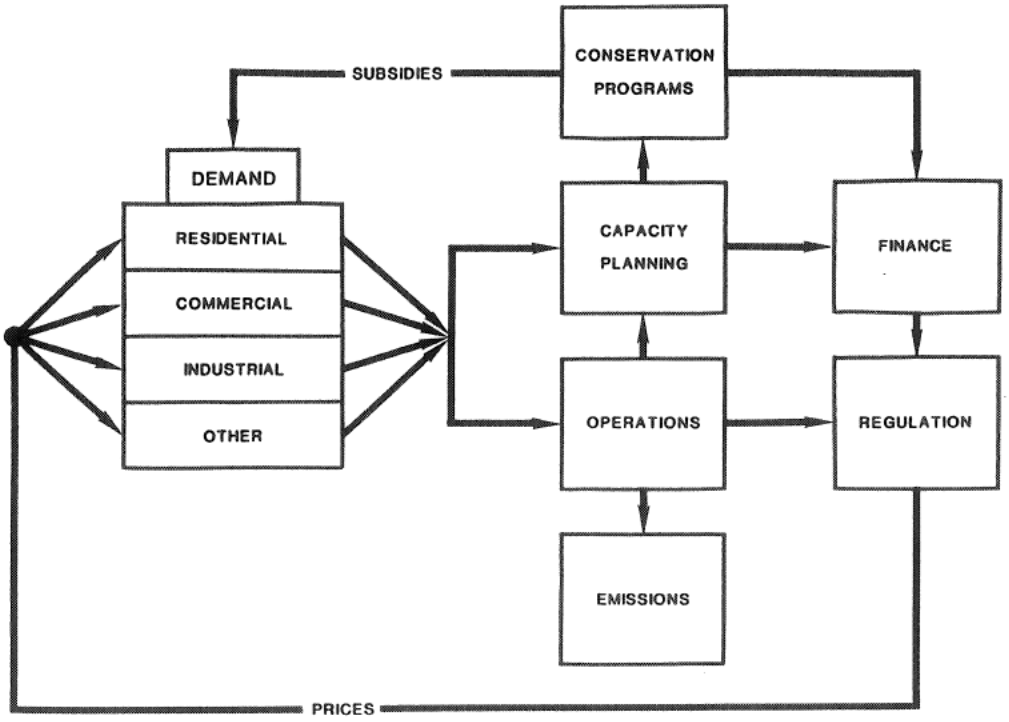


FIGURE B.2

SO2 EMISSION RATES BY UNIT

1980 ECAR REGION

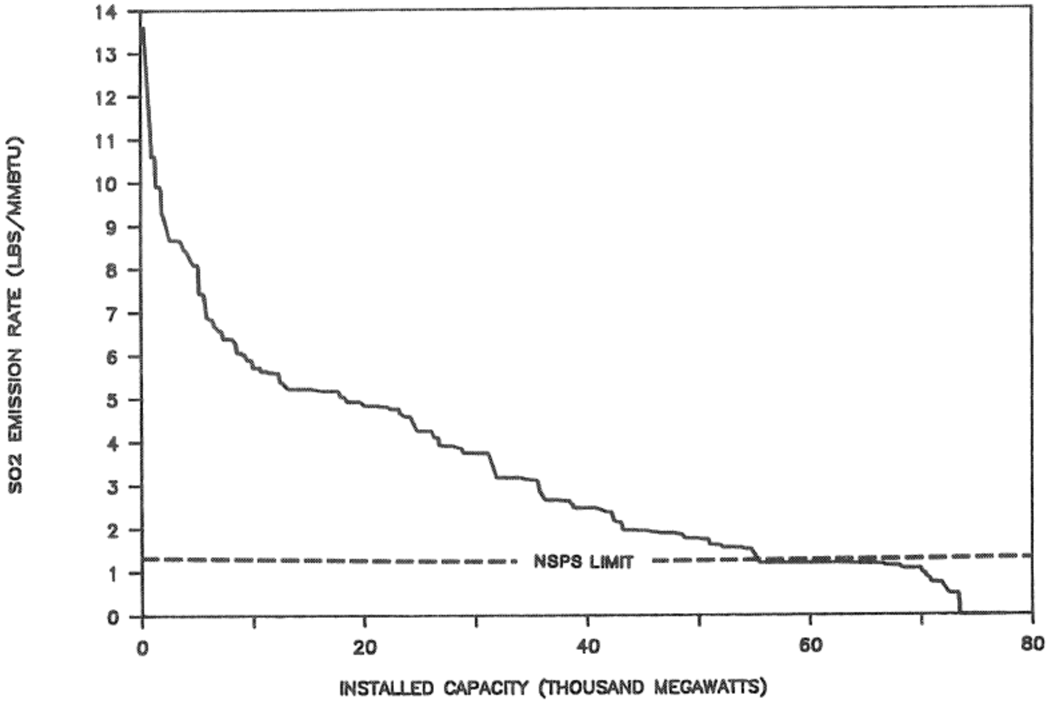


Table B.1

GENERATING CAPACITY IN THE ECAR REGION
(1985 NAMEPLATE MEGAWATTS)

Type	Existing	Under Construction	Percent of Total
Coal	78,520	3,321	78%
Nuclear	6,685	2,831	9%
Oil	2,880	0	3%
Gas Turbine	6,509	115	6%
Hydro/ Pumped Storage	4,217	0	4%
TOTAL	98,811	6,267	100%

Table B.2

CUSTOMER CATEGORIES IN THE DEMAND SUB-MODEL

RESIDENTIAL
- Space Heat
- Water Heat
- Appliances (includes lighting, air conditioning, clothes dryers, refrigerators, and freezers)

COMMERCIAL
- General (includes HVAC, lighting, and control systems)

INDUSTRIAL
- General (includes electric motors and lighting use for all major industries in the ECAR region)

OTHER
- Includes street lighting (exogenous to the model)

In each customer category, the base demand for electricity without conservation beyond what occured in 1985 is called the service demand. For residential customers, service demand is simply the building stock in the region multiplied by the 1985 electricity use per house and the saturation of electric devices for each end-use. For the commercial sector, the service demand is calculated based on the total square footage of commercial buildings in the region times the base energy use per square foot and the electric market share for devices in each end-use. For the industrial sector, the service demand is the economic activity level in the region times industrial electricity use per unit of economic output.

Table B.3 shows the major economic and demographic inputs. The growth in housing stock, commercial floorspace, and economic output are obtained from macroeconomic forecasts [4]. Changes in the price of electricity relative to alternative fuels, and changes in the fraction of homes or buildings using electricity also affect the demand for electricity. In this analysis, we have not assumed that consumers switch fuels or significantly alter their behavior related to electricity consumption. Electricity conservation occurs solely as a result of technological improvements at the point of end use.

The economic feasibility of end-use efficiency measures is evaluated in the IEUPM from the perspective of consumers. The demand sub-model determines which measures from the conservation supply curves will be adopted by comparing the extra cost of installing the conservation device with the savings from reduced electricity purchases over the life of the device. The comparison is not made by simply equating the extra cost of the device with the annual cost savings over the expected lifetime. Consumers value or act as if they value costs which occur in the future less than costs which occur in the present. The rate at which they do this is generally called the "implicit discount rate". Based on actual market behavior, researchers have calculated that consumers act as if they have high discount rates when investing in energy efficiency, with implicit discount rates in excess of 35% [5].

In theory, consumers will invest in energy efficiency up to the point at which the discounted operating savings equals the extra first cost for the last increment of operating savings. The IEUPM uses the implicit discount rate, the conservation supply curves, and the price of electricity to calculate the level at which consumers will invest in conservation saving technologies. This level is the maximum cost of saved energy that consumers are willing to accept in a particular end-use category.

Utility incentive programs which offer to pay some or all of the cost of the conservation device will increase the level at which consumers will invest in efficiency. It is straightforward to capture the effects of such incentives in the demand sub-model. For

Table B.3

GROWTH INPUTS TO THE DEMAND SUB-MODEL

Sector	1985	1995	2005	Average Growth Rate
Residential housing stock (Million homes)	16.4	20.4	25.4	2.2%/yr
Commercial floor area (Billion square feet)	2.4	2.9	3.5	1.9%/yr
Economic output (Ratio to 1985 output)	1.0	1.11	1.47	1.9%/yr
Other electricity demand (Ratio to 1985 demand)	1.0	1.18	1.38	1.6%/yr

Table B.4

COAL PLANT GROUPINGS AND ASSUMED EMISSIONS CONTROL COSTS

Group	Capacity (MW)	Average Emission Rate (Lbs/MMBtu)	Retrofit Scrubber Cost ($/kW)	Fuel Switching Premium ($/ton of coal)
First grouping based on emissions rate				
Group 1	55,111	4.16	$220	$10
Group 2	23,960	0.88	$220	$10
Second grouping based on emissions control cost				
Group 1	29,816	5.36	$184	$10
Group 2	49,601	1.88	$242	$10

example, if utilities are willing to pay 50% of the cost for conservation measures, then the maximum cost of saved energy which consumers are willing to accept doubles. In this way, utilities can increase the number of conservation devices installed by consumers. It is also straightforward to capture the effect of equipment efficiency standards in the sub-model by specifying that the efficiency of all new purchases be above a minimum point on the conservation supply curve.

As the model progresses from year to year, changes in the price of electricity, utility incentives, and possibly other factors will change the set of conservation measures that consumers find acceptable. The rate at which consumers actually adopt these measures is determined by several additional factors, and provides another opportunity for utilities to increase the magnitude of conservation investments.

Retrofit conservation measures such as upgrading the thermal integrity of buildings can be done at any time and the rate of implementation can be greatly affected by incentive programs. Appliances generally remain in use for 10-20 years, with large efficiency improvements only possible at the time of replacement. However, incentive programs can also stimulate the early retirement of appliances and other equipment. The demand sub-model contains implementation-period assumptions for conservation measures deemed cost effective in each end-use category. The model also tracks new construction (and retirement) of buildings and industrial facilities. The actual assumptions regarding implicit discount rates, implementation periods, and other inputs are provided in Chapter 3.

Figure B.3 summarizes the process of calculating the change in electricity demand from conservation. The model calculates which investments in conservation are cost effective, adjusts for the annual implementation rate, and then calculates the aggregate change in electricity demand. The resulting changes in demand affect the price of electricity through changes in electric production costs and expenditures on new capacity. Electricity prices affect the level of conservation investment, creating a feedback loop.

The model keeps track of all costs of conservation investments for both the consumer and the utility. If there is no rebate program in effect, or if a scenario includes mandatory conservation standards, consumers pay the full cost of the conservation measures. These costs are paid in the year in which they occur assuming no financing. If there is a rebate program in effect, the utility pays a specified fraction of the initial cost of the measures. This fraction can vary from 0% to 100%. Overall costs paid by the utility include a 20% administrative and promotion charge on top of the rebate payment. This is consistent with the experience of utilities conducting full scale rebate programs [6].

FIGURE B.3

CONSERVATION SAVINGS
IN THE INTEGRATED PLANNING MODEL

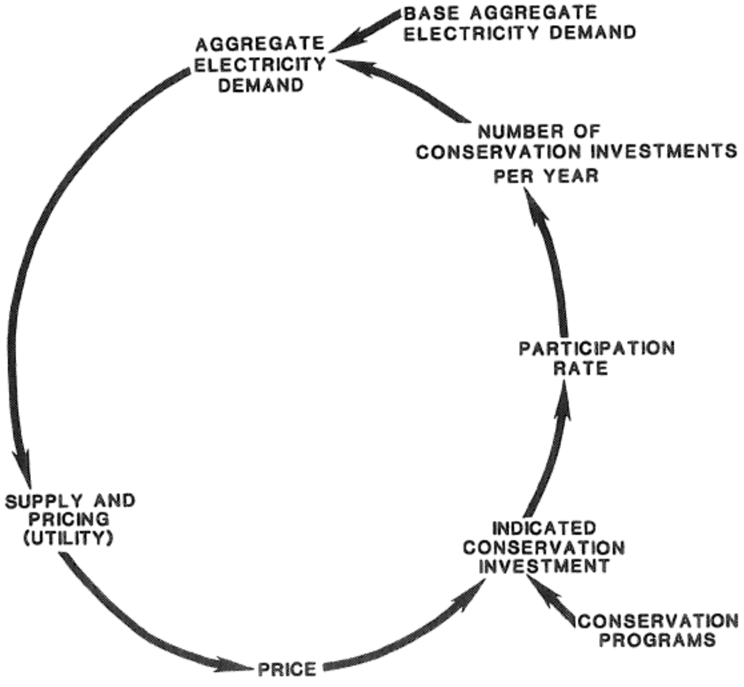
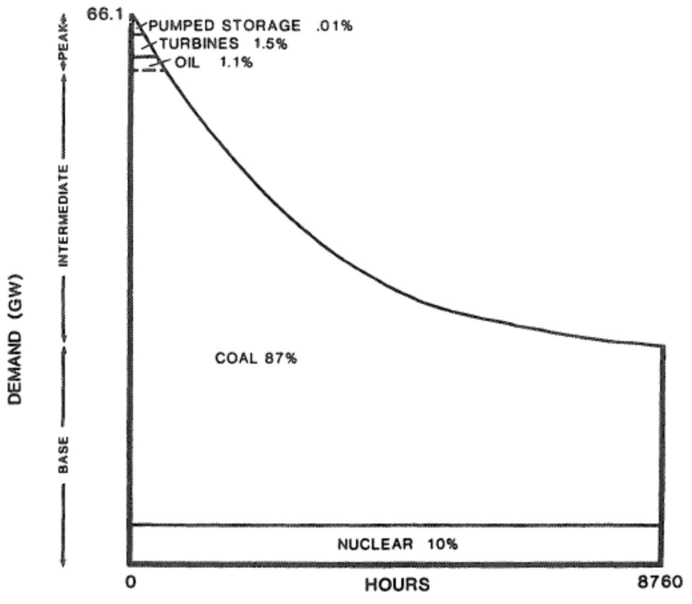


FIGURE B.4

1985 ECAR REGION LOAD DISPATCH
384 BILLION KWH



IV. SUPPLY AND PRICING SUB-MODEL

The supply and pricing sub-model simulates all of the key functions of utility operation in the region including dispatching, capacity planning, financing, rate making and emissions control. These operations are linked to the actual demand for electricity as explained previously. The utility meets demand by dispatching its generating resources to meet the load at the lowest cost. The generating resources in the region are grouped together by plant type in the model.

A. GENERATING CAPACITY

The ECAR region contains over 400 individual electric generating plants. In order to keep the model and the analysis tractable, the many different types of resources were categorized into groups. The model keeps track of the existing capacity and capacity under construction for each group. Additional generating resources are added as necessary based on the rate of demand growth. Capacity planning and additions by the model will be discussed later.

Utilities in the region are not projected to retire very much capacity over the next 20 years. Because of the high cost of new capacity, most of the existing coal fired plants in the region are likely to be "life-extended". Life-extension is a process of refurbishing old generating stations to improve their efficiency and reliability. This process generally costs much less than building a new plant and can add many years to a plant's useful life. A 1985 review estimates that life-extension of coal-fired plants typically costs $200-400/kW [7]. With life-extension, it is assumed that coal-fired plants have a 60 year operating life. Based on NERC forecasts, only 80 MW of coal-fired capacity is retired in the ECAR region during 1985-94 [8].

B. DISPATCHING

The IEUPM simulates the annual operation of the region's generating units in a simplified manner. In reality, power plants are operated in least-cost first order on an hourly basis throughout the year. The large number of generating units, and the large volume of hourly load data make a detailed, plant-by-plant analysis impractical.

Power plants cannot be relied upon to operate all of the time. They require routine maintenance, and sometimes break down unexpectedly. The IEUPM captures this fact through a figure called average availability. The availability represents the fraction of the year that plants are able to operate. These figures vary by the age and type of generating unit. The model multiplies the maximum, or "nameplate" capacity in each plant group by the average availability for that type of unit in the ECAR region [9]. The resulting figure is the reliable generating capacity capable of meeting the demand over the entire year. Table B.5 lists the assumed availabilities by plant type.

For simplicity, the model dispatches resources by group and not by individual plant. We do, however, separate the coal units into three categories to permit some degree of flexibility in targeting specific plant types for emissions control or reduced operation. New coal-fired plants are assumed to be used for base load duty and are kept separate from the existing plants. The existing plants are broken into two arbitrary groups for testing various emissions control strategies. To test the effects of a least emissions, or "environmental" dispatch strategy, we separate out the plants with the highest emissions rates and dispatch them last. To test a least-cost strategy, we separate out plants with highest emissions control costs and dispatch them last (Table B.4).

Both retrofit flue gas scrubbers and switching to low-sulfur coal are considered as emissions control options. The retrofit scrubber costs and fuel switching costs shown in Table B.4 are based on other studies of emissions control costs [10]. The low-sulfur coal premium is appropriate for the ECAR region. In Table B.4, the number of plants in each category is not significant; the categories are only used to group plants with similar characteristics such as high emission rates or low emission control costs.

The IEUPM dispatches capacity on an annual basis by allocating the various plant groupings to fill a "load-duration curve" (Figure B.4). The load-duration curve shows the number of operating hours at particular power demand levels, and how different types of generating capacity are utilized. The dispatching algorithm in the IEUPM first assumes that cogeneration facilities, nuclear capacity, and new coal plants operate at their full availability to meet baseload demand. The model then allocates the peak demand to pumped storage, combustion turbines, and oil plants using typical capacity factors for the region [11]. The remaining demand (87% in the ECAR region) is allocated to existing coal plants. If these plants are not capable of meeting all power needs, small shortages are assumed to be met by purchases from outside the region. When the power deficit becomes significant, construction of new capacity is initiated as explained in the next section.

Other dispatching assumptions used in the IEUPM include 7% transmission and distribution losses [12]. Also, the ratio of peak electricity demand to annual average demand is held constant at the value observed in the ECAR region in 1984, 1.5 [13].

The operating costs for each capacity group are computed by multiplying the actual generation for each type of capacity by the average heat rate for plant group, and by fuel price for each type of

Table B.5

ASSUMED POWER PLANT AVAILABILITY AND HEAT RATE

PLANT TYPE	AVAILABILITY	HEAT RATE (Btu/kWh)
Existing Coal	70%	10,100
New Coal	75%	9,900
Nuclear	65%	10,160
Oil	85%	10,600
Gas Turbine	95%	15,000
Pumped Storage (1)	50%	13,100
Cogeneration	85%	9,500

Notes:

(1) Heat rate includes 25% energy loss in pumping.

Table B.6

FUEL PRICE AND INFLATION ASSUMPTIONS

	FUEL PRICES (Current $/MMBtu)				
FUEL TYPE	1985	1990	1995	2000	2005
Oil	6.39	4.79	7.51	14.06	21.42
Gas	3.19	2.44	4.22	7.69	11.82
Coal	1.73	2.08	2.77	3.55	5.01
Nuclear	0.96	1.13	1.46	1.92	2.54
Inflation	3.2%	3.2%	5.2%	5.4%	5.6%

plant. The heat rate is a value which indicates the Btu of fuel input per kWh of electricity generated. The lower the heat rate, the more efficient the plant. Table B.5 includes the heat rates by plant type, compiled by averaging actual data from the ECAR region.

Table B.6 lists the fuel price and inflation assumptions used throughout the analysis. They are based on the Summer 1986 long-term fuel price and inflation forecast by Data Resources, Inc. The coal prices are for typical high-sulfur coal now burned by utilities in the region. Power plant operating and maintenance costs are not available on a regionwide basis, so there is no way to compare actual operating expenses with those forecast by the supply sub-model. However, the overall electricity costs generated by the IEUPM calibrate well with actual data and more detailed production cost models.

C. CAPACITY PLANNING

A principal feature of the IEUPM is that it can actually initiate construction of new power plants as needed. The model forecasts future demand and capacity availability and constructs new facilities whenever the utility is projected to fall below a target reserve margin. The reserve margin is the percent of total capacity in excess of peak demand for electricity in any year. For Midwest utilities, a 20% reserve margin is considered adequate [14].

The region currently has considerable excess generating capacity. The reserve margin in the region in 1985 was about 30% [15]. The extra capacity combined with the anticipated low load growth means that relatively few generating plants will need to be added over the next 20 years. Chapter 3 describes in detail the projections of the timing and magnitude of capacity additions. In this section, the algorithm used by the model to initiate new construction is explained.

For considering generating capacity additions (see Figure B.5), the IEUPM first forecasts future electricity demand over the number of years required to construct new capacity (about 7 years) based on recent trends in demand growth. Future demand is then converted to generating requirements using a reserve margin of 20%. Next the model compares this figure to available generating capacity, accounting for projected plant retirements and completions over the planning horizon. If available capacity falls below the projected generating requirement, construction of new capacity is initiated to fill the shortfall. This procedure is repeated each year during a simulation run.

Generating capacity is added in a least-cost first order based on the assumptions shown in Table B.7. The capacity planning algorithm first adds peaking capacity until peak capacity has reached 15% of the total capacity (as is typical for most utilities). The model then

Table B.7

NEW PLANT CAPITAL COSTS AND CONSTRUCTION PERIODS

PLANT TYPE	CAPITAL COST IN 1985 (1) ($/kW)	CONSTRUCTION PERIOD (Yrs)
Plants under construction:		
Nuclear	2770	(2)
Coal	1500	(2)
Gas Turbine	400	(2)
Plants not yet started:		
Coal	1210	7
Gas Turbine	400	5

Notes:

(1) All construction costs escalate 2.1%/yr in real terms [18].

(2) Construction periods and completion dates for capacity in progress are based on the NERC projections for the ECAR region [15].

adds coal-fired units for base and intermediate load needs. No new nuclear capacity is initiated, but units currently under construction are assumed to be completed as planned [16]. The new capacity costs shown in Table B.7 are based on plant completion in 1985 [17]. These costs are escalated at 2.1% per year in real terms [18].

The model accumulates Construction Work in Progress (CWIP), and Allowance for Funds Used During Construction (AFUDC) as power plants are being built. Upon completion, these assets become part of the rate base and begin to earn a return. The cost of the construction financing, and the costs of long term financing are determined by the current mix of debt, common stock and preferred stock. The financial sector of the supply sub-model keeps track of these values.

D. FINANCING

The financing sector of the model accounts for the capital requirements needed to pay for new generating capacity, pollution control equipment, and investments in end-use efficiency on the part of utilities. The model keeps separate account of debt, preferred stock and common stock (see Figure B.6). The financial sector issues debt and stock to cover investments according to target capitalization ratios (50% debt, 20% preferred stock and 30% common stock). These figures are the average values for the utilities in the ECAR region [19].

The costs of utility conservation programs can be either expensed in the year in which they occur, or capitalized and included in the rate base. If they are expensed, they simply are passed through to the rate payer in the year in which they occur. If the costs are capitalized, the utility must finance the costs, but can include the cost of the conservation as part of the rate base, and earn a return on the investment. In the analysis which follows, we will be testing aggressive conservation programs which are designed to provide enough savings over about 10 years to defer numerous new power plants in the region. As the utilities will incur large costs for such programs, we assume that they will capitalize the full cost of the conservation incentives just as they would capitalize supply-side investments. This approach treats conservation consistently with conventional generation resources, and allows the utility to earn a return on conservation investments.

E. ASSETS, DEPRECIATION, AND PRICING

The assets and depreciation sector tracks the total asset base of existing capacity and new construction as it is completed. The assets for existing plants are calculated by taking the original capital costs for typical plants in the region and depreciating them over the average age of the plants in each group. For simplicity, we only track book depreciation. We adjust the tax rate to compensate for the increased income due to the lower depreciation. The tax rate

FIGURE B.5

CAPACITY PLANNING

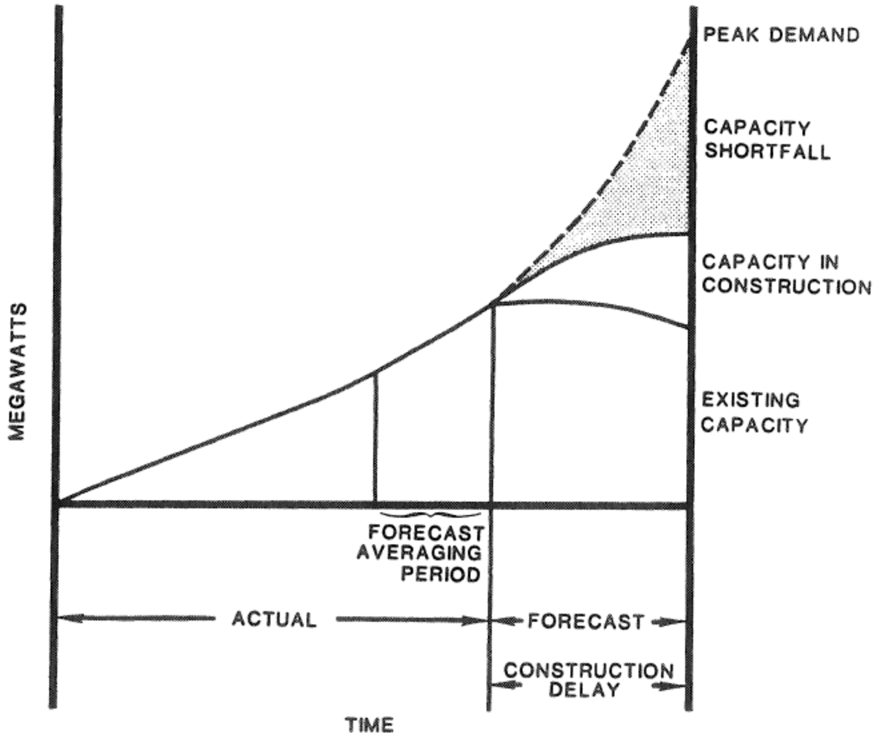
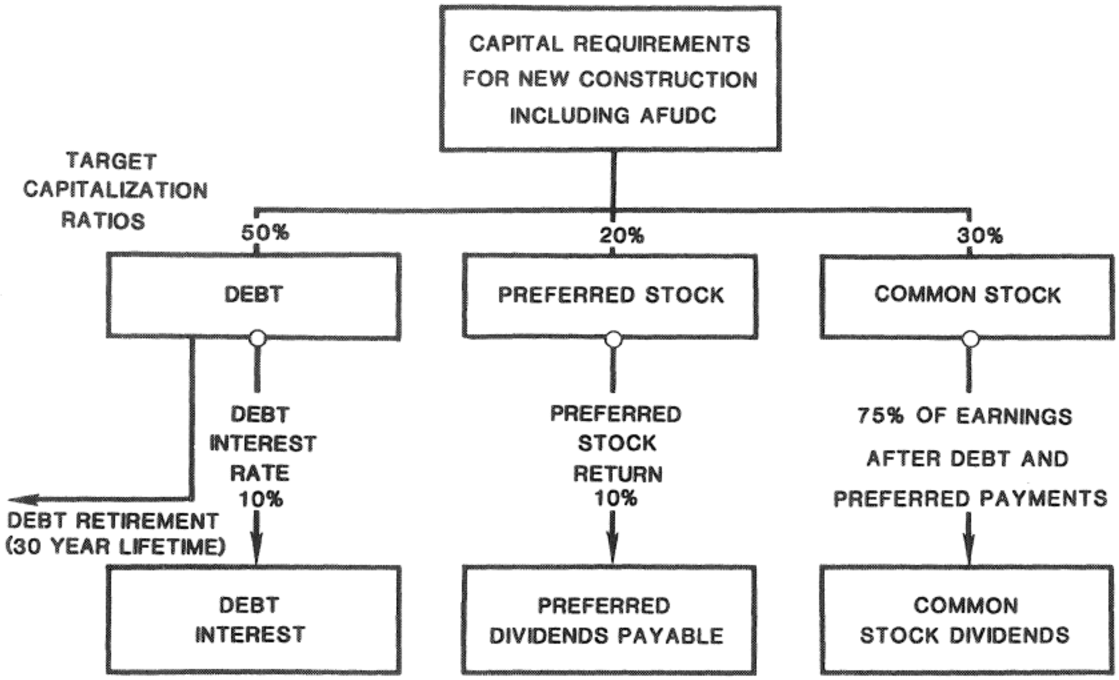


FIGURE B.6

FINANCIAL SECTOR



adjustment takes into account the 1986 tax reform legislation.

The assets, depreciation, financing costs, operating costs, and electric demand feed into the price regulation sector of the supply sub-model (see Figure B.7). This sector calculates revenue adjustments and allocates them to the individual rate classes. It is assumed that electricity prices are distributed among customer classes during 1985-2005 in the same proportion as in 1985 [20].

Figure B.7 presents an example of the way in which the pricing sector computes the price of electricity. The model allocates rate adjustments using traditional regulatory practices. The utility book plant, transmission and distribution, capital administrative costs, and capitalized conservation investments are included in the rate base. The rate base is multiplied by the allowed rate of return (assumed to be the weighted cost of capital, about 13%) to calculate allowed income. No construction work in progress is allowed in the rate base, but the utilities can include the costs of construction financing in the rate base (AFUDC).

Allowed expenses include production costs, depreciation, working capital allowance, administrative overhead, taxes, and expensed conservation costs. Allowed income and allowed expenses are added together and compared to current revenues to compute any revenue adjustment. The revenue adjustment is allocated to individual rate classes according to historical distributions. The revenue adjustments are then divided by the current demand in each sector to compute the new prices. The new prices then pass through a one year regulatory delay before becoming the rates seen by consumers.

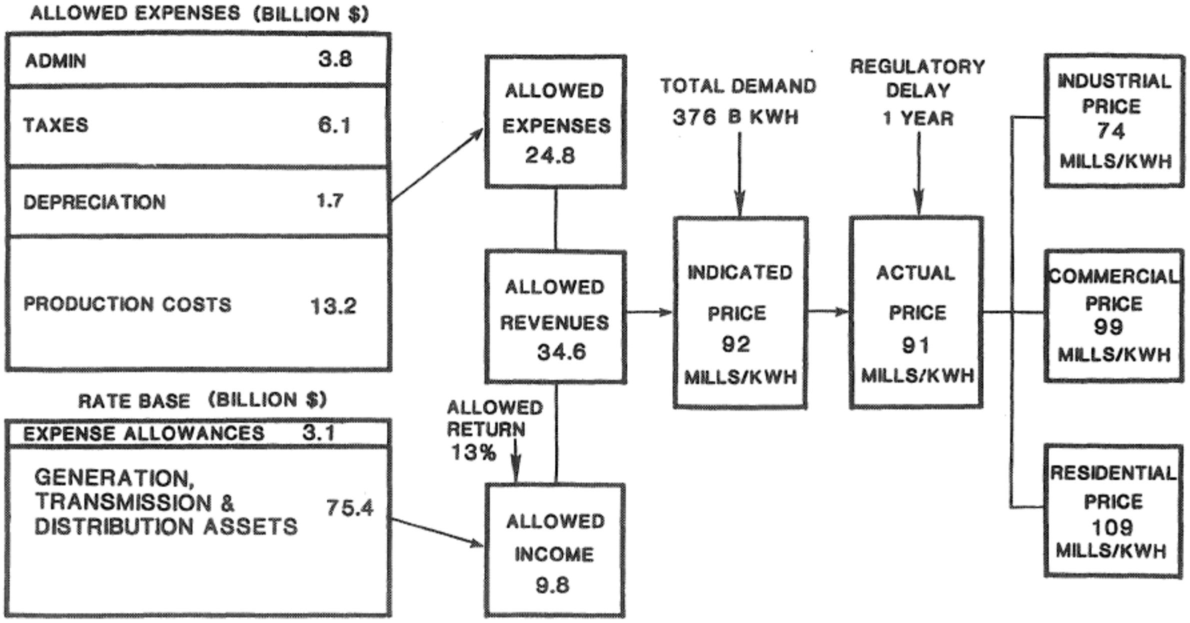
F. SO2 EMISSIONS SECTOR

An important characteristic of the IEUPM is the tracking of SO2 emissions and consideration of pollution control options and costs within the integrated framework. The model deals with emissions from three groups of coal capacity (the two groups of existing plants and new plants). Separate SO2 emission rates are possible for each group, and for plants within these groups which have retrofit scrubbers or are switched to low-sulfur coal. The user can input which fraction of each group will retrofit emission control equipment or switch fuels at any point in time, and how much it will cost. The model uses this data and the actual load dispatch for each year to calculate annual SO2 emissions and emission rates for each type of capacity.

Table B.4 shows the groupings for existing coal plants, along with the assumed emissions control costs. Grouping according to both emissions rate and control cost is considered. The average emissions rate for each group is based on the actual characteristics of coal-fired power plants in the ECAR region.

FIGURE B.7

PRICE REGULATION
(1990)
NOMINAL $



New plants and plants burning low-sulfur coal are assumed to emit at the effective rate of 0.9 lbs of SO_2 per MMBtu of fuel input. The cost of switching to low-sulfur coal is included as a premium on the fuel cost for the fraction of plants affected.

Retrofit scrubber applications are assumed to operate at 90% sulfur removal efficiency when high-sulfur coal is burned. Heat rate and availability penalties of 5% each are factored into the availability and operating cost calculations for the plants assumed to have retrofit emission controls [21]. It is assumed that retrofit scrubbers are constructed in 3 years and are financed in the same manner as new generating resources. In reality, utilities might be able to finance the emission control equipment at lower cost than new generating facilities. For simplicity, however, we have not examined special financing strategies for pollution control equipment.

V. NOTES AND REFERENCES

1. E.L. Miller, "The Impacts of Conservation on Electric Utility Pollution Control Strategies", Thayer School of Engineering, Dartmouth College, June 1985.

2. Electric Power Supply and Demand 1984-1993, North American Electric Reliability Council, Princeton, NJ, 1984, pp. 22-40.

3. ECAR Coal Fired Utility Units Emissions Database, compiled by Eric L. Miller from: "Existing Generating Unit Capability", NERC ECAR region, 1984. "Estimates of Sulfur Oxide Emissions from the Electric Utility Industry", Volume I and II, E. H. Pechan and Assoc., 1985. "Power Directory", Edison Electric Institute, 1981.

4. Residential and industrial growth forecasts based on assumptions used in the 1985 National Energy Policy Plan developed for the Department of Energy by Applied Energy Services Inc., Arlington, VA. Commercial growth forecast based on regional projections by the Electric Power Research Institute COMMEND model. The total stock in 1985 is calculated by dividing the regional energy use in each customer class by the average consumption per customer as developed in Appendix A.

5. "An Estimate of Consumer Discount Rates Implicit in Single-Family Housing Construction Practices", ORNL/CON-62, Oak Ridge National Laboratory, Oak Ridge, TN, April 1981. H. Ruderman, et al., "Energy Efficiency Choice in the Purchase of Residential Appliances", in W. Kempton and M. Neiman, eds., Energy Efficiency: Perspectives on Individual Behavior, American Council for an Energy-Efficient Economy, Washington, DC, 1987.

6. "A Compendium of Utility-Sponsored Energy Efficiency Rebate Programs", American Council for an Energy-Efficient Economy and Consumer Energy Council of America, Washington, DC, 1987.

7. Acid Rain and Transported Air Pollutants, OTA-O-204, Office of Technology Assessment, Washington, DC, June 1984.

8. "Electric Power Supply and Demand 1985-1994", North American Electric Reliability Council, Princeton, NJ, 1984, pp. 82-104.

9. Computed by averaging actual plant operating data within the ECAR region. The data was compiled from FERC Form 1 reports for the major utilities in the region.

10. "An Economic Analysis of HR-4567, The Acid Deposition Control Act of 1986", report prepared by ICF Inc. for the Environmental Protection Agency, Washington, DC, 1986. "Economic Evaluation of FGD Systems", Volume 5, EPRI CS-3342, Electric Power Research Institute, Palo Alto, CA, Oct. 1986. "Impacts of Selected Acid Rain Policy Options on the AEP System", draft analysis prepared by ICF Inc. for the Acid Rain Policy Options Dialogue, Washington, DC, Jan. 1987.

11. "Electric Power Supply and Demand 1984-1993", North American Electric Reliability Council, Princeton, NJ, 1984, pp. 22-40.

12. Average value for utilities in the region based on FERC Form 1 filings.

13. "Electric Power Supply and Demand 1984-1993", North American Electric Reliability Council, Princeton, NJ, 1984, pp. 22-40.

14. The 20% figure is used, for example, by the Ohio Public Utility Commission when determining excess capacity for the purposes of rate setting, personal communication from the Ohio Consumers Council, 1986.

15. "Electric Power Supply and Demand 1984-1993", North American Electric Reliability Council, Princeton, NJ, 1984.

16. The Perry 1 and Beaver Valley 2 nuclear plants cost approximately $4000/KW each while the capital cost of the Zimmer plant conversion that will be allowed in the rate base is capped at $2750/KW, based on 1986 Ohio Power and Ohio Edison Long Term Load Forecasts.

17. "Capital Costs for Projected New Power Plants Through 1993", UDI-004-86, Utility Data Institute, Washington, DC, June 1986.

18. "Projected Costs of Electricity from Nuclear and Coal-Fired Power Plants", DOE/EIA-0356-1, Energy Information Administration, Washington, DC, 1982, p. 23.

19. Compiled from FERC Form 1 filings for ECAR utilities.

20. "1985 Statistical Yearbook of the Electric Utility Industry", Edison Electric Institute, Washington, DC, 1986.

21. "Economic Evaluation of FGD Systems", EPRI CS-3342, Vols. 1-3, Electric Power Research Institute, Palo Alto, CA, Dec. 1983.

About the American Council for an Energy-Efficient Economy

The American Council for an Energy-Efficient Economy (ACEEE) is a non-profit organization which gathers, evaluates, and disseminates information to stimulate the adoption of energy conserving technologies and practices. ACEEE conducts research and analysis leading to books, reports, and guides for utilities, federal, state, and local energy officials, and individual consumers. ACEEE also sponsors conferences to foster information exchange between the various groups interested in energy efficiency.

About the Energy Conservation Coalition

The Energy Conservation Coalition is a non-profit coalition of 20 national consumer, environmental, scientific, and church organizations formed to publicize and promote energy conservation and improve the efficiency with which America uses energy. ECC conducts advocacy work at the federal level in support of strong conservation-oriented policies and legislation. ECC also provides assistance to state regulators, government officials, and citizen activists to promote the implementation of least-cost energy strategies.