RECOMMENDATIONS FOR REGULATORY ACTIONS TO PROMOTE POWER PLANT PRODUCTIVITY IMPROVEMENTS

prepared by
The Working Group on Power Plant Productivity

THE NATIONAL REGULATORY RESEARCH INSTITUTE
2130 Neil Avenue
Columbus, Ohio 43210

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FOREWORD

This report was prepared for The National Regulatory Research Institute (NRRI) under contract No. EC-77-C-01-8683 with the U.S. Department of Energy (DOE), Economic Regulatory Administration, Division of Regulatory Assistance. The opinions expressed herein are solely those of the authors and do not necessarily reflect the opinions nor the policies of either the NRRI or the DOE.

The NRRI is making this report available to those concerned with state utility regulatory issues since the subject matter presented here is believed to be of timely interest to regulatory agencies and to others concerned with utilities regulation.

Douglas N. Jones
Director.

EXECUTIVE SUMMARY

The National Regulatory Research Institute (NRRI), under contract from the U.S. Department of Energy, instituted a program to assist state regulatory agencies in the evaluation of power plant productivity and the promotion of improved power plant performance. The focus of this program has been based on state regulatory responsibilities to ensure adequate energy supply at reasonable cost to the consumer. The objectives in the following report have been to provide recommendations for regulatory actions to promote cost-effective power plant productivity improvements and to furnish appropriate state regulatory agencies with a reference document to assist in the evaluation of utility power plant productivity improvement programs.

Power plant productivity and performance improvements, as discussed below, refer to increasing the time that a plant is available for operation, reducing the time that a plant is not available at rated power and improving plant on-line efficiency. This report was prepared by the Working Group on Power Plant Productivity organized by NRRI. The Working Group was comprised of representatives from regulatory agencies in California, Illinois, Michigan, New York, North Carolina, Ohio, Texas, Virginia, Wisconsin, from NRRI, and from the Department of Energy. Prior to organizing this Working Group, NRRI surveyed productivity related activities in forty states; finding ten states which are explicitly addressing the issue of power plant productivity.

Studies conducted by the Department of Energy, in cooperation with state agencies, power pools and utilities, have shown that improved productivity can significantly reduce the cost of energy. These savings mainly result from more efficient utilization of base load units.

The Working Group reviewed existing mechanisms for evaluating power plant productivity and the potential for improvements and surveyed relevant data systems and analytical methods for applying such data. The Working Group developed a program of regulatory activities to promote power plant productivity improvements and made an assessment of such current industry, federal and state programs.

The Working Group found that:

- Power plant productivity has been adversely affected by 1) deficiencies in the design and manufacture of plant equipment; 2) deficiencies in the design and construction of power plants; 3) deficiencies in operating and maintenance practices; 4) deteriorating fuel quality; 5) regulatory requirements related to environmental and safety issues (i.e., emission levels, pollution abatement equipment); and 6) a regulatory climate that has sometimes encouraged a lowest first cost at the expense of reliable operation.

- No single index is sufficient to assess plant performance. The commonly used terms such as capacity factor, forced outage rate, equivalent availability, and operating availability must be considered together in order to form any conclusions as to a utility's performance.

- The major existing data bases are the Generation Availability Data System (GADS) (formerly maintained by the Edison Electric Institute (EEI)) operated by the National Electric Reliability Council (NERC), the Gray Book published by the Nuclear Regulatory Commission (NRC) and the Nuclear Plant Reliability Data System (NPRDS) of the American National Standards Institute (ANSI).

- None of the existing plant performance data bases provide sufficient information with which to determine the fundamental causes of plant outages.

- Comparisons of performance by unit size, type, and vintage can be made from the existing data bases. Such analyses have been made by EEI, the U.S. Department of Energy (DOE), the Electric Power Research Institute, and NRC.

- Cooperative studies conducted by DOE and state agencies have demonstrated that the expected benefits of improved power plant productivity are substantial. Such benefits include reduction in fuel cost, oil and gas conservation, and possible deferral of capacity additions.

- The opportunities for actions by state regulatory agencies may be limited by technical and statutory constraints. These constraints and the cost-effectiveness of potential improvements may vary from state to state.

Recommendations

The Working Group recognizes that power plant productivity improvements are primarily the responsibility of the utility industry. However, the Working Group believes that state regulators must be committed to ensuring the proper discharge of this responsibility. At this time (October, 1979) only a small number of states have implemented productivity improvement programs. There is a need to continue existing regulatory programs to encourage productivity improvements, and for additional states to implement such programs. The Working Group recommends that regulatory agencies implement the generic program suggested in this report which includes taking the following actions to promote power plant productivity improvements:

- Acquire and support the development of power plant performance data and information systems;
- Acquire the capability to perform independent in-house analysis of performance;
- Direct the establishment of productivity improvement programs, including explicit performance objectives for existing and planned power plants;
- Develop a system of performance assurance;
- Establish a system of incentives, sanctions and/or penalties; and
- Participate in on-going efforts and initiate new actions to promote productivity improvements.

MEMBERS OF THE WORKING GROUP ON POWER PLANT PRODUCTIVITY

Mr. Geoffrey Check, Illinois Commerce Commission

Mr. Carl Evans, Public Utilities Commission of Ohio

Mr. Richard Finnstom, California Public Utilities Commission

Dr. Tony George, Texas Energy Advisory Council

Dr. Mark Gerber, National Regulatory Research Institute

Mr. Fred Heizer, Public Utilities Commission of Ohio

Ms. Cynthia Hunt, Public Utilities Commission of Ohio

Mr. John Koubek, New York Public Service Commission

Mr. Evan Kovacic, Consultant, formerly with the U.S. Department of Energy

Mr. Lockie MacGregor, Michigan Public Service Commission

Mr. Jerry Mendl, Wisconsin Public Service Commission

Mr. James Padgett, Michigan Public Service Commission

Dr. Chris Poseidon, Working Group Coordinator, Consultant to the National Regulatory Research Institute

Mr. Richard Rhodes, California Public Utilities Commission

Mr. Charles Teclaw, Illinois Commerce Commission

Mr. Andy Williams, North Carolina Utilities Commission

Dr. John H. Williams, U.S. Department of Energy

Mr. James Wittine, Virginia State Corporation Commission

The National Regulatory Research Institute acknowledges the contribution of the members of the working group to this report. Of the members of the working group, those representing state regulatory agencies volunteered considerable time and effort beyond their usual duties.

TABLE OF CONTENTS

Table of Contents (continued)

Table of Contents (continued)

Table of Contents (continued)

LIST OF TABLES

List of Tables (continued)

CHAPTER 1
INTRODUCTION

1.1 Purpose

The purpose of this report is to provide state regulatory agencies with a reference document to assist in the evaluation of power plant productivity and in the promotion of improved power plant productivity. Several reports in this area have shown that improvements in power plant productivity are possible, cost effective, and beneficial [1,20,33-35].* This report identifies current regulatory activities related to power plant productivity improvement, describes a model program for power plant productivity improvements, and recommends regulatory actions that would motivate utilities to increase the productivity of their generation units. The underlying premise of the recommendations is that state regulatory agencies can appropriately take an active role in motivating utilities to promote cost-effective productivity improvements of their generating units--particularly coal and nuclear.

In this report, improvement of power plant productivity and improvement of power plant performance refer to increasing the amount of time that a plant is available for operation, reducing the amount of time that a plant is not available for generation at its full potential, and increasing a plant's operating efficiency.

*Numbers in brackets refer to the list titled "References" at the end of the text of the report and not to the "Bibliography".

1.2 Background

Unprecedented cost increases for fossil fuels and greatly increased lead times and costs for adding new generating capacity have made improving power plant performance an important issue for utility management and state regulators [7,13,27,38]. Simultaneously, oil supply disruptions and the nation's growing dependence on oil imports have led to federal policies that set high priority on reducing oil and gas consumption by utilities. Reduced oil and natural gas consumption can be achieved in part through improved performance of coal and nuclear units. Recent studies conducted by the U.S. Department of Energy in cooperation with state regulatory agencies, power pools, and utilities have shown that improved productivity can yield substantial benefits at the utility, state, and regional levels [34-36].

Power plant productivity is not measurable by any single parameter or index. It is defined adequately by four indices of plant performance which are in widespread use throughout the power industry, both in the United States and abroad: forced outage rate, operating availability, equivalent availability, and capacity factor.

Beginning in the early 1970's, and continuing for several years, there was a gradual decline in power plant productivity in the United States, followed by a recent levelling-off and possible upturn [12]. Generally, on the average, the nation's nuclear and large coal fired units are unavailable for service 15 percent of the time due to unscheduled outages, are available for service 75 percent of the time, and operate at about 60 percent capacity factor [7]. These levels of performance are considerably below previous experience and far below those anticipated by utilities and vendors alike.

1.3 Report Scope

This report was prepared as part of a project by the National Regulatory Research Institute (NRRI) under contract to the U.S.

Department of Energy (Economic Regulatory Administration, Office of Utility Systems). The goal of this project has been to identify current state programs related to improving power plant productivity and to outline activities which promote power plant productivity for the consideration of state regulatory commissions.

In the first phase of this project, NRRI contacted 40 of 50 state regulatory agencies to gather information on their activities and practices which are aimed at improving power plant productivity. The results of the first phase revealed that there is concern over the issue of productivity among state regulators but only a small number of states are actually involved in programs to improve power plant performance.

In the second phase of the project, NRRI organized a Working Group on Power Plant Productivity to prepare a reference document on power plant productivity for state regulatory agencies and to develop recommendations for such agencies to initiate programs directed toward improving power plant performance. The Working Group is comprised of members of those state regulatory agency staffs where efforts towards improving power plant productivity have been evident through regulation, hearings and special studies. Regulatory agencies from nine states are represented on the Working Group.* In addition, representatives from NRRI and the Department of Energy' Office of Utility Systems participated.

Load management as a means to improve power plant utilization was considered by the Working Group. Successful demand shaping through load management could improve the capacity factor of certain plants if these plants were capable of increased operating levels. The principle focus of this report is on productivity improvements within the plant to assure that units are capable of increased operating levels. To the extent that the various load management programs are successful, the need to improve power plant performance will

*States represented include: California, Illinois, Michigan, New York, North Carolina, Ohio, Texas, Virginia and Wisconsin.

become even more important. If base-load plants are not able to perform at substantially improved levels in the future, the potential benefits of load management will not be fully realized.

1.4 Organization of the Report

Opportunities for regulatory initiatives directed at improving power plant performance vary among states. Consequently, the Working Group developed a generic program of possible regulatory activities and incentives. Current efforts of the federal government, the state regulatory agencies, and the industry were reviewed and the outcomes identified. The recommendations presented in this report were developed by comparing a model program to the outcomes of actions already implemented (or in progres).

The report is organized as follows:

Chapter 2 contains background information in the area of power plant performance. It includes definitions of the most commonly used power plant performance parameters, a discussion of available data bases and their limitations, and a discussion of data analysis efforts. The benefits from cost-effective productivity improvements are discussed, and the need for such improvements is demonstrated.

Chapter 3 presents a model program of regulatory activities to improve power plant productivity. This program includes the generic development of productivity goals and suggested monitoring and enforcement activities.

Chapter 4 contains a description of current activities by the federal government, the state governments, and the industry to improve plant performance. Such activities include studies and implementation of measures to improve plant performance. This chapter identifies the types of programs being conducted and the experience from the outcomes of these programs.

Recommendations for actions by state regulatory agencies are presented in Chapter 5. These recommendations are based on the experience of programs and activities which have been implemented, the model program of regulatory activities as presented in Chapter 3, and the review of mechanisms for evaluating power plant productivity (Chapter 2).

Appendices A through G contain the details of specific state programs. Included are descriptions of state activities in California, Illinois, Michigan, New York, North Carolina, Ohio and Texas. Following the appendices, there is a bibliography of available literature on power plant performance. The purpose of the bibliography is to provide the reader with background information on power plant productivity beyond the scope of this report. Numbers in brackets throughout the text do not refer to the bibliography but to the list of references which follows Chapter 5.

CHAPTER 2

MECHANISMS FOR EVALUATING POWER PLANT PRODUCTIVITY AND BENEFITS FROM PRODUCTIVITY IMPROVEMENTS

2.1 Introduction

This chapter presents background information on power plant productivity indices, data bases of power plant performance, and the potential benefits from power plant productivity improvements. This chapter deals with the data base status as it currently exists. The data base deficiencies as described herein are recognized by the industry and in fact have substantially been identified through industry efforts. As discussed in Section 4.2., the industry has a wide ranging effort aimed at correcting the data base deficiencies.

A number of indices are being used to measure overall power plant performance. The most widely recognized and publicized are the forced outage rate, operating availability, equivalent availability, and capacity factor. Others in use include heat rate, equivalent forced outage rate, and scheduled outage rate.

Power plant performance data are collected by many organizations. The major sources of published data are the following:

1. The Edison Electric Institute (EEI) Report of the Equipment Availability Task Force of the Prime Movers Committee (Effective January 1, 1979, the responsibility for data collection has been transferred to the National Electric Reliability Council (NERC)). There is a quarterly report for 600 MW and larger units* and an annual report for all unit sizes. The data include nuclear and fossil-fired units.

*In the future the quarterly report will include 400 MW and larger units.

2. The Nuclear Regulatory Commission (NRC) "Operating Units Status Reports" commonly known as the "Gray Book" (and referred to as such in this report). The Gray Book is published monthly. The data include only nuclear units.

3. The American National Standards Institute (ANSI)-sponsored "Nuclear Plant Reliability Data System" (NPRDS). This data system covers only safety-related equipment in nuclear power plants.

In Section 2.2, the most widely recognized indices are defined and discussed. In Section 2.3, the usefulness and limitations of existing data bases are discussed, analyses performed using such data are reviewed, and the methods of data collection are evaluated. In Section 2.4, the benefits from productivity improvements are discussed and the immediate need for productivity improvements is demonstrated.

2.2 Definition of Performance Indices

The following definitions of performance indices are those used in the Edison Electric Institute data base [29]. (Note: as discussed in Section 4.2 there is an industry effort to propose national standard definitions. The proposed standard definitions differ somewhat from the EEI definitions.)

The fraction of time that a plant is available for operation is called "Operating Availability" (OA). This parameter is defined by:

$$OA = \frac{AH}{PH} \times 100 \qquad (2.1)$$

where

AH = service hours + reserve shutdown hours,

"service hours" is the number of hours a unit was in the in-service state, "reserve shutdown hours" is the number of hours a unit was in the economy shutdown state, and

PH = the number of hours in the period of measurement.

A unit is not considered "available" when it is forced out of service or is down for planned maintenance. The number of "service hours" includes the number of hours that a plant operates at rated capacity and at derated capacity due to planned or unplanned partial outages. The operating availability measures the percentage of time that a unit is capable of producing power at any power level.

In order to account for the effects of partial outages in the measurement of availability, the parameter "Equivalent Availability" (EA) has been defined. This parameter is defined by

$$EA = \frac{AH - (EFOH + ESOH)}{PH} \times 100 \qquad (2.2)$$

where

$$EFOH = \frac{\text{Forced Partial Outage Hours x Size of Reduction in MW}}{MDC},$$

$$ESOH = \frac{\text{Scheduled Partial Outage Hours x Size of Reduction in MW}}{MDC},$$

and

MDC = maximum dependable capacity in MW.

The equivalent availability is a measure of the unit's true ability to produce power since it takes into account partial outages. This index is important since it is possible to have a unit with 100 percent availability but with less than 100 percent equivalent availability. Operating availability can be used to indicate the percent of time the unit is fully out of service. When compared to operating availability, equivalent availability can be used to indicate the additional loss in production capability due to partial outages.

The "Capacity Factor" is a measure of the actual output (MWh) of a unit within a specified time period relative to its potential output.

The "Capacity Factor" (CF) is defined by

$$CF = \frac{\text{Total Gross Generation in MWh}}{(PH)\ (MDC)} \times 100 \ . \qquad (2.3)$$

The "Total Gross Generation", Eq. (2.3), can be affected by factors other than forced or scheduled outages. Such factors include economy dispatch and regulatory deratings. If there is no economy dispatch (base-loaded plants) and no deratings other than due to forced or scheduled partial outages, then the capacity factor approaches the equivalent availability.

The "Heat Rate" is a measure of the thermal efficiency of a generating unit. It is defined by

$$\text{Heat Rate (Btu/kWh)} = \frac{\text{Btu Fuel (Heat Input)}}{\text{kWh Output}} \tag{2.4}$$

and it represents the fuel-heat input required to generate a kWh and deliver the generated power to the transmission line leaving the station. The heat rate is inversely proportional to the unit's efficiency. Equation (2.4) is not included in the EEI definitions of Reference [29].

A parameter used to express a plant's total unavailability due to full forced outages (i.e. unscheduled outages) is the "Forced Outage Rate" (FOR).

This parameter is defined by

$$\text{FOR} = \frac{\text{FOH}}{\text{SH} + \text{FOH}} \times 100 \tag{2.5}$$

where

FOH = full forced outage hours, and

SH = service hours.

Partial forced outages are taken into account by defining an "Equivalent Forced Outage Rate" (EFOR).

This parameter is defined by

$$\text{EFOR} = \frac{\text{FOH} + \text{EFOH}}{\text{FOH} + \text{SH}} \times 100 \quad . \tag{2.6}$$

A parameter used to express a plant's unavailability due to planned and scheduled outages (such as maintenance and nuclear refueling) is the "Scheduled Outage Rate" (SOR).

This parameter is defined by

$$SOR = \frac{SOH}{SH + SOH} \times 100 \qquad (2.7)$$

where

SOH = scheduled outage hours.

None of the above indices taken individually indicate the overall performance of a unit; however, these indices, when considered in the aggregate, provide an extremely good indication of a power plant's performance and direct the investigator's attention toward the general categories of outages which affect plant performance most. Thus, for example, using the "Forced Outage Rate," the "Equivalent Forced Outage Rate" and the "Scheduled Outage Rate," one can gain a sense for which type of outage is responsible for lost production capability.

A more detailed discussion of the usefulness and limitations of performance indices can be found in Appendix A, Section A.2.

2.3 Existing Data Bases - Usefulness and Limitations

Three major plant performance data bases are the Edison Electric Institute's (EEI) data system which has been recently transferred to the National Electric Reliability Council (NERC); The Nuclear Regulatory Commission's (NRC) "Operating Units Status Reports" (commonly known as the "Gray Book"), and the American National Standards Institute's (ANSI) "Nuclear Plant Reliability Data System" (NPRDS).

All three data bases contain data for nuclear power plants but only EEI includes data for fossil-fired plants.

In addition to the three data systems mentioned, some major equipment manufacturers maintain unit performance data, which are used for improving and tracking the performance of their equipment. Generally, these data are not available to the public.

The above three data bases have been studied in great depth by the Department of Energy (DOE), The Electric Power Research Institute (EPRI), ANSI and other governmental, industrial and professional organizations.

A major conclusion derived from the studies is that existing data bases are presently inadequate for satisfying the needs of government and industry for timely, accurate and useful performance data.

Participation in the EEI data base is voluntary; hence, the data base does not include all units. Also, reporting is often very slow. In addition, processing of the data by EEI has been a low level effort. Consequently, publication has been untimely. For example, at this date (middle of 1979), the most recent report on 600 MWh and larger units is for the 4th quarter, 1977, and the most recent report for all units is for calendar year 1977.

There has been no provision in the EEI data base for assuring data accuracy. Recent studies sponsored by DOE and EPRI have identified anomalies and errors in the data. Data anomalies include inconsistencies among the equivalent availability factor, availability factor and forced outage rates.

One of the most revealing studies sponsored by DOE was performed by the Oak Ridge National Laboratory entitled "An Assessment of Anomalies in the EEI Data Base on Power Plant Performance" [32]. This study evaluated raw data supplied by EEI on four units (3 coal-1 nuclear) for one year of operation for a total of 4 unit-years of operation. The analysis uncovered anomolies such as:

1. Double reporting of forced outages;
2. Double reporting of forced outages with planned outages;
3. Double reporting of maintenance outages with planned outages; and,
4. Overlapping of outages.

A rough check showed that 20 to 25 percent of the unit-year data are suspect because service hours exceed available hours, or capacity factor exceeds operating availability or equivalent availability.

Another problem with the EEI data base is in the area of component outage causes which was analyzed by Stone & Webster for EPRI [2]. Stone & Webster's findings are:

1. Equipment covered by the cause codes are not adequately described by the design data.

2. Only major outage causes are required to be reported. When a unit experiences an outage where several components from different major equipment groups are being repaired, only one cause code from each group need be selected to cover them all. This method of reporting outages affects the recording of the frequency of failure of components, since necessary maintenance and repair which are done while the unit is out of service for some other cause are not reported.

3. The duration of component outages that occur during non-operating system tests in which a component failure is revealed cannot be determined. The reason is that only the start date of the system test is recorded unless the entire system failed. The end date is omitted per instructions.

4. Specific cause codes are applied to broad descriptions of equipment components, events, and combinations thereof. They do not distinguish precise items of equipment that have experienced outages. Examples are: Safety System Valves and Piping (Cause Code 229) and Operating Training and License Testing (Cause Code 290), or Auxiliary or Standby Feedwater Supply System Malfunction (Cause Code 220).

5. Neither cause codes nor equipment design data are provided for some important components and systems. This is especially true for instruments, controls, and station electrical systems. A few very generalized codes in the 900 series must be used.

Thus it can be seen that EEI cause codes are too general and incomplete to be of much value. It is also indicated in the findings that there is a need of a program for verifying the EEI data submitted by the utilities.

Stone & Webster under the same EPRI contract performed a similar analysis for nuclear unit outage data and derived the following limitations to data reported in the Gray Book [2].

1. Significant reductions in power level (those of greater than 20 percent reduction in average daily power level for the preceding 24 hours) do not list the elapsed time, the cause, or the amount of reduction. In fact, the instructions direct the reporter to enter "0" in the DURATION column and to list the METHOD as "9" (Other). Data on these periods of reduction would be useful for analysis if information on duration, cause, and amount of reduction were included. This would permit computation of the previously mentioned major productivity indices.

2. The numbering of shutdowns and reductions is to be assigned sequentially for the year by the reporter. However, the instructions are not clear in the use of the same number for a shutdown or reduction that is continued into the next report period, whether the following month or year. Because the instructions are not explicit on this desired procedure, there are many instances of dual or different numbering of the same shutdown in the monthly reports processed for the Gray Books file.

3. As with the numbering of shutdowns, the instructions similarly do not specify carrying over the data of the start of each shutdown or power reduction that is continued into the following report. This is implied but the number of cases where this is not practiced show that it is ambiguous.

4. Many reporters gave the cumulative time of a shutdown from its start in the monthly reports rather than the actual time for that month, though the instructions appear clear on this point.

5. Although the instructions are explicit on the use of the REASON code, reporters have erred many times in their selection. This can be detected from the narrative identifying the cause of shutdown. REASON code "H" (Other) appears to be the catch-all reason to use, and seldom are even brief comments given to explain its usage.

6. As with the numbering and dates of continued shutdowns, the number designation used for the "METHOD OF SHUTTING THE REACTOR OR REDUCING POWER" is not carried over into succeeding reports of a continuation. The instructions are lacking here because they do not tell the reporter to use the same METHOD number in the following reports for a continued shutdown.

7. The COMMENTS, given in narrative form, are intended to explain what caused the shutdown and the corrective action taken. The reports are rarely explicit in identifying the specific equipment that caused shutdowns and power reductions. A SUMMARY block is provided on the reporting form for recording the highlights of unit operation for the month. This was found to be helpful whenever it was filled in. However, the summary was not always provided. (Recent changes to instructions provide for equipment identification.)

The Nuclear Plant Reliability Data System (NPRDS), unlike the EEI and NRC data systems, does not provide data on overall powerplant performance. Rather NPRDS provides engineering and reliability information on safety classes 1 and 2 equipment for nuclear power plants. (Classes 1 and 2 refer to engineered safeguard systems in nuclear power plants; class 1 equipment is the most critical while classes 2 and 3 are less critical.) It is the only major file in use that has been specifically structured to classify and summarize data to determine system and component failure rates. The reporting system consists of four kinds of data: Nuclear unit information, engineering data, quarterly operating data, and failure reports. The failure report is an attempt to describe the failure with codes for type, mode, cause and effect of a failure, as well as failure detection, action taken and licensee event report submittal date. Failure types are identified as mechanical, electrical and other. Selections for a mode are derived from a table listing 18 possibilities such as "crack," "won't start," etc. Failure is represented by two groups: category (A) cause and (B) description. The category section is typically denoted by items such as manufacturing, operating error, etc. The description section contains 28 selections of which typical descriptions are weld-related, abnormal flow, open circuit, and excess vibration.

The NPRDS comes closest to a data system which permits the calculation of reliability parameters such as failure rates, mean-time-to-repair, etc.

A major limitation of all the data systems is that they cannot be used to accurately determine the root causes of plant outages. Accomplishing this function on a national basis would entail tremendous efforts by government and industry, including (1) extensive training programs for people reporting and evaluating outages, (2) computerization of data collection and analysis, (3) expanding component outage causes including verbal descriptions of outages where appropriate, (4) industry dedication.

2.4 Analyses of Data

This section contains a description of data analyses performed by the Edison Electric Institute (EEI), the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI), and the Nuclear Regulatory Commission (NRC).

EEI analysis has been on a macroscopic level. Performance indices (e.g., CF, FOR, OA, etc.) are reported based on grouping fossil units into various capacity ranges [29]. EEI has made individual generating unit data available on request for more specific analysis (e.g., for comparing units by similar design, vintage, size, etc.).

DOE analysis has compared large nuclear and coal units utilizing EEI and Gray Book data. A 1978 report on "The Performance of 400 Megawatt and Larger Nuclear and Coal Fired Generating Units" utilizing performance data up to 1975 categorized units by size, vintage and primary fuel capabilities [12]. This report focuses attention on the annual performance of generating units aggregated by state and utility. Capacity factors, availability factors, equivalent availabilities and forced outage rates are the parameters listed. Such data can be used by utilities and state regulatory agencies for comparison purposes. An updated report utilizing 1976 data will be released at the end of 1979.

One of the most useful analyses conducted to date has been reported in "Use of Nuclear Plant Operating Experience to Guide Productivity Programs" [14]. This reference presents the results of an extended evaluation of the operational performance of light water reactor nuclear generating units whereby relevant operating and outage data have been compiled and analyzed.

This evaluation isolated component outage causes indicating durations of outages as well as failure rate per component year. For example, steam turbines were shown to have the highest failure rate of all plant equipment and for the period studied had a failure rate of 1.5 incidents per turbine year. A frequency/intensity plot for turbines indicated outage durations ranging from 1 hour to almost 3000 hours with more than 50 percent of the incidents being 10 hours or less. Investigation of these low duration outages show that they are typically associated with the turbine control subsystem or with seal leakage. Durations in excess of several hundred hours imply turbine casing removal and extensive repair or replacement of low pressure turbine blading or rotors. Examination of both the frequency of failure and frequency/intensity information show that the manufacturer has improved blading through corrective design and field-fix programs. Thus this EPRI paper serves as a model for examining the productivity of existing nuclear units using a systematic analysis technique for evaluating outage causes and contribution to lost productivity as well as identifying fix programs to increase the component's productivity. With this information, high pay-off areas can be identified and determinations can be made in terms of cost-benefits.

The NRC in its monthly Gray Book publication compares performance of nuclear units on a monthly and yearly basis, primarily for trending of capacity factors, availability and forced outage rates. It also compares these indices with the performance of large fossil units.

2.5 Auditing of Data

In previous sections, the most prevalent data indices and data systems used by the utility industry, and their limitations, were discussed. The industry is well aware of these limitations and is attempting to improve the accuracy, usefulness and timeliness of its data systems through EPRI, NERC, and industry task forces [8,17]. To accomplish these improvements, EPRI is undertaking a study which addresses the development of a national data system. This study will concentrate on consolidating existing data systems into one central system and developing methods for improving outage reporting and descriptions.

In addition, NERC is developing verification procedures to avoid repetition of previous problems of duplicate reporting, overlap, etc. When the data are received from the utilities, they will be manually screened for obvious errors prior to entering a data bank. After the screening, the data will be edited and analyzed through computer programs with acceptable data stored in a data base. Data which do not clear the editing programs are returned to the submitting utility for correction and resubmittal. NERC is also working toward a common data base to avoid duplication among utilities, manufacturers and regulators. It is anticipated that this concept will take two or three years to implement.

In the final analysis, the utilities themselves must be dedicated to accomplishing the goal of developing an effective, accurate and useful data base, by ensuring that data are accurately reported at the source (in the power plant).

2.6 Demonstration of the Need for Power Plant Productivity Improvements and Benefits from Productivity Improvements

Data inadequacies notwithstanding, the available data establish that there is substantial potential for productivity improvements.

Average values stated in Section 1.2 support this statement as evidenced by availabilities and capacity factors listed here.

Numerous studies by the Department of Energy (and previously by the Federal Energy Administration) and state agencies have demonstrated significant benefits from productivity improvements. Government studies have been reported in references [2,24,33-35], and state-agency studies in references [20,31,36] and in Appendices of this report. Specifically, a recent study [7] sponsored by the Department of Energy indicates that approximately 54 million barrels of oil could be saved in the northeast and east central regions of the USA if a 5 percentage point improvement of forced outage rates can be attained for large coal fired and nuclear units. Savings from this improvement could be well over a billion dollars per year. The magnitude of the potential savings for a utility and its consumers suggests that immediate steps be taken to establish programs to promote productivity improvements. In pursuing improved power plant productivity, additional capital and operations and maintenance expenditures may be required. In most cases, however, the magnitude of the potential savings is expected to overshadow such expenditures.

Benefits from productivity improvements will be manifested in the form of reduced fuel costs and improved system reliability. Reductions in fuel cost will occur because a greater portion of the energy generation will come from the less-expensive-to-operate plants. The cost differential between these types of electricity generation can be seen in Table 2.1 which shows the cost of energy generation (¢/kWh) for different fuels.

Concurrent with the savings in the cost of fuel is the added advantage of decreasing the use of oil and thus the dependence on oil imports. Improved reliability and improved opportunities for effective load management activities for a given system promise additional benefits. These latter benefits, while important for a given system, offer still more potential cost savings in the longer term. Improved performance of existing units and increased system reliability may provide the opportunity to defer or cancel additional new units that may otherwise be required. It should be noted that while improved performance of existing units tends to mitigate the need for new units, it could also prove to be detrimental to some degree in oil dependent areas where delay of new units results in less new nuclear and coal generation being made available to displace oil. The overall savings potential, however, both in the short and long term is significant and should be aggressively pursued.

Table 2.1

REPRESENTATIVE ENERGY COSTS BY FUEL TYPE IN 1978
Source: J. Wittine, Virginia Commerce Commission

FUEL TYPE	¢/kWh
Nuclear	.4 - .7
Coal	1.0 - 2.0
Heavy Oil	1.5 - 2.5
Light Oil	3.5 - 5.5

CHAPTER 3

OPPORTUNITIES FOR ENHANCING REGULATION REGARDING POWER PLANT PRODUCTIVITY

3.1 Introduction

In the period 1950-1970, impressive advances in the public utility sector resulted in declining rates to cunsumers. Given these advances of the industry during this period, the question of regulatory incentives to improve productivity was seldom raised. The low power plant productivity experienced by electric utilities in the seventies, in conjunction with spiraling inflation in the cost of fuels and new construction, have sparked a review of the adequacy of the traditional regulatory role. Recognizing that the level of return on investment is the direct result of the efficiency of the production process in the competitive market, regulators are searching for methods to simulate competition in an effort to improve utility productivity. This position was summarized by Alfred Kahn, in his foreward to Public Utility Productivity:

> ...a regulatory commission has an obligation, if it is to be something more than a rubber stamp automatically translating cost increases into rate increases, continuously to monitor the efficiency of the companies it regulates, and to exercise the utmost ingenuity in devising rewards and penalties related to the efficiency with which those companies perform [3].

Regulatory actions which can lead to improvements in plant performance are described in this chapter. Historically, plant performance has been adversely affected by the following factors:

1. Deficiencies in design, manufacturing and construction of plant components;

2. Utility specifications in the procurement process that minimize plant cost at the expense of plant reliability;

3. Deficiencies in operating and maintenance practices;

4. Deteriorating fuel quality; and,

5. Regulatory requirements related to environmental and safety issues (for example SO_2 removing equipment, emission levels).

The role of state regulatory agencies with regard to plant performance includes providing motivation for its improvement and overseeing the achievement of improved performance. Other agencies whose actions affect productivity through regulation are the Nuclear Regulatory Commission (NRC), the Federal Energy Regulatory Commission (FERC), the U.S. Department of Energy, (Economic Regulatory Administration) and the Environmental Protection Agency (EPA). Organizations which affect productivity through technology development are the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI), the EPA, and the research departments of the industry.

The opportunities for actions by a state regulatory agency may be limited by either technical or statutory constraints or both. Technical constraints refer to the lack of funds, personnel and electronic data processing capabilities. Statutory constraints refer to the lack of legislative authority to implement certain parts of a productivity improvement program. These constraints may vary among states. Also the need for plant improvements may differ among states. For this reason, the following generic approach is described. It consists of a step-by-step development of a model productivity improvement program. The intention is for state regulatory agencies to select those activities which are applicable and feasible. The major parts of this program are:

1. Collect plant performance data;

2. Undertake studies to assess the need for productivity improvements, and demonstrate the gross benefits from productivity improvements;

3. Ascertain existing productivity improvement programs and direct utilities to develop productivity improvement programs including cost-effective productivity improvement goals;

4. Monitor plant productivity and the status of productivity improvement programs;

5. Facilitate the attainment of higher productivity; and,

6. Enforce the attainment of higher productivity.

The preliminary parts of the program such as data analyses, assessment of the need for productivity improvements and associated gross benefit estimation can, in many cases, be accomplished by one or two staff members who should become intimately familiar with the factors that affect power plant productivity. However, depending upon the scope and maturity of the program, the services of a consulting firm or the creation of a special group within the agency may be required. That group should have access to computer facilities and personnel which can monitor plant performance, develop/maintain computer programs and system simulation techniques, and ultimately establish mechanisms for facilitating and enforcing the attainment of improved productivity.

3.2 A Model Program of Regulatory Activities to Improve Power Plant Productivity

PART 1: COLLECT PERFORMANCE DATA TO INITIATE THE PROGRAM

In the initial phases of this program, data must be collected to assess the potential for productivity improvements and to estimate gross potential benefits from productivity improvements. The potential for performance improvements may be assessed by comparing the plants under consideration with similar plants nationwide. Suitable performance indices are the Equivalent Availability Forced Outage Rate, Equivalent Forced Outage Rate and Scheduled Outage Rate. The gross potential benefits from productivity improvements may be measured by the effects of a specified percentage point improvement in selected performance indices on system fuel and construction expenditures and system reliability. Historical values of these indices can be obtained from the EEI data base and clarified by the utilities as needed.

PART 2: UNDERTAKE STUDIES TO ASSESS THE POTENTIAL FOR PRODUCTIVITY IMPROVEMENTS AND DEMONSTRATE THE GROSS POTENTIAL BENEFITS

Having assessed the potential for productivity improvements, the gross benefits from such improvements can be estimated by using simulation techniques of system planning and operations. The former techniques may be used to generate the optimum expansion plan of the utility and the latter to estimate the fuel cost, reliability and purchase power under hypothetical scenarios of improved indices of performance. Certain existing simulation techniques are described in references [19,33].

PART 3: ASCERTAIN EXISTING PRODUCTIVITY IMPROVEMENT PROGRAMS AND DIRECT UTILITIES TO DEVELOP PRODUCTIVITY IMPROVEMENT PROGRAMS INCLUDING COST-EFFECTIVE PRODUCTIVITY IMPROVEMENT GOALS.

Productivity improvement programs must be developed by the utilities under the direction of regulatory agencies. Prior to establishing such programs, a regulatory agency should request the utilities to identify factors contributing to productivity loss, evaluate the feasibility of improvements and analyze the costs and potential benefits of corrective actions.

Factors contributing to productivity loss may be specific equipment problems, poor coal quality, and inefficient management/operating/maintenance procedures. Problems of technical nature can be identified by inspecting outage records. "Root-cause" analysis is a technique by which plant breakdowns can be traced back to their source and this method should be used, as needed, to suggest effective corrective actions. Certain poor management/operational practices may not be easy to identify. In validating the factors identified by the utility as contributory to lost productivity, a regulatory agency may also question suspect management/operational practices.

The first step in estimating the benefits from a corrective action is to estimate the corresponding percentage point improvement in equivalent availability (or other suitable parameter). This can be done by finding the plant outage time (and/or partial outage time) attributed to the particular factor from the plant's outage records. Such an approach was developed for the U.S. Department of Energy [24]. In cases of organizational or procedural changes, such a quantification of benefits may be difficult. It should be attempted, however, to trace the effects of such changes to specific causes of equipment failure. The second step in evaluating the benefits from a corrective action is to calculate the effects on system cost and reliability, as discussed in Part 2.

A regulatory agency must validate these studies paying particular attention to whether all important factors contributing to productivity loss have been identified correctly, to the reasonableness of data used, and to the accuracy of methods used for cost and benefit estimation. The availability of accurate data is important to estimate changes in productivity resulting from specific factor improvement. However, the fact that such data may not be available at the present time does not necessarily prevent identifying factors contributing to lost productivity and establishing corrective actions.

Based on the above analyses, a regulatory agency together with the utility will assess existing productivity improvement programs and develop such programs as needed. Such programs must include specifications of activities, explicit goals, timetable, budget, management organization and responsibilities. Typically, activities may include personnel training, data gathering programs, procurement of computerized maintenance-scheduling systems, changes in management/operational practices and management reorganization. Goals for existing plants may be the replacement or repair of specific components and/or the attainment of specific levels of performance (such as EA = 80%) with a graduated scale of penalties for not achieving the goal. For new plants, goals may be established to meet specific levels of performance and the requirement for such levels to be stipulated at the time of procurement.

In setting goals, a regulatory agency must make sure that their achievement does not lead to inefficient system operation. One possible scenario is to set a level of capacity factor as a goal, and, instead of improving the plant's performance, the utility would choose to operate the plant in a non-optimum loading order.

PART 4: MONITOR THE STATUS OF PRODUCTIVITY IMPROVEMENT PROGRAMS

A regulatory agency must devise a system of productivity monitoring and verification by agency personnel. Utility activities to be monitored include:

1. Adherence to the timetable set for performance improvements;
2. The annual maintenance plan and budget;
3. Documentation of actual maintenance activities (dates, budget differences, timetable, man hours, spare parts);
4. Contingency plan (how the utility is planning to handle certain types of outages including timetable, man hours, spare parts); and,
5. Documentation of forced outages (dates, cause, duration, corrective actions taken, expenditures, cost of replacement power).

By monitoring these activities, a regulatory agency may recommend changes to planning, and recommend appropriate improved outage management practices.

PART 5: FACILITATE THE ATTAINMENT OF HIGHER PRODUCTIVITY

The information submitted regarding performance problems may be useful to other utilities statewide. A regulatory agency can, therefore, assume a central role in the dissemination of information on equipment problems, corrective actions and outage management procedures. This can be accomplished through publications, workshops and related activities. Eventually, a productivity improvement plan should include all regulated utilities as this information is obtained and utilized.

A regulatory agency may also assume a central role in other productivity-related issues requiring cooperation among utilities. Such issues include centralized dispatch, power pooling benefits for the better performers, common spare-parts inventory, personnel training, and maintenance coordination (possibly establishing rotating maintenance teams).

A state may have several agencies involved with different aspects of electric utility regulation (typically, a Power Siting Commission, an Environmental Protection Agency, a Department of Energy, and/or a Public Utilities Commission). The policies and actions of all such agencies in a state can affect plant productivity. For example, certain environmental/safety regulations may require plant retrofit and modifications of existing plants. Such modifications may contribute to poor plant performance. The regulatory agency with the responsibility to ensure high plant productivity may require the evaluation of proposed regulations and environmental and safety measures for their impact on productivity, and require debating the issue before such measures are adopted.

Many outages in coal-fired power plants are due to equipment breakdown related to poor quality. In many cases poor coal quality is due to moisture, rock, and ash content. The regulatory agency may set standards for the quality of delivered coal.

A regulatory agency may take steps to facilitate the licensing of standard-design plants. Standard designs are expected to be more reliable than custom designs. In addition, a spare parts inventory of standard components may be readily shared by different utilities in the state.

Other possible actions by a regulatory agency are:

- Allow for plant designs that have a higher construction cost but are also more reliable;
- Allow for recovery and reduce lags in recovery of productivity-related capital expenditures;
- Identify and reduce possible disincentives in the regulatory process to improved plant productivity. For example, address questions such as:
  - Does the fuel adjustment clause remove the incentive for performance improvement?
  - Does a heat rate incentive make the utility allocate money for the improvement of heat rate at the expense of availability improvement?
- Ascertain that utilities have sufficient money available in a timely manner for maintenance; and,
- Support efforts by EPRI and NERC to develop an accurate national data base by inspecting the data sent by the utilities to these agencies.

PART 6: ENFORCE THE ATTAINMENT OF HIGHER PRODUCTIVITY THROUGH REGULATION

State regulatory agencies have the option of utilizing a number of possible mechanisms to encourage and enforce power plant productivity improvement. The issue can be reviewed in a rate or fuel adjustment proceeding, or in a procedure outside the province of traditional rate base regulation, such as in a generic investigation, or an independent hearing.

Rate Case Hearing

In a rate proceeding, the issue of power plant productivity can be examined within each of the three major components of the revenue requirements equation: rate base, rate of return, and expenses.

The rate base represents the net capitalized investment the utility has in plant, materials, supplies, and other assets which are used and useful in providing service to the utility's consumers. Adjusting a company's rate base as a result of a power plant productivity assessment is theoretically valid; it is an adjustment of the value of the plant for a portion of the plant that cannot be utilized. However, the long-term impact of adjusting the utility's rate base should be measured against the record of the plant in question. Poor power plant productivity, as measured by a performance index such as operating availability factor or capacity factor, is often a short-term effect and can vary significantly on a monthly basis.

In a more positive sense, the rate base component can also be used to reflect a utility's increased investment in spare parts inventory for its existing plants or in capital improvements to existing plants or those under construction.

An incentive for power plant productivity improvement can also be incorporated into a regulatory body's evaluation of a utility's rate of return. The rate can be adjusted to reflect the positive or negative difference in a utility's system (or unit) performance when compared with a target set by the regulatory agency. This type of adjustment is probably the easiest to implement, since the rate of return valuation is the most judgmental element in the revenue requirements equation. A target mechanism also has the advantage of having a potentially significant impact on the utility; a small percentage change in the rate of return will affect the utility's entire rate base return.

The appropriateness of incorporating power plant productivity considerations into the rate of return calculation is not clear. Since a regulatory agency's role, in economic terms, is to simulate competition for a utility, the efficient operation of that utility could be considered a valid criterion for adjustment of the rate of return. Certainly, the inefficient operation of a utility is reflected in an increased cost of capital for that utility. However, the concept of economic efficiency is usually applied in more general terms than specific power plant performance. Some economists believe that adding a specific power plant productivity incentive to the rate of return calculation is inappropriate because the rate is designed to reflect only the cost of capital to the utility, and because the efficiency factor is implicit in that cost. However, this is not necessarily a universally accepted premise.

The expense component of the revenue requirements equation is composed of expenses incurred in furnishing service to the utility's consumers. The regulatory agency could permit the inclusion of a specific (or system-based) corrective action or preventive maintenance expense, either recurrent or non-recurrent, based on the results of a cost-benefit calculation. The predicted benefits could be monitored, either through examination in the subsequent rate case or through a shorter-term proceeding such as a fuel adjustment clause hearing. Such a mechanism is justifiable on the grounds that the money expended on a corrective action, preventive maintenance, or spare parts can be classified as an operations and maintenance expense.

A major problem with this type of adjustment is that current methods might not be sufficiently refined to accurately quantify potential benefits to support a dollar adjustment. Also commission proceedings have been traditionally based on historical information and this type of forward-looking adjustment could be limited or prohibited by statute.

Fuel Cost and Purchased Power Adjustment Hearing

Power plant productivity improvement could also be encouraged in a fuel cost adjustment clause proceeding. An adjustment to the fuel and purchased power recovered by the utility, perhaps through a target mechanism, would have an immediate impact and could be reevaluated on a regular, more frequent basis than in the rate case proceedings.

Independent Hearing

Assuming that a regulatory agency has, or can obtain, the authority to require utilities to improve their performance, the issue of power plant productivity can be considered outside traditional regulatory procedures.

Careful implementation of any target incentive program, whether it is based on a systemwide index or on the performance of a specific unit, is necessary to avoid compounding the adverse effect of a substantial outage. In addition, outages must be examined carefully to avoid penalizing the company for factors not within its control.

In most of these examples, the potential for a positive as well as a negative adjustment reflecting the status of power plant productivity exists. In the development of an enforcement mechanism, each regulatory agency should evaluate the potential impact of a positive incentive against the concept that a utility should not earn more than it has expended. In addition, each agency must evaluate existing statutes; they may limit or prohibit adjustments such as those described above.

CHAPTER 4

CURRENT ACTIVITIES AND PROGRAMS TO IMPROVE POWER PLANT PRODUCTIVITY

4.1 Introduction

Before 1970, little attention was given to formal industry-wide programs to improve availability, design, reliability, maintenance and operation of generating facilities. However, since the 1973 oil embargo and the increasing tide of inflation in recent years, the need for cost effective power supply planning has become increasingly important. Significant increases in the cost of oil have resulted in major increases in the cost of generation when nuclear and coal units are down. The availability and reliability of these units is becoming a critical path item in the wake of the nation's petroleum shortfall and regulations prohibiting the use of oil or gas for generation. In addition, the cost of constructing and operating new facilities has escalated to the point that improvements to existing facilities are, in many instances, more cost effective than adding new capacity.

No determinations have been made with regard to the extent that improved productivity programs are national in scope. The following discussion, taken from the available literature, represents industrial, federal, and state activities directed towards improving power plant productivity.

4.2 Industry Activities and Programs

4.2.1 Data

Industry efforts to assess and upgrade existing data bases have accelerated greatly since 1975 when the Federal Energy Administration (FEA) Task Force on Improving Power Plant Productivity concluded that existing sources of data on power plant performance were inadequate [30]. Numerous industry initiatives in the area of performance data have been taken which are responsive to the FEA Task Force recommendation for a coordinated industry effort for the collection, storage, analysis, verification, and dissemination of power plant performance and reliability data.

As a follow-up to the FEA Task Force recommendation, the American National Standards Institute (ANSI) established in May 1976 the Ad Hoc Steering Committee on Power Plant Data Systems [28] for the purpose of obtaining a national consensus on what data is needed and how best to obtain it. The Committee, made up of representatives from industry and government, held a series of meetings with various sectors of industry and with various federal agencies to obtain a comprehensive assessment of the following questions: What data is needed and how is it used? Of what use are the existing data systems and what are their inadequacies? What is the scope of other data systems and what is their use? What are the recommended actions for establishing an adequate national data base? A total of 59 industry organizations and 8 federal agencies responded to these questions. This comprehensive assessment led to the following key findings and conclusions:

1. Data reporting already is a major effort and represents an increasing burden of concern to utilities.
2. No one system can satisfy all power plant reliability data and problem-solving needs without becoming unwieldly and unworkable.
3. A national, industry/government-supported, unified, centralized information system is needed for key performance and reliability data.

4. Existing data systems are inadequate, do not meet many of the needs of industry and government, and have not been readily accessible.

5. Improved communications and educational programs are needed to put power plant performance and reliability in the right perspective.

6. Root causes and corrective actions for generic problems must be determined to achieve widespread improvements in power plant reliability.

7. Standardized uniform terminology and definitions are needed in the reporting of performance and reliability data.

8. An early-alert reporting system is needed for generic equipment problems.

The Committee recommended the following industry/government actions:

1. A unified, centralized information system on power plant performance and reliability should be established with the cooperation of industry and government.

2. Industry should continue to improve existing industry data systems to increase their usefulness while a unified, centralized information system is being established.

3. Industry and government should adopt standard definitions and terminology in using existing systems and in a unified, centralized information system.

4. Industry should establish an early-alert reporting system to be adopted on an industry-wide basis for reporting generic equipment problems that have a high probability for causing unit unavailability.

5. Industry should improve its problem analysis and solution efforts with a coordinated plan of action involving utilities, architect/engineering firms, steam system suppliers, and manufacturers.

6. Industry should implement reliability engineering methods in the design, construction, operation, and maintenance of power plants, beginning with plant specifications and continuing through operations.

7. Industry should clarify the confusion over power plant performance through improved communication of performance and reliability data and its interpretation.

8. Industry and government should establish a joint committee on data activities in order to continue and consolidate ongoing fragmented efforts to coordinate data collection.

9. Industry and government should eliminate redundant information systems and should utilize the unified, centralized system.

In parallel with the broad based assessment of the ANSI Committee, the Electric Power Research Institute (EPRI) conducted a 16-month investigation of the data needs of the industry [18] together with recommended actions [21]. These investigations essentially confirmed the Committee's findings and conclusions and resulted in recommended actions that were consistent with the Committee's recommendations. Most of the recommendations of the ANSI Committee are in the process of being implemented.

1. Development of a national data system is underway at EPRI. Initially, EPRI studied the experience of a number of large organizations, both inside and outside the utility industry, with the collection of data related to equipment performance in large complex systems and assessed the feasibility of consolidating power plant data bases [4]. The study concluded that a consolidated data system would be cost effective and should be developed. In October 1978 EPRI conducted separate studies, one aimed at unit outage and performance statistics and the other aimed at component failure data, to establish the applications that would be made of the data system, the data requirements for such applications, the data collection/reporting methods, and the data system scope. In April 1979 EPRI issued Request for Proposal to do Phase II of the national data base development. In Phase II, a set of detailed specifications for the data base will be developed covering the reporting procedures, computer system, and computer software requirements. Bids were received in July 1979. Due to the higher priority of work associated with the Three Mile Island accident, the Phase II effort has been suspended temporarily. Phase III of EPRI's program is planned to be a pilot demonstration program involving several utilities. Very recently, the Chairman of NERC formally urged the President of EPRI to reactivate this project and to get the Phase II effort under contract.

2. In parallel with development by EPRI of a national data system, which will take several years, the industry is taking new initiatives to improve the accuracy, timeliness, and availability of the existing systems. Responding to the ANSI Committee's specific recommendations, the Edison Electric Institute (EEI)

has released its data base to all interested parties, and has developed and begun implementation of a data quality assurance system. To improve the timeliness of the data as well as its accuracy, the industry has greatly increased the resources being applied to the EEI data base. Effective January 1, 1979 the responsibility for the data base was transferred to the National Electric Reliability Council (NERC). Whereas the total manpower assigned to the data base at EEI had been less than one full-time professional, the industry has now provided sufficient funding such that at NERC a staff of five is already at work, an in-house computer has been procurred, and a substantial amount of contract support is authorized. To further strengthen NERC's efforts, a Joint Advisory Committee on the Generating Availability Data System (GADS) was established in May 1979 made up of representatives from EEI, EPRI, NERC and DOE. The Committee provides advice and consultations to the NERC staff, interfaces with EPRI on development of the national data system, encourages industry and government use of the central data systems, and works to eliminate duplicative data collection efforts. DOE and its contractor, the Oak Ridge National Laboratory (ORNL) has conducted a detailed assessment (on a small sample) of data accuracy and NERC is currently applying the tools developed therein to check the data currently being received from utilities. A detailed, comprehensive description of NERC's data base rebuilding program is included in a paper given at the April 1979 Reliability Conference for the Electric Power Industry [17].

3. An ad hoc committee made up of industry and government representatives, under the auspices of the EEI Equipment Availability Task Force has prepared a draft standard of terminology relevant to power plant productivity and of standardized definitions for power plant performance indices. Under the sponsorship of the Institute of Electrical and Electronics Engineers (IEEE) this standard is currently in the process of being published as an IEEE standard which will be submitted to ANSI for approval as an ANSI national standard.

   In the past year, the Power Generation Committee of the Power Engineering Society, IEEE, established the Ad Hoc Working Group on Availability of Generating Units to develop recommended guidelines for recording and presenting in narrative form the failures which occur in power plants. The working group has drafted its recommendations and will present them to the industry in a paper at the winter meeting of the Power Engineering Society.

4. Through EPRI, the industry has initiated action to establish an early-alert problem reporting system. The scope and proposed operating methodology for the system have been developed [22]. As proposed, the system would become an integral part of the national data system.

5. Although the industry still lacks a coordinated plan of action for problem analysis and solution, it has taken several initiatives that constitute significant progress in that direction. EPRI has conducted industry workshops on its own in September 1977 [25], November 1977 [26] and August 1978. In addition, in September 1976, EPRI co-sponsored with the American Nuclear Society an Executive Conference on Improving Power Plant Availability.

6. Significant steps have been taken leading to increased implementation by all sectors of the industry of reliability engineering methods in the design, construction, operation and maintenance of power plants. In June 1978, EPRI, EEI, NERC and DOE co-sponsored three seminars for top utility management on Availability Engineering and Power Plant Productivity Improvement. These same four organizations, in early 1979, sponsored a series of five workshops on Availability Engineering and Productivity Improvement for staff and project personnel from utilities, architect engineers and equipment manufacturers. These 3-day workshops provided in-depth demonstrations and practice of various availability and productivity improvement methods that have been developed by industry and the DOE in recent years. In addition to the coordinated, industry-wide efforts described above, numerous utilities, some equipment suppliers, and the steam system suppliers have initiated in-house efforts to improve the collection and use of power plant performance data.

4.2.2 Design Improvements

A major element in the improvement of design activities to achieve better productivity has been the establishment of high productivity as an explicit requirement in the design process. To bring this about, Combustion Engineering has formed a standing committee on availability and reliability of the steam supply system. The committee is usually charged with the regular analysis of operating experience data and its responsibilities may include the publication of alert notices for design improvements, or ensuring that design, manufacturing and operating problems that affected initial reliability are corrected.

The feedback of operating experience data to the design process is an effective means for improving productivity in component and system design. Most organizations involved in design use feedback in one form or another, and significant design accomplishments have been achieved. Testing to support design efforts is being used by several firms. As an example, Combustion Engineering has carried out an extensive field test program to broaden the data base on coal fired units. These data provide the basis for upgrading performance prediction tools to deal with current design deficiencies and set the foundation for handling new unit designs.

Boston Edison used models in a study of reactor refueling, while in the design stage, to improve efficiency and reduce outage. The study concentrated on activities and equipment inside the reactor containment structure. The study was used to analyze the critical path in refueling to provide a basis for cost-benefit analysis of improvements. It was established that implementation of certain findings would cut an estimated five days off of a 42-day refueling outage.

Present actions to improve the productivity aspects of design may be summarized as establishment of productivity in policy and organizational arrangements, use of operating experience including both data and participation of operating personnel, feedback, testing and laboratory research to verify designs, and use of models to evaluate design. These actions have already led to important improvements and offer potential for even greater ones with wider implementation to the utilities themselves.

4.2.3 Manufacture and Construction

Quality assurance during manufacture and construction of components and units is vital to the reliability and productivity of power plants. The use of models of parts of a plant is helpful in understanding each step in the construction sequence, thereby improving the quality of construction and helping to ensure that construction activities do not cause problems that will ultimately reduce power plant productivity.

An example of the use of models for design and construction is found in the Standard Nuclear Power Plant System (SNUPPS) project, where a set of models, including a construction sequence model, was used for design and construction. The set included the entire power block and associated excavations and yard facilities. The construction sequence model was used by a group of experienced construction field supervisors as a means for providing early input to the engineering design effort. It has been used to develop a civil-structural sequence and schedule for important construction operations. The engineering and construction personnel have made use of the model to create particular construction situations in advance of detailed design portions under construction.

4.2.4 Operations and Maintenance

The technical skills of the operations and maintenance staff are very important to the overall productivity of power plants. To achieve a high level of technical skill, most utilities operate a training program for personnel. Vendors also support training by establishing and operating training programs and by providing special capabilities such as training simulators. Some utilities have established training units and formal training programs within their organization. In most cases, the programs address the training requirements of both management and technical personnel, though the scope, level of implementation, and participation vary widely throughout the industry.

One of the highest payoff areas for investment in productivity improvement is initial path maintenance and outage planning. Analysis of activities during outages can lead to significant reductions in the time required and resulting outage duration. Development and documentation of procedures for preventive maintenance and outage activities will improve performance and achieve planned outage goals.

Adherence to planned maintenance schedules will reduce forced outage rates. With some utilities, maintenance guidelines are developed and followed to the fullest extent possible. For example, turbine generators being maintained on the basis of planned inspection and repairs rather than on a breakdown basis. More attention is given to improving outage schedules and to expediting equipment and materials during overhauls. Also, it is less costly to make greater use of company personnel in place of contract labor.

As part of a concerted effort to reduce fuel use and energy purchases, San Diego Gas and Electric has developed a computerized optimization technique for the overhaul of major generating units. By proper scheduling of maintenance, down time is minimized and the complete system is operated at the best average efficiency. A series of computer programs is used to iteratively select the most economical overhaul schedule. By using these programs in conjunction with an overall heat rate improvement program, the utility's system heat rate improved from 10,945 Btu/kWh in 1974 to 10,481 Btu/kWh in 1975; a rise from 70th to 41st place in a survey of heat rates among other utilities. The use of the computer program alone resulted in saving more than $1 million in system fuel costs.

The availability of spare parts during maintenance outage is of particular importance. Several organizations have addressed this issue. Stone and Webster developed a comprehensive procurement and inventory control program for a reactor that included steps to improve its equipment specification preparation procedures so that spare parts requirements are anticipated and specified, developed a system for evaluating the spare parts needed to support plant equipment, established the procurement control necessary for effective quality assurance and accurate cost accounting, and determined the scheduling required to ensure timely order placement and delivery.

Performance goals have been established by many utilities as targets and measures of success for improved power plant productivity. As reported to the Federal Energy Administration's 1975 regional meetings on power plant productivity, the goals vary widely in level of detail. In some cases, vague, general goals were reported; in others, very specific goals related to several aspects of individual units with accompanying accomplishment plans were presented. Together with an improved data collecting system, there is a need for more consistency in utility operation and maintenance programs in order to improve power plant productivity.

4.2.5 Fuel Quality

Several equipment breakdown problems have been attributed to low coal quality. The rock content of coal has, in many cases, caused coal handling equipment breakdowns, and moisture and ash content in coal has been affecting boiler performance. The ability of a boiler to handle a wide range of coals has become a crucial design consideration. There are active programs currently underway (some in conjunction with the U.S. Department of Energy) to promote design improvements and for fuel treatment to prevent such equipment problems.

4.2.6 Standardization

Standardization based on reliable designs is still another step towards improving productivity. Few projects designed for standardized plants have been achieved; however, the thrust toward more efficient power plant operation and performance has been increasingly lent to standardized design of nuclear and coal fired units.

4.2.7 Research Activities

The Electric Power Research Institute has underway a number of projects specifically aimed at improving the productivity of fossil and nuclear power plants. The objectives of the fossil program are:

1. Within five years provide the capability for a five percentage point improvement in large fossil plant reliability and a 0.5 percentage point improvement in plant efficiency;

2. Identify and investigate the factors affecting reliability and performance of both power plants and plant components;

3. Initiate projects which will improve plant reliability by providing a better operating environment for critical components, better inspection and quality control in plant design, improved operating conditions and control techniques, and improved materials and equipment designs; and,

4. Develop standards of performance for use as a basis for generating plants and components specifically by the utility industry.

This fossil program has been put into place within the last two years. A comparable nuclear program has been in existence for a longer period of time. In general, EPRI has substantially increased its efforts to obtain the maximum productivity from existing units and is initiating projects with a near term payback.

4.3 Federal Activities and Programs

Energy programs in the federal government relating to power plant productivity are diverse as well as specialized in several cases. Most of the studies originated in parent agencies (Energy Research and Development Administration, Federal Energy Administration, Federal Power Commission, etc.) but have since been incorporated into functions of the Department of Energy. This section focuses on three major programs sponsored by the U.S. Department of Energy: the Power Plant Productivity Improvement Program, the Light Water Reactor Technology Program and the Fossil Energy Programs. At the end of this section, a project sponsored by the U.S. Department of Agriculture is also cited.

4.3.1 Power Plant Productivity Improvement Program

This program was initiated with the Federal Energy Administration in 1974 and continued by the U.S. Department of Energy. The objectives of the program are to increase productivity awareness, encourage productivity improvement programs, highlight the cost effectiveness and benefits of improved productivity, and publicize examples of improvements that are well documented. Activities to meet these objectives include power plant performance data analysis, documentation of model methodologies for improving power plant productivity, assessments of potential benefits and cost-effectiveness of improved power plant productivity, workshops and seminars to disseminate and exchange information, and cooperative projects with states to demonstrate analytic techniques for performance evaluation and to develop regulatory mechanisms for productivity improvement. This report on regulatory mechanisms is a portion of the ongoing effort of the Power Plant Productivity Improvement Program.

The FEA program was initiated by a comprehensive assessment by an interagency task force of the status of power plant productivity. The results of this assessment including the task force conclusions and recommendations were published in 1975 [30] and were mailed to the heads of all utilities and state PUC's.

An in-depth assessment of the status of efforts within the utility industry, conducted in late 1975 - early 1976 in a series of nine regional meetings, showed growing utility awareness of the increasing economic value of improved power plant productivity but revealed a very wide disparity among individual utilities in actions being taken to improve productivity. The results of their assessment also were mailed to all utilities and PUC's [38].

In parallel with their assessment, three separate investigations were made on a total of 12 large power plants to determine the underlying causes of poor productivity. These studies revealed that the actions of utility management, regulatory commissions, and the impacts of legislation to preserve the environment were affecting productivity as much or more than equipment failures.

The importance of systematic, in-depth assessments of the root causes of plant outages and de-rates was made vividly clear by these investigations; yet, at the same time, they revealed a serious lack of reliable up-to-date information on equipment performance and the causes of outages as well as the absence of proven analytical methods and tools for conducting rigorous engineering economic evaluations of poor productivity and productivity improvement projects [37]. To overcome these deficiencies, the FEA/DOE program includes extensive efforts to develop, document, and publicize analytical methods for assessing the potential benefits of productivity improvements and for evaluating their cost effectiveness.

Under contract to the General Electric Company and in cooperation with several utilities, an approach was developed for making a realistic assessment of the potential benefits in terms of fuel and capital cost savings, reduced use of oil and gas, and reduction in needed capacity [33-35]. The methodology is applicable at the plant, utility, regional and national levels and it takes into account all of the constraints under which utilities operate. Although the benefits estimated in this manner are only about 40 percent of the theoretical estimates on a nationwide basis, they still are significant. For example, increasing the average capacity factor of 400 MW and larger coal and nuclear units by 10 percentage points between now and 1990 on an industry-wide basis would, in the year 1990, reduce fuel costs by over 8 billion dollars (current dollars), reduce oil and gas consumption by 870,000 barrels per day, and reduce capacity requirements by more than 30,000 MW.

In parallel with the development of the GE methodology for assessing potential benefits, methodologies were developed under contract to Mechanics Research Inc. (now Systems Development Corporation) for systematically tracing plant problems back to their root cause. Under the same contract, an analytical method, which makes use of conventional reliability analysis, was developed which can be utilized to predict the effect of changes in improved power plant component reliability upon overall power plant reliability. Approaches also were described and demonstrated for evaluating the cost-effectiveness of specific improvement projects. All of this work was done with the cooperation and participation of three major utilities [24].

Following development of the above mentioned analytical methods, the DOE entered into cooperative projects with the Ohio and Illinois PUC's to demonstrate their usefulness and validity. These projects are described in Section 4.4 of this report. The application of these methods were introduced earlier this year to hundreds of utility staff and project engineers through the DOE/EPRI sponsored workshops on Availability Engineering and Productivity Improvement. (See Section 4.2.1, item 6.)

Recognizing that policies and regulations of state PUC's may contribute to poor productivity, the DOE has undertaken cooperative projects with the Ohio and Illinois PUC's and the Texas Energy Advisory Council for an assessment of such policies and regulations and for identification and development of alternative actions that might be feasible at the state level for motivating utilities to improve productivity. These projects are described in Section 4.4 of this report.

Over the past several years, the FEA and DOE have taken a variety of actions aimed at the establishment of an accurate, timely, and accessible data base on power plant performance. The FEA and DOE policy has been to improve and make more effective use of the existing industry data systems rather than have the government get into the data collecting business. Consistent with its overall position that the industry has the lead responsibility for improving power plant productivity, the FEA and DOE have encouraged and supported the industry data efforts described in Section 4.2.1. While the industry's upgrading efforts are going on, DOE has compiled productivity data from available sources and has performed analyses of power plant performance through its contractor, ORNL. In 1978 DOE published and distributed to industry and the states a statistical summary of the performance of nuclear and coal units 400 MW and larger [12]. With the EEI and NRC Grey Book data bank on file, DOE has an in-house computer capability that has been used to fulfill many requests from state PUC's and other agencies for power plant performance information. DOE also has conducted special investigations including a statistical analysis of the effects of various power plant design parameters on productivity [16] and an investigation into the causes of widespread anomolies in the EEI data base [32].

4.3.2 Light Water Reactor (LWR) Technology Program

The Department of Energy's LWR technology program is directed towards providing technology developments which are beneficial to the public interest and not likely to be accomplished without federal initiatives [15]. Consistent with the President's National Energy Plan, DOE's technology program is aimed at endorsing the role of light water reactors in the nation's energy economy.

The LWR technology program revolves around objectives which seek to (1) improve performance of existing reactors, and (2) investigate the evolution of light-water-reactor technology and economics. The rationale underlying these objectives is to provide relevant benefits from nuclear technology without increased regulation, and to avoid replication or duplication of effort by industry and/or research organizations.

Efforts to improve the performance of existing reactors include identification of problem areas, assessment of the potential for improvement in problem areas, and identification of the proper role of DOE in developing and demonstrating improvements. These efforts deal not only with known problems but also diagnose impacts of potential problems.

The potential for improvement in problem areas is directed toward developing maintenance and repair technologies which would contribute to higher productivity and developing techniques designed to change reactor components, when necessary, in an efficient manner. There is a series of demonstration projects planned which will entail utility/vendor teams working to improve refueling/maintenance outages based on results of studies completed by DOE in 1978. These demonstrators will involve not only the reactor system but the balance of the plant as well. Areas to be worked on include chemical cleaning techniques, diagnostic techniques related to non-radioactive systems, and flow induced vibration improvements.

Portions of the program to detect future problems and methods for diagnosing them are directed towards evaluation of Boiling Water Reactor pipe cracking and radiation embrittlement of reactor pressure vessel materials. The purpose is to develop techniques for detecting problems at an early stage and to develop techniques to resolve them through their root cause. Future problems' detection is based on current reactor design and an assessment of what information exists for better resolving future problems such as in-place-repair techniques.

The above mentioned programs have been included in the DOE's Fiscal Year - 1979 projections within the Office of Nuclear Energy Programs under the Assistant Secretary for Energy Technology. Entitled Productivity Improvement Technology, the programs accompany other objectives in the areas of uranium utilization, radiation dose reduction, and safety technology in the implementation plan. It is generally assumed that these policy objectives are all in the interest of improving performance and supportive of technical advances in reactor operations.

4.3.3 Fossil Energy Programs

The Department of Energy's Fossil Energy Program was initiated in 1977 and has experienced a stronger thrust toward developing solid fuel-related strategies in recent months [9]. This has been due, in part, to the need to develop domestic supplies and utilize the nation's coal supply.

The objectives of the Fossil Energy Program, relative to power plant productivity, encompass the need to assure that current and proposed facilities be able to burn coal in an economically viable and environmentally acceptable manner, as well as to create a more efficient and economically attractive option for utilities in the choice of fuel. In order to develop a strong technology base for further development, these objectives are sought through a wide range of basic and applied research activities.

Coal cleaning tests are primarily directed toward desulfurization technologies. Six basic processes, which remove pyritic and organic sulfur from coal, are presently being performed and tested to determine commercial feasibility. Eventually, coal cleaning processes will aid utilities by reducing the need for scrubbers and increasing boiler efficiency by furnishing a higher Btu content in treated coal. Coal cleaning techniques are differentiated between physical and chemical processes under the umbrella of coal preparation technologies. The amount of impurities has increased in recent years and there is a need for greater uniformity in coal feedstocks, particularly for power plant use. Unlike chemical cleaning, as found in desulfurization techniques, physical cleaning is less expensive and more environmentally acceptable. Physical cleaning methodologies are particularly important for western coal with specific attention to the lignites. As the nation relies on greater coal utilization in the years ahead, the development of methods for coal cleaning will play an important economic and environmental role. Evaluation studies by the DOE for physical cleaning techniques cover a time frame between Fiscal Year - 1979 through Fiscal Year - 1983. Schedules for chemical cleaning studies' completion and commercial application range between Fiscal Year - 1982 for some cleaning procedures to Fiscal Year - 1987 for others which have serious technical and economic issues to be resolved. DOE demonstration projects for more promising techniques can begin as early as Fiscal Year - 1981 and 1982. Over the long run, the advent of coal cleaning technology should lend significant help in improving power plant performance.

Environmental standards represent a severe constraint on the direct use of coal by electric utilities. New technologies are needed in order to maintain the standards without sacrificing greater coal use for more imported oil. One avenue being pursued, leading to improved performance standards for coal boilers, is improving flue gas cleanup and removing pollutants from stack gases of conventional combustion units. The Fossil Energy Program includes an Advanced Environmental Control Technology Program which addresses means by which cleanup systems can be developed and integrated into power generation. The flue gas cleanup activity includes examination of lime/limestone scrubber reliability, advanced flue gas desulfurization and advanced flue gas cleanup. Given that poor scrubber availability in the past few years has resulted in plant shutdowns, this work is particularly important. In addition, the New Source Performance Standards now in effect almost mandate improved technology in conventional combustion in order to realize cost-effective production over the long term.

The status of the flue gas cleanup program is detailed in the Office of Program Control and Support Summary Document [9]. Initiated in Fiscal Year - 1979, the program will see expanded efforts in Fiscal Year - 1980 and will utilize cooperative efforts of other organizations including industry, associations and federal power systems.

The Fossil Energy Program also includes research and development in the area of combustion systems. The objectives here include the development of fluidized-bed combustion systems capable of burning all types of coal with environmental compatibility, a technology to improve the reliability and efficiency of boilers and furnaces, including present operations and future advances. The efforts are being directed towards environmentally acceptable methods of combustion and advanced technology for coal utilization. The DOE already has several programs underway in this area and some demonstration projects exist for fluidized-bed and coal-oil mixture technologies. The emphasis on this program is geared toward burning coal efficiently and cleanly in compliance with the Clean Air Act, and developing methods for substituting coal or coal derivatives for oil and gas. The outlook for commercial demonstration and operation of this program is optimistic, based on DOE budget allocations through Fiscal Year - 1980.

The Fossil Energy Program is extensive and comprehensive and follows the national plan for greater use of coal. In addition to the above mentioned projects, the program also includes research and development programs geared for more economic and efficient use of coal in utility and industrial boilers. The Fossil Energy Strategy envelopes research and development programs in coal liquefaction, coal gasification, as well as gas and oil recovery programs, all designed to increase our independence of energy supply. Not the least important goal of this program is the eventual benefit to be derived by the utility industry in the use of coal as a prime energy source. The DOE program is trying to combine economic feasibility with environmental acceptability in order to further satisfy the needs of power generation. Performance standards of utility boilers should be enhanced by fossil energy research and development before 1990.

4.3.4 Preventive Maintenance Management

A strong preventive maintenance program can, in many cases, greatly improve power plant productivity. In an effort to enhance the opportunity of its Generation and Transmission Borrowers to capture these benefits, the Rural Electrification Administration has developed a comprehensive bulletin, "Preventive Maintenance Management Manual." This manual, U.S.D.A. Bulletin 163-2, will be published in the fall of 1979 and will provide the required elements to build a strong preventive maintenance program.

4.4 State Activities and Programs

The extent to which state regulatory agencies have concerned themselves with power plant productivity has been identified by The National Regulatory Research Institute in a series of interviews with state agency staff and a review of available literature published by state agencies. The interviews revealed that most state regulatory agencies do address the issue of productivity in either rate cases, fuel adjustment clauses, or in power plant siting proceedings. One state, Michigan, addresses productivity through a separate availability hearing.

Seventeen state regulatory agencies reported being involved in projects aimed at improving power plant productivity--the projects having been either funded by the Department of Energy or by state grants. The most widely used measures of productivity were availability factor, capacity factor, equivalent availability, equivalent forced outage rate, forced outage rate and heat rate, though not necessarily in that order or priority. It was found that many state agencies recognize that the primary benefit from improved power plant productivity would be savings to the ratepayer. However, the majority of states were not considering plant performance as a determining factor in fuel adjustment clauses, nor did they employ financial incentives to compel utilities to improve power plant productivity.

This section summarizes activities and programs to improve power plant productivity in California, Illinois, Michigan, New York, North Carolina, Ohio, Texas and Virginia. More detailed descriptions of the activities and programs can be found in Appendices A through G.

CALIFORNIA

California is pursuing improved power plant productivity along two fronts: new power plants and energy cost adjustments. The California Public Utilities Commission is responsible for obtaining the most cost-effective level of reliability and productivity for existing power plants through utility regulation, while the California Energy Commission (CEC) is principally responsible for the same activity for new plants through its power plant siting authority.

Energy Cost Adjustment

In order to reduce utility risk due to widely fluctuating fuel prices, the Public Utilities Commission instituted an Energy Cost Adjustment Clause (ECAC) which provides a cost adjustment mechanism. Under the ECAC procedure, the staff is responsible for investigating the utility's energy costs and recommending an adjustment factor.

A recent decision by the Public Utilities Commission indicates that both productivity improvement and a system of incentives to stimulate improvement by the utility can be a part of the ECAC. Orders No. 4 and No. 5 of Decision No. 90488, July 3, 1979, of Southern California Edison's Application No. 90488 states as follows:

> . . . .
>
> 4. Edison shall prepare as a part of its ECAC application for rates to become effective November 1, 1979, a proposed system of incentives for improved operation of its coal-fired power plants and shall recommend standards of performance for these plants on which to base incentives.
>
> 5. In cooperation with the staff, Edison shall select and retain an independent expert consultant to assess, evaluate and report on Edison's coal plant operating practices and the standard performance that can be expected of these plants.

The staff is responsible for review and recommendations on the utility's response to these orders. The recommendations will likely be based on a combination of one or more of the following indices:

1. operating availability;
2. equivalent availability;
3. capacity factor.

The staff is considering including both a penalty for poor performance and a reward for good performance in recommendations concerning incentives.

Also the staff is considering the concept of post mortem analysis which would be based on the use of production cost simulation and historical data. Thus, it will be possible for the staff to judge how well a utility has made use of interconnections in search of cheaper power as well as of its own resources. This analysis is only in the formative stage.

New Power Plants

The California Energy Commission (CEC) is responsible for the siting of new power plants within the state. A recent commission study of power plant reliability and efficiency has established guidelines, indices and ranges of reliability and power plant performance to be used in assessing the productivity of proposed new generating stations [23]. A two-part guideline has been developed to assure that the most cost-efficient levels or ranges of reliability and efficiency will be obtained by plants to be sited in California. The first part addresses the utilities' establishment of the most cost-effective range of reliability for new plants within the power system. The second part insures that specific actions will be taken by the utility to achieve established ranges of efficiency in the most cost-effective manner. There is a standard agenda in the guidelines in the form of a list of key issues for use by the utility and CEC to assess the cost effectiveness and attainability of reliability levels.

Indices of power plant performance have been recommended for the CEC's and utilities' use in assessing reliability and efficiency for new power plants: (1) operating availability; (2) equivalent availability; (3) capacity factor; and (4) heat rate. These indices have been suggested because they may be used individually and in combination to assess the cost effectiveness of a proposed facility. The analysis of historical power plant reliability data acts as a guide in formulating meaningful questions on the ability of new facilities to achieve desired levels of reliability and efficiency. While the data are useful in this manner, they are not proposed as standards for predicting future performance of new units. A more comprehensive description of the guidelines study can be found in Appendix A.

ILLINOIS

Prior to its current study with the U.S. Department of Energy, the Illinois Commerce Commission took note of power plant productivity only when the issue arose on a case-by-case basis. In 1976, the commission ordered a management audit of one utility. One of the recommendations emerging from this audit was to establish a productivity strike force at a certain plant. Improved maintenance practice and the setting of availability progress goals were also encouraged. The management audit report acknowledged the complexity of the problem and the efforts undertaken by the utility, but stated that the approach has been fragmented and lacked direction and force. The commission monitored the activities of the utility in carrying out the recommendations.

Power plant productivity became an issue during a rate case with another Illinois utility during 1976. The utility petitioned the commission for a purchased power adjustment clause due to low productivity at a nuclear plant. The utility was a joint owner of the facility and needed expensive purchased power when the reactor was out of service. The commission recognized the disincentive effects of such a clause in this case and rejected the petition.

Cases such as these have served to sensitize the commission and staff to the growing importance of power plant productivity. This realization led to involvement in the joint study with DOE which is scheduled for completion in the near future. The goals of the DOE project were to increase staff expertise in the area, examine current levels of power plant productivity in Illinois, and to study possible methods of encouraging improvements where they would be cost beneficial.

Preliminary observations from the study suggest the need for increased commission staff monitoring of productivity figures. The monitoring will most likely be based on EEI data with backup from data furnished by utilities. After the establishment of a data base, it is recommended that such information be introduced into the rate case forum. With regard to comparison of productivity figures, this may be done using statewide and national data. Also, comparison could be made by life year and generating unit and size. Where low productivity could not be justified by the utility, adjustments might be made to replacement power expense or to the allowed rate of return.

The commission is also just now embarking on a study of what might be the appropriate level of productivity for future generating stations in Illinois. This study will attempt to establish groundwork for determining how much reliability should be anticipated in the design for new facilities. Information in this regard will be used in future plant certification proceedings. A more comprehensive description of the activities related to productivity improvements in Illinois is included in Appendix B.

MICHIGAN

The Michigan Public Service Commission has established a system availability incentive provision for the state's two major utilities which rewards or penalizes the companies financially, based on a scale of rate of return on common equity and system availability [31].

To date, two availability incentive provision cases have been reviewed. In one instance, the commission determined that the utility had qualified for a bonus return on common equity based on the system availability achieved for a previous calendar year.

In December 1977, the commission staff formed an availability task force to identify contributory causes of power plant availability decline within the industry and also within the regulatory structure. In March 1979, the task force issued a paper entitled "Report on Power Plant Availability" which defined power plant availability problems in Michigan and the industry as a whole. Presently, the group is developing recommendations aimed at improving availability levels in the state, and also suggesting a revision in the existing availability incentive plan. Further details of the Michigan Public Service Commission program are available in Appendix C of this report.

In addition, the task force is pursuing a project with the purpose of developing regulatory techniques to improve power plant availability. The goals of the project include: (1) establishing baseline data on the performance of power plants in Michigan; (2) evaluating the current production maintenance process for the two major Michigan utilities; (3) evaluating the commission's present regulatory policies and techniques as they impact power plant productivity; (4) analyzing the impact of major productivity improvement projects for large baseload power plants in Michigan; and (5) developing recommendations for improvement in present regulatory policies and techniques and developing new regulatory policies and techniques that could be implemented by the commission to further improve power plant availability.

As a further incentive to improving power plant availability, the commission has disallowed purchase power expenses in certain purchase power adjustment clause hearings where it was determined that the utility was at fault for a particular plant outage that had resulted in increased purchase power.

NEW YORK

The objective of the State of New York Department of Public Service's Power Plant Productivity Improvement Program is to encourage the state's utilities to develop a systematic permanent reliability program based on sound engineering and cost-effective principles. In order to realize accomplishments in this objective, the department has established a power plant productivity working group comprised of department staff and utility personnel. This working group serves as a vehicle for obtaining information as well as for discussing and evaluating information obtained and suggestions made for future improved procedures concerned with productivity.

Fundamentally the program consists of four parts:

1. compilation and analysis of performance data;
2. evaluation of utility response to outage/derating events;
3. cost-benefit analysis;
4. evaluation of procedures and policies.

The first part, compilation and analysis of performance data, is designed to obtain data for individual units from the separate utilities. Categories for data acquisition include planned maintenance, forced and partial outages; additional information is gathered from other sources such as EEI, EPRI, and DOE. Efforts are devoted to distinguishing basic, generic problems from random malfunction problems, and to avoiding masking of singularities in the data. Data are organized by utility, fuel type, and unit size. In addition to gathering the statistical data, the working group reviews maintenance and outage practices at similar plants. Where differences are observed, reasons behind the alternative procedures are examined to determine if these may lead to improved procedures at similar plants.

One of the reasons for gross data compilation is to compare the performance of generating units; for example, how well are specific New York coal and nuclear units performing relative to each other and how well are they performing to comparable units in the United States, begging the question: "Why the difference?"

While the gross performance indices are very useful for comparisons and measuring overall performance, they are somewhat limited in that they do not identify equipment component outage causes which is the basis of determining root causes, alternative corrective actions and cost-benefit analyses. Therefore, an outage/derating reporting system has been instituted under which every outage or derating of every unit involved in this program is reported. Such items as duration, size and root cause (as best as can be determined) are recorded by station personnel, in handwriting, on a one-page form. The root-cause analysis focuses on causes of outages, solutions, similar outages at various plants and corrective actions and policies of each utility for preventing outages.

The second part deals with utility response to outage/derating events. Under this action, the working group reviews procedures for responding to outages. Attention is given to variations in these responses as a function of time-of-day, time-of-year, etc., and to the differences between average response and response at crucial times. In addition, the working group also reviews procedures for deciding scheduled maintenance outages. In effect, the utility response to instrumentation signals is considered as important as response to actual outages when they occur.

Obviously, the Department of Public Service would like to see a systematic procedural approach. Such an approach should include the following components.

1. Record, review and analyze operating data to detect and prevent equipment failures and load reductions.

2. Investigation and correction of forced and partial outages: establish a framework to insure that forced and partial outages are investigated and root cause identified.

3. Methodology for evaluating physical options for reducing outages. This methodology would involve evaluating alternative corrective actions in terms of technical feasibility. Project control, periodic review procedures and feedback would also be evaluated.

The third part involves performing cost-benefit analysis of power replacement of each outage. The analysis considers several alternatives which include purchase of contingency power, use of spinning reserve, use of already operating facilities at full power and utilization of oil generation as well as long range planning options.

The fourth part of the program involves the development of procedures and policies. This is subcategorized into two areas of concentration: rate mechanism evaluation and monitoring procedures. In general, the utility is not penalized for poor power plant performance. Fuel adjustment clauses, such as the standard adopted by this state, tend to aggravate the situation by flowing through to the ratepayer any gain or loss of productivity of power plant operation on a monthly basis. Applicability of the fuel adjustment clause does tend to lessen the urgency of restoring a generating unit to service from an outage, forced or scheduled, since there is no penalty of unrecovered energy costs and an opportunity to avoid overtime charges. Conversely, the alleviation of this urgency is not necessarily undesirable if the end result is to promote more thorough maintenance and improve reliability.

Setting target levels against which actual productivity is judged for the purpose of administering rewards and penalties is a subject to be investigated. This is an area which is very important, but which also requires great care to avoid oversimplification. Simple numerical criteria probably would not be adequate. A particular concern is that inappropriate criteria could lead to actions that are penny-wise and pound-foolish. Staff and consultant reviews of power plant reliability, to date, have provided evidence that some major problems were caused or exacerbated by lack of prompt response to trouble signals. Accepting an outage immediately may prevent a more serious outage later. A numerical index in rate setting may encourage the utility to delay maintenance that really should be done immediately until the next planned outage and take its chances for the future. Accepting an outage of increased length in order to make equipment modifications designed to reduce future outages should not absolutely be discouraged.

One of the challenges of this project will be to devise mechanisms that do not turn out to be counterproductive and do not, on the other hand, turn out to be totally subjective. Setting performance standards and requiring reporting to the Department of Public Service for evaluation of outages specifically identifiable as precautionary for discounting from the performance standard may constitute a fruitful approach.

Rewards and penalties should be meaningful to the utility, but penalties should not be sufficiently severe that they impact adversely the financial standing of the company, increasing interest rates and providing penalties to the consumer. Fuel adjustment penalties may have the disadvantage of being applied coincidentally with an adverse cash-flow situation occasioned by the outage, while a rate of return penalty has the disadvantage of being delayed. Rate of return is an easier mechanism of the reward side.

The monitoring procedures involve placing a qualified person in the field to collect on-site information. This individual assesses operator logs and outage forms in order to better evaluate outage hours and reporting procedures. One result of this program has been the development of reporting forms by the commission which better define the details of the outage problems. Additional details of the New York Power Plant Productivity Improvement Program may be found in Appendix D of this report.

NORTH CAROLINA

The North Carolina Utilities Commission has instituted a procedure providing for hearings and review of power plant performance on a semi-annual basis as part of the fuel cost adjustment mechanism. The expanded procedure is designed to incorporate outage experience at low cost base-load generating stations into other performance and procurement evaluations existing in the commission's fuel cost monitoring program. The commission established a 60 percent minimum capacity factor as an objective for base-loaded nuclear plants, and it requires monthly reports from each electric utility showing details of the generation mix, outages, causes and remedial actions. Base-loaded fossil plants are also included, but no minimum capacity factor objective is specified.

The commission schedules semi-annual hearings so that any company which fails to achieve the objective on a six-month to twelve-month moving average basis must justify the outages which prevented it from reaching the objective. If the commission finds, from evidence at the hearings, that failure to achieve the objective was caused by imprudent management, it may disallow some fuel adjustment charges. The amount of such disallowment will be based on time of outage, duration, magnitude of cost, prior performance of units, vintage of units, break-even level between nuclear-generating capacity and coal-fired generation capacity, general diligence of management, and other relevant factors suggested by the parties at the hearings. The commission believes that this procedure provides the utilities with a continuing incentive to ensure that their plant performance is maintained at high level and provides a proper data base for independent evaluation of outage experience by the commission public staff and other parties.

In a separate but related proceeding, the commission requested the public staff to perform a detailed investigation of the causes of relatively higher rates of one utility operating in the state. The findings by the staff indicated that the major causes of higher rates were related to poor plant availability and efficiency (heat rate) experience resulting from inadequate maintenance practices. Recommendations for adjustments in the fuel cost adjustment charges to reflect the alleged inadequacies were adopted by the commission. Refunds were ordered and similar adjustments are currently being made in each request for fuel cost adjustment.

A more detailed description of the North Carolina power plant performance evaluation mechanism is provided in Appendix E.

OHIO

The Public Utilities Commission of Ohio has addressed the issue of power plant productivity in three major areas. First, a target thermal efficiency mechanism has been utilized in commission semi-annual fuel cost adjustment clause hearings since December of 1976; second, a PUCO/U.S. Department of Energy Cooperative Agreement to study the costs and benefits of improved power plant productivity is nearing completion; and third, the commission staff is currently formulating both short and long range procedures to introduce the issue into regulatory proceedings.

The Fuel Adjustment Clause

The system target thermal efficiency is established by the commission for each electric utility within Ohio based upon the utility's past system performance, future system additions, and other relevant factors.

To derive the allowable FAC fuel charge, the allowable fuel charge per kWh of an electric utility company in a given month equals the allowable includable fuel cost for the month divided by the total number of includable kWh for that month. The includable fuel costs are those direct and justifiable consumed fuel costs attributable to the includable kWh.

The amount of includable fuel costs allowed is determined by the performance of the company's system thermal efficiency. The thermal efficiency ratio is defined as the ratio of the system weighted average thermal efficiency (WATE) to the system target thermal efficiency (TTE). For any month, the system WATE is determined by dividing the kWh of net generation for that month and the preceding eleven months by the heat value (in MMBtu) of the corresponding fuel consumed during the same twelve-month period.

If the WATE is greater than or equal to the TTE, all includable fuel costs are recovered by the utility. If the WATE is less than the TTE, not all includable fuel costs are allowed. All includable net system nuclear fuel costs and all includable purchased power costs are allowed, but the includable fossil fuel costs are multiplied by the thermal efficiency ratio. This results in the recovery of an amount less than actual fuel costs, and constitutes an incentive for the utility to improve the efficiency of its generating system.

PUCO/DOE Cooperative Agreement: The Costs and Benefits of Improved Power Plant Productivity

This project utilizes existing analytical techniques to assess the costs and benefits of power plant productivity improvements. The project has been divided into five tasks:

I. Assessment of Power Plant Performance;

II. Cost/Performance Changes Associated with Specific Productivity Improvements;

III. Benefits of Specific Productivity Improvements;

IV. Incentives/Disincentives for Power Plant Productivity Improvements;

V. Impact of Load Shape Changes on Benefits of Improved Productivity.

Tasks I and IV have not been completed at the time of the writing of this report. The findings of Tasks II, III and V are described below.

Task II utilized the DOE/MRI methodology [24] to assess its applicability and to estimate the costs and performance changes associated with eight specific problems at four Ohio power plants. The Energy Systems Planning Division of TRW supervised the implementation of the methodology. Table 4.1 presents a summary of the results of this analysis rounded to the nearest tenth [36]. Shown in Table 4.1 are the

TABLE 4.1 ESTIMATED IMPROVEMENT IN EQUIVALENT AVAILABILITY AND ASSOCIATED COST AND BENEFIT

Unit Name	Improvement in Equivalent Availability (Percentage Points)	Cost of Improvement ($ millions)*	Value of Improved Performance Benefits ($ millions)*
Mansfield Unit 1			
(1) Pulverizer	0.2	1.5	2.1
(2) I.D. Fan	5.2	7.1	73.0
Conesville Unit 4			
(1) Cooling water limitation	0.2	4.0	8.5
(2) Economizers	0.7	.2	22.9
Gavin Unit 1			
(1) Superheater	1.7	2.6	28.2
(2) F.D. Fans	0.1	0.0	0.1
Muskingum Unit 3			
(1) Superheater-reheater	1.1	5.9	7.2
(2) Cyclones	0.7	4.4	6.0

* Present Value

units' names, problem areas, the percentage point improvement in equivalent availability, the cost of improvement and the benefits from the improvements.

In Tasks III and V, methods of probabilistic simulation of system operation were utilized to quantify the benefits associated with improving power plant performance with and without load management [20]. The benefits were quantified in terms of changes in loss of load probability (LOLP), unserved energy, and average fuel costs for six Ohio utilities based on actual system operating data. The work performed was specific to the following six Ohio utilities: Dayton Power and Light, Toledo Edison, Ohio Edison, Cleveland Electric Illuminating, Columbus and Southern Ohio Electric and Cincinnati Gas and Electric.

The cases of availability improvements evaluated were:

PI-0 No productivity improvements;

PI-1 Equivalent forced outage rate of all base-loaded plants reduced by 5 percentage points over 10 years;

PI-2 Equivalent forced outage rate of all base-loaded plants reduced by 10 percentage points over 10 years; and

PI-3 Equivalent forced outage rate of all base-loaded plants reduced by 10 percentage points and equivalent availability improved simultaneously to a maximum of 85 percent over 10 years. Minimum maintenance time was set to 20 days per plant per year.

These improvements were simulated on all base-loaded plants simultaneously. Improvements were phased in linearly over the period 1979-1988 assuming a base year of 1978.

Load management was simulated by modifying the load duration curve of each utility for each period of study. There were four three-month periods (seasons) of study in each year. The following cases of load management were evaluated:

LM-0 No load management;

LM-1 A 5 percent reduction of the peak load of the load duration curve, with 10 percent of the energy in the peak region shifted to the base and shoulder regions. (The peak region of the load duration curve was defined as the region in which the load exceeded 70 percent of the season's peak-hour load);

LM-2 A 5 percent reduction of the peak load of the load duration curve, with 20 percent of the energy in the peak shifted to the base and shoulder regions;

LM-3 A 10 percent reduction of the peak load of the load duration curve, with 40 percent of the energy in the peak shifted to the base and shoulder regions.

Simulations were run for each case of availability improvement by first assuming no load management and then assuming each case load management. A partial summary of results for the six Ohio utilities is presented in Table 4.2. The results show the computed percentage improvements relative to the base case (PI-0, LM-0) in average fuel cost, LOLP, and expected unserved energy over the period 1979-1988 for the extreme case of productivity improvements, PI-3, coupled with the case of no load management, LM-0, and with the extreme case of load management, LM-3. Results of additional cases, evaluating the effects of delaying capacity additions for one and two years, respectively are presented in Appendix F. The findings from this work indicate significant potential improvement in system reliability.

Current Action: Introducing Power Plant Productivity into the Regulatory Process

The staff of the PUCO is currently in the process of developing and implementing a two-phase plan to introduce the issue of power plant productivity into the regulatory process. The purpose of the first phase is to identify the issue in the rate case proceedings. In this phase, the staff will assess the status of the company's generating system, quantify potential system benefits, identify cost-effective examples of corrective actions for existing plants, and analyze current utility operations, maintenance, and data collection policies.

TABLE 4.2 THE EFFECTS OF PRODUCTIVITY IMPROVEMENTS AND LOAD MANAGEMENT ON SYSTEM PARAMETERS OVER THE PERIOD 1979-1988 ASSUMING TIMELY CAPACITY ADDITIONS

Company Name	LOLP			UNSERVED ENERGY			AVERAGE FUEL COST		
	Base Case (Days)	PI-3 LM-0 (%)	PI-3 LM-3 (%)	Base Case (10^3 MWh)	PI-3 LM-0 (%)	PI-3 LM-3 (%)	Base Case ($/MWh)*	PI-3 LM-0 (%)	PI-3 LM-3 (%)
Cincinnati Gas and Electric	63.15	-71.7	-82.1	340.5	-78.3	-87.5	8.691	-2.1	-2.4
Cleveland Electric Illuminating	33.87	-75.9	-89.5	228.8	-81.2	-93.0	10.258	-3.3	-3.4
Columbus and Southern Ohio Electric	54.35	-60.1	-73.0	233.4	-66.8	-79.7	9.149	-1.4	-1.5
Dayton Power and Light	271.68	-54.5	-68.5	1550.9	-63.5	-78.7	9.274	-3.2	-3.8
Ohio Edison	177.57	-55.5	-66.3	1406.1	-62.1	-72.7	8.662	-3.7	-4.1
Toledo Edison	194.74	-40.8	-47.6	707.0	-44.2	-52.9	8.023	-6.8	-7.6

* 1978 dollars

The second phase of the plan is currently under discussion. Facilitating the exchange between utilities of information concerning data collection, problems with similar units, and preventive maintenance programs through an ad hoc committee composed primarily of utility engineers is being considered as well as several more formal regulatory mechanisms and incentives. The direction of this phase will depend on the results obtained from both the first phase and Task IV of the PUCO-DOE Cooperative Agreement. A more detailed description of the activities of the Public Utilities Commission of Ohio in the area of power plant productivity is presented in Appendix F.

TEXAS

The interest of the Texas Energy Advisory Council and the Center for Energy Studies at the University of Texas in power plant productivity was started and developed in response to a Department of Energy request for proposal (RFP No. EB-78-F-01-6427).

The primary objective of that study is to examine the influence of the existing electric utility institutional framework on power plant productivity and to analyze both the short run and long run impacts of alternative regulatory incentives, designed to encourage improved power plant efficiency upon optimal capital mix and the cost of fuel.

The research project involves the determination of current levels and trends in power plant productivity in the State of Texas. Short term costs of power plant outages will be computed using a production simulator which treats outages and system load in a probabilistic manner. The benefit to be derived from an improvement in outage rates (or other performance factor), therefore, can be determined by running the probabilistic simulator for the normal and improved outage (or other performance factor) levels and comparing the respective operating costs.

A more detailed description of this project and preliminary results are provided in Appendix G.

VIRGINIA

To varying degrees, utilities possess the potential of exercising control over each factor which influences and determines the total annual costs of providing electric service. The goals of the work performed by the Virginia Commission Staff is to assess each utility's effectiveness in the exercise of that control and the ultimate recognition of such success, or lack thereof, in the ratemaking process. In short, the purpose is to place the commission in a greater active rather than reactive regulatory position.

Although work has been undertaken to monitor and evaluate the principal areas which determine the total costs of providing electric service, major emphasis has been placed on fuel expenses. The primary reason for this emphasis is that incurred fuel expenses, including interchange power, typically represent between 40 percent, to in excess of each utility's total annual costs.

So as to assure that the charges to customers only reflect a reasonable level of expenses, the automatic fuel adjustment clause was abolished. In its place, a procedure was established wherein fuel expenses are projected annually and rates set at the beginning of each calendar year which reflect the level of projected fuel expenses per kWh.

Various tools were developed to assist the staff in its development and/or evaluation of the reasonableness of the assumption necessary to project expenses. These tools consist of:

A. Fuel Price Index;

B. Identification and establishment of generating unit performance measures;

C. Production Cost Simulation (PCS) model.

A. The Fuel Price Index requires monthly reporting by utilities of the costs of fuel purchased and consumed. The index permits the tracking of delivered fuel prices and comparison with regional averages of comparable quality fuels and, additionally, provides a basis for determining the reasonableness of projected delivered fuel prices as well as those actually incurred.

B. With respect to generating unit performance, five factors were identified as being extremely good measures of performance. These are: availability factor, equivalent availability factor, capacity factor, forced outage rate and heat rate. Generating unit comparison groups were developed for each of the utility's units. The units in each comparison group consist of those which are the same (similar) fuel type, size, vintage, and design. The EEI data base and NRC Gray Book were the principal sources of information, supplemented and/or verified by each utility. From these comparison groups, zones of reasonableness were established with respect to the five factors listed above.

C. The PCS model provides the staff with the in-house capability of projecting fuel expenses and is used, among other things, to evaluate utility sponsored forecasts and also provide information necessary to monitor actual results, incurred expenses and generating unit performance.

4.5 Summary

Industry action can be divided into the following categories: performance data, plant design, plant manufacture and construction, operations and maintenance, fuel quality, and standardization.

Data-related activities focus primarily on programs to provide feedback data to design activities and to improve the quality of plant operation.

Present actions to improve the productivity aspects of design may be summarized as establishment of productivity in policy and organization arrangements, use of operating experience including both data and participation of operating personnel, feedback, testing and laboratory research to verify designs and use of models to evaluate design. These actions have already led to important improvements and offer potential for even greater ones with wider implementation to the utilities themselves.

In the area of manufacture and construction, the use of plant models is expected to improve the understanding of each step of construction and thus improve plant reliability.

Operation and maintenance related programs include personnel training, improved spare parts management, and improved outage planning and management. There is need for more utilities to undertake such programs.

Programs to improve fuel quality are currently under way in conjunction with the U.S. Department of Energy.

There is need for expanding plant design standardization projects.

The major federal programs are the Power Plant Productivity Improvement Program, the Light Water Reactor Technology Program, and the Fossil Energy Program.

The objectives of the Power Plant Productivity Improvement Program are to increase productivity awareness, encourage productivity improvement programs, highlight the cost effectiveness and benefits of improved productivity, determine major causes of lost productivity and possible corrective actions, and publicize examples of improvements that are well documented. Projects within this program have been completed by General Electric, and others are currently under way by several states.

The objectives of the Light Water Reactor Technology Program are (1) to improve performance of existing reactors, and (2) to investigate the evolution of light water reactor technology and economics. Based on results of studies completed in 1978, a series of demonstration projects to improve refueling/maintenance outages is being planned for 1979.

The objectives of the Fossil Energy Program are to support research on physical and chemical coal cleaning technology, flue gas cleanup, and on the development of boilers that can use a wide range of coals. The program also includes projects for coal liquefication, coal gasification, and for gas and oil recovery. The timetable for this program extends into the 1980's.

State activities include implementation of regulations aiming to promote power plant productivity improvements and studies in areas related to power plant productivity. The most notable states in this regard are California, Illinois, Michigan, New York, North Carolina, Ohio, Texas, and Virginia.

In California, the Public Utilities Commission is using the energy cost adjustment mechanism to encourage attainment of higher levels of productivity. The California Energy Commission has recently completed a two-part guideline to ensure that the most cost-efficient levels of plant reliability and efficiency are obtained by proposed plants. As part of the same project, indices for assessing performance were developed, and ranges of performance for evaluating the productivity of proposed power plants were established.

The Illinois Commerce Commission is conducting a project in conjunction with the U.S. Department of Energy. The goals of this project are to increase the expertise of commission staff in the area of power plant productivity, examine current levels of power plant productivity in Illinois, and study possible methods of encouraging cost/beneficial improvements.

The Michigan Public Service Commission has established an availability incentive provision whereby the rate of return on equity is linked to system availability. A task force on availability has also been formed and has identified availability-related problems in Michigan. The task force is currently involved in developing recommendations aimed at improving availability, suggesting a revision in the existing availability-incentive plan, and developing regulatory techniques to improve power plant availability.

The New York Public Service Commission has established a working group on power plant productivity comprised of Commission staff and utility personnel. The program of the working group is to compile and analyze performance data for root-cause analyses of outages, to perform cost/benefit analyses of alternative ways to supply power for each case of outage and for the longer term, and to develop productivity monitoring and enforcement procedures.

The North Carolina Utilities Commission has instituted a procedure providing for hearings and review of power plant performance as part of the fuel cost adjustment mechanism. Failure to achieve set performance factor of 60 percent has been established for nuclear plants; the performance of base loaded, coal-fired plants is also being monitored, but no minimum levels of performance have been set.

The Public Utilities Commission of Ohio has established a target thermal efficiency program linking thermal efficiency to fuel cost adjustment. Additionally, projects are currently under way in conjunction with the U.S. Department of Energy to study the costs and benefits of improved power plant productivity, and to formulate procedures to introduce the issue into regulatory proceedings.

The Texas Energy Advisory Council is conducting a project in conjunction with the U.S. Department of Energy to examine the influence of the existing electric utility framework on power plant productivity, and to analyze impacts of alternative regulatory incentives for improved productivity upon fuel costs and optimal plant mix.

In Virginia, Commission staff have identified measures of plant performance suitable for use in the rate-making process. Fuel expenses are projected and rates are set assuming reasonable levels of performance.

CHAPTER 5
RECOMMENDATIONS

5.1 Introduction

The potential benefits of improving power plant performance have been established. The specific actions necessary to bring about improvements are the direct responsibility of the utility involved. However, state regulatory agencies have the responsibility of ascertaining that the necessary actions are taken. Therefore the Working Group recommends that regulatory agencies take the following actions to promote plant productivity improvements:

- Acquire and support the development of plant data and information systems;
- Acquire the capability to perform independent in-house analysis of performance;
- Direct the establishment of productivity improvement programs including explicit objectives for existing and planned power plants;
- Develop a system of performance assurance;
- Establish a system of incentives, sanctions and/or penalties; and,
- Participate in ongoing efforts (and plan new ones) to promote productivity improvements.

5.2 Discussion of Recommended Actions

PLANT DATA

Regulatory agencies must obtain and maintain information about the performance of power plants. The plant data files should include date of outage, outage code and duration for plants nationwide and for the specific plants within the jurisdiction of the particular state. The acquisition of such data is important for the following reasons. First, such data are necessary for the identification of causes of productivity loss. Second, they are useful in the evaluation of costs and benefits associated with productivity changes (improvements). Third, such data will enable the regulatory agency to monitor the implementation of productivity improvements. It is, therefore, recommended that regulatory agencies:

1. Initiate an ongoing effort to acquire information regarding plant performance;
2. Upgrade existing reporting efforts, eliminate duplication, support the efforts of the National Electric Reliability Council and the American National Standards Institute to develop data systems; and,
3. Support and participate in developing a national standard data base.

IN-HOUSE CAPABILITY

Regulatory agencies should be capable of performing independent analyses to evaluate productivity, verify the analyses made by the utilities and monitor and enforce the implementation of productivity improvements. It is recommended, that regulatory agencies acquire the capability for:

1. Analyzing and assessing the benefits, cost-effectiveness, and impact of regulatory policies and utility methods;
2. Auditing utility data, operations and methods; and,
3. Monitoring compliance and enforcing the achievement of productivity goals.

PERFORMANCE PROGRAMS AND GOALS

State regulatory agencies should direct utilities to establish performance improvement programs with explicit goals and to document their methods for achieving such goals. To accomplish this task, the following actions are recommended:

1. Utilities document the basis/analyses for goals set to upgrade existing plants and document their plan of action;
2. Utilities document management plan for vendor compliance/enforcement; and,
3. Utilities establish performance objectives for new units, justify any custom design features, and establish a management plan to assure custom feature reliability.

PERFORMANCE ASSURANCE

To guarantee their commitment to achieve improved productivity, utilities should regard the set goals as management objectives. It is recommended that utilities be required to document the organization hierarchy (names, titles) including specific responsibilities of each person. Utilities should also document how performance assurance responsibilities are divided, implemented and accounted for.

PRODUCTIVITY INCENTIVES/SANCTIONS/PENALTIES

To motivate the attainment of cost-effective higher productivity, it is recommended that state regulatory agencies establish a system of incentives and/or sanctions and penalties. Certain states have established such systems. In Michigan, a provision has been established whereby the rate of return on common equity has been linked to availability. In North Carolina, capacity factor of nuclear units is considered in fuel cost adjustment proceedings. In New York, the response of utilities to forced and scheduled outage events is being evaluated. Rate of return and the fuel adjustment clause are possibilities being considered in that state as potential mechanisms to ensure productivity improvements. In Virginia, the issue of power plant productivity is addressed in regulatory proceedings on a case-by-case basis. In addition to the above, other approaches include adjustments to the rate base and establishing a link between plant output and plant depreciation, fuel cost recovery, purchase power allowance, and purchase power cost within pools. No particular incentive/sanction/penalty is recommended in this report. Each state will have to determine what incentives/sanctions/penalties are appropriate for its own situations.

OUTREACH ACTIVITIES

State regulatory agencies should notify the utilities of their interest and of programs to improve productivity. In addition, the following actions are recommended.

1. All state agencies whose regulations impact on plant productivity should coordinate their actions;
2. The NARUC committee on electricity should appoint a subcommittee on power plant productivity to exchange information and ideas among regulatory commissions;
3. Communication among utilities should be established to develop regional spare-parts strategies and organize regional repair shops and maintenance crews; and,
4. Information/education-activities should be undertaken between the regulatory agency and the utilities including special studies with NRRI, DOE, in-house/in-utility studies, workshops and publications.

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APPENDIX A

CURRENT ACTIVITIES RELATED TO IMPROVED POWER PLANT PRODUCTIVITY IN THE STATE OF CALIFORNIA

(Power Plant Performance Analysis and Guidelines Study)

A.1 Introduction

Responsibility for regulation of electric utilities is shared in California principally between the Public Utilities Commission and the Energy Commission. Each Commission is seeking ways to improve power plant productivity. The following pages outline the most ambitious project to date, the Energy Committee's "Power Plant Performance Analysis and Guidelines Study" for use as a part of new power plant applications [23].

One of the responsibilities of the Energy Resources Conservation and Development Commission is to establish minimum standards of reliability and efficiency during its approval for siting new power generating facilities. The present study was undertaken by the commission in cooperation with the FEA (now DOE) to develop a uniform and systematic approach to the review and evaluation of the performance of new power plants.

The stated purpose and intent of the "Power Plant Performance Analysis and Guidelines Study" was to: (1) identify power plant performance indices, and data sources; (2) tabulate the historical performance of power plants on a national and California basis;

(3) assess the impact of plant design and construction procedures, site and regulatory factors, contract procedures, plant operation and maintenance factors and other factors which affect power plant reliability and efficiency; (4) determine issues which must be addressed by utilities in proposing the most cost-effective levels of reliability and efficiency in power plants; and (5) recommend guidelines and follow-up procedures that might be implemented by the commission to assess and bring about improvements in the performance of new plants.

The scope of the study was extremely broad in that it encompassed: (1) assessing national data systems; (2) literature searches; (3) in-depth review and evaluation of the many possible indicators of electrical generating unit reliability and efficiency; (4) interviews with California utilities; and (5) on-site investigations. In addition, the selection of performance measures had to consider the variability in indicators in terms of direct and indirect impact of operating philosophies, maintenance strategies, design concepts, unit loading order, regulatory effects and other categories on the indicator. In this effort, the study concentrated primarily on seven (Coal-fired, Geothermal, Combined Cycle, Nuclear, Oil, Gas and Combustion Turbines) discrete unit fuel types, five of which were known to be projected for possible siting in the State of California (Coal, Geothermal, Combined Cycle, Nuclear and Combustion Turbine).

Additional elements which influenced the scope of this nine-month study include: (1) the degree to which historical data accurately reflects common power plant performance indicators; (2) the depth, quality and availability of historical data; and (3) the degree to which the California utilities could openly discuss institutional as well as management and technical factors affecting power plant costs and performance.

The technical approach employed relied heavily on the work of previous researchers, including special studies and data from the

Federal Power Commission (FPC), the Federal Energy Administration and the Electric Power Research Institute. The Edison Electric Institute provided many special analyses of their data for the evaluation of specific unit types and indicators of performance. In addition, five major California utilities were contacted for (1) access to their in-house data systems; (2) interviews with utility and unit personnel on factors and institutional barriers affecting cost-effective levels of reliability and efficiency; (3) review and comment of interim reports and analyses; and (4) their perspective of cost-effective methods of implementation of guidelines.

In section A.2 of this appendix, the results and conclusions from this study are outlined. In section A.3, recommendations are made for future work.

A.2 Results and Conclusions

The major results of this study provide:

1. Four (4) indices of unit reliability and efficiency for use in the siting process

   - Capacity Factor
   - Equivalent Availability
   - Operating Availability
   - Heat Rate

2. A meaningful definition and method of computation of each index.

3. Recommendations for application of each index during the siting process.

4. Analysis of historical data to arrive at averages and ranges of averages of the four indices for seven (7) fuel types (coal, nuclear, geothermal, combined cycle, combustion turbine, oil and gas plants) for use by the commission to assess the level or ranges of reliability and efficiency proposed for new units.

5. A two-part guideline which presents a standard agenda of key issues for assessing the optimality and attainability of the reliability and efficiency levels or ranges proposed.

- Implementation of the first part of the guideline will provide assurance to the commission that levels or ranges of reliability and efficiency proposed for the new facility are the most cost-effective levels or ranges.

- Implementation of the second part of the guideline will provide assurance to the commission that specific actions will be taken by the applicant to ensure that the levels or ranges of reliability and efficiency proposed will be achieved in accordance with the cost estimates and accounts of the first part of the guideline.

6. Outline of a monitoring and reporting system to track key elements associated with unit costs, unit operation and maintenance and utility action to achieve the most cost-effective levels of performance.

The approach to determining a set of indices of power plant reliability and efficiency that would be of greatest use to the Energy Commission in the evaluating of utility "Application for Certification" (AFC) submittals was based upon two separate evaluations; namely, (1) an evaluation of the indicators presently used to assess the performance of power plants with special emphasis on plant reliability and efficiency; and (2) identification of indices of reliability and efficiency that could be used for siting decision information requirements.

Historical performance data was formatted and analyzed to arrive at the ranges and averages of the recommended reliability and efficiency indices. The available literature was surveyed along with visits to the participating utilities for face-to-face interviews, and with plant design, construction, operation, management organization personnel to identify the key issues impacting plant reliability and efficiency.

The recommended indices, their attributes and limitations, and a summary of data are presented in Tables A.1, A.2, A.3 and A.4.

TABLE A.1

RELIABILITY AND EFFICIENCY INDICES RECOMMENDED IN REF. [23]

$$\text{CAPACITY FACTOR, (CF)} = \frac{\text{Actual Net Generation}}{\text{Period Hours x Design Electrical Rating}}$$

$$\text{OPERATING AVAILABILITY, (OA)} = \frac{\text{Service Hours + Reserve Shutdown Hours}}{\text{Period Hours}}$$

$$\text{EQUIVALENT AVAILABILITY, (EA)} = \frac{\text{Available Hours} - \begin{array}{c}\text{Equivalent Full}\\ \text{Power Forced}\\ \text{Outage Hours}\end{array} - \begin{array}{c}\text{Equivalent Full}\\ \text{Power Scheduled}\\ \text{Outage Hours}\end{array}}{\text{Period Hours}}$$

$$\text{HEAT RATE, (HR)} = \frac{\text{Fuel Energy Demand}}{\begin{array}{c}\text{Total Electrical}\\ \text{Energy Generated}\end{array} - \begin{array}{c}\text{Electric Energy}\\ \text{Used by Plant}\end{array}}$$

TABLE A.2

ATTRIBUTES & LIMITATIONS OF INDICES RECOMMENDED IN REF. [23]

CAPACITY FACTOR

ATTRIBUTES	LIMITATIONS
• Quantifies production utilization	• Inconsistency of historical data base
• Useful for establishing energy planned for distribution	• Subject to load demand and many other influences
• Provides systematic accounting method of power production	
• Useful in evaluating cost-effectiveness of proposed facilities	

OPERATING AVAILABILITY

ATTRIBUTES	LIMITATIONS
• Establishes production requirement (time)	• Inconsistency of historical data base
• Bounds time available for full forced and planned outages	• Power level available upon demand unknown
• Provides method for determining effectiveness of programs to control unavailability	
• Measure of reliability	

EQUIVALENT AVAILABILITY

ATTRIBUTES	LIMITATIONS
• Establishes full power production capability	• Inconsistency of historical data base
• Bounds time available for full and partial outages	
• Provides method for determining effectiveness of programs to control outages	
• Measure of reliability	

HEAT RATE

ATTRIBUTES	LIMITATIONS
• Measure of thermodynamic efficiency	• Inconsistency of historical data base
• Indicator of cost-effectiveness of alternate fuel types and production rates	• Not uniformly recorded for individual units
• Useful for evaluating loading order	• Measurement accuracy

TABLE A.3

SUMMARY OF RELIABILITY INDEX ANALYSIS

UNIT SIZE TYPE RANGE (MW)	Capacity Factor Annual Averages (%)*			Operating Availability Annual Averages (%)*			Equivalent Availability Annual Averages (%)*		
	Low	Mean	High	Low	Mean	High	Low	Mean	High
Coal	60.1	65.5	68.9	79.4	82.4	85.4	75.5	79.4	83.3
60-89	61.0	70.0	73.3	82.7	85.2	88.5	79.8	83.5	87.7
90-129	57.2	63.6	67.5	82.8	85.2	87.4	80.4	83.6	86.2
130-199	63.9	69.6	73.1	82.7	85.6	88.6	80.4	83.9	87.4
200-389	60.8	66.0	69.0	78.4	82.5	85.3	74.1	78.8	83.0
390-599	55.4	60.5	63.2	73.3	75.8	79.8	68.3	70.9	75.9
600 & above	56.8	59.8	63.4	72.2	73.9	76.0	66.3	67.5	70.1
600-699	57.8	60.9	65.1	66.3	75.8	77.3	63.8	68.0	71.6
700-799	52.0	60.8	65.9	71.2	72.8	73.9	65.3	65.3	66.8
800-899	48.5	56.4	60.7	53.6	70.8	75.7	52.5	62.5	65.9
900 & above	55.4	60.6	66.0	67.2	72.8	80.5	56.4	64.5	74.9
Nuclear	58.1	59.1	61.6	66.2	70.0	74.6	62.6	64.8	69.8
400 & below	53.8	57.7	61.5	63.9	70.7	74.2	59.4	61.0	62.7
400-499	63.3	71.8	83.6	77.1	80.2	84.6	76.0	79.3	83.4
500-599	35.5	59.7	73.1	67.2	75.6	87.9	65.1	73.4	87.9
600 & above	54.9	58.3	72.1	64.9	67.5	74.3	57.6	61.3	67.9
600-699	63.3	67.0	80.8	67.8	75.3	79.9	69.4	69.9	84.1
700-799	41.6	67.5	82.1	46.7	73.3	85.2	46.7	69.6	84.5
800-899	39.6	54.9	59.4	58.4	66.0	70.6	43.4	59.2	65.0
900-999	45.7	53.1	68.0	54.2	68.9	98.4	50.3	66.3	98.4
1000 & above	47.3	47.7	48.0	55.3	58.4	62.1	46.6	51.1	56.4
Geothermal	36.8	74.5	83.4	49.0	83.3	89.9	42.5	76.8	83.0
55	36.8	74.8	85.9	49.0	83.6	91.6	42.5	77.1	85.3
110	68.5	68.5	68.5	75.6	75.6	75.6	69.1	69.1	69.1
Gas Turbine	5.5	9.7	16.4	77.9	81.3	91.3	77.7	81.2	91.3
below 25	4.6	9.4	17.7	80.6	84.4	92.6	80.5	84.5	92.6
25 & above	7.8	10.4	46.1	70.1	73.3	81.4	69.5	73.0	81.4

* Annual averages over the period 1971-1975.

TABLE A.4

SUMMARY OF EFFICIENCY INDEX RESULTS

UNIT SIZE TYPE RANGE (MW)	Heat Rate Annual Averages (Net)		
	Low	Mean	High
Coal(1)	10168	10303	10403
60-89	11490	11899	12045
90-129	10723	10762	10789
130-199	10206	10265	10320
200-389	9951	10000	10035
390-599	9739	9943	9948
600 & above	9584	9792	9797
600-699	9788	9914	10022
700-799	9520	9555	9590
800-899	10190	10190	10190
900 & above	9267	9337	9460
Nuclear (2)	10897	11220	11336
400 & below	11239	11628	12359
400-499	10517	10764	10944
500-599	10452	11013	11168
600 & above	-	-	-
600-699	10498	10600	10661
700-799	10988	11487	12851
800-899	10699	11316	11843
900-999	10376	10376	10376
1000 & above	11593	12322	14146
Geothermal(3)	21989	26826	26060
55	22128	22895	25056
110	21156	21156	21156
Gas Turbine(4)	12328	16918	23680
below 25	12328	16364	23680
25 & above	12356	17753	22702

(1) Annual averages over the period 1972-1973

(2) Annual averages over the period 1971-1974

(3) 1973 average

(4) Annual averages over the period 1971-1975

The results of the data analysis, shown in Tables A.3 and A.4 present an overview of the historical performance of the indices from a perspective quite different from that which may be achieved by reviewing individual fuel types and size classifications separately. In addition to illustrating the average performance levels, the table identifies the worst level and the best level achieved by distinct fuel types and size classes. Since these are all annual averages, they illustrate more than one-time lows or highs and for this reason are believed to better represent the feasibility of achieving specific performance levels.

Virtually all levels are feasible for all plant or fuel types and sizes. The attainability of any level is a function of the deliberate action that a utility takes. These actions encompass the life cycle of the plant and can be summarized under six distinct categories: design, procurement, construction, operation, maintenance and management organization. The actions of a utility can take under each of these categories are constrained by the requirements of the utility generation system and the cost incurred in implementing each action. For an individual plant the utility strikes a balance between: (1) the energy demand on the units (e.g. its loading order); (2) the target level of each index; and (3) the cost of achieving the targets. The historical level actually achieved is the result of trade-offs a utility is required to make among the above factors.

The three elements of plant age, plant design and utility experience influence the achievable levels of each of the four indices. Immaturity in any of these elements can cause significant decreases in capacity factor, equivalent availability and operating availability or increase in heat rate. A review of the data did not provide strong evidence that all of these elements had acquired a significant degree of maturity for the historical data to provide significant insight into future utility design, or operational processes. Also, expected future design changes such as addition of pollution equipment and compliance with new regulations will influence the achievable levels of reliability and efficiency.

The recommended guideline is issued in two parts. The first part, titled "Establishing the most cost-effective levels or ranges of reliability and efficiency for new power plants," is to be used for ensuring that the maximum levels of reliability and efficiency which are technically and economically feasible for the operation of a new power generating unit within the electrical supply system are met. The second part, titled "Applicant action to ensure the achievement of established reliability and efficiency levels or ranges," is to be used to ensure that specific actions will be taken by the applicant to achieve the established cost-effective reliability and efficiency levels.

The establishment of the most cost-effective reliability and efficiency levels requires analysis of the impact of the new unit upon the existing power generation and distribution system. This analysis shall be based upon the applicant's costs of bringing a new power plant on-line, and operating, maintaining and managing it to achieve the proposed reliability and efficiency levels through the useful life of the new plant. The uncertainties involved in such an analysis shall be specifically discussed by the applicant to assure the commission of its awareness of future technical, environmental, socio-economic and socio-political issues, and the best estimate of their effect on plant life cycle costs.

For the purpose of this guideline, the proposed reliability and efficiency levels of the new plant shall be cost-effective if the costs of addition of the new plant and its planned operation result in reduced or minimized individual consumer cost.

It is the intent of the recommended guideline that the establishment and subsequent justification of the most cost-effective reliability and efficiency levels or ranges and the utility plan of action to achieve the levels or ranges proposed by the applicant be expressed in and be measured by the Capacity Factor, Operating Availability, Equivalent Availability and Heat Rate.

The guideline provides a standard agenda for the applicant and Energy Commission for assessing the cost-effectiveness and attainability of levels of reliability and efficiency proposed by the applicant in the facility siting process. This is accomplished, in part, in the guidelines by:

- identifying commission review and acceptance criteria;
- identifying key issues to be addressed by the applicant;
- identifying methods for use by the applicant for acceptable responses to the guidelines.

The recommended key issues are listed in Table A.5. It is recognized that individual applicants, when complying with the requirements, may propose alternates to the recommendations. These alternates need not be consistent with the recommendations of this guideline. It is recommended that the justification for these alternates be reviewed by the Energy Commission staff and their acceptability be determined on a case-by-case basis during individual AFC submittal reviews. The recommended guideline, thus, defines the items that the utility monitoring and reporting system is required to address. It is recommended that the monitoring and reporting system be applied in a step-by-step time staged process. It is anticipated that the applicant utility shall define this process. The objective is to bring new capacity into commercial operation, within the time period available, with minimal impact (cost, manpower, etc.) upon the applicant utility. The reporting procedures and requirements should be consistent with current Federal Power Commission, California Public Utilities Commission, etc. guidelines to minimize the amount of new information generated. The suitability and acceptability of the process shall be judged by the commission and used to develop the regulatory process required to overview the recommended utility monitoring and reporting system.

TABLE A.5

KEY ISSUES

OBJECTIVE	RECOMMENDED BY ISSUE
ESTABLISHING MOST COST-EFFECTIVE LEVELS OR RANGES OF RELIABILITY AND EFFICIENCY	1) Validity of the projected impact of the new facility on the system. 2) Optimality of the balance obtained between facility considerations.
APPLICANT ACTIONS TO ENSURE THE ACHIEVEMENT OF ESTABLISHED RELIABILITY & EFFICIENCY LEVELS AND RANGES	1) Adequacy of plant design. 2) Quality of plant construction. 3) Effectiveness of procurement. 4) Emphasis of personnel training and retraining. 5) Assurance of maintenance effectiveness. 6) Organization and plant management.

A.3 Recommendations for Further Work

The background, purpose, objectives, range and results of the "Power Plant Performance Analysis and Guidelines Study" provided the basis for recommendations for further work in the development of improved criteria and guidelines for application in the siting process. The recommendations provided for continuity between the results of this study and their application in the siting process. In particular, these recommendations call for: (1) the development of a single performance (cost-effective reliability and efficiency) index; (2) the establishment of a comprehensive data base; (3) the creation of incentives for better utilization of existing resources; (4) the development of methods to quantify the cost-effectiveness of improved productivity; (5) the establishment of a regulatory environment that does not inhibit advances in the state-of-the-art of plant technology and engineering. A brief discussion of each recommendation follows:

1) Recommendation for the Development of a Single Performance Index: The four reliability and efficiency indices recommended for use in the siting process were specifically developed to apply at the unit level. The results of this study, however, indicate that decisions with respect to cost-effectiveness of proposed levels and ranges of reliability and efficiency must be made with respect to the performance of the total power generation and supply system, viewed in terms of the needs and demands imposed upon the system. To aid in the assessment of the reliability and efficiency levels that are cost-effective and those that are not, it is recommended that a single index be developed that is sensitive to changes in the power generation and supply system (the demands on the system, the manner of meeting the demand) and also to change each and every unit that makes up the system. It is recommended that, as far as possible, the single index be comprised of existing system level indices (system heat rate, loss-of-load probability, system load factor, etc.) and the four recommended unit level indices

(capacity factor, operating availability, equivalent availability and heat rate). The single index should also be considerate of the consumer base that bears the total cost of generating and supplying electric power. It is also recommended that the development of the single index result in the planned conclusion that the numerical value of the index be directly proportional to the cost incurred by each individual customer in the customer base.

2) Recommendation for the Establishment of a Comprehensive Data Base: Historical performance data is indicative of the reliability and efficiency levels of existing plants. For the commission to base key elements of the siting decision process upon historical performance data, it is necessary that the data be authentic, its proper interpretation be documented, and the data be current, up-to-date and readily accessible. It is, thus, recommended that: (1) the problems (missing data, unvalidated data, conflicting data, etc.) with the current data bases be thoroughly evaluated; (2) the manner of data collection and documentation be rigorous to ensure proper interpretation of compiled data; and (3) efforts be directed towards keeping the data base current and up-to-date. The first recommendation may be accomplished by a thorough statistical analysis; the second recommendation may be accomplished by collecting and formatting the data with the expected future use in mind; and the third recommendation may be accomplished by establishing a continuous data collection program.

3) Recommendation for the Creation of Incentives for Better Utilization of Existing Resources: The underlying objective of the commission siting decision process is to provide an environment conducive to the best utilization of existing resources. Increase in existing electric plant capacity requires a commitment of increased resources. To ensure that the addition of new capacity to meet increases in energy demand is the proper utilization of the state's finite energy resources, it is recommended that the commission provide incentives to either control the demand of energy or the manner in which it is supplied. Two

incentive areas have been identified during the course of this study that the commission can address:

- The consumer should have an incentive to either reduce his total power consumption or to stagger his power utilization to time periods of low demand. The incentive has to be more cost-effective for him to do so. This in turn will help reduce increases in the average and peak load.

- An incentive for the electric power supplier to minimize the need for new generating capacity is that it has to be more cost-effective for him to improve the productivity of his existing generation capacity than to install more new capacity.

Modifying both the demand and supply of electrical power, thus, requires cost incentive for both the consumer and the supplier. A detailed study of rate structures (rate base, allowable rates-of-return) is recommended to determine how both groups can be accommodated in a cost-effective manner.

4) Recommendation for the Development of Methods to Quantify the Cost-Effectiveness of Improved Productivity: This study has defined a commission action or a utility action to be cost-effective if implementation of the action(s) results in either a reduced cost or a minimum increase in cost to the individual customer. The most cost-effective action is one that results in the most reduction or a minimum increase in cost to the individual customers. To ascertain if an action is merely cost-effective or most cost-effective, it is necessary to be able to quantify the cost impact of an action. Also choosing between alternative courses of action requires a quantitative evaluation of the costs of the alternate course. It is recommended that the commission explore the development of rigorous methods to assess the cost impact of actions. It is recommended that in the early stages of the methods development, the commission identify its anticipated actions and those of the electric supplier and develop rigorous methods to quantify the cost of these actions. It is expected that the method development will entail a study of, among others, the utility rate structure, its costs and performance.

5) <u>Recommendation for Establishing an Environment That Does Not Inhibit Advances in the State-of-the-Art of Plant Technology and Engineering</u>: The recommended guideline has been developed for application by utilities under the jurisdiction of the commission. The guideline identifies the key issues that an applicant for new capacity should address but does not identify the step-by-step procedure to be followed in justifying the need for new capacity, of "the cost-effectiveness of proposed reliability and efficiency levels or ranges for the new unit(s)," or in substantiating that proposed actions will assure the attainment of the proposed reliability and efficiency levels or ranges. This provides the utilities with a forum for presenting new ideas and developments. It is recommended that the form of this guideline and future guidelines be maintained to provide this forum. It is also paramount to ensure that in the application of these recommended guidelines and future guidelines by the commission, this forum is not eliminated.

APPENDIX B

CURRENT ACTIVITIES RELATED TO IMPROVED POWER PLANT PRODUCTIVITY IN THE STATE OF ILLINOIS

B.1 Introduction

Prior to its current study with DOE, the Illinois Commerce Commission took note of power plant productivity only when the issue arose on a case-by-case basis. Two instances are cited below as examples. Following those will be a brief description of the ongoing study together with possible future activities.

In 1976 the commission ordered a management audit of Central Illinois Public Service Company (CIPS) by Ernst and Ernst. One of the major recommendations was to establish a productivity strike force at the CIPS Coffeen Plant. Improved maintenance practices and the setting of availability progress goals were also encouraged. The report acknowledged the complexity of the problem and the efforts undertaken by the company, but stated that the approach had been fragmented and lacked direction and force. The commission monitored the activities of CIPS in carrying out the recommendations of Ernst and Ernst.

Power plant productivity became an issue during a rate case of Iowa-Illinois Gas and Electric (IIGE) during 1976. The utility petitioned the commission for a purchased power adjustment clause due to low productivity at the Quad Cities nuclear station. The plant is 25 percent owned by IIGE; and when it is not available, much more expensive purchased power must be obtained. The commission recognized the disincentive efforts of such a clause in this case, and the request was rejected.

Cases such as these have served to sensitize the commission and staff members to the growing importance of power plant productivity. This led to involvement in the joint study with DOE which is just now being completed. The goals of this project were to increase staff expertise in the area, examine current levels of power plant productivity in Illinois, and study possible methods of encouraging cost-beneficial improvements.

Though the final report is still being formulated, some preliminary observations can be made. It appears that one recommendation will be increased commission staff monitoring of productivity figures. This would be probably based on EEI data with backup from utility supplied data.

After the establishment of a data base, a second recommendation would be to introduce such information into the rate case forum. This could be done in terms of a comparison of productivity figures using statewide and national data. Also, comparison could be made by life year and generating unit type and size. Where low productivity could not be justified by the utility, adjustments might be made to replacement-power expense or to the allowed rate of return.

Initially, it would be intended that the issue of power plant productivity would be raised on a discretionary basis. As staff expertise is gained and regults are determined, more general measures could be considered.

The Illinois Commerce Commission is also just now embarking on a study of what might be the appropriate level of productivity for future generating units. The project will attempt to lay groundwork for determining how much reliability should be "designed in" to a new plant. Information obtained would be used in future plant certification proceedings.

B.2 Power Plant Productivity Improvement Study

Participants:

U.S. Department of Energy (Sponsor)
Illinois Commerce Commission
Energy Resources Center, University of Illinois at Chicago Circle
Private Consulting Firm (Trident Engineering Associates, Inc.)
Selected Electric Utilities in Illinois

Execution Period: November 1977 to June 1979

Purpose:

Exploration of methods for improving the productivity of base-loaded generating units in Illinois.

Major Objectives:

1. Estimate future benefits to electric utilities and customers in the state of Illinois resulting from improved power plant productivity. Impact on fuel consumption, capital requirements, and revenue requirements will be estimated.

2. Apply and evaluate a systematic methodology developed by the Department of Energy for analyzing productivity improvement projects. This activity will be undertaken with the cooperation of participating electric utilities, a private consulting firm with electric utility experience, and the Energy Resources Center.

3. Document current methodologies employed by Illinois electric utilities in the analysis of costs and benefits of candidate projects for improving power plant productivity.

4. Examine current Illinois regulatory practice to identify existing disincentives to productivity improvements. Experimental incentive mechanisms adopted by other state public utility commissions will be evaluated. Appropriate incentive systems will be identified for consideration by the Illinois Commerce Commission.

The following is an outline of the power plant productivity study as it was intended at its inception.

Project I
Task 1

Documentation of Utility Approach to Define Performance Improvement Projects

During this task, it is planned that the participants will become familiar with this program and the documented studies on productivity, efficiency and reliability improvement.

During the initial phase of this task, corporate staff of Illinois utilities will be informed as of the activities in this study.

Shortly after this, it is expected that meetings will be held with designated technical staff members, assigned by the utilities, to discover, for documentation, the methodology and approach in use by the utility to monitor, define the cause of reduced power plant performance and implement performance improvement projects.

Once the data bases are documented, the Illinois Group will work with the utility in selecting a project(s) that the utility has undertaken to improve the performance of a base-load unit(s). From the utility analysis and documents study, the methodology and approach employed by the utility prior to undertaking the project, as well as the methods employed to determine the level of improved performance as a result of the project(s), will be documented.

Project I
Task 2

Power Plant Analysis

The Illinois Group, with input from the DOE, will select a consultant to implement the MRI methodology cited in reference [24] and approach for this task.

The contractor will be retained to model and determine the equivalent availability equation for the power plant under study. The contractor will prepare a complete unit description, perform a unit functional analysis, construct and formulate functional diagrams of the power plant.

Next, the necessary data will have to be collected to formulate unit equivalent availability prediction equations. The approach that will be followed is outlined in Volume II (Phase B) of the report filed for the FEA by Mechanics Research, Inc. [24].

The Illinois Group will be working with the contractor throughout this activity to assure a background for the next tasks in Project I, and will coordinate the activities of the contractor with the utilities.

Project I
Task 3

Establishment and Analysis of Costs and Benefits

This task will follow from results of the contractor's work under Project I, Task 2. Analysis will be made of costs and benefits that would be obtained by implementation of productivity improvement projects.

Input for this task will be derived from the contractor's study of improvement projects and the resulting increase in equivalent availability. Cost and benefit will then be analyzed in terms of both the DOE methodology and utility methodology in current practice.

Project II
Task 1

Analysis of Utility Historic Performance

The purpose of this task is to assemble a uniform data base of performance indices for the utilities used in this study and, if feasible, for all Illinois utilities.

During the first phase of this project, the Illinois Group will be identifying the various performance measures now used by the utility industry. This initial information will serve to identify the various data elements, possible sources of the various records currently being made, and the accuracy of such records.

Differences in the definitions used to formulate the various data bases will be resolved and a uniform set of definitions will be derived for use in the study.

After the data base is compiled, a statistical analysis will be performed of the various unit groupings by size, maturity, type and utility.

Project II
Task 2

Quantification of Benefits and Costs

The purpose of this task is to quantify the reduction in capacity requirement and/or fuel savings that may be obtained for various levels of productivity improvement.

The first step of this task will be a review of the General Electric Study making note of the methodology used in performing this study [33-35]. The Illinois Group will then review and document the current utility models in use for generation planning.

Once this information has been assembled, the key assumptions, variables and performance measures that are in the planning models will be identified.

With the utility cooperation, the Illinois Group will then provide input to the utility in-house generation planning models utilizing plant reliability and performance indices as determined above. The resulting output of the computer models will be analyzed by the Illinois Group with utility input as to the viability of the data.

The goal of this task is to estimate the effects of an attainable increase in equivalent availability on the State of Illinois as a whole.

Project II
Task 3

Policy Analysis and Incentive Assessment

The purpose of this task is to assess the impact of various policies on the Illinois Commerce Commission and to formulate candidate policies for commission review.

The Energy Resource Center will review the Publications of Regulatory Incentives and prepare a bibliography indicating the possible schemes that have been suggested for productivity improvement projects.

The compiling of this information with utility input will be put in a report format which will contain a number of candidate policies that might be implemented into Illinois rate setting procedures. An analysis of how these policies might affect the Illinois customers and utilities will be included.

Project Report

This report will be a self-standing summary of the entire study. The major findings will be presented together with analyses and interpretation. All of the task reports will be drawn upon in reaching conclusions and recommendations.

Another important area to be covered is a comparison between methods currently used to assess productivity improvement projects. The comparison will involve those procedures which were investigated in varying tasks of the study. Included will be methods used by Illinois utilities as well as the method developed by the Department of Energy.

Recommendations for future actions to promote improved power plant productivity will also be set forth in this report. Possible actions will be accompanied by expected impacts both to Illinois utilities and to the commission staff.

APPENDIX C

CURRENT ACTIVITIES RELATED TO IMPROVED POWER PLANT PRODUCTIVITY IN THE STATE OF MICHIGAN

C.1 Introduction

The following is a short summary of programs and activities that the Michigan Public Service Commission and its staff are pursuing in order to improve power plant availability in Michigan. Included are the Current Availability Incentive Provision, Proposed Modifications to the Current Availability Incentive Provision, and the Power Plant Availability Project.

C.2 The Current Availability Incentive Provision

In its opinion for Case U-5108, dated May 27, 1977, and Case U-5331 dated July 31, 1978, the Michigan Public Service Commission established system availability incentive provisions for The Detroit Edison Company and Consumers Power Company, respectively. The incentive provision allows each company to adjust their rate of return on common equity according to the scale listed in Table C.1.

The Detroit Edison Company's total system annual availability was to be calculated using the East Central Area Reliability (ECAR) method, and testimony and exhibits supporting this computation during the first week of April for the preceding calendar year filed. Consumers Power was required to furnish a similar computation and supporting evidence during the first week of May for the preceding calendar year.

TABLE C.1

THE CURRENT SCALE OF AVAILABILITY ADJUSTMENT

ECAR Availability	Common Equity Adjustment
0% - 70%	-.25%
70.1% - 80%	0%
80.1% - 85%	+.25%
85.1% - 100%	+.50%

C.3 Proposed Modifications to the Current Availability Incentive Provision

In Detroit Edison's Case U-6006, the staff of the Michigan Public Service Commission has proposed to modify the current Availability Incentive Provision by expanding both the ECAR availability and common equity adjustment ranges. One advantage of this modification is that it provides a more continuous incentive to increase system availability once the 80.1 percent availability is obtained. It also reduces the neutral zone from 10 percent to 6 percent and encourages operation of the generating system in a higher availability range. The net effect of this modification is to provide smaller incremental incentives for smaller incremental changes in system availability. The proposed expanded scale of availability adjustment is listed in Table C.2.

TABLE C.2

THE PROPOSED EXPANDED SCALE OF AVAILABILITY ADJUSTMENT

System Availability (ECAR)	Equity Return Incentive
100% - 85.01%	+.50%
85.00% - 83.76%	+.40%
83.75% - 82.51%	+.30%
82.50% - 81.26%	+.20%
81.25% - 80.01%	+.10%
80.00% - 74.01%	- 0 -
74.00% - 73.01%	-.05%
73.00% - 72.01%	-.10%
72.00% - 71.01%	-.15%
71.00% - 70.01%	-.20%
70.00% - 0	-.25%

A second proposed modification is the inclusion of scheduled maintenance in the determination of the ECAR availability scale. The system performance would be determined by adding a projected periodic or scheduled maintenance factor to the ECAR availability as is currently computed. Therefore, by using this summation as the measure of system performance, the potential to manipulate the amount of periodic or scheduled maintenance to achieve the incentive is eliminated. System performance could only be improved by reducing random outages. The current scale of availability adjustment including the periodic maintenance factor, and the proposed expanded scale including maintenance factor are listed in Tables C.3 and C.4 respectively.

TABLE C.3
CURRENT SCALE OF AVAILABILITY ADJUSTMENT
INCLUDING PERIODIC MAINTENANCE FACTOR

System Availability (ECAR) Plus Periodic Factor	Equity Return Incentive
100% - 92.1%	+.50%
92.0% - 87.1%	+.25%
87.0% - 77.1%	- 0 -
77.1% - - 0 -	-.25%

C.4 The Power Plant Availability Project

The purpose of the Power Plant Availability Project is to develop regulatory techniques to improve power plant availability. The goals of the project are as follows: (1) establish baseline data on the performance of power plants in Michigan; (2) evaluate the current production maintenance process for Detroit Edison and Consumers Power; (3) evaluate the Michigan Public Service Commission's present regulatory policies and techniques as they impact power plant productivity; (4) analyze the impact of major productivity improvement projects for large baseload power plants in Michigan; and (5) develop recommendations for improvement in present regulatory policies and techiques, and develop new regulatory policies and techniques that could be implemented by the Michigan Public Service Commission to improve power plant availability.

TABLE C.4

THE PROPOSED EXPANDED SCALE OF AVAILABILITY ADJUSTMENT INCLUDING PERIODIC MAINTENANCE FACTOR

System Availability (ECAR) Plus Periodic Factor		Equity Return Incentive
100%	- 92.01%	+.50%
92.00%	- 90.76%	+.40%
90.75%	- 89.51%	+.30%
89.50%	- 88.26%	+.20%
88.25%	- 87.01%	+.10%
87.00%	- 81.01%	- 0 -
81.00%	- 80.01%	-.05%
80.00%	- 79.01%	-.10%
79.00%	- 78.01%	-.15%
78.00%	- 77.01%	-.20%
77.00%	-	-.25%

C.5 The Report on Power Plant Availability

On December 1, 1977, the Executive Management Committee of the Michigan Public Service Commission formed an Availability Task Force composed of commission staff members to initiate a study to determine the causes and impacts of such a decline [31].

The study was issued in March 1979 and has addressed the advantages of high system availability, how availability is measured, the availability trends experienced by Consumers Power and Detroit Edison since 1970, and the identification of key factors and constraints that affect availability. These factors and constraints include: increasing system age, lower operating availabilities of new units, declining coal quality, environmental equipment modifications, nuclear refueling, governmental warranty and insurance requirements, statistical reporting improvements, maintenance constraints, spare parts, shape of the load curve, and the impact of regulation.

The study also includes a review of the production maintenance process of both Consumers Power and Detroit Edison focusing on organization, scheduling techniques, budgeting, and spare parts philosophies.

The following is a summary of the general findings of the study.

Michigan's two major electric utilities have experienced a general decline in power plant availability for the greater part of this decade. The term "availability" is defined as the means of having some resource accessible, obtainable, ready for use, or at one's disposal. When used by the electric utility industry, availability refers to the status of any generating unit or piece of equipment within a specific system.

During this decade, Consumers Power and Detroit Edison experienced highest system equivalent availabilities of 80.5 percent and 83.6 percent, respectively, in 1970. For this same period, system availabilities hit lows of 70.0 percent for Consumers Power in 1974, and 66.7 percent for Detroit Edison in 1975. In response to this decline, both companies began accelerated preventive maintenance programs and, as a result, each company improved its system availability to slightly over 74 percent in 1977.

The primary cause of this decline, at least on a statistical basis, was a steady increase in the number of random mechanical failures occurring within each system. There are numerous reasons for this increase, many of which are complex and interrelated.

One reason is the increasing age of existing generating units within the system. As is true with any mechanical device, the older a unit gets and the more it is used, the more prone it is to wearing out or breaking down. Further complicating this situation is the fact that most mature coal-fired generating units are burning coal with different characteristics than that which they were designed to burn. This situation can be attributed primarily to environmental restrictions on sulfur dioxide emissions and the declining quality of coal burned by utilities in this country. Another factor is environmental equipment modifications that were mandated by the imposition of strict environmental requirements. The additions or modifications to existing plants rarely result in improved capability and, in most cases, cause increases in station power use and losses in overall plant efficiency. Adding equipment to an already functional unit increases the complexity of its operation and the probability that something can malfunction and force the unit out-of-service.

New units are not immune to this trend of lower availability. These units are usually more complex in design, physically larger, and subject to more severe operating stresses than smaller and older units. As a result, they tend to incur a higher incidence of random outages and require more maintenance time than smaller units of equivalent age. An extensive preventive maintenance program is utilized by both utilities in an attempt to reduce random outage occurrences and improve system availability. For a preventive maintenance program to be effective, a utility must have sufficient time as well as adequate financial resources to perform maintenance. In addition, the existence of adequate spare-parts resources is also necessary to maintain and improve power plant availability. In periods of reduced or insufficient revenue, production maintenance expenditures are usually reduced; thus, almost surely resulting in an increase in system random outages.

Over the past three years, production maintenance expenses have increased for Consumers Power and Detroit Edison. Inflation aside, the increase is the result of an attempt by both companies to reverse the trend of falling availability and make up for maintenance projects that were postponed or deferred because of earnings and cash flow problems in the first half of this decade.

The responsibility of improving the availability of electric power plants lies with the utility management, but regulatory bodies must allow for the necessary financial requirements. Both are concerned with providing the consumer with an adequate and reliable source of electricity at the lowest possible cost. It is evident that a high level of power plant availability is a necessary ingredient in the fulfillment of these concerns.

APPENDIX D

CURRENT ACTIVITIES RELATED TO IMPROVED POWER PLANT PRODUCTIVITY IN THE STATE OF NEW YORK

D.1 Introduction

New York State utilities presently consume close to 90 million barrels of oil annually in the generation of power. At this rate of consumption, coupled with the Organization of Petroleum Exporting Countries' (OPEC) continual escalation of oil prices, the annual fuel cost to the ratepayer from oil-fired generation will eclipse the two billion dollar mark soon.

In addition to costs, the State of New York is vulnerable to the political vagaries of OPEC which would result in supply interruptions similar to that experienced during the 1973-74 oil embargo. The state's dependence on oil, in terms of generation capability and energy production, are 59 percent and 43 percent respectively.

To reduce this dependence, the State of New York must increase its use of non-oil power generation sources. Reclaimed and small hydro generation may help; however, much has to be done to reconcile the economic realities with state potential. Cogeneration schemes explored to date, while utilizing oil more efficiently, are still related to the continued dependence on oil. Fuel cells are also efficient; but like cogeneration, are linked to oil or natural gas.

The obvious solution is to install additional coal and nuclear generation as quickly as possible. The present generation mix for New York State shows approximately 3,500 MW of coal and 3,600 MW of nuclear generation installed with 2,000 MW of nuclear generation under construction and 3,250 MW of coal and 7,200 MW of nuclear generation planned in the next 15 years. Thus, the potential savings of oil for New York State utilities are tremendous, both in the near term and the future. The magnitude of these oil savings is highly dependent on the productivity of the nuclear and coal units in operation, under construction and planned for New York State. In the near term, it is estimated that a 10 percent improvement in capacity factor for the existing coal and nuclear units in New York State could save the United States over 10 million barrels of oil annually.

The New York Department of Public Service has been dedicated to power plant productivity improvement for some time as indicated in Section D.2 on our capabilities and commitment. We are of the opinion that power plant productivity can be improved and have set up a separate analysis and engineering group responsible for the achievement of this goal. The United States Department of Energy is funding a portion of this group's start-up costs through their Power Plant Productivity Improvement Program.

The Department of Public Service also believes that the initial analysis of productivity and the setting of goals is not enough and that continued follow-up and monitoring of utility practices affecting productivity will be required. To accomplish this, the commission has established a compliance and monitoring section which will have this responsibility as part of their overall charge.

D.2 State of New York Department of Public Service Existing Procedures Related to Power Plant Productivity Improvement

For the past eight years, it has been the policy of the Department of Public Service to hire technically qualified people in its Power

Division/System Planning Section with specialized skills in the area of power plant equipment design, operation and maintenance, as well as people with experience in electric utility system planning and engineering economics. Most of the engineers in the Power Division/System Planning Section have come to the Department from electric utilities, architect-engineers and manufacturers. The Department of Public Service's capability and commitment to improved power plant productivity can be demonstrated by a summary review of the following commission procedures:

1. Case 26937 - Proceeding on motion of the commission as to the plans and procedures of Electric Corporations for load shedding in times of emergency.

2. Case 27123 - Order instituting Proceeding to investigate the prolonged outage of Indian Point No. 2 Nuclear Generating Plant.

3. Case 27137 - Order establishing generic proceedings to investigate fuel adjustment clauses of electric utilities (issued February 1977).

4. Case 80003 - Testimony of Dr. Martin Becker in the proposed siting of two 1150 MW Nuclear Units at Jamesport, Long Island.

5. Case 80003 - Testimony of John H. Koubek in the proposed siting of two 1150 MW Nuclear Units at Jamesport, Long Island.

In Case 26937, the Department's Power Division/System Planning Section staff made a thorough survey and analysis of all the New York utilities' maintenance organization and procedures. Maintenance questionnaires were sent out to each utility followed up by field trips and meetings with the utility's maintenance managers and supervisory personnel. The result of this analysis was a Commission Order requiring Consolidated Edison to put a more comprehensive preventive maintenance program in effect.

Case 27123 was concerned with determining if Consolidated Edison Company of New York, Inc.'s (Con Edison) fuel adjustment account should be adjusted as a consequence of a prolonged refueling outage of Indian Point No. 2 in 1976. In this proceeding, staff presented a detailed analysis of 12 tasks where delays were encountered and sought to establish that the outage was needlessly delayed by 60.5 days. Staff not only made an analysis of these 12 tasks, but evaluated the organizational and planning mechanisms of the refueling outage.

The State of New York Public Service Commission concluded that the refueling shutdown was extended unnecessarily for at least 54 days within the company's control and that the "avoidable delay" had cost Con Edison's customers some $15 million in higher fuel costs.

In Case 27137, the Power Division/Rates and Valuation Section is involved in a generic evaluation of the entire concept of fuel adjustment clause. A facet of this case involves the incentives a utility has for achieving high productivity of low-fuel-cost coal and nuclear generating units.

The commission staff is also in a unique position in that it is charged with evaluating the engineering and design characteristics of proposed generating units for New York State. This responsibility comes from Article VIII of the Public Service Law which makes the Department of Public Service the lead agency for evaluating power plant siting applications.

In the Article VIII cases, the Power Division/System Planning Section has developed considerable testimony on projecting nuclear and coal generation productivity and has explored root causes of failure and their contribution to reduced productivity. Staff has also cross-examined the utilities' witnesses with regard to selection of vendors, component materials (titanium versus copper-based condenser tubes), cycle selection (supercritical vs. subcritical), number of feedwater heaters, selection of turbine back ends for efficiency consideration, etc.

D.3 Power Plant Productivity Improvement Program

D.3.1 General

The Department of Public Service has established a working group consisting of the project team (Department of Public Service staff and consultants) and key individuals from each major utility in the state (the Power Authority of the State of New York has been invited to participate even though the Department of Public Service has no regulatory jurisdiction over it). This working group serves as a vehicle for obtaining information as well as for discussing and evaluating information obtained and suggestions made for future improved procedures and productivity. It is expected that, if found effective, this working group will be maintained in the future. The following is a list of specific tasks contained in the United States Department of Energy and the State of New York Department of Public Service co-sponsored Power Plant Productivity Improvement Program.

D.3.2 Task 1 - Power Plant Outage Events and Performance

Task 1A - Outage Event Data Analysis

With the assistance of the working group, data for individual units has been, is being, and will be obtained in suggested categories (planned, maintenance, forced, and partial outages) from individual utilities, the Edison Electric Institute (EEI), the Electric Power Research Institute (EPRI), the United States Department of Energy (DOE), the New York Power Pool (NYPP), the United States Nuclear Regulatory Commission (NRC), etc. In addition, attention is given to potential subtleties, e.g., the degree to which maintenance outages extend beyond a weekend (or off-peak time) to a time when reserve requirements are affected.

With respect to partial outages, attention is given to identification of extended basic problems such as regulatory (as experienced with early operation of some nuclear units) and design (as experienced with some supercritical coal units). In other words, effort is devoted to distinguish basic, generic problems from random malfunction problems, and to avoid masking singular effects in the data categorized by utility, fuel type and plant size.

The above data is compiled and aggregated by the following categories:

(i) Individual utility

(ii) Unit type - Nuclear: Pressurized or Boiling Water Reactor
Coal: Supercritical, drum type

(iii) Fuel type; i.e., coal and nuclear

(iv) Coal characteristics, sulfur and ash content

(v) Plant size; i.e., 0-400 MW, 401-800 MW, 801 MW and up

(vi) Contributions of individual components to performance indices; i.e., turbine, boiler, recirculation pump, etc.

In addition to gathering the statistical data, the working group reviews maintenance and outage practices at similar plants. Where differences are observed, reasons behind alternate procedures will be examined to determine if these may lead to improved procedures at other stations (see Task 3).

<u>Task 1B - Performance Data Analysis</u>

In addition to the four indices cited (equivalent availability, availability factor, capacity factor, forced outage rate) to be given in the categories requested, effort is made to distinguish the singular effects noted in Task 1A from the general, random failures.

The Department of Public Service personnel and their consultants perform component root-cause analysis for each outage or derating of each unit involved in this program. This detailed root-cause analysis focuses on causes and solutions of outages or deratings, similar outages or deratings at other plants, corrective actions by individual utilities procedures and policies of each utility to prevent outages or deratings, etc. The depth of this root-cause analysis will depend upon actual available information from the operating, maintenance and engineering personnel of each utility.

D.3.3 Task 2 - Costs and Other Impacts Associated with Outage/Derating Events

Task 2A - Utility Response to Outage/Derating Events

The working group reviews procedures for responding to outages/deratings of units at several utilities. Attention is given to variations in these responses as a function of time of day, time of year, etc., and to differences between "average" response and response at crucial times.

In addition, the working group reviews procedures for deciding on scheduling maintenance outages. This is deemed to be important because maintenance outages could result in avoiding major problems later, but excessive conservatism could lead to excessive downtime. In effect, utility response to instrumentation signals may be as important as utility response to actual outages once they occur.

Task 2B - Short-Term Cost Impacts

The working group performs cost-benefit analyses of power replacement of each outage considering the following alternatives:

(i) Purchase of contingency power

(ii) Use spinning reserve

(iii) Increased output of operating plants which are not fully loaded to maintain reserve requirement

(iv) Bringing oil-fired units on line for the duration of the outages to maintain reserve requirement

(v) Increase system reserve margins by adding new generation (long-range planning)

(vi) Increase interconnection capacity adding new transmission line (long-range planning)

(vii) Increase purchase power commitments from out of state.

The above cost will include capital cost, operation and maintenance cost, interest, escalation and fuel differential cost, in terms of $/kW and/or $/kWh.

Task 2C - Long-Term Impacts on Consumer Costs, Oil Consumption, Capacity and Capital Requirements

Long-term impacts will relate to alternate assumptions about system expansion. If expansion is to minimize additional capacity, subject to maintaining reliability, then the major impact may be in the requirements for additional capacity. If expansion is to reduce oil consumption, then the major impact may be on the degree to which oil consumption is actually reduced. Subtleties which have to be addressed exist in this area.

D.3.4 Task 3 - Documentation and Development of Regulatory Policies and Procedures

Task 3A - Impact of Current Policies

Current regulation is not conducive to providing incentives for improving power plant operation. A high level of inflation makes rate revision almost an annual affair for most utilities; revenues are continuously matched to expenses, thus, removing from the utility any productivity benefits achieved through plant operation. Conversely, the utility is also not penalized for poor operation. Fuel adjustment clauses, such as the standard adopted by this state, tend to aggravate the situation by flowing through to the ratepayer any gain or loss of productivity of power plant operation on a monthly basis. The condition is somewhat alleviated by permitting the full cost of economy power in the average fuel cost consumption; buyers break even while sellers realize a markup over fuel costs. Thus, full operation of nuclear and coal-fired plants tends to be encouraged.

Applicability of the fuel adjustment clause does tend to lessen the urgency of restoring a generating unit to service from an outage, forced or scheduled, since there is no penalty of unrecovered energy costs and an opportunity to avoid overtime charges. The alleviation of this urgency is not necessarily undesirable; it may well promote more thorough maintenance and improve reliability.

Task 3B - Potential Uses of Existing Mechanisms

The commission is concerned that the automatic flow-through of fuel costs does not tend to promote improvement of generation productivity and has instituted a generic proceeding to explore the various aspects of fuel adjustment clauses including:

1. whether there is a need for a mechanism within the fuel adjustment clause to encourage optimum availability, utilization and efficiency of production facilities, including the question whether the cost of unnecessarily prolonged outages of generating units should be shared between stockholders and ratepayers;

2. whether existing fuel adjustment clause procedures provide an adequate incentive for utilities to seek the lowest prices for the fuel they purchase; and

3. whether the existing fuel adjustment clause should be modified in view of the emergence of rates based on marginal running costs.

Task 3C - Development of New Mechanisms

1. Identification of Physical Options

Considerable emphasis will be placed on physical options, technical and procedural, in recognition of the fact that an outage results from a physical failure or required physical maintenance of certain equipment and that an outage can be extended if the physical procedures followed are inefficient or ineffective. The mechanism of the working group will be utilized to enhance cognizance among all utilities of means available for improvement in productivity.

a. From the comparisons of procedures followed in similar facilities (Task 1), suggestions may arise for productivity improvement.

b. Specific choices will be postulated for evaluation. Some options below for pressurized water reactors are illustrative.

- Should pump seals be replaced at refueling outages, as a precaution (at significant expense), even though no defect is observed, to avoid pump seal failure outages?

- Should investment be made to install demineralization equipment for the secondary water system for plants not so equipped to provide long-term steam generator protection?

- Should procedures be instituted to provide effective blanketing during refueling of moisture separator reheaters to avoid corrosion problems?

- Should water chemistry specifications be followed very strictly; i.e., shutdown if any specification is exceeded for any significant period of time?

- Should fuel-cycle length be extended to improve average capacity factor, consistent with sound maintenance practice?

2. Target Performance Levels - Reward and Penalties

This is an area which is very important, but which also requires great care to avoid oversimplification. Simple numerical criteria on availability probably would not be adequate. A particular concern is that inappropriate criteria could lead to actions that are penny-wise and pound-foolish. Staff and consultant reviews of power plant reliability, to date, have provided evidence that some major problems were caused or exacerbated by lack of prompt response to trouble signals. Accepting an outage immediately may prevent a more serious outage later. A numerical availability index in rate setting may encourage the utility to delay maintenance that really should be done immediately until the next planned outage, and take its chances for the future. Accepting an outage of increased length in order to make equipment modifications designed to reduce future outages should, also, not absolutely be discouraged.

One of the challenges of this project is to devise incentive mechanisms that do not turn out to be counterproductive and do not on the other hand, turn out to be totally subjective. Setting performance standards and requiring reporting to the Department of Public Service for evaluation of outages specifically identifiable as precautionary for discounting from the performance standard may constitute a fruitful approach.

3. Rewards and Penalties and Their Impacts

The mechanisms for setting rewards and penalties must be examined carefully to recognize subtle implications. Possibilities that exist include adjustment of the rate of return a utility receives during a rate hearing and adjustment of their fuel adjustment clause.

Rewards and penalties should be meaningful to the utility, but penalties should not be sufficiently severe that they impact adversely the financial standing of the company, increasing interest rates and providing penalties to the customer. Fuel adjustment penalties may have the disadvantage of being applied coincidentally with an adverse cash-flow situation occasioned by an outage, while a rate-of-return penalty has the disadvantage of being delayed. Rate of return appears to be an easier mechanism on the reward side.

Consideration also must be given to the criteria for the selection of base line data points against which actual productivity is judged for the purpose of imposing rewards and penalties - national averages, best-run utilities, etc. Another question is whether these norms should be fixed or moving targets; e.g. whether a level of performance to be rewarded in 1980 should be considered simply acceptable by 1985.

APPENDIX E

CURRENT ACTIVITIES RELATED TO IMPROVED POWER PLANT PRODUCTIVITY IN THE STATE OF NORTH CAROLINA

(Description of North Carolina Power Plant Performance Evaluation Mechanism)

The electric power companies in North Carolina are authorized by the North Carolina General Statutes and by the Rules of the North Carolina Utilities Commission to seek periodic rate adjustments based solely upon the increased cost of fuel. During such periodic fuel adjustment hearings in 1977 for three major electric power companies, the Public Staff recommended a modification in the method used to determine periodic adjustments to fuel charges. In essence, the modification introduced the concept of generating plant performance as one of the factors in determining an appropriate fuel charge adjustment.

Fuel costs vary from month to month as a function of three basic components: procured fuel costs, the efficiency of units (heat rate), and plant performance (generation mix). Currently used procedures were adequate to allow the commission to monitor the first two of these components. However, the original procedures did not adequately monitor changes in fuel costs resulting from changes in generation mix arising from poor individual plant performances.

Generation mix refers to the proportionate utilization of the coal, oil, and nuclear plants (hydro is minimal) on the system which provides the total generation. These three types of plants have different fuel costs; and, consequently, the burned cost of fuel at any given time will depend on which plants are being used to produce power. Nuclear plants are the most expensive to install; but once built, they are the least expensive to operate. Large base load coal plants are the next most expensive to install and the next least expensive to operate. Nuclear fuel costs considerably less than coal or oil; and, therefore, the more total kWhs produced by nuclear plants, the lower the total system fuel costs. Due to the high cost of building nuclear plants, and due to their low fuel costs, the efficient dispatch of power requires that nuclear plants run at all times consistent with sound safety and operational practices. When available, large nuclear plants are normally run 24 hours a day at the upward bounds of their capacity. For that reason, they are generally referred to as "base loaded" plants. Similarly, each utility presently has one or more large coal-fired units that are normally operated as base loaded plants. However, due to their lower capacity costs and operational considerations, these base loaded fossil plants may also be flexibly operated to carry intermediate loads from time to time.

When a nuclear plant suffers an outage, the kWhs it would have produced must be replaced by coal-fired or oil-fired units which have fuel costs considerably greater than nuclear units. During certain past periods when fuel prices have been relatively stable, fluctuations in monthly fuel adjustment charges have been due, primarily, to such changes in generation mix.

The previously used fuel formula and procedures largely provided financial insulation for the companies against changes in generation mix. If a large nuclear unit was out for six weeks during a peak season, the required supply of electricity would typically be provided by a coal-fired unit. The company simply burned more coal, and the increased cost was passed to the consumers in the form of an increased fuel surcharge.

Other than the incentive to do a good job in the face of regulation and audits by regulatory bodies, together with the lag which normally delayed fuel cost recovery, the companies had little financial incentive to guarantee that generation mix was at all times the most economical possible.

The Public Staff proposed that the commission adopt a procedure that would establish an automatic evaluation of power plant performance so that only fuel costs resulting from "acceptable" performance would be charged through the fuel factor, but that costs resulting from "substandard" operation could be passed along only with specific commission approval. Essentially, the Public Staff recommended a procedure whereby the companies would be expected to operate their base load plants, both fossil and nuclear, at predetermined minimum capacity factors. If the companies failed to achieve the minimum factors, then these capacity factors would be proformed into a fuel adjustment recovery formula, unless the companies could present evidence sufficient to convince the commission to allow the full recovery of expenses.

The companies opposed the Public Staff proposal on grounds that the proposed formula contained an unwarranted presumption of mismanagement, usurped management's perogative to make decisions, created operating disincentives, placed too much reliance on capacity factors as valid measures of efficiency, created unmanageable regulatory requirements, and alarmed investors.

The commission decided that its current review procedures should include a means to provide additional incentives for better plant performance. Simply stated, the commission believes that even the best management is subject to being less diligent in saving costs if automatically shielded from any mistakes that might be made.

The commission decided that its current review procedures and evaluations should continue for the purpose of monitoring all those fuel costs which were attributable to factors other than plant performance, and that an additional procedure providing for hearings and review of plant performance should be instituted on a semi-annual basis. The commission decided that an effective procedure for review should focus on the establishment of a commission objective for plant performance, and that a detailed review should be mandated semi-annually only for a company which fails to meet this objective. This objective serves two purposes: (1) it serves notice to the companies of the commission's expectations for plant performance under normally expected operating conditions; and (2) it serves as a trigger, or flag, for review. Such a procedure gives the companies a continuing incentive to ensure that their plant performance is maintained at a high level. The commission made it clear that no presumption of inadequate performance would arise from a failure to achieve the objective. The objective established serves only as a flag that further investigation is necessary, and any finding of inadequate performance must be based on evidence given at a hearing.

The commission also concluded that the companies can be reasonably expected to seek, as an objective, to operate base loaded nuclear plants at a minimum 60 percent capacity factor on a system wide basis. The commission concluded that this objective is reasonable and attainable in that 60 percent is near the nationwide average capacity factor for nuclear plants.

The commission chose to limit the capacity factor objective which triggers examination to base loaded nuclear plants, because it is convinced that, for the particular mixes of the utilities under consideration, setting of a predetermined minimum capacity objective for the fossil base loaded plants might create a disincentive for efficient operation of the overall system. Reporting requirements and a review mechanism for the base load fossil plants was, however, required.

The commission saw a major difference between the operation of base loaded fossil and nuclear plants in that economic dispatch of the system generally dictated that nuclear units be operated to the maximum extent possible. It believed that exceptions to this general practice would be rare and would affect the average capacity factor only by a slight amount.

The commission concluded that semi-annual hearings should be scheduled so that companies failing to achieve the objective on both a six-month and 12-month moving average basis could be examined in detail as to the outages which prevented it from reaching the objective. The commission made it clear that once a hearing was triggered and scheduled, the hearing would not be limited to investigating and determining possible remedial measures for poor plant performance. If the commission finds from the evidence that any outage was caused by imprudent management, it will determine to what extent any resulting excess fuel expenses will be disallowed as an adjustment to the fuel costs to be charged in subsequent periods. In determining the amount of this adjustment, the commission considers the following as relevant factors: the time of the outage, its duration, the magnitude of the cost, the minimum capacity level at which nuclear generation "breaks even" with coal-fired generation on an economic basis, prior performance of the unit, the vintage of the units, and the general diligence and responsibility of management. The commission also considers other relevant factors suggested by the parties. Examination of outages is limited to the most recent six-month period, and this period serves as the test period for any adjustments made to rates in the event imprudent management has been shown.

In summary, the commission's present method for determining periodic adjustments to fuel charges includes a system for review of nuclear power plant performance. The system includes a trigger mechanism, automatic utility reporting, a Public Staff review, plus the burden of proof on the utility to support its actions in a hearing before the commission, and provides for a potential adjustment for recovery of some or all of the subject expenses should imprudent management be determined. The trigger mechanism recognizes that plant performance will vary from time to time as part of normally expected operations, and does not operate each time performance level drops for a short period of time.

The mechanics for review of power plant performance are contained in North Carolina Utilities Commission Rule R8-46, as follows:

Rule R8-46. Base Load Power Plant Performance Review Plan.

(a) Every electrical public utility which uses fossil or nuclear fuel, or both, in the generation of electrical power shall, on or before the 25th day of each month, file a Base Load Power Plant Performance Report as required in paragraph (e) below.

(b) The Public Staff should review the base load unit operating performance.

(c) If the nuclear capacity factors for the six months and the 12 months ending with October or April, as appropriate, are less than 60 percent, or upon Motion by the Commission, the Public Staff, or another party, the commission will review the performance of the system's base load generating plants during the next semi-annual fuel adjustment hearing, December or June, as appropriate. Both the Public Staff and the affected utility will be required to present to the commission an explanation and comments concerning the causes of the low performance and concerning any remedial actions taken.

(d) If the commission finds that responsibility for some or all of the poor performance lies with the utility because of management practices deemed to be imprudent, the commission may disallow some or all of the cost of below minimum performance, as appropriate. In determining the amount of this adjustment, the commission considers the following as relevant factors: the time of the outage, its duration, the magnitude of the cost, the minimum capacity level at which nuclear generation "breaks even" with coal-fired generation on an economic basis, prior performance of the unit, the vintage of the units, and the general diligence and responsibility of management. The commission will also consider other relevant factors suggested by the parties.

(e) Requirements for Base Load Power Plant Performance Report. The following shall be separately reported for fossil generation and nuclear generation.

(1) List each outage during the monthly period and include:

- (i) Duration of each outage;
- (ii) Cause of outage;
- (iii) Explanation for occurrence of cause, if known; and,
- (iv) Remedial action to prevent recurrence of outage, if any.

Note: List scheduled outages before forced outages.

(2) Provide the following information for the monthly period and provide a summary for the three-month, six-month, and the 12-month periods ending with the current month:

- (i) Maximum dependable capacity (MDC) in Megawatts (MW);
- (ii) Hours in period;
- (iii) Megawatt-hours (MWH) generated in the period;
- (iv) MWH not generated due to scheduled outages;
- (v) MWH not generated due to forced outages;
- (vi) MWH not generated due to economic dispatch or other causes; and,
- (vii) Total MWH possible in period [(i) x (ii)].

Note: Provide (i) through (vii) in the units required and provide (iii) through (vi) as a percent of (vii)).

(3) The base load plants to be included in the report are the following: CP&L - Roxboro, Robinson #2, Brunswick; Duke - Belews Creek, Oconee; VEPCO - Mt. Storm, Surry, North Anna. Subsequent base loaded plants shall be reported beginning with their first full calendar month of commerical operation.

APPENDIX F

CURRENT ACTIVITIES RELATED TO IMPROVED POWER PLANT PRODUCTIVITY IN THE STATE OF OHIO

F.1. Introduction

The Public Utilities Commission of Ohio has addressed the issue of power plant productivity in three major areas. First, a target thermal efficiency mechanism, based on a heat rate measure, has been utilized in commission semi-annual fuel cost adjustment clause hearings since December of 1976; second, a PUCO/U.S. Department of Energy Cooperative Agreement to study the costs and benefits of improved power plant productivity is nearing completion; and third, the commission staff is currently formulating both short and long-range procedures to introduce the issue into regulatory proceedings.

F.2. The Fuel Cost Adjustment Clause

The fuel cost of a utility is a combination of the cost of procurement and the efficiency with which its generating stations convert that fuel to electrical energy. Section 4905.69, Revised Code, requires the commission to establish a fuel adjustment clause which "establishes incentives, in terms of costs that may be recovered by electric light companies pursuant to a fuel cost adjustment clause for implementation and employment by such companies of efficient fuel procurement and utilization practices." Based on this legislative directive, the commission included a thermal efficiency feature in its Revised Code of Rules and Regulations (4901:1-11).

As delineated in the Commission's Fuel Cost Adjustment Clause (FCA) (4901:1-11), the thermal efficiency feature is a reference measure of the electric utility's efficiency in operating its total system of electric generating plants. The system target thermal efficiency is established by the commission for each electric utility within Ohio based upon the utility's past system performance, future system additions, and other relevant factors.

To derive the allowable FCA fuel charge, the allowable fuel charge per kWh of an electric utility company in a given month equals the allowable includable fuel cost for the month divided by the total number of includable kWh for that month. The includable fuel costs are those direct and justifiable consumed fuel costs attributable to the includable kWh. These costs equal the direct cost of fuel F.O.B. at the plant plus the fuel cost attributable to purchased power, less the fuel charges attributable to power sold for resale, and less the fuel charges attributable to any additional kWh to be excluded that were sold within the State of Ohio, but outside the jurisdiction of the Public Utilities Commission. The includable kilowatt-hours are the kWh of system net generation plus the kWh purchased, less the kWh sold for resale, and less any additional kWh to be excluded that are sold within the State of Ohio, but outside the jurisdiction of the Public Utilities Commission.

The amount of includable fuel costs allowed is determined by the company's system thermal efficiency. The thermal efficiency ratio is defined as the ratio of the system weighted average thermal efficiency (WATE) to the system target thermal efficiency (TTE). For any month, the system WATE is determined by dividing the kWh of net generation for that month and the preceding 11 months by the heat value (in MMBtu) of the corresponding fuel consumed during the same 12 month period.

The three possible scenarios are:

1. When the WATE is equal to the TTE, all includable fuel costs are allowed, and there is a direct pass-through of actual costs to the consumer.

2. When the WATE is greater than the TTE, all includable fuel costs are allowed. The utility recovers all its includable fuel costs, and the savings due to increased efficiency are automatically passed on to the consumer.

3. When the WATE is less than the TTE, not all includable fuel costs are allowed. All includable net system nuclear fuel costs and all includable purchased power costs are allowed, but the includable fossil fuel costs are multiplied by the thermal efficiency ratio. This results in the recovery of an amount less than actual fuel costs, and constitutes an incentive for the utility to improve the efficiency of its generating system.

The commission holds two annual FCA hearings for each utility in the state. The first hearing is based on the results of an independent audit of the company's fuel procurement policies and procedures, and the second hearing is an interim review proceeding which can also be used to identify major issues for the annual audit.

If, as is usually the case, the mechanism results in an under-recovery of fuel costs (scenario 3, above), the utility has recourse to two options. First, it can argue in the fuel case that the target thermal efficiency measure as established by the commission is unrealisitically high. Second, the fuel costs that were not recovered in the FCA proceedings can be addressed in the company's next permanent rate case.

Several elements in the TTE calculation have been modified over the course of the FCA implementation; however, the basic concept, as outlined above, has remained intact. The fuel cost adjustment clause mechanism is currently under discussion in the Ohio Legislature where several alternative proposals are being considered as possible replacements for the existing legislation.

F.3. PUCO/DOE COOPERATIVE AGREEMENT: The Costs and Benefits of Improved Power Plant Productivity

This project utilizes existing analytical techniques to assess the costs and benefits of power plant productivity improvements. The project has been divided into five tasks; the purpose and status of each task is explained below.

F.3.1 Task I: Assessment of Power Plant Performance

This task was originally scheduled as the initial phase of the project but it has been delayed because of data discrepancies discovered between the existing major data bases (FEA/EEI, NRC). Ohio utilities have been requested to furnish verified and updated data.

This task will assess historical power plant performance in Ohio in terms of capacity factor, operating availability, equivalent availability and forced outage rate. These parameters will be presented by unit fuel type, size, and age on an individual unit, utility, and state level. Although this assessment has not been used as the basis for the four succeeding tasks, the discrepancies discovered in the data base alerted both the commission and the utilities within the state of the problems inherent in the existing power plant performance data sources.

F.3.2 Task II: Costs/Performance Changes Associated with Specific Productivity Improvements

In Task II, the applicability of the DOE/MRI methodology [24] was assessed, and the costs and performance changes associated with eight specific problems at four Ohio power plants were estimated [36]. The Energy Systems Planning Division of TRW supervised the implementation of the methodology.

Four power plants were selected for study. Two major problem areas in each plant were investigated and the root causes of the problems were identified. Data for the units selected for study and the two major problem areas identified for each unit are listed in Table F.1.

For each root cause, corrective actions and equipment or operational modifications were suggested. The capital, operating and maintenance-related costs associated with the suggested modification were calculated. Next, the participants constructed analytical models for their respective units in accordance with the DOE methodology. From these models, the predicted benefits in terms of improved equivalent availability (EA) were quantified for each unit. The estimated improvement in equivalent availability and the associated costs and benefits are listed in Table F.2.

The following conclusions regarding the DOE/MRI methodology were reached:

- The methodology is valid and appropriate for use by electric utilities and regulatory agencies.
- The methodology is beneficial to plant engineers. It provides them with a method of communicating the impact of a power plant improvement to management.
- The methodology can be used in regulatory proceedings to evaluate specific productivity improvements and their impact on utility operations.
- The level of effort required from a utility to apply the methodology is not disproportionate to potential benefits that can be accrued.

The following items should be addressed to improve the existing methodology:

TABLE F.1 UNITS AND PROBLEM AREAS SELECTED FOR STUDY

Unit Name	Principal Owner (Operator)	Date of Commercial Operation	Unit Rating (MWe)	Problem Area
Mansfield Unit 1	Ohio Edison Co./ Pennsylvania Power Company	April 1976	825	1) Pulverizer failures 2) Induced draft fan casing failure
Conesville Unit 4	Columbus & Southern Ohio Electric Co.	June 1973	800	1) Cooling water temperature limitation 2) Economizer tube leaks and pluggage
Gavin Unit 1	Ohio Electric (Subsidiary of AEP)	October 1974	1300	1) Secondary superheater tube leaks and slagging 2) forced draft fan inlet valve linkage arm failure
Muskingum River Unit 3	Ohio Power (Subsidiary of AEP)	December 1957	215	1) Superheater reheater tube leaks 2) Cyclone tube leaks

TABLE F.2 ESTIMATED IMPROVEMENT IN EQUIVALENT AVAILABILITY AND ASSOCIATED COST AND BENEFIT

Unit Name	Improvement in Equivalent Availability (Percentage Points)	Cost of Improvement ($ millions)*	Value of Improved Performance Benefits ($ millions)*
Mansfield Unit 1			
(1) Pulverizer	0.2	1.5	2.1
(2) I.D. Fan	5.2	7.1	73.0
Conesville Unit 4			
(1) Cooling water limitation	0.2	4.0	8.5
(2) Economizers	0.7	.2	22.9
Gavin Unit 1			
(1) Superheater	1.7	2.6	28.2
(2) F.D. Fans	0.1	0.0	0.1
Muskingum Unit 3			
(1) Superheater-reheater	1.1	5.9	7.2
(2) Cyclones	0.7	4.4	6.0

*Present Value in 1978 discounted over the life of each unit.

- The methodology does not require a separate justification of alternative corrective actions, only for the corrective action selected. This may result in selection of a less attractive option.

- The methodology is incapable of taking concurrent plant outages into account.

- The methodology does not include a rigorous test of the model's ability to monitor future plant performance.

- The methodology should be expanded to include cost variance analysis, to describe a range of uncertainty for plant improvement cost factors and the cost sensitivity of the overall improvement program.

- Utility company engineers should use a fixed charge rate (FCR) in estimating the cost of capital expenditures. However, the components of the FCR must be detailed.

In conclusion, the study indicated that the following recommendations, if implemented, would improve the overall effectiveness of studies such as this and the DOE/MRI methodology.

- The problems associated with use of the current EEI cause code structure should be brought to the attention of the National Electric Reliability Council (NERC).

- Each utility should develop a plant reliability data base which expands upon the existing EEI system as an interim solution to the data base problem.

- Utilities should make current engineering, design, and maintenance information records easily accessible to plant engineers.

- An independent, automated, utility-operated data base for reporting plant outages should be developed for application in power plant productivity improvement programs.

- Utilities should rigorously apply a cost/benefit methodology of this type to avoid drawing inaccurate conclusions.

F.3.3 Task III - Benefits of Specific Productivity Improvements Task V - Impact of Load Shape Changes on Benefits of Improved Productivity

The work performed in these tasks was specific to the following six Ohio utilities: Dayton Power and Light, Toledo Edison, Cleveland Electric Illuminating, Columbus and Southern Ohio Electric, Cincinnati Gas and Electric and Ohio Edison. The benefits were quantified in terms of change in the system loss-of-load probability, expected unserved energy, and average fuel cost [20]. Calculations were made using probabilistic simulation of system operation [19].

The cases of productivity improvements evaluated were:

PI-0 No productivity improvements;

PI-1 Equivalent forced outage rate of all base-loaded plants reduced by five percentage points over 10 years;

PI-2 Equivalent forced outage rate of all base-loaded plants reduced by 10 percentage points over 10 years; and,

PI-3 Equivalent forced outage rate of all base-loaded plants reduced by 10 percentage points and equivalent availability improved simultaneously to a maximum of 85 percent over 10 years. Minimum maintenance time was set to 20 days per plant, per year.

These improvements were simulated on all base-loaded plants simultaneously. Improvements were phased in linearly over the period 1979-1988 assuming a base year of 1978.

Load management was simulated by modifying the load duration curve of each utility for each period of study. There were four three-month periods (seasons) of study in each year. The following cases of load management were evaluated:

LM-0 No load management.

LM-1 A 5 percent reduction of the peak load of the load duration curve, with 10 percent of the energy in the peak region shifted to the base and shoulder regions. (The peak region of the load duration curve was defined as the region in which load exceeded 70 percent of the season's peak-hour load.)

LM-2 A 5 percent reduction of the peak load of the load duration curve, with 20 percent of the energy in the peak shifted to the base and shoulder regions.

LM-3 A 10 percent reduction of the peak load of the load duration curve, with 40 percent of the energy in the peak shifted to the base and shoulder regions.

Two sets of scenarios were evaluated. In the first set, it was assumed that future capacity additions were brought on line as specified by the expansion plans of each utility. Simulations were run for each case of productivity improvement by first assuming no load management and then assuming each case of load management. A partial summary of results for the six Ohio utilities studied is presented in Table F.3. Table F.3 compares loss-of-load probability, expected unserved energy and average fuel costs as estimated for the extreme case of load management and productivity improvements (LM-3, PI-3) with the extreme case of productivity improvements without load management (LM-0, PI-3) and with the base case (LM-0, PI-0). The results show the computed percent improvements relative to the base case (PI-0, LM-0) in average fuel cost, LOLP, and expected unserved energy over the period 1979-1988 for three of the 16 cases investigated. The findings from this work indicate significant improvement in system reliability. The expected reduction in average fuel cost is small because most of the energy in Ohio is generated from coal-fired plants and only a small fraction from oil.

In the second set of scenarios, it was assumed that plant delays did occur and that productivity improvements and load management were implemented. These evaluations were made in order to investigate whether productivity improvements and load management could alleviate capacity shortages. The following cases of plant deferrals were specified:

1) All capacity additions after 1981 were delayed by one year (Plan 1).

2) All capacity additions after 1981 were delayed by two years (Plan 2).

TABLE F.3 THE EFFECTS OF PRODUCTIVITY IMPROVEMENTS AND LOAD MANAGEMENT ON SYSTEM PARAMETERS OVER THE PERIOD 1979-1988 ASSUMING TIMELY CAPACITY ADDITIONS

	LOLP			UNSERVED ENERGY			AVERAGE FUEL COST		
Company Name	Base Case (Days)	PI-3 LM-0 (%)	PI-3 LM-3 (%)	Base Case (10^3 MWh)	PI-3 LM-0 (%)	PI-3 LM-3 (%)	Base Case ($/MWh)*	PI-3 LM-0 (%)	PI-3 LM-3 (%)
Cincinnati Gas and Electric	63.15	-71.7	-82.1	340.5	-78.3	-87.5	8.691	-2.1	-2.4
Cleveland Electric Illuminating	33.87	-75.9	-89.5	228.8	-81.2	-93.0	10.258	-3.3	-3.4
Columbus and Southern Ohio Electric	54.35	-60.1	-73.0	233.4	-66.8	-79.7	9.149	-1.4	-1.5
Dayton Power and Light	271.68	-54.5	-68.5	1550.9	-63.5	-78.7	9.274	-3.2	-3.8
Ohio Edison	177.57	-55.5	-66.3	1406.1	-62.1	-72.7	8.662	-3.7	-4.1
Toledo Edison	194.74	-40.8	-47.6	707.0	-44.2	-52.9	8.023	-6.8	-7.6

* 1978 dollars

Each of the above plans was evaluated with no productivity improvement nor load management (PI-0, LM-0) and also with the most extreme case of productivity improvement in combination with the most extreme case of load management (PI-3, LM-3).

A summary of the results from these evaluations is shown in Tables F.4 and F.5. The results show the computed percentage changes relative to the base case in average fuel cost, LOLP, and expected unserved energy over the period 1979-1988 for Plan 1 and for Plan 2.

The general conclusions which were reached from this work are:

1. Productivity improvements and load management can increase system reliability and reduce fuel costs.
2. Productivity improvements in conjunction with load management results are more significant in improving system reliability and reducing fuel costs than productivity improvements alone. However, the cost of implementation of productivity improvements and load management was not considered in this work. For this reason cost/benefit results are not presented in this report.
3. In certain cases, productivity improvements and load management may alleviate the effects of delaying capacity installations. In other cases, however, they may only reduce the impact of capacity shortages.

F.3.4 Task IV - Incentives/Disincentives for Power Plant Productivity Improvements

The purpose of this task, to be completed by members of the commission staff, is to examine current regulatory and non-regulatory policies and procedures in order to assess the existing incentives and disincentives affecting power plant productivity. Following this initial assessment of the current situation, alternative incentive proposals will be developed, if necessary.

TABLE F.4 THE EFFECTS OF PRODUCTIVITY IMPROVEMENTS AND LOAD MANAGEMENT ON SYSTEM PARAMETERS OVER THE PERIOD 1979-1988 ASSUMING ONE-YEAR DELAY IN ALL FUTURE CAPACITY ADDITIONS

Company Name	LOLP			UNSERVED ENERGY			AVERAGE FUEL COST		
	Base Case (Days)	PI-0 LM-0 (%)	PI-3 LM-3 (%)	Base Case (10^3 MWH)	PI-0 LM-0 (%)	PI-3 LM-3 (%)	Base Case ($/MWH)*	PI-0 LM-0 (%)	PI-3 LM-3 (%)
Cincinnati Gas and Electric	63.15	+36.9	-66.9	340.5	+36.3	-76.0	8.691	+1.7	-0.9
Cleveland Electric and Illuminating	33.87	+39.6	-81.7	228.8	+41.5	-87.2	10.258	+2.8	-0.3
Columbus and Southern Ohio Electric	54.35	+34.0	-60.4	233.4	+35.4	-69.6	9.149	+1.1	-0.4
Dayton Power and Light	271.68	+33.5	-48.7	1550.9	+33.2	-64.0	9.274	+2.9	-1.3
Ohio Edison	177.57	+69.2	-38.8	1406.1	+86.3	-47.1	8.662	+5.0	+0.8
Toledo Edison	194.74	+63.5	-12.7	707.0	+77.8	-17.1	8.023	+8.5	-0.3

* 1978 dollars

TABLE F.5 THE EFFECTS OF PRODUCTIVITY IMPROVEMENTS AND LOAD MANAGEMENT ON SYSTEM PARAMETERS OVER THE PERIOD 1979-1988 ASSUMING TWO-YEAR DELAY IN ALL FUTURE CAPACITY ADDITIONS

	LOLP			UNSERVED ENERGY			AVERAGE FUEL COST		
Company Name	Base Case (Days)	PI-0 LM-0 (%)	PI-3 LM-3 (%)	Base Case (10^3 MWH)	PI-0 LM-0 (%)	PI-3 LM-3 (%)	Base Case ($/MWH)*	PI-0 LM-0 (%)	PI-3 LM-3 (%)
Cincinnati Gas and Electric	63.15	+92.0	-45.8	340.5	+95.5	-59.4	8.691	+1.7	+0.7
Cleveland Electric and Illuminating	33.87	+113.0	-67.0	228.8	+128.7	-75.8	10.258	+5.6	-1.6
Columbus and Southern Ohio Electric	54.35	+86.5	-41.1	233.4	+305.8	-53.1	9.149	+2.3	+0.6
Dayton Power and Light	271.68	+66.8	-19.6	1550.9	+86.4	-41.3	9.274	+5.9	+1.5
Ohio Edison	177.57	+155.2	-0.1	1406.1	+210.1	-8.0	8.662	+9.6	+5.3
Toledo Edison	194.74	+140.9	+31.5	707.0	+186.8	+31.0	8.023	+16.7	+7.0

* 1978 dollars

F.4 Current Action: Introducing Power Plant Productivity Into the Regulatory Process

The staff of the Public Utilities Commission of Ohio is currently in the process of developing and implementing a two-phase plan to introduce the issue of power plant productivity into the regulatory process. The purpose of the first phase is to identify the issue in the rate case proceedings. In this phase, the staff will assess the status of the company's generating system, quantify potential system benefits, identify cost-effective examples of corrective actions for existing plants, and analyze current utility operations, maintenance, and data collection policies.

The second phase of the plan is currently under discussion. Facilitating the exchange between utilities of information concerning data collection, problems with similar units, and preventive maintenance programs through an *ad hoc* committee composed primarily of utility engineers is being considered, as well as several more formal regulatory mechanisms and incentives. The direction of this phase will depend on the results obtained from both the first phase and the fourth task of the PUCO-DOE Cooperative Agreement discussed previously.

APPENDIX G

CURRENT ACTIVITIES RELATED TO IMPROVED POWER PLANT PRODUCTIVITY IN THE STATE OF TEXAS

(Power Plant Productivity Study)

G.1 Introduction

The interest of the Texas Energy Advisory Council and The Center for Energy Studies at the University of Texas in topics such as power plant productivity stems from the common objective of both groups to encourage efficient utilization of all energy resources. The involvement with the specific topic of power plant productivity was started and developed in response to a Department of Energy request for proposal (RFP No. EB-F-01-6427).

The primary objective of this study is to examine the influence of the existing electric utility institutional framework on power plant productivity, and to analyze both the short run and long run impacts of alternative regulatory incentives designed to encourage improved power plant efficiency upon optimal capital mix and the cost of fuel.

The research project involves the determination of current levels and trends in power plant productivity in the State of Texas. Short term costs of power plant outages will be computed using a production simulator which treats outages and system load in a probabilistic manner. The benefit to be derived from an improvement in outage rates (or other performance factor), therefore, can be determined by running the probabilistic simulator for the normal and improved outage (or other performance factor) levels and comparing the respective operating costs.

The estimation of long-run costs will be implemented by means of the University of Texas Regional Electricity Model. As in the case of the short run, the long-run benefits associated with alternative improvement strategies can be estimated by iterating the Regional Electricity Model for standard and improved performance levels for all relevant years. The Regional Electricity Model has the capability of determining a cost minimal capital and fuel mix as well as final price to the consumer and other balance sheet entries, given a multitude of parameters some of which include outage rate (or other performance factor) and regulated rate of return. This facet permits the examination of the impact of alternative combinations of performance and rate of return levels upon future generation expansion and fuel usage.

The regulatory section of this project contains a number of critical tasks. First, a review of relevant economic literature is made and then combined with engineering evidence to support the general methodology of the study. Second, existing and planned incentive provisions instituted by state level regulatory agencies (including Texas) are summarized and compared. Third, several alternative incentive strategies are developed and discussed in detail (in reference to their possible effects on power plant productivity and the efficient allocation of resources). The final step is to then utilize the production simulator and the Regional Electricity Model to measure the feasible range of economic impacts associated with the incentive provisions.

In section G.2, preliminary findings of the study of performance level of Texas utilities are discussed. In section G.3, preliminary findings on the long term impacts from improved productivity are discussed.

G.2 Performance Levels of Texas Utilities - Preliminary Findings

In this analysis, the following utilities were studied: Central Power and Light, Dallas Power and Light, Houston Lighting and Power, Texas Electric Service, and Texas Power and Light. Analyses were made using data from EEI.

In general, the representative utilities of Texas had an equivalent availability factor that was greater than the national average. The only utility that averaged less than the national average for the equivalent availability factor was Dallas Power and Light. Similarly, all the utilities investigated had a lower (or better) forced outage rate than the national average. However, the utilities' capacity factor did not compare quite as well to the national average as the equivalent availability or the equivalent forced outage rate. Only two of the utilities' averages were as good or better than the national average for capacity factor. Houston Lighting and Power had an average capacity factor of about 10 percent greater than the national average for the same period of years. Texas Electric Service showed a similar average over the same period, although not as high as Houston Lighting and Power average. The other utilities all averaged below the national average; some by quite a percentage. Central Power and Light averaged 10-15 percent lower than the national average.

These conclusions are not finalized as yet because additional data has been requested from the five utilities.

G.3 Long Term Impacts from Improved Power Plant Productivity - Preliminary Findings

G.3.1 Scenarios of Study

The objective of this part of the study is to evaluate long term potential benefits of improved nuclear and coal power plant productivity. Analysis has been made for the Electric Reliability Council of Texas region (ERCOT). Nuclear and coal power plant productivity improvement has been simulated by a 5 percentage point improvement in the forced outage rate (FOR) over an eight year period (1980-1987).

The present results are based on simultaneous improvement in nuclear and coal units by 5 percentage points. Other cases of interest would be an improvement in only nuclear or only coal plants.

Two scenarios can be considered.

(1) Fixed Planned Expansion

This case of study holds the future planned generation expansion fixed while improving power plant productivity. The benefits are principally in the form of savings in oil and gas consumption.

(2) Variable Expansion

As power plant productivity is improved, effective capacity of existing plants increases; therefore, there would be less need of new additional generation capacity. This means construction of new plants can be deferred. The benefits would be in the form of less capital investment.

Presently we are concentrating on the Fixed Expansion Case. The following are the results obtained with a simultaneous improvement in nuclear and coal plant FOR while keeping future generation expansion fixed. We are planning to look into the Variable Expansion Case after evaluation of the Fixed Expansion Case is complete.

The simulation tool used in the study is the Regionalized Electricity Model (REM).

G.3.2 Results

FIXED PLANNED EXPANSION

In this part of the study, coal and nuclear power plant forced outage rates are improved simultaneously by 5 percentage points over an eight-year period (1980-1987), and future planned generation expansion has been kept fixed. The new coal and nuclear power plants that come on line after 1987 have the improved forced outage rates incorporated in them.

The potential benefits obtained by keeping future generation expansion fixed and improving FOR are reduced oil and gas consumption. Considering the tight supply market for imported oil and gas and continuous price increases by OPEC makes this saving of real value. Reduction in consumption of expensive and scarce oil and gas benefits the consumer, the utility and the nation. The benefits to the consumer are in the form of lower electricity cost. The utility benefits by being in the better position in the event of shortage or price increase of oil and gas. And the nation pays a reduced energy bill.

Table G.1 presents some of the results. Since no significant oil fired generation exists in the ERCOT region, the major fuel saving is in gas consumption. Column 2 presents reduction in gas consumption in MCF for the corresponding years indicated in column 1. The gas saving nearly remains constant over the 15-year period. This is due to the fact that no new gas plants are to be constructed in this period.

Column 3 shows percentage increases in the generation from nuclear. These increases are expected because nuclear fuel cost is the lowest and as productivity of nuclear plants is improved, more electricity is generated from nuclear.

Column 4 shows changes in coal consumption. There is a slight increase in coal consumption as cheaper coal replaces gas. In the year 2000 nuclear, which is the cheapest fuel, replaces a part of the coal, so the coal consumption drops slightly.

Column 5 presents reductions in production expenses. The major portion of this saving is in fuel costs.

Column 6 is the reduction in the cost of electricity and column 7 is the benefit to the consumers. Comparing columns 5 and 7, we can conclude that almost all the saving in generation goes to the consumers.

It can be concluded at this state that if utilities decide to continue their generation expansion as it is planned even after improving forced outage rates of nuclear and coal plants, the benefits would be in the form of expensive-fuel savings and the major portion of the dollar benefits go to the consumer.

TABLE G.1

FIXED PLANNED CAPACITY EXPANSION - ERCOT REGION

5 percentage point improvement in coal and nuclear plant's FOR over 8 years (1980-1987)

Year	Reduction in Gas Consumption MCF/Yr	(%)	% Increase in Generation from Nuclear	Change in Coal Consumption Short Tons / Yr (Million)	Reduction in Production Expenses 10^9\$	Reduction in the Cost of Electricity Mills/kWh	Benefit to Consumers 10^9\$
1985	47.77	8.3	4.56	+1.64	0.0271	0.1391	0.0257
1990	66.1	19	6	+1.85	0.0648	0.2147	0.0508
1995	60	26	6	+0.99	0.1223	0.2743	0.0817
2000	54.16	30	6	-0.04	0.228	0.4047	0.1509

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