Massachusetts Institute of Technology
Energy Laboratory
Energy Model Analysis Program
Cambridge, MA 02139

METHODOLOGY AND RESULTS OF THE IMPACTS OF MODELING ELECTRIC UTILITIES: A COMPARATIVE EVALUATION OF MEMM AND REM

MIT Energy Laboratory Report #MIT-EL 81-031

Energy Model Analysis Program
Study Group

Martin L. Baughman
Supriya Lahiri
Martha J. Mason
Alicia H. Torre
David O. Wood

This research was supported by the Department of Energy under M.I.T.-D.O.E. Institutional Agreement No. EX-76-A-01-2295, task order 41.

Room 14-0551
77 Massachusetts Avenue
Cambridge, MA 02139
Ph: 617.253.5668 Fax: 617.253.1690
Email: docs@mit.edu
http://libraries.mit.edu/docs

NOTICE

PREFACE

This study compares two models of the U.S. electric utility industry including the EIA's electric utility submodel in the Midterm Energy Market Model (MEMM), and the Baughman-Joskow Regionalized Electricity Model (REM). The method of comparison emphasizes reconciliation of differences in data common to both models, and the performance of simulation experiments to evaluate the empirical significance of certain structural differences in the models.

The study was organized as a joint effort of the MIT Energy Laboratory's Energy Model Analysis Program and Southwest Energy Associates, Inc. under the general direction of David Wood (MIT) and Martin Baughman (SEA, Inc.). John Herbert was the EIA technical project officer. Martin Baughman and Alicia Torre prepared the analysis and the reconciliation of MEMM and REM data bases. Supriya Lahiri implemented the current version of REM at MIT as well as structural changes required for the simulation experiments, and directed the computational effort. All participants collaborated in the design of the computational experiments, and in the interpretation of results. Martha Mason coordinated the preparation of this report.

Table of Contents

List of Figures and Tables

Introduction

The Energy Information Administration (EIA) is charged by the U.S. Congress to prepare projections of energy production, consumption, and prices, in addition to estimates of economic and other consequences of energy policies. In order to support this analytic work, the EIA has developed or sponsored, and maintains, an energy information analysis system. This complex computer system known as MEFS (Midterm Energy Forecasting System) is composed of many submodels integrated through a component entitled MEMM (Midterm Energy Market Model). In order to meet both professional and legislated requirements, EIA is also very interested and actively involved in documenting, validating, and evaluating the components of the MEFS System. EIA has developed and applied procedures and guidelines for such activities, both within DOE, and by outside analysts. A survey of these various activities is provided in Wood [1981].

This report has been prepared in the context of EIA's model validation activities. The purpose of the project was to perform a comparative evaluation of the Electric Utilities Model of MEMM and the Baughman-Joskow Regionalized Electricity Model (REM). The major research goal was to contrast and compare the effects of alternative modeling structures and data assumptions on model results. In particular, the research plan considered each model's approach to the impacts of generation technology and fuel use choices on electric utilities. These issues have become particularly important to EIA and the electric utilities since the enactment of Public Law 95-620, the Powerplant and Industrial Fuel Use Act, in November 1978. This law essentially promotes the use of coal, rather than oil and gas, in new and existing electric power plants and new major fuel-burning installations. The law in effect prohibits the use of natural gas after the year 1990, and contains provisions to curtail use of gas and oil prior to that year under special circumstances, although exemptions to these actions are permitted. Therefore, it has become an increasingly important issue to government and electric utility planners to understand the likely effects of utilizing alternative equipment and fuels.

The methodology for this study was as follows. First, the most current version of REM was transferred to the MIT Energy Laboratory, and made operational on the MIT IBM computer system. The model was first run without a representation of the Power Plant and Industrial Fuel Use Act (PIFUA). Then, to the greatest extent possible, the data used in the REM Model was normalized to mimic comparable data contained in the version of MEMM used to prepare the EIA's 1978 Annual Report to Congress. The model was then run again, this time including a representation of PIFUA. Two scenarios from the 1978 Annual Report to Congress (ARC) were used: Scenario C, in which medium supply and demand curves are assumed, and Scenario C-High, which also assumes medium supply and demand curves, but contains higher prices for imported oil (in C-High the oil price rises to $31.5 by 1995). In addition, researchers performed computational experiments relating to fuel use and load factors.

This report is divided into four further sections. First, the models are briefly described and the data structures of the two models are outlined and compared. Second, the original 1978 data used in MEMM and REM are analyzed and compared. These two sections present the necessary background for the normalization of the data in the two models. In the third section are described the computational experiments which were designed and performed to test the different modeling structures and assumptions of MEMM and REM, particularly as they affect fuel use decisions. Since it was possible for researchers to run only REM, no experiments were performed directly on the MEMM System. However, some insights were gained as to computational exercises which researchers within EIA may wish to undertake on their model. In the fourth section are presented the adjusted REM data required to perform the experiments described. Finally, in the last section we compare and contrast the simulation results of the two models, and draw some conclusions about the affects of the model structures on results.

1. Introduction to the Data Structures of MEMM and REM

The Midterm Energy Market Model (MEMM) is an equilibrium model which indicates the market-clearing quantities and prices for all basic fuels. The Electric Utility Model of MEMM functions to transform basic energy forms into electricity, to transmit and distribute this energy to consumers, and to calculate the costs of these activities. The electricity submodel of MEMM is basically a linear programming model whose constraint is that supply equals demand. It simultaneously makes optimal capital expansion decisions and determines the most economical load dispatching schedule for both existing and new capacity. The generation expansion path is obtained through static optimization. The electricity supply model of REM on the other hand is a deterministic simulation model which simulates the operation of the electric utility industry and is descriptive in nature as opposed to being prescriptive. REM contains optimization concepts in part of its structural detail, but overall is formulated as a simulation tool for the analysis of policy issues affecting the electric utility industry.

REM is disaggregated over nine NERC regions and the output of this model includes a monthly schedule for maintenance of different generating plants over a future projection period and a least-cost pattern of simulated monthly usage rates for meeting the current demands of electricity. These simulated usage rates are used to determine the fuel requirements and total production costs for the particular configuration of production. This also helps to determine the required annual capital expenditures for new plants and equipment. The output also includes the revenue requirements of electric utilities and the rate base on which the regulated rate of return is calculated. The output of the financial regulatory model of REM gives an estimate of the average price of electricity over each region by incorporating the institutional regulatory and financial detail of REM.

As part of a larger equilibrium model, the electricity submodel is dependent on data used throughout MEMM. This discussion, however, will deal principally with the inputs or endogenous variables used in this submodel as demand, supply, and pricing data.

Since MEMM is an equilibrium model, actual demand for electricity is one of its principal outputs. But MEMM does make assumptions about the form of that demand by specifying annual load shape. MEMM uses historical data on the annual percentage of load in each of four categories -- base, cycling, daily peak, and seasonal peak -- and annual system load factors. These inputs are given for each of the ten DOE regions identified in Figure 1.1.

MEMM's supply section is the most detailed part of the electricity submodel. Much of MEMM's supply data is also divided by region and by these four load types, although some inputs apply to plant used in any load category or apply to all regions. Regional capacity in a given plant type is divided into capacity in each of the four generation modes. Generation is modeled by using regional historical data on actual annual capacity factors for plants of that type in each mode. These capacity factors report the fraction of time a plant is actually operated and not shut down for repairs or scheduled maintenance or unused for lack of sufficient demand; forced outages and maintenance outages are not used explicitly.

MEMM uses 30 plant categories, including 14 coal categories (distinguished

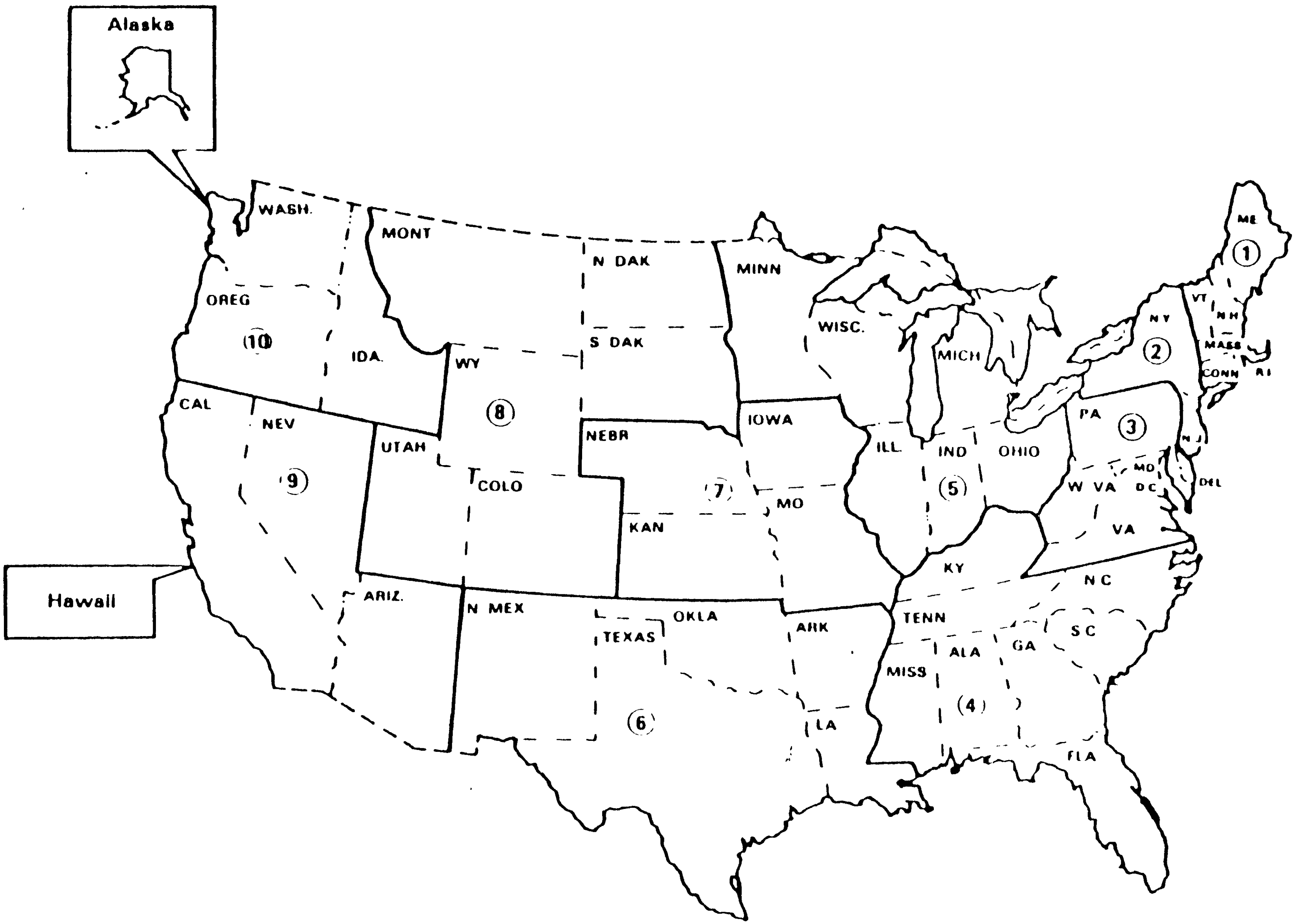


Figure 1.1

DOE ELECTRIC UTILITY REGIONS

by type of coal used, sulfur content, and the presence or absence of scrubbers) and 8 emerging technologies. Additionally, old and new capacity in each type is distinguished since some important statistics differ by age.

Figure 1.2 depicts the basic structure of demand and supply data used in MEMM. Data that vary by region, generation mode, and plant type include: capacity, capacity factors, and heat rates for existing plant. Data that vary by region and plant type include: retirement rates, committed and deferrable capacity, and new plant capacity limits. Heat rates for new plants and heat values of fossil fuels are the same in all regions.

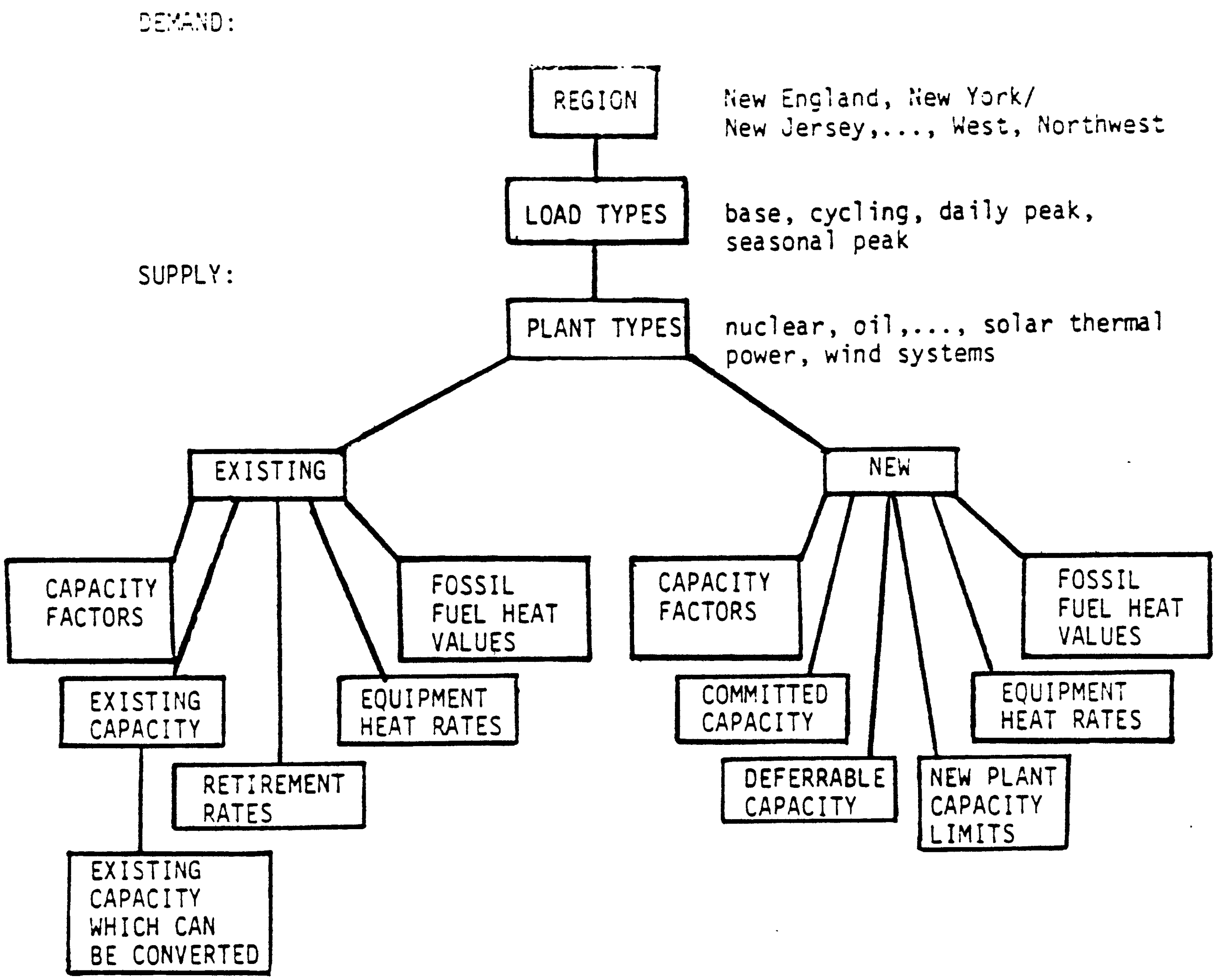
Not all of MEMM's supply data is depicted in this figure. Transmission and distribution is modeled with efficiency rates and costs which differ by region. MEMM also models the decision to invest in new plant and the merit-order dispatch of existing plant. For the capacity expansion decision, inputs used include capital costs (distinguished by plant type and by region) and capital charge rates for investment decisions (distinguished by plant type only), while fuel prices are endogenous variables. For merit-order dispatch only variable costs -- fuel and exogenous operation and maintenance costs for each plant type -- are necessary.

MEMM does not model regulatory decision making in detail. Assumptions are made on the capital structure and costs of each type of financing which are used in estimating capital costs outside of the model. In determining the price of electricity MEMM utilizes costs of operation and maintenance (by plant type), capital costs for new plants (by plant type and region), and transmission and distribution capital costs and operation and maintenance costs (by region). Although MEMM in general finds the marginal price of fuels to integrate supply and demand, for electricity average-cost rate regulation is approximated by incorporating data on revenue requirements for existing assets (by region)

Figure 1.2

MEMM

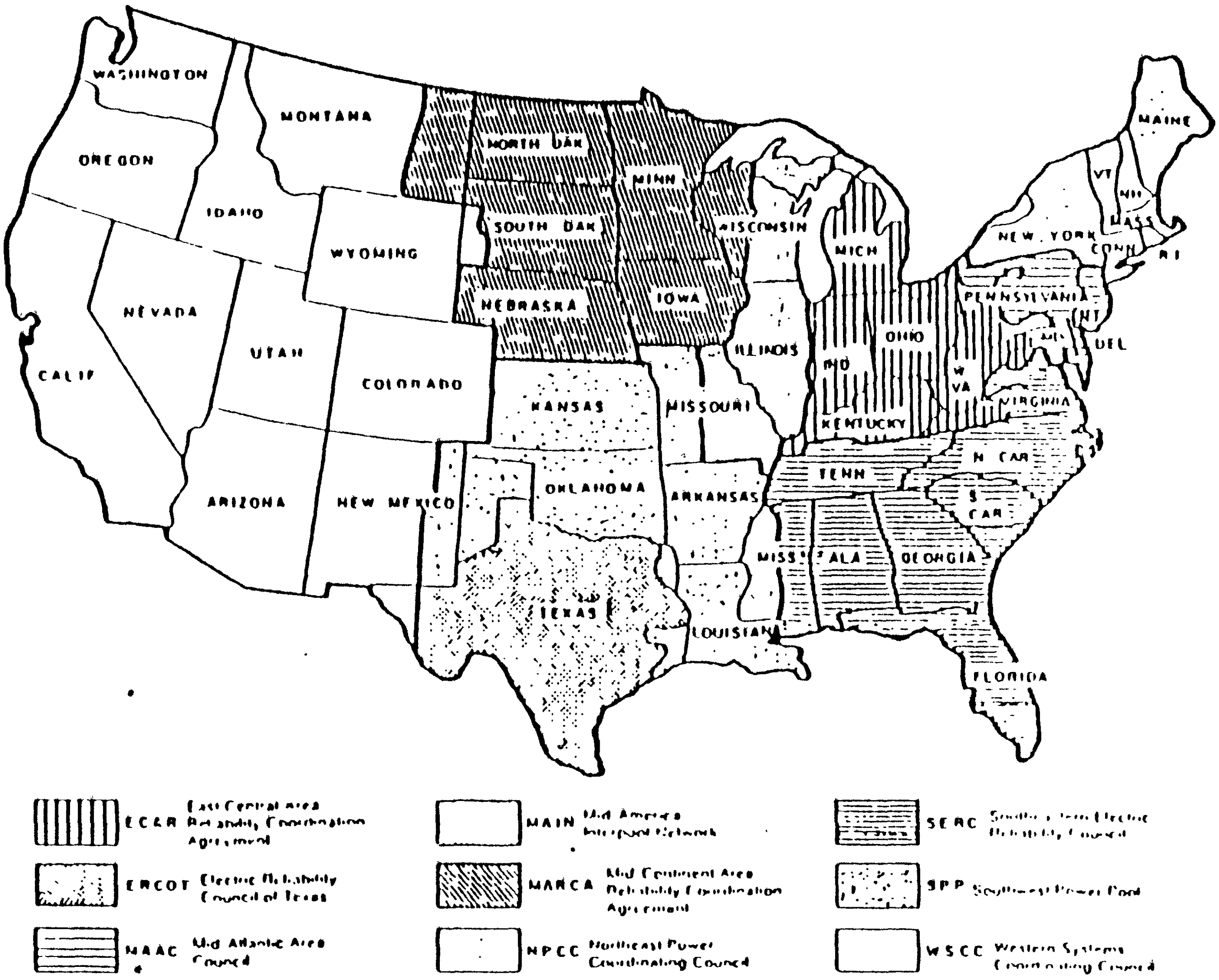
OUTLINE OF DEMAND AND SUPPLY AGGREGATION



and capital charge rates for new plants (by region). The difference between marginal and average cost prices is included as an adjustment to the objective function of the linear program on the next iteration of the optimization procedure. No further financial or regulatory detail is considered.

The Regionalized Electricity Model (REM) does not model the entire energy market and it is not a linear program designed to establish equilibrium prices and quantities for all basic fuels. Rather REM simulates the operation of the electric utility industry and tests policies directed particularly at that industry. Unlike MEMM's Electric Utility submodel, REM is much more than a supply model. Its components are a demand model, a supply model, a nuclear fuel cycle model, a transmission and distribution model, and a financial/regulatory model. This brief discussion will concentrate on the first two and final submodels since the transmission and distribution model has no counterpart in MEMM, and the nuclear fuel cycle submodel will be bypassed in the computational experiments to be made with REM. (See section on fuel prices in part 4.)

REM's demand model can either accept exogenously specified estimates of annual regional peak capacity demand and electric energy demand, or predict these items with a set of econometrically estimated demand functions. In the latter case, industrial and residential-commercial energy consumption are determined by the substitution between alternative energy sources and such factors as economic growth, income, population, demand price elasticity, and temperature data. These estimates are made for each of the nine National Electric Reliability Council (NERC) regions shown in Figure 1.3. Although the demand model accepts annual regional data on peak and energy demand, REM uses this data to generate monthly load duration curves according to historical ratios of monthly peak to annual peak and monthly energy demand to annual energy



Source : NERC

Figure 1.3

NATIONAL ELECTRIC RELIABILITY COUNCIL REGIONS demand in each region. MEMM uses inputs on percentage of annual load in each of four generation modes and system load factors and determines total demand endogenously, thereby also defining regional peaks; REM, on the contrary, uses inputs on the ratios of monthly to annual peak and energy demand in each region and either determines endogenously or accepts as inputs annual peak and energy demand for each region, thereby defining regional load factors.

Rather than modeling capacity expansion decisions like MEMM, REM's supply submodel currently uses exogenous schedules for commercial operation dates of new capacity. REM uses ten plant categories and does not distinguish the many different types of coal plants as does MEMM. Regional capacity in a given plant type is not assigned to a given generation mode but plant availability is modeled using forced and scheduled outages specified for each plant type. An algorithm for scheduling the maintenance over the months of the year is incorporated.

Like MEMM, REM dispatches existing plants according to marginal costs. However, hydro and pumped storage generation are modeled differently since they are energy-limited. For these categories REM uses regional projections of annual energy and monthly availability patterns and positions the available energy optimally to serve the highest position on the regional load curve. The section of the load curve thus served is then removed from the curve prior to dispatching other plants.

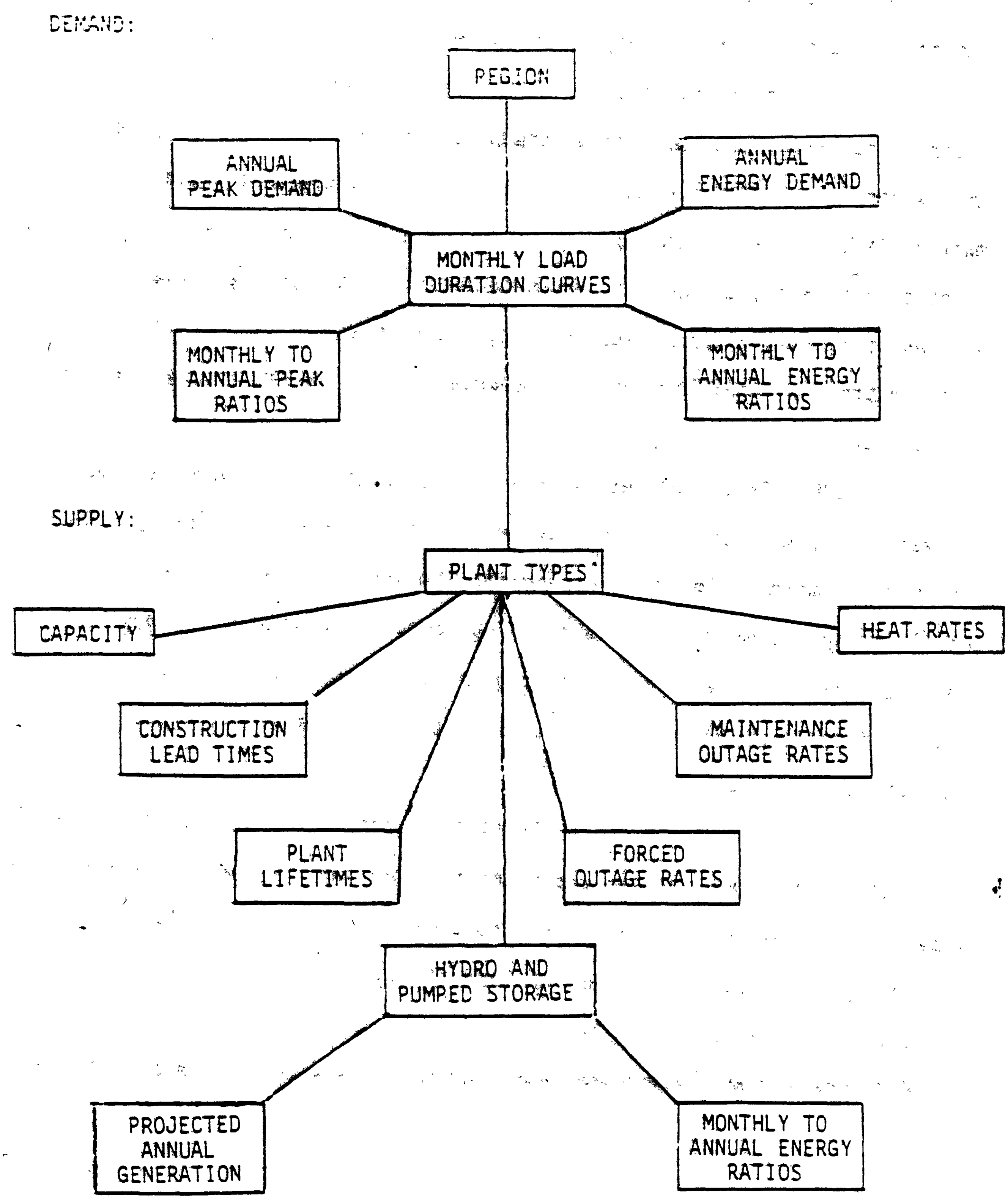
Figure 1.4 depicts the basic structure of demand and supply data used in REM. Data that vary by region and plant type include: capacity and hydro and pumped storage generation and monthly to annual energy ratios. Data that vary by plant type include: construction lead times, plant lifetimes, forced and maintenance outage rates, and heat rates.

REM models transmission and distribution in considerable detail using a

Figure 1.4

REM

OUTLINE OF DEMAND AND SUPPLY AGGREGATION



set of econometrically estimated functions which relate equipment needs, capital expenditures, and operation and maintenance expense to the configuration of demand and other characteristics of the load area. REM assumes that 10% of generation is used by generation stations and line losses in all regions. PIES-77 data indicates that MEMM simply uses regional per kilowatt-hour markups to reflect allocated capital costs and operation and maintenance costs for transmission and distribution. Rather than assuming a set cost per kilowatt-hour, REM uses regional costs for residential/commercial and industrial meters, transmission lines, distribution lines, substations, and line transformers. Transmission and distribution costs are derived from these equipment costs as they are related to electricity consumption and such service area characteristics as the configuration of customers, area of the region, and load density.

REM also models the different steps in the nuclear fuel cycle. This submodel uses a set of cost and material balance relationships encompassing the calculation of raw uranium ore requirements, fuel processing, enrichment, fabrication, and reprocessing needs and costs.

The most striking difference between MEMM and REM is the latter's final submodel: the financial/regulatory model. Like MEMM, REM uses inputs on capital structure and cost of financing and similar categories of cost data. Plant unit capital costs are distinguished by plant type and region and operation and maintenance costs by plant type. Some transmission and distribution costs are distinguished by region and others do not vary. REM inputs exogenous regional average fuel prices to the electric utility sector rather than determining marginal prices as does MEMM.

But besides these expected variables, REM also models the tax, rate-making, and accounting rules for the electric utility industry on a regional basis. REM offers normalized and flow-through accounting, different treatments of construction work in progress, and detailed calculations of the investment tax credit, federal and local taxes, and book and tax depreciation. Semiannual cash flows for new construction are derived using data on lead times and cash flow schedules for each plant type; allowance for interest during construction (AFDC) is also calculated. The detail of this submodel allows a more sophisticated average-cost pricing than the method used in MEMM. It also permits the output of regional financial statements which measure the financial integrity of the industry.

2. Comparison of MEMM and REM Data Bases for 1978

Introduction

In this section we compare the original 1978 data used in MEMM and REM and offer some explanation of the discrepancies in figures where they exist and the reasons are known. This inquiry will indicate where data from MEMM can appropriately be substituted into REM and when variables are not directly comparable. We present here the necessary background for the normalization of data to be undertaken in section 4.

Before examining the data on supply and demand and fuel and capital costs, it is appropriate to outline the scenarios this data is based on and the issues affecting all data comparisons between the two models. Throughout the following sections the data listed for MEMM is that from Scenario C (medium supply, medium demand, medium costs) of the Annual Report to Congress, 1978. A comparison with the data from Scenario C-High is offered in this report only where particularly different from Scenario C. Both scenarios incorporate mandated coal conversions and effects of PIFUA, which will be clarified in later sections. The data listed for REM is that of the base case described in Southwest Energy Associates' The Regional Economic Impacts on Electricity Supply of the Powerplant and Industrial Fuel Use Act and Proposed Amendments (hereafter SEA). This scenario is based on the absence of the Fuel Use Act and of the Proposed Oil/Gas Displacement Program.

Several problems beset the comparison of data in REM and MEMM. Both data inputs and outputs for the two models are compared in the next sections. In some cases, an input from one model is compared to an output of the other model. This situation complicates the comparison of data, particularly in the case of fuel prices. REM's input prices are average prices while MEMM's output prices are marginal prices defined by supply and demand curves. Even where prices compared are both inputs, different definitions and functions of variables in the two models can generate the same problem of lack of comparability, as in the case of overnight unit capital costs used in REM and delivered unit capital costs used in MEMM.

Another difficulty in comparing data arises from the different aggregations used in the two models. The chief difficulties here stem from the different regional structures and degrees of detail in plant and fuel categories. REM's inputs and outputs are all given in terms of the nine regions of the National Electric Reliability Council. MEMM uses different regional structure for different segments of the energy system. DOE's ten demand regions are used for the electricity segment; none of these ten regions exactly matches any of REM's nine NERC regions, although rough comparisons can be made. The approach taken here has been to group MEMM regions with the closest comparable REM regions (e.g. data from MEMM regions 1, 2, and 3 is compared to data from REM regions NPCC and MAAC -- see Table 2.1). Even the totals of the two models are not comparable since MEMM offers a national total or national average while REM offers totals or averages for NERC only.+

MEMM offers greater detail than REM in plant and fuel categories. This is particularly true in the case of coal plants and fuel. While REM lumps all coal together in reporting, MEMM distinguishes between types of coal (bituminous, subbituminous, and lignite) and further details sulfur content; in the case of coal plants, capacity, generation, and costs are further distinguished by the presence or absence of scrubbers. In the following sections MEMM's coal categories have been totalled or ranges offered for comparison with REM's single category.

+ For example, NERC cites 1978 installed capacity at 530,902 megawatts at the time of the summer peak and 542,050 megawatts at the time of the winter peak while the ARC-79 reports 579,000 megawatts of generating capacity. [See 1979 Summary of Projected Peak Load, Generating Capability and Fossil Fuel Requirements for the Regional Reliability Councils of NERC, (July, 1979), pp. 14, 21, and 28. Annual Report to Congress, 1979, Volume III, p. 108.]

Table 2.1

COMPARISON OF REGIONS

	MEMM: DOE Demand Regions	REM: NERC Regions
1	NEW ENGLAND Me., N.H., Vt., Mass, R.I., Conn.	NPCC Me., N.H., Vt., Mass., R.I., Conn., N.Y.
2	NEW YORK/NEW JERSEY N.Y., N.J.	
3	MID ATLANTIC Penn., Md., W.Va., Va.	MAAC N.J., part Penn., part Md.
4	SOUTH ATLANTIC Ky., Tenn., N.C., S.C., Miss., Ala., Ga., Fla.	SERC part Va., Tenn., N.C., S.C., part Miss., Ala., Ga., Fla.
5	MIDWEST Minn., Wisc., Mich., Ill., Ind., Oh.	ECAR part Va., W.Va., part Penn., part Md., Mich., Ind., Ky., Oh. MAIN part Wisc., Ill., part Mo.
6	SOUTHWEST Tex., N.Mex., Ok., Ark., La.	ERCOT Tex. SPP Kan., part Mo., part N.Mex., Ok., Ark., La., part Miss.
7	CENTRAL Neb., Kan., Iowa, Mo.	MARCA Neb., Iowa, N.D., S.D., Minn., part Wisc.
8	NORTH CENTRAL Mont., N.D., S.D., Wy., Ut., Col.	WSCC Mont., Wyo., Ut., Col., Cal., Nev., Ariz., part N.Mex., Wash., Or., Id.
9	WEST Cal., Nev., Ariz., Haw.	
10	NORTHWEST Wash., Or., Id., Al.	
	ARC-79, III, p. 267	SEA, p. 3

A further difficulty with data comparisons between MEMM and REM concerns data availability. Some of the assumptions, inputs, and outputs of MEMM are documented in the Annual Report to Congress, 1978, Vol. III and Supplement 1 (hereafter ARC-78, III and ARC-78, III/S1), which list electricity generation figures and fuel prices. Wherever possible REM's data has been compared to data in these two volumes. These sources, however, do not offer a breakdown of regional capital costs and other data used in MEMM and needed for this comparison. The inputs of the Annual Report to Congress, 1977 have been well documented in the six volumes of The Integrating Model of the Project Independence Evaluation System (hereafter PIES-77). Where data for the 1978 projections is not available, the PIES-77 data is listed for reference. In some cases, such as plant heat rates, the estimates would not be expected to change much in one year. In the case of capital costs, however, this assumption is not justified. However, there does not appear to be more comprehensive documentation of the 1978 data base. According to Bill Weinig of EIA's Office of Analysis Oversight and Access, the 1978 data base was not archived and any attempted re-creation, even by DOE, would be suspect.

The comparison of MEMM and REM data is made in the following sections: (1) technical data, (2) supply and demand assumptions, (3) fuel prices, (4) capital costs, and (5) other financial data. Originally data for REM was given in 1980 dollars, MEMM 1978 inputs were given in 1975 dollars and outputs in 1978 dollars, and PIES-77 inputs were given in 1975 dollars. For the following comparisons, all costs have been converted to 1978 dollars using the deflators assumed by each model.

Technical Data

REM and MEMM include technical data on capacity factors, line losses, and plant heat rates. These data inputs in both models are directly comparable, although degree of detail and use vary somewhat. Their differences are noteworthy only in the case of capacity factors for two plant categories and the trend in generating plant heat rates.

As has been discussed, MEMM utilizes actual capacity factors while REM utilizes forced and scheduled outage rates to model plant availability. From REM's forced and scheduled outage rates, a maximum capacity figure can be derived. This maximum capacity figure can be compared to the actual capacity figures for base load given for MEMM, since base load plants are operated almost continuously when they are available. The capacity factors reported for MEMM are PIES-77 data but there is little reason to expect these figures to have changed radically in one year.

A comparison of capacity factors (see Table 2.2) reveals important differences between the two models only with oil-and gas-fired plants. REM assumes these plants are available 82% of the time while MEMM assumes a significantly lower 70% for oil and gas. Other maximum capacity factors are either quite close or irrelevant. The two models assume quite different maximum capacity factors for combustion turbines, but this data will be largely irrelevant in practice since turbines are not used for base load duty. Although REM's estimate for hydro availability is higher than MEMM's, in practice REM utilizes historical data for hydro generation directly rather than dispatching hydro plants as it does with other plant categories.

REM and MEMM make fairly consistent estimates of line losses. REM assumes that 10% of generation is used by generation stations and line losses in all regions. MEMM provides different estimates of the average efficiency rate for

Table 2.2

MAXIMUM CAPACITY FACTORS (%)

Plant Type	MEMM	REM
Residual, Distillate, and Gas Steam	70.0	82.0
Coal	65.0	64.0
Nuclear	65.0	68.0
Combined Cycle	80.0	76.0
Combustion Turbine	80.0	59.0
Hydro	85.0	95.0
Pumped Storage	85.0	78.0
Geothermal	--	78.0

Sources:

MEMM: PIES-77, VI/I, pp. II-222-231
assuming baseload capacity factor = MCF

REM: SEA, p. A-6, Table A.5
MCF = (1 - scheduled outage rate) x (1 - forced outage rate)

Values for 1985 and 1990 in all regions are the same. No values are given for 1995 in the PIES-77 documentation.

each region. In the PIES-1977 model, and presumably in the 1978 model, these estimates were close to REM's and ranged from a low of 88.30% to a high of 92.50%. The estimates of average efficiency used in 1977 by region were: (1) 91.40 (2) 91.80 (3) 92.40 (4) 91.40 (5) 92.30 (6) 92.50 (7) 91.20 (8) 88.30 (9) 90.80 (10) 91.00. (PIES-77, VI/I, pp. II-240 and II-267) Both MEMM and REM assume that these estimates are constant over the forecast period.

Both REM and MEMM use comparable variables for generating plant heat rates but their estimates are somewhat different. And as usual, MEMM offers data on more specialized plant categories than does REM. In Table 2.3, MEMM's categories are combined and ranges offered for comparison with REM's more aggregated categories. The estimates used in 1977 are listed as well as those for 1978 since greater detail is available in the PIES documentation.

Two trends are noteworthy. First, the DOE's estimates show an improvement in heat rates from 1977 to 1978. The 1978 ranges of heat rates are lower for all plant types. Second, REM's estimates are uniformly on the low end of the range or slightly lower than MEMM's estimates. This discrepancy may be expected to affect fuel consumption in the two models. Since REM's heat rates are uniformly lower than MEMM's, however, this difference probably would not alter the fuel mix.

Table 2.3

GENERATING PLANT HEAT RATES (btu/kwh)

Plant Type	MEMM[1]	PIES[2]	REM[3]
Existing Coal	9,850 - 10,700	9,900 - 12,900 (10,300 - 11,000)	10,000
New Coal	9,850 - 10,700	9,840 - 11,000 (10,300 - 10,710)	10,300
Gas	10,010 - 11,400	10,100 - 13,900 (11,400 - 11,800)	10,000
Residual Oil Fired Steam	9,650 - 12,000	9,650 - 15,000 (10,300 - 10,800)	10,000
Distillate Fired Steam	9,650 - 12,000	10,000 - 16,200 (13,000 - 14,500)	10,000
Nuclear	11,000	--	10,500
Gas Turbines	--	12,200 - 17,000 (14,200 - 15,200)	12,000
Combined Cycle	--	8,500 - 9,000	8,500
Geothermal	--	--	21,500
Hydro	10,389	--	--

[1]ARC-78, III/S1, p. 55. Presumably these figures apply to 1985, 1990, and 1995.

[2]PIES-77, VI/I, pp. II-240-243 and pp. II-268-270, Tables 14-18. Since PIES-77 data is close to the ranges given in ARC-78, these numbers are also listed for comparison. PIES data is broken down by region and by old and new plant types used in the four categories of load: base, cycling, daily peak, and seasonal peak. Ranges offered in parentheses include those heat rates most frequently listed for the category in question. Heat rates given for 1985 are the same as those for 1990: no 1995 data is included in the PIES-77 documentation.

[3]SEA, p. A-5, Table A-4. Heat rates for 1985, 1990, and 1995 are equal and no regional differentiation is offered.

Supply and Demand Assumptions

Not all of the variables involved in supply and demand data play the same role in MEMM and REM. Existing capacity data are indeed inputs and generation data are outputs in both models. But while MEMM models investment in new capacity so that new capacity is an output of the model, REM accepts utility capacity expansion schedules as exogenous inputs. Hence MEMM's capacity scenarios are sensitive to fuel prices and capital costs while in REM the capacity scenarios are changed only with changes in data.

REM's inputs were prepared at a later time than MEMM's, a fact that frequently helps explain differences between the two data sets, particularly in the case of estimates for the early years of the forecast period. In the case of electricity supply data, the two models are much closer in 1995 than in 1985. Installed capacity is greater in REM in 1985 but practically equal in REM and MEMM in 1990 and 1995 (see Tables 2.4 and 2.5). MEMM consistently estimates greater total generation than REM, but by 1995 the difference is negligible (see Table 2.7). This can be accounted for by the different growth rate assumptions: REM assumes a 4.3% national average annual growth rate while MEMM assumes a 4.7% annual growth rate for 1977-85, a 4% annual growth rate for 1985-90, and only 3.7% for 1990-95.

The most striking differences in estimates of installed capacity occur in nuclear and coal data which are higher in REM, particularly in 1985 (see Tables 2.4 and 2.5). In 1985, MEMM's nuclear build limits are set to be consistent with the capacity of plants already in construction or on order (see Table 2.6); the series C data assume that there are no regulatory difficulties and that reactors with construction permits are built in 82 months and second units are built in accordance with utility assumptions for reactor sequencing. REM estimates are based on FERC reports of April 1979 but nuclear capacities are

Table 2.4

INSTALLED CAPACITY BY PLANT TYPE (GWe): NATIONAL TOTAL

Plant Type	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM
Nuclear	101.69	122.9	145.84	160.0	197.43	186.2
Coal[1]	285.00	311.1	398.89	409.3	517.51	533.2
Residual Oil Fired Steam	100.3	101.6	96.98	98.6	94.14	98.6
Gas Fired Steam	56.58	51.6	58.34	50.4	58.72	50.4
Hydro	66.10	65.3	70.03	70.2	72.91	80.4
Other[2]	87.34	79.6	103.99	92.2	100.45	114.2
Emerging Technologies[3]	2.84	--	5.14	--	22.95	--
Total	699.82	732.1	879.21	880.7	1,064.11	1,063.0

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4

[1] MEMM's coal category includes 14 breakdowns: bituminous high, medium, and low sulfur with and without scrubbers and subbituminous and lignite medium and low sulfur with and without scrubbers.

[2] For MEMM, Other includes pumped storage, distillate turbines, distillate combined cycle, and gas turbines. For REM, Other includes pumped storage, turbines, combined cycle,.and geothermal.

[3] Emerging Technologies includes low/medium btu gas combined cycle, central electric atmospheric fluidized-bed combustors, hydrothermal, solar thermal power, photovoltaics, wind systems, biomass-electric, and ocean thermal. REM does not incorporate these new technologies.

Table 2.5

INSTALLED CAPACITY (GWe): TOTAL

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	24.91	59.7	30.35	64.7	41.94	71.9	NPCC
2	50.38		72.75		81.93		
3	69.21	57.8	76.98	62.4	94.93	66.8	MAAC
4	144.76	154.3	181.29	196.8	218.64	249.3	SERC
5	133.42	118.4	161.95	142.8	193.80	171.8	ECAR
		57.8		71.8		91.1	MAIN
6	108.54	49.4	159.37	60.8	194.13	72.5	ERCOT
		75.8		92.1		116.1	SPP
7	38.10	31.1	45.05	38.7	52.77	47.6	MARCA
8	21.56	128.6	21.92	150.7	25.68	175.9	WSCC
9	68.71		84.28		108.69		
10	40.21		45.26		51.61		
NAT	699.82	732.1	879.21	880.7	1,014.11	1,063.0	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4

Table 2.5

INSTALLED CAPACITY (GWe): NUCLEAR

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	4.20	13.6	7.74	14.8	11.31	17.9	NPCC
2	8.20		13.20		17.99		
3	11.53	13.9	15.46	17.3	18.13	18.1	MAAC
4	28.42	35.0	44.01	51.6	60.63	58.8	SERC
5	26.29	13.2	30.30	15.8	40.10	20.2	ECAR
		15.7		18.9		21.3	MAIN
6	8.94	3.6	12.80	6.2	18.32	7.5	ERCOT
		8.9		11.1		13.8	SPP
7	4.31	3.7	4.31	3.7	7.20	4.0	MARCA
8	0.33	15.3	0.33	20.6	0.33	24.6	WSCC
9	6.98		10.44		11.71		
10	3.50		7.25		11.71		
NAT	101.69	122.9	145.84	160.0	197.43	186.2	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4

Table 2.5

INSTALLED CAPACITY (GWe): COAL[1]

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	2.70	5.9	6.96	7.3	11.24	8.6	NPCC
2	7.04		23.58		26.87		
3	37.12	16.1	37.92	18.5	48.88	21.3	MAAC
4	71.71	72.2	90.50	95.3	107.13	132.7	SERC
5	84.81	91.3	106.92	109.7	128.01	131.5	ECAR
		32.2		42.6		56.2	MAIN
6	32.29	15.0	77.53	24.3	104.59	32.4	ERCOT
		29.6		44.1		65.0	SPP
7	24.20	19.9	28.44	27.0	34.53	34.9	MARCA
8	13.88	28.9	13.88	40.5	16.97	50.6	WSCC
9	7.04		9.93		36.07		
10	3.26		3.25		3.26		
NAT	285.00	311.1	398.89	409.3	517.51	533.2	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4

[1] MEMM's coal category includes 14 breakdowns: bituminous high, medium, and low sulfur with and without scrubbers and subbituminous and lignite medium and low sulfur with and without scrubbers.

Table 2.5

INSTALLED CAPACITY (GWe): RESIDUAL OIL FIRED STEAM

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	10.54	25.2	10.45	24.7	10.31	24.7	NPCC
2	19.76		19.41		18.85		
3	9.83	14.0	9.76	13.7	9.64	13.7	MAAC
4	18.27	17.8	16.04	17.4	15.94	17.4	SERC
5	10.87	5.7	10.68	5.5	10.62	5.5	ECAR
		4.5		3.9		3.9	MAIN
6	4.77	--	4.73	--	4.67	--	ERCOT
		9.0		9.0		9.0	SPP
7	1.53	0.5	1.00	0.4	0.28	0.4	MARCA
8	0.32	24.9	0.32	24.0	0.32	24.0	WSCC
9	24.22		24.42		23.35		
10	0.16		0.16		0.16		
NAT	100.30	101.6	96.98	98.6	94.14	98.6	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4

Table 2.5

INSTALLED CAPACITY (GWe): GAS FIRED STEAM

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	--	--	--	--	--	--	NPCC
2	--		--		--		
3	--	--	--	--	--	--	MAAC
4	0.24	0.1	2.41	0.1	2.39	0.1	SERC
5	0.16	--	0.31	--	0.31	--	ECAR
		--		--		--	MAIN
6	53.93	28.9	53.48	27.8	52.73	27.8	ERCOT
		21.3		20.6		20.6	SPP
7	1.05	0.2	1.54	0.2	2.18	0.2	MARCA
8	--	1.1	--	1.7	--	1.7	WSCC
9	1.07		0.52		1.03		
10	0.08		0.08		0.08		
NAT	56.58	51.6	58.34	50.4	58.72	50.4	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4

Table 2.5

INSTALLED CAPACITY (GWe): HYDRO

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	1.30	5.4	1.61	7.3	1.82	10.1	NPCC
2	3.80		3.80		3.80		
3	1.20	0.5	1.49	1.2	1.64	1.4	MAAC
4	10.61	10.2	10.97	11.7	11.17	14.8	SERC
5	1.05	0.7	1.13	1.3	1.17	2.8	ECAR
		0.5		0.8		1.8	MAIN
6	2.14	0.2	2.28	0.3	2.37	0.6	ERCOT
		2.5		2.5		2.6	SPP
7	0.79	2.7	0.80	2.7	0.81	2.7	MARCA
8	5.40	41.9	5.71	42.4	6.13	43.6	WSCC
9	10.95		11.24		11.49		
10	28.85		30.98		32.49		
NAT	66.10	65.3	70.03	70.2	72.91	80.4	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4

Table 2.5

INSTALLED CAPACITY (GWe): OTHER[1]

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	6.12	9.6	3.54	10.6	3.54	10.6	NPCC
2	11.57		12.76		13.26		
3	9.51	4.9	12.33	11.7	14.50	12.3	MAAC
4	15.49	19.0	17.34	20.6	18.38	25.5	SERC
5	10.23	7.5	12.59	10.5	13.57	11.8	ECAR
		4.9		5.6		7.9	MAIN
6	6.41	1.7	8.34	2.2	11.24	4.2	ERCOT
		4.5		4.8		5.1	SPP
7	6.23	4.1	8.96	4.7	7.63	5.4	MARCA
8	1.63	16.5	1.63	21.5	1.88	31.9	WSCC
9	15.79		22.97		12.55		
10	4.36		3.53		3.91		
NAT	87.34	79.6	103.99	92.2	100.45	114.2	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SFA, p. 12, Table 4

[1] For MEMM, Other includes pumped storage, distillate turbines, distillate combined cycle, and gas turbines. For REM, Other includes pumped storage, turbines, combined cycle, and geothermal.

Table 2.5

INSTALLED CAPACITY (GWe): EMERGING TECHNOLOGIES[1]

MEMM Regions	1985	1990	1995
1	0.05	0.05	3.72
2	--	--	1.16
3	0.02	0.02	2.14
4	0.02	0.02	3.00
5	0.02	0.02	0.02
6	0.06	0.21	0.21
7	--	--	0.14
8	--	0.05	0.05
9	2.66	4.76	12.49
10	--	--	--
NAT	2.84	5.14	22.95

Source: ARC-78, III/S1, Table 26

[1] Emerging Technologies includes low/medium btu gas combined cycle, central electric atmospheric fluidized-bed combustors, hydrothermal, solar thermal power, photovoltaics, wind systems, biomass-electric, and ocean thermal. REM does not incorporate these new technologies.

INSTALLED CAPACITY

MEMM'S ASSUMPTIONS ON CONVERSIONS AND NUCLEAR BUILD LIMITS FOR 1985

	Mandated Conversions ESECA 1974 (GWe)		Actual Conversions (GWe)					Build Limits (GWe)	
						Distillate Liq./Lo. S			
Region	Oil to Coal	Gas to Coal	Oil to Bit./Hi. S. No Scrub.	Gas to Bit./Hi. S. No Scrub.	Gas to Oil Steam	to Gas Turb.	to Med. S with Scrub.	Nuclear[1]	Coal
1	1.25	--	1.25	--	--	--	--	?0	0
2	1.169	--	1.17	--	--	--	--	2.07	0.850
3	3.486	--	3.49	--	--	--	--	5.51	7.267
4	1.206	0.022	1.21	0.02	2.18	--	--	15.58	26.619
5	0.35	--	0.35	--	0.15	--	--	14.92	19.681
6	--	--	--	--	--	0.22	3.41	7.09	27.086
7	--	2.208	--	2.21	1.25	--	--	2.03	9.941
8	--	0.270	0.27	--	--	--	--	0.33	14.383
9	--	--	--	--	--	--	--	5.57	3.551
10	--	--	--	--	--	--	--	2.37	0.600
NAT	7.461	2.5	7.46	2.50	3.57	0.22	3.41	55.73	

ARC-78, III/S1, p. 27 ARC-78, III/S1, Table 26

[1]Corresponds to mid value assumed in series C, C high, C low. Assumes (1) utilities perceive increasing demand for baseload (2) no financial or regulatory difficulties (3) reactors with construction permits are built in 82 months,

adjusted to reflect cancellations and deferrals announced before Spring 1980.

MEMM limits coal capacity to announced plans only in 1985. REM accepts utility plans for expansion of coal capacity, but when supply projections are not adequate to meet peaks given maintenance needs and expected forced outages, the input data on coal capacity has been adjusted upward. To compensate for nuclear delays, approximately 9 gigawatts of coal capacity is added in 1985 and 15 gigawatts in 1990. These assumptions account in part for the consistently higher figures for coal capacity in REM. Another factor affecting the generation mix in MEMM is the cost of different fuels: MEMM's coal prices are higher and oil prices lower than REM's, a difference that can be expected to decrease coal capacity and increase oil capacity, particularly in later years.

Since REM's nuclear capacity is greater than or almost equal to MEMM's, it is not surprising that REM's generation from nuclear plants is also greater than or almost equal to MEMM's (see Tables 2.7 and 2.8). Yet MEMM's generation from coal is consistently greater than REM's despite MEMM's lower coal capacity and lower maximum capacity factor for coal. (See section on technical data.) In part MEMM's increased reliance on coal results from high oil prices and the requirements of the Fuel Use Act (PIFUA) and the ESECA mandated conversions (see Table 2.6) which do reduce oil and gas generation, particularly after 1990. But the Annual Report also ascribes increased coal use to a shift in consumption patterns to off-peak periods due to peakload pricing. Improved load factor allows baseload capacity to be more heavily utilized, thereby reducing generation from less economic capacity, i.e. gas- and oil-fired plants.

The discrepancies between REM's generation mix and MEMM's raise important questions about the data and methods of both models. Consider the 1995 capacity and generation figures of Tables 2.4 and 2.7. Total capacity and total generation estimates are both extremely close: MEMM's are greater by only 1% or less.

Table 2.7

NATIONAL TOTAL GENERATION BY PLANT TYPE
(billions of KWH)

Plant Type	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM
Nuclear	572.39	713.4	824.20	926.4	1,115.39	1,079.0
Coal[1]	1,517.85	1,474.1	2,174.53	1,912.6	2,792.18	2,487.4
Residual Oil Fired Steam	390.30	239.5	270.32	238.8	29.60	294.5
Gas Fired Steam	197.46	172.2	43.44	169.0	15.32	181.3
Hydro	287.42	235.9	291.46	237.5	298.61	237.5
Other[2]	69.52	75.9	75.89	98.9	62.23	137.9
Emerging Technologies[3]	19.27	--	34.37	--	132.36	--
Total	3,054.21	2,911.0	3,714.21	3,583.7	4,445.69	4,417.6

Sources: ARC-78, III/S1, Table 26
SEA, pp. 16-17, Table 5. Figures are for "Total NERC".

[1] MEMM's coal category includes 14 breakdowns: bituminous high, medium, and low sulfur with and without scrubbers and subbituminous and lignite medium and low sulfur with and without scrubbers.

[2] For MEMM, Other includes pumped storage, distillate turbines, distillate combined cycle, and gas turbines. For REM, Other includes pumped storage, turbines, combined cycle, and geothermal.

[3] Emerging Technologies includes low/medium btu gas combined cycle, central electric atmospheric fluidized-bed combustors, hydrothermal, solar thermal power, photovoltaics, wind systems, biomass-electric, and ocean thermal. REM does not incorporate these new technologies.

Note: The REM results presented in this table were produced on a CDC computer, while those in Table 5.1 were produced on M.I.T.'s IBM computer. Slight differences in reported base case figures are due to differences in the computing equipment: placement of hyrdo generation in the load curve was slightly affected, and therefore, the dispatch of other plants was also affected slightly.

Table 2.8

TOTAL GENERATION BY REGION
(billions of KWH)

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	112.51	238.2	139.24	272.4	172.60	311.6	NPCC
2	229.12		270.27		312.42		
3	297.60	204.6	354.53	237.8	414.91	276.4	MAAC
4	660.11	620.6	807.39	787.2	981.75	998.6	SERC
5	621.41	477.9	749.38	581.3	885.92	707.0	ECAR
		233.1		292.4		366.8	MAIN
6	435.11	203.5	549.40	256.3	689.37	322.9	ERCOT
		275.9		358.6		466.1	SPP
7	146.08	128.0	176.13	160.1	210.42	200.3	MARCA
8	83.46	529.3	101.99	637.6	122.67	768.0	WSCC
9	289.92		361.39		419.23		
10	178.90		204.51		236.41		
NAT	3,054.21	2,911.0	3,714.21	3,583.7	4,445.69	4,417.6	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 11, Table 3

Furthermore, the capacity configuration is fairly close: REM estimates greater coal, oil, and hydro than MEMM and less nuclear and gas capacity. Yet the generation mix demonstrates some noteworthy differences. In MEMM's forecast, oil and gas generation are sharply lower and coal generation is 12% higher than REM forecasts.

The causes of this result will be discussed further in this report. In the Annual Report the DOE attributes this shift to the improved load factors which follow the institution of time-of-day prices (see Table 2.9). Yet their estimates are also based upon an interpretation of current law and not economic considerations alone; indeed the Annual Report points out that coal plants are only substituted for oil plants based on economic considerations alone when the supply of oil is low or coal capital costs are low (see ARC-78, III, p. 270). It is not clear what part of the generation results is due to the assumed increase in load factors and what part is due to the mandated off-gas provisions of the PIFUA, recently rescinded by Congress.

At issue also is the extent to which the results discussed are due to modeling as opposed to data differences between the two models. Further investigation of this point requires the comparison of capacity and generation results from four cases: MEMM and REM must both be run with the load factors assumed by REM and with the higher load factors assumed by MEMM. Such an experiment was performed on REM for this research project, and results are discussed in Section 5. For MEMM, EIA has studied the effects of not implementing peak load pricing in its ARC-78 "no rate reform case." This scenario assumes a national factor of .626 which is close to REM's national load factor of .625. In 1990 - the only year the ARC-78 discusses for this case - it results in increased operation of oil turbines and reduced generation from coal; utility oil consumption increases by 25% while coal usage falls by

Table 2.9

REGIONAL SYSTEM LOAD FACTORS

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	.624	.646	.644	.646	.664	.646	NPCC
2	.638		.658		.678		
3	.626	.595	.646	.595	.666	.595	MAAC
4	.677	.623	.697	.623	.717	.623	SERC
5	.662	.660	.682	.660	.702	.660	ECAR
		.585		.585		.585	MAIN
6	.612	.600	.632	.600	.652	.600	ERCOT
		.557		.557		.557	SPP
7	.529	.597	.549	.597	.569	.597	MARCA
8	.696	.689	.716	.689	.736	.689	WSCC
9	.631		.651		.671		
10	.666		.686		.706		
NAT	.636	.625	.656	.625	.676	.625	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 11, Table 3

nearly 4%. Turbine capacity is increased by 25 gigawatts and coal capacity is reduced by 5.2 gigawatts while the national average price of electricity increases by 1% (see ARC-78, III, p. 271).

MEMM data not only assumes that time-of-day pricing improves load factors in 1985, but it also assumes that load factors will continue to improve over the forecast period (see Table 2.9). This assumption also helps explain contrary trends in MEMM and REM data on capacity, peak load, actual capacity factors, and reserve margins (see Tables 2.4, 2.10, and 2.11). Although MEMM's generation estimates are always greater than REM's, the same trend is not true of capacity and peak estimates. On the contrary MEMM's capacity estimate slowly catches up to and surpasses REM's while its peak estimate falls behind REM's. In the ten-year period between 1985 and 1995, MEMM's capacity increases at a national average annual growth rate of 4.2%, while its generation and peak estimates increase by only 3.75% and 3.3% respectively; load factors and reserve margins rise while capacity factors fall. On the other hand REM assumes the reverse trend of capacity factors rising and reserves falling while the load factor remains constant; capacity grows at only 3.84% while generation and peak grow at a higher 4.2% each.

Table 2.10

REGIONAL SYSTEM PEAKS (GWe)

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	20.58	42.1	24.68	48.1	29.67	55.1	NPCC
2	41.00		46.87		52.60		
3	54.27	39.3	62.65	45.6	71.12	53.0	MAAC
4	111.31	113.7	132.24	144.3	156.31	182.0	SERC
5	107.16	82.6	125.43	100.5	144.06	122.2	ECAR
		45.5		57.1		71.7	MAIN
6	81.16	38.7	100.24	48.7	120.70	61.4	ERCOT
		56.6		73.5		95.6	SPP
7	31.52	24.4	36.90	30.6	42.22	38.3	MARCA
8	13.69	87.7	16.26	105.6	19.03	127.3	WSCC
9	52.45		63.37		71.32		
10	30.66		34.03		38.23		
NAT	548.20	530.6	646.34	654.1	764.31	807.5	TOTAL NERC

Sources: ARC-78, III/S1, Table 26. MEMM's regional peaks are derived from data on total generation and load factors by using the following equation: System Peak = Total Generation/(8.76 x System Load Factor).

SEA, p. 11, Table 2

Table 2.11

REGIONAL SYSTEM CAPACITY FACTORS

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	.516	.455	.524	.481	.470	.495	NPCC
2	.519		.424		.436		
3	.490	.410	.525	.435	.499	.472	MAAC
4	.520	.459	.508	.457	.513	.457	SERC
5	.532	.461	.528	.465	.522	.470	ECAR
		.460		.465		.460	MAIN
6	.458	.470	.394	.481	.405	.508	ERCOT
		.416		.444		.458	SPP
7	.437	.470	.446	.472	.455	.480	MARCA
8	.441	.470	.531	.483	.545	.498	WSCC
9	.482		.489		.440		
10	.508		.516		.523		
NAT	.498	.454	.482	.465	.470	.474	TOTAL NERC

Sources: ARC-78, III/S1, Table 26
SEA, p. 11, Table 3 and pp. 12-13, Table 4. REM's regional capacity factors are derived from data on total generation and total capacity by using the following equation: System Capacity Factor = Total Generation/(8.76 x Total Capacity).

Fuel Prices

REM and MEMM presently use substantially different fuel prices in their calculations. More importantly, the function and interpretation of these prices are different in each model. While REM uses average prices delivered to utilities as exogenous inputs, major outputs of MEMM are the equilibrium fuel prices which balance supply and demand. Hence MEMM's fuel prices are marginal prices, not average prices. This difference is particularly important in a comparison of natural gas prices where long term contracts can be expected to reduce the average price of fuel significantly below the marginal price or price of new contracts.

The Supplement to the Annual Report to Congress, 1978 reports not only regional fuel prices but prices specifically to the electric utility sector. As usual, there are many coal categories not differentiated by REM. Therefore the more general estimates of delivered coal prices to the electric utility sector of the Annual Report, Vol. III are compared to REM's prices in Table 2.12; these prices correspond to the Supplement's prices for industrial coal. All other fuel prices are those reported in the Supplement as MEMM utility region prices (see Tables 2.14-2.17). MEMM and REM are in reasonable agreement on coal and uranium prices, but quite divergent in their estimates of oil and natural gas prices.

REM's coal prices are generally about 75% of MEMM's (see Table 2.12). This difference makes sense because REM's prices are average prices on coal delivered to utilities and MEMM's prices are marginal prices; that MEMM's annual real price escalation rate of 1.2% is slightly above REM's escalation rate of 1% is also consistent with this explanation since average prices rise more slowly than marginal prices. Table 2.13 points up the difference between average and marginal coal prices. Besides the 1985 marginal price which is an output of

Table 2.12

COAL PRICES (78$/mmbtu)

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	2.05	1.61	2.20	1.71	2.35	1.73	NPCC
2	1.92		2.06		2.21		
3	1.79	1.35	1.93	1.45	2.08	1.51	MAAC
4	1.89	1.32	2.02	1.46	2.14	1.58	SERC
5	1.64	1.22	1.76	1.37	1.88	1.44	ECAR
		1.32		1.51		1.55	MAIN
6	1.72	1.61	1.80	1.71	1.91	1.73	ERCOT
		1.25		1.36		1.33	SPP
7	1.56	1.13	1.65	1.33	1.76	1.49	MARCA
8	1.16	0.94	1.16	1.08	1.27	1.10	WSCC
9	1.96		2.01		2.25		
10	1.87		1.87		1.98		
NAT	1.74	1.26	1.84	1.40	1.96	1.46	TOTAL NERC

Sources: ARC-78, III, p. 233, Table 13.4 and ARC-78, III/S1, Table 30. Table 13.4 offers marginal delivered coal prices to the electric utility sector; these prices are identical to Table 30's prices for industrial coal in MEMM demand regions. A more detailed breakdown of coal prices by type is given in ARC-78, III/S1, Table 31.

SEA, p. A-7, Table A.6. These are average prices delivered to the electric utility sector. Total NERC prices are derived from the above tables and SEA, p. 10, Table 6 which lists consumption of fuels by region.

MEMM, Table 2.13 reports the 1977 historical average coal price reported in the Annual Report for 1978 and a 1985 estimate based upon it with an assumed 1% real price increase. Comparing national average prices for 1985 shows that REM's prices are fairly consistent with those based on the 1977 historical price reported in the Annual Report and a 1% escalation rate. In regions 1-5 the prices are quite close but REM's prices are significantly higher in the western U.S.

REM's price estimates for distillate and residual fuel oil and natural gas are much higher than MEMM's although both models do assume the same real price escalation rate of 4% (see Tables 2.14-2.16). REM's prices for distillate oil, residual oil, and natural gas are all so substantially above MEMM's because REM's prices were established after the Iranian cut-off and took account of the subsequent price increase while MEMM's prices were established before this event. However, the divergence in the natural gas prices is the most striking since here long-term contracts should reduce the estimate of average prices below marginal prices. The difference between average and marginal oil prices on the other hand should be slight.

Both MEMM and REM estimate nuclear fuel prices based on the use of an open fuel cycle with no reprocessing of spent fuel. Nuclear prices are constant throughout the U.S. in both models. Many variables are involved in the nuclear fuel cycle. Both models are in substantial agreement on the net result of this process -- the cost of fuel per kilowatt-hour. MEMM's prices are always slightly higher than REM's, but the difference is less than 10% except in 1990 (see Table 2.17). Since the Supplement does not report assumptions on the many variables behind this price, we are dependent on the sketchy material of the ARC-78, Vol. III which only offers a detailed breakdown of costs for 1990. However, the ARC-78 indicates that only enrichment and natural uranium production experience real price increases under series C assumptions. In generating these prices

Table 2.13

COMPARISON OF AVERAGE AND MARGINAL FUEL PRICES: COAL PRICES (78$/mmbtu)

MEMM Regions	1977† Average Price	1985* Average Price	1985 REM Average Price	1985 MEMM Marginal Price	REM Regions
1	1.40	1.52	1.61	2.05	NPCC
2	1.34	1.45		1.92	
3	1.14	1.23	1.35	1.79	MAAC
4	1.16	1.25	1.32	1.89	SERC
5	1.03	1.12	1.22	1.64	ECAR
			1.32		MAIN
6	0.57	0.62	1.61	1.72	ERCOT
			1.25		SPP
7	0.89	0.96	1.13	1.56	MARCA
8	0.48	0.52	0.94	1.16	WSCC
9	0.54	0.58		1.96	
10	0.77	0.83		1.87	
NAT	1.02	1.10	1.26	1.74	TOTAL NERC

Sources: ARC-78, III, p. 233, Table 13.4. 1977 data are historical average prices and 1985* data are derived from the 1977 prices using a 1% real price escalation rate.

SEA, p. A-7, Table A.6.

Table 2.14

DISTILLATE OIL PRICES (78$/mmbtu)

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	2.95	5.69	3.64	6.98	4.61	8.65	NPCC
2	2.92		3.64		4.61		
3	2.92	5.49	3.63	6.76	4.61	8.37	MAAC
4	2.89	4.90	3.61	6.08	4.59	7.53	SERC
5	2.84	5.77	3.56	7.09	4.56	8.80	ECAR
		5.41		6.64		8.22	MAIN
6	2.85	4.59	3.56	5.65	4.55	7.00	ERCOT
		5.20		6.36		7.88	SPP
7	2.80	4.81	3.52	5.84	4.50	7.22	MARCA
8	(2.80)	5.39	(3.52)	6.62	(4.49)	8.19	WSCC
9	2.84		3.27		4.16		
10	(2.80)		(3.27)		(4.16)		
NAT	2.88	5.45	3.46	6.74	4.37	8.34	TOTAL NERC

Sources: ARC-78, III/S1, Tables 30 and 31. Prices from Table 31 are marginal prices delivered to utility regions. Parentheses indicate that a regional price is not given in Table 31 presumbaly because that fuel is not used in that region in MEMM. In these cases the price reported is from Table 30 which gives marginal prices delivered to the city gate for MEMM demand regions. Where Table 31 reports regional oil prices, its prices are identical to those of Table 30.

SEA, p. A-9, Table A.8. These are average prices delivered to the electric utility sector. Total NERC prices are derived from the above tables and SEA, p. 10, Table 6 which lists consumption of fuels by region. Since all oil is reported together in Table 6, the total NERC prices for distillate and residual oil are only approximate.

Table 2.15

RESIDUAL OIL PRICES (78$/mmbtu)

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	2.57	4.78	3.19	5.95	3.87	7.36	NPCC
2	2.57		3.19		3.87		
3	2.57	4.72	3.19	5.88	3.87	7.27	MAAC
4	2.56	4.20	3.16	5.23	(3.87)	6.47	SERC
5	2.48	4.81	3.13	6.00	3.85	7.42	ECAR
		4.64		5.76		7.12	MAIN
6	(2.50)	3.83	3.10	4.77	3.82	5.90	ERCOT
		4.42		5.51		6.81	SPP
7	2.47	3.99	3.09	4.63	(3.80)	6.13	MARCA
8	(2.44)	5.07	(3.07)	6.31	(3.76)	7.80	WSCC
9	2.48		2.82		3.43		
10	(2.48)		(2.82)		(3.43)		
NAT	2.53	4.80	3.00	6.00	3.82	7.43	TOTAL NERC

Sources: ARC-78, III/S1, Tables 30 and 31. Prices from Table 31 are marginal prices delivered to utility regions. Parentheses indicate that a regional price is not given in Table 31 presumably because that fuel is not used in that region in MEMM. In these cases the price reported is from Table 30 which gives marginal prices delivered to the city gate for MEMM demand regions. Where Table 31 reports regional oil prices, its prices are identical to those of Table 30.

SEA, p. A-10, Table A.9. These are average prices delivered to the electric utility sector. Total NERC prices are derived from the above tables and SEA, p. 10, Table 6 which lists consumption of fuels by region. Since all oil is reported together in Table 6, the total NERC prices for distillate and residual oil are only approximate.

Table 2.16

NATURAL GAS PRICES (78$/mmbtu)

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	(3.23)	4.20	(3.55)	5.23	(4.19)	6.47	NPCC
2	(3.10)		(3.42)		(4.05)		
3	(2.99)	4.24	(3.31)	5.28	(3.93)	6.53	MAAC
4	2.65	4.16	(2.96)	5.21	(3.56)	6.98	SERC
5	2.84	4.14	3.28[I]	5.14	3.82	6.37	ECAR
		4.14		5.14		6.37	MAIN
6	2.32	2.81	3.18[I]	3.49	3.91	4.32	ERCOT
		3.83		4.77		5.90	SPP
7	(2.61)	3.92	3.10	4.86	3.66	6.03	MARCA
8	(2.65)	4.06	(2.68)	5.06	(3.13)	7.86	WSCC
9	(3.28)		(3.33)		(3.79)		
10	(3.30)		(3.34)		(3.79)		
NAT	2.66 2.32[I]	3.24	3.10 3.18[I]	4.11	3.81	5.17	TOTAL NERC

Sources: ARC-78, III/S1, Tables 30 and 31. Table 30 reports marginal natural gas and natural gas, intrastate prices delivered to the city gate for MEMM demand regions. Table 31 reports marginal natural gas and natural gas, intrastate prices delivered to utility regions. Table 31 does not list prices for all regions in either category, presumably because natural gas is not used in all utility regions in MEMM. Wherever possible I have used natural gas prices from Table 31. An I indicates a natural gas, intrastate price from Table 31. Parentheses indicate natural gas prices from Table 30 which we may presume to be lower than utility prices since utilities are not preferential users of natural gas. National averages for natural gas and natural gas, intrastate are not identical, so both averages are given here.

SEA, p. A-8, Table A.7. These are average prices delivered to the electric utility sector. Total NERC prices are derived from the above tables and SEA, p. 10, Table 6 which lists consumption of fuels by region.

Table 2.17

NUCLEAR FUEL CYCLE

Unit Prices

	1985 REM	1990 MEMM	1990 REM[2]	1995 REM
Processing Uranium ($/lb.)	31.14	53	41.825	52.51
Conversion ($/lb)	2.59	2	2.59	2.59
Enrichment ($/SWU)	97.39	88	92.73	88.07
Fabrication ($/kg)	129.17	100	129.17	129.17
Shipping Fresh Fuel ($/kg)	1.00	--	1.00	1.00
Shipping Spent Fuel ($/kg)	35.22	16	35.22	35.22
Pool Storage[1]	70.46	6	70.46	70.46
Waste Disposal ($/kg)	117.41	232	117.41	117.41

Contribution to Nuclear Generation Cost (mills/kwh)[3]

	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM
Processing U_3O_8		2.71	5.01	3.48		4.24
Conversion		0.18	0.13	0.18		0.18
Enrichment		2.28	2.07	2.26		2.23
Fabrication		0.61	0.48	0.61		0.61
Shipping Fresh Fuel		0.004	--	0.004		0.004
Shipping Spent Fuel		0.13	0.05	0.13		0.13
Pool Storage		0.27	0.23	0.27		0.27
Waste Disposal		0.45	0.80	0.45		0.45
Total	6.89	6.59	8.77	7.35	8.88	8.11

Sources: ARC-78, III, p. 220, Table 12.5 and ARC-78, III/S1, Table 31
SEA, pp. A-13-14, Tables A.13 and A.14

1 MEMM's cost is in dollars per kilogram per year; REM's cost is in dollars per kilogram.

2 By straight line interpolation of the 1985 and 1995 data.

3 Data for both models include carrying charges on working capital.

both models assume a 65% capacity factor for nuclear plants.

The greatest differences in the 1990 nuclear cycle estimates concern uranium processing, enrichment, and waste disposal. MEMM assumes a steadily increasing price for new contracts for uranium production, the greatest expense in the fuel cycle. Despite the fact that MEMM uses marginal fuel prices elsewhere, the price for uranium processing of Table 2.17 is an average delivered price, not a new contract price. (For confirmation of this point see the graph contrasting average and new prices in ARC-78, III, p. 214.) Hence, the difference on this item between the two models cannot be attributed to the differences between average and marginal prices. For enrichment MEMM forecasts a continuing real price increase resulting from the increasing cost of electricity used by enrichment plants; REM assumes a slight decline in enrichment costs in constant dollars, yet its estimates remain above MEMM's in 1990. MEMM's estimate of waste disposal is almost twice that of REM. Still, the differences between the two models on nuclear fuel prices remain much less glaring than for fossil fuels.

A comparison of the average national fuel prices for Scenarios C and C-High is presented in Table 2.18. The C-High oil and natural gas prices are closer to REM's estimates although they remain below those of REM in all years of the forecast period.

Table 2.18

SENSITIVITY OF AVERAGE NATIONAL FUEL PRICES TO OIL PRICES
(78$/mmbtu)

		Coal	Distillate	Residual	Natural Gas	Uranium
1985	MEMM-C	1.74	2.88	2.53	2.66	6.89
					2.32[I]	
	MEMM-C-High	1.77	4.03	3.56	3.17	6.89
					2.72[I]	
	REM	1.26	5.45	4.80	3.24	6.59
1990	MEMM-C	1.84	3.46	3.00	3.10	8.77
					3.18[I]	
	MEMM-C-High	1.88	4.32	3.89	3.42	8.77
					3.22[I]	
	REM	1.40	6.74	6.00	4.11	7.35
1995	MEMM-C	1.96	4.37	3.82	3.81	8.88
	MEMM-C-High	1.99	5.91	5.08	4.35	8.88
	REM	1.46	8.34	7.43	5.17	8.11

Sources: ARC-78, III, p. 233
ARC-78, III/S1, Tables 30 and 31. I indicates a national average intrastate natural gas price.
SEA, pp. 19, A-7-10, A-13-14, Tables 6, A.6, A.7, A.8, A.9, A.13, A.14

Capital Costs

This section focuses on unit capital costs of generation plants in MEMM and REM. Capital costs for transmission and distribution are not discussed because of the lack of comparability in method (see part 1). Despite the fact that unit capital costs for generation plants are inputs in both models, many problems beset a comparison of capital costs for new plants. These problems fall into two categories: (1) different items are included in capital costs or the variables function differently in the two models, and (2) lack of data or documentation. The importance of capital costs in each model differs also. In MEMM, capital costs and fuel costs are factors affecting capacity mix and fuel use. REM does not utilize a capacity planning model; rather capacity expansion schedules are input as data. Hence in REM, generation plant capital costs only affect the cost of service and not capacity and fuel mix as well.

While MEMM's capital costs for a particular year are estimates of the cost of the average plant delivered in that year, REM's capital costs are overnight construction costs in that year. It appears that MEMM's figures include the accumulated allowance for funds used during construction (AFDC) as well as direct construction costs (see ARC-78, III, p. 269). REM's costs do not include AFDC which can be a significant part of the completed plant value. Rather REM uses typical patterns of construction expenditures and the overnight construction expense in each year of the construction period to generate construction cash flows from which AFDC is figured; in so doing an AFDC rate of 8% in nominal terms is used and AFDC is compounded on an annual basis. It is not clear whether the two models assume the same or different lead times since the ARC-78 is not explicit on this point. However, because REM's AFDC rate is only slightly above its assumed inflation rate of 5.5%, REM's installed capital costs including AFDC should in fact be quite close to the overnight construction costs.

A major problem in comparing the regional assumptions on generating plant capital cost inputs for this study arises from lack of data documentation. It is clear that MEMM uses a regional format for this variable, but the ARC-78 reports regional values for nuclear plants only. The PIES-77 documentation does offer detailed regional data but the assumptions behind these costs are quite different than the assumptions outlined in the ARC-78. Hence the PIES-77 data are unreliable as proxies for MEMM-78 data. The PIES-77 data do, however, permit a comparison of regional variation in capital costs on the assumption that this pattern of regional variation remained the same in MEMM's data for 1977 and 1978.

Table 2.19 compares REM's non-nuclear capital costs and MEMM's. MEMM values are those for DOE Region 5 which the ARC-78 reports as representative national average values. Ranges in MEMM coal capital costs arise from differences in coal plant categories; the "typical" value is the most frequent or median value. REM's ranges arise from regional variation and its "typical" value is that of region ECAR which coincides rather well with DOE region 5.

This table shows that REM's non-nuclear capital costs are always greater than MEMM's except for combined cycle in 1985. REM's capital costs are particularly greater than MEMM's in 1990 and 1995 since REM assumes real cost increases and the ARC-78 does not. Of the fossil fuel plant categories, by far the most important difference occurs in the estimate of capital costs for coal plants, both because of the dollar difference and because most new fossil fuel plant installations are designed to burn coal. In 1995, REM's coal plant capital costs are 50% above MEMM's. In series B and E, the ARC-78 did study the effects of higher capital costs (25% for noncoal and 38% for coal -- see ARC-78, III, p. 269) due to direct cost increases, longer construction periods, higher interest rates, and tougher sulfur dioxide emission standards; but these costs were not varied

Table 2.19

NON-NUCLEAR UNIT CAPITAL COSTS (78$/kw)

	MEMM[1]	REM[2]		
	1985, 1990, 1995	1985	1990	1995
Coal Under Construction:				
Range	510-660	677-1,269	726-1,360	787-1476
(Typical)	(600)	(846)	(907)	(984)
Coal New:				
Range	595-700	677-1,269	726-1,360	787-1,476
(Typical)	(655)	(846)	(907)	(984)
Oil:				
Range	435	392-735	414-777	445-834
(Typical)		(490)	(518)	(556)
Gas:	None given:			
Range	Presumably no	370-685	392-735	426-800
(Typical)	new plants are built	(457)	(490)	(533)
Gas Turbines:	170	234	244	252
Combined Cycle	315	298	322	345

Sources: ARC-78, III/S1, p. 29
SEA, pp. A-1-2, Tables A.1 and A.2

[1]MEMM values are 1985 national average values which are assumed to be the same as DOE Region 5. The estimates reflect the cost of plants delivered on December 31, 1984. No real cost escalation is assumed for the 1985-1995 period. No regional detail is offered. Ranges represent differences in coal plant types.

[2]REM tables list 1982, 1987, and 1992 cost estimates. The costs listed here were derived using straight-line interpolation. Ranges represent regional differences while the figures in parentheses are those for ECAR, which corresponds to DOE Region 5. No regional variation is offered for turbines and combined cycle plants. In REM these prices are treated as overnight construction costs. Fixed operation and maintenance costs are included.

within series C projections. The relatively low capital costs of series C are particularly important because these costs affect capacity mix and fuel usage as well as electricity prices. According to the Annual Report, "... a substitution [of coal for oil] based solely on economics will only occur when the supply of oil is low or the capital costs for building new coal plants are low." (ARC-78, III, p. 270)

Table 2.20 illustrates the variation in regional capital costs for fossil baseload generation plants based on data from PIES-77 and REM. The table reports the regional multipliers derived by dividing each region's capital costs by the costs of a representative region. For PIES-77, DOE region 5 is the representative region while REM's multipliers are based on costs for ECAR, a region which corresponds closely to region 5. REM uses the same regional multipliers for all fossil baseload plants but PIES-77 data indicates fuel type variation as well.

The range of regional variation is greater for REM (0.81-1.35) than for MEMM (0.91-1.28). Nonetheless the pattern of regional variation is close. Both models concur in assigning the lowest costs in all fuel categories to the Southeast (region 4 and SERC) and the Southwest (region 6 and ERCOT). PIES-77 data attributes the highest oil- and gas-fired plant costs to the Northeast (regions 1, 2, and 3) but assigns the highest coal plant costs to the West (regions 8, 9, and 10). Since most new baseload plants burn coal, the latter multipliers are more significant. In the coal category both models use highest costs in the West (regions 8, 9, and 10 and WSCC), but REM's estimates are significantly higher when compared to costs in other regions.

The ARC-78 offers much more regional detail on nuclear than on non-nuclear capital costs. The Annual Report also presents results of several different nuclear scenarios; it analyzes the impacts of high and low capital costs, high

Table 2.20

REGIONAL VARIATION IN CAPITAL COSTS FOR FOSSIL BASELOAD

MEMM Regions	Coal	Oil	Natural Gas	Fossil Baseload	REM Regions
1	1.01	1.01	1.12	1.15	NPCC
2	1.07	1.07	1.12		
3	0.96	0.96	1.12	0.93	MAAC
4	0.91	0.91	0.91	0.80	SERC
5	1.00	1.00	1.00	1.00	ECAR
				0.97	MAIN
6	0.92	0.92	0.91	0.80	ERCOT
				0.97	SPP
7	0.99	0.99	1.00	0.97	MARCA
8	1.19*	0.98	1.05	1.35	WSCC
9	1.28*	1.03**	1.03		
10	1.22*	0.99	1.02		

Sources: PIES-77, VI/I, pp. II-237 and II-264, Table 10
SEA, pp. A-1-2, Tables A.1 and A.2

Regional multipliers are based on capital costs from Region 5 for PIES-77 and from ECAR for REM. REM's multipliers apply to all years of the forecast period for all fossil baseload plants. In the few cases where PIES-77 regional multipliers are different in 1985 and 1995, this difference is less than 5% so that the average multiplier is reported here; the only exception occurs with oil plants for Region 9 where costs are 1.28 times those of Region 5 in 1990 and only 1.03 times in 1985. The coal multipliers for PIES-77 are based on comparisons of the lowest cost coal plant in each region; a comparison of medium cost coal plants would generate the same multipliers except in Regions 8, 9, and 10 where medium cost plants are only 10%, not 20% more costly than Region 5 plants. The cost of the highest cost coal plant is exactly the same in Regions 1-8 and 10 and only 2% higher in Region 9.

* Medium cost coal plants in Regions 8, 9, and 10 are only 1.08, 1.13, and 1.11 times those of Region 5.

**In 1985 costs of oil plants in Region 9 are 1.03 times those of Region 5 but in 1990 they are 1.28 times those of Region 5; this is a striking difference given the otherwise narrow range of regional variation in oil plant cost.

and low supply, a nuclear moratorium, and an upswing in orders for new plants. As with other capital costs, REM's nuclear plant capital cost estimates are substantially above MEMM's, particularly in the West (see Table 2.21). The ARC-78 reports costs for committed reactors as a separate category from deferrable and new reactors to be completed by 1995. This class of nuclear plants is due for completion within two years, i.e. by 1980. MEMM's costs for committed reactors are taken from the EIA data base of historic utility, architect engineer, and public utility commission estimates for applicable reactor projects. MEMM's cost estimates for committed reactors are at least 20% less than REM's costs for 1985 and 1990. MEMM's costs for deferrable and new reactors come from the CONCEPT cost accounting code.

Series C projections use medium-cost estimates for deferrable and new reactors which are well below REM's estimates for 1995. These medium costs are based on current labor and material rates, a licensing delay of 32 months, and a construction period of 82 months for the first reactor at a site. Although REM's values assume a similar time period for construction expenditures of 78 months, they also incorporate steady escalation in labor and material rates and safety-related costs.

MEMM's high cost estimates also presented on Table 2.21 but not used in series C projections assume not only direct and indirect cost escalation due to resolution of safety problems but also real escalation of commodity-labor costs above inflation through the mid-80's. In addition, licensing requires 46 months, construction requires at least 96 months, and some utilities experience financial or regulatory difficulties. These high cost estimates are quite close to the base values used in REM except in the West (regions 8, 9, and 10 and WSCC). As with capital costs for fossil plants, REM's capital costs for nuclear plants are substantially higher in region WSCC than in the rest of the country.

Table 2.21

UNIT CAPITAL COSTS: NUCLEAR (78$/kw)

MEMM Regions	1980 MEMM	1985 REM	1990 REM	1995 MEMM	1995 REM	1995 MEMM-High	REM Regions
1	855	1135	1190	980	1262	1180	NPCC
2	945			1040		1255	
3	910	996	1044	1065	1107	1265	MAAC
4	625	857	898	840	952	955	SERC
5	740	1071	1123	970	1191	1145	ECAR
		868	910		964		MAIN
6	655	1071	1123	900	1191	1025	ERCOT
		1071	1123		1191		SPP
7	995	953	999	1090	1060	1280	MARCA
8	1280	1606	1684	--	1786	--	WSCC
9	885			875		1015	
10	945			1095		1305	
NAT. AV.	775			920		1070	

Sources: ARC-78, III, p. 387. These costs are unit capital costs for reactors expected to be in operation sometime before 1995. Reactor refurbishment cleaning and decommissioning costs are not included. What I have designated as MEMM 1980 costs are MEMM costs for committed reactors which are scheduled for completion within two years, hence by 1980. (See PIES IV, p. VII-10) Committed reactor costs are from the EIA data base. MEMM 1995 costs are for deferrable and new reactors and are derived from the CONCEPT cost accounting code. 1995 MEMM costs are used in all series C scenarios; these costs assume some direct and indirect cost escalation due to resolution of outstanding safety related issues at issue before TMI. Also reported here for comparison with REM's costs are 1995 MEMM-High cost estimates which assume significant direct and indirect cost escalation due to safety issues <u>and</u> historic real escalation of commodity-labor costs above inflation through the mid-80's.

SEA, pp. A-1-2, Tables A.1 and A.2. These prices are treated in REM as overnight construction costs. Fixed operation and maintenance costs are included.

<u>Other Financial Data</u>

This section covers operation and maintenance costs for electric plants, various other financial variables, and average electricity prices. The ARC-78 does not report operation and maintenance costs, so Table 2.22 compares REM's inputs to those used in 1977. The other financial parameters and prices, however, are reported in the ARC-78, although some of the financial variables function differently in REM and MEMM.

Both REM and PIES-77 use the same operation and maintenance costs in all regions through 1995. REM's estimates are always greater than those used in PIES-77 except for distillate fired plants (see Table 2.22). REM's estimates for hydro and pumped storage are close to MEMM's while its estimates for coal plants are comparable to the high end of the range in costs reported in PIES-77 for bituminous coal plants with scrubbers. In several remaining categories REM's costs are approximately double MEMM's values. See, for example, the costs for gas-fired steam, residual-fired steam, gas turbines, and combined cycle. REM's cost for operation and maintenance of nuclear plants is only 20% greater than MEMM's cost.

Both MEMM and REM make assumptions on utility financial structure and costs, but these financial variables do not function in exactly the same way in both models. MEMM uses a fixed capital structure made up of 55% debt, 10% preferred stock, and 35% common stock. REM, on the other hand, models capital structure dynamically. Debt is the preferred financing instrument and is used until the interest coverage ratio falls to 2.5 times or the proportion of debt in the capital structure rises to 55%; the proportion of preferred stock is fixed at 10% and common stock makes up the remainder. If the minimum interest coverage ratio is dropped to zero, REM will produce the same static capital structure as MEMM.

Table 2.22

OPERATION AND MAINTENANCE COSTS
(78 mills/kwh)

Plant Type	PIES-77	REM
Existing Coal	1.31 - 3.33	3.05
New Coal	1.31 - 3.33	3.14
Gas Fired Steam	0.60	1.17
Residual Fired Steam	1.07	2.70
Distillate Fired Steam	3.27	2.70
Nuclear	1.96	2.34
Gas Turbines/Combustion Turbines	3.27	5.84
Combined Cycle	1.49	2.83
Hydro	0.83	0.88
Pumped Storage	0.83	0.87
Geothermal	--	0.96

Sources: PIES-77, VI/I, pp. II-236 and II-263, Table 8. Since PIES-77 input data are given in 1975$, an inflator of 1.19 is used to convert to 1978$. (See ARC-78, III/S1, p. 15) Costs for 1985 and 1990 are equal. No 1995 costs are listed. Coal plant costs are low for plants without scrubbers and high for plants with scrubbers.

SEA, pp. A-3-4, Table A.3. Only variable O & M costs are reported here since fixed O & M costs were included in unit capital costs. Costs for 1985, 1990, and 1995 are equal.

Data on the cost of capital function in the same way in MEMM and REM except that MEMM uses real costs and REM uses nominal costs. While the Annual Report sidesteps the issue of inflation by reporting all results in real dollars, REM assumes an annual inflation rate of 5.5%, makes calculations in nominal terms, and outputs results in current dollars. Removing the inflation factor from REM's costs reveals estimates quite different from the medium costs assumed in the ARC-78 Scenario C (see Table 2.23). REM's costs of debt and preferred stock are less than MEMM's but its cost of common stock is one and a half times MEMM's cost. REM's cost of common stock is even substantially higher than MEMM's high cost case. To date few utilities have received such a liberal rate of return on equity.

Tables 2.24 and 2.25 contain the results of the many assumptions described in this section: the average prices of electricity for the forecast period. Although REM and MEMM project the same national average electricity price for 1985 (36.8 mills/kwh), REM's prices continue to rise much faster than MEMM's do (see Table 2.24). Doubtless this difference arises in part from the lack of escalation in capital costs assumed by the ARC-78 and REM's higher fuel prices. However, even under the high oil price scenario, MEMM's electricity prices are not as high and do not rise as fast as REM's; under C-High assumptions, national average prices for 1985, 1990, and 1995 are 38.78, 38.94, and 39.06 -- still substantially less than REM's. The Annual Report ascribes the leveling of prices between 1990 and 1995 in Scenario C to "...the benefits of replacing expensive oil plants with new coal units and the effects of peak-load pricing..." (ARC-78, III, p. 269). The Annual Report's sensitivity studies show that higher oil prices raise the national average price of electricity by 1.6% and lack of rate reform raises it by 1% (see ARC-78, III, p. 271).

Both MEMM and REM output regional average prices of electricity. MEMM

Table 2.23

FINANCIAL PARAMETERS

Factor		MEMM		REM
CAPITAL STRUCTURE:				
% Debt:		55		up to 55
% Preferred:		10		10
% Common:		35		at least 35
Minimum Interest Coverage Ratio:		--		2.5
REAL COST OF FINANCING (%):[1]	High	Medium	Low	
Debt:	3.5	3.0	2.5	2.8
Preferred:	4.0	3.5	3.0	3.0
Common:	7.5	6.5	5.5	10.0
ASSUMED INFLATION RATE (%):		--		5.5

Sources: ARC-78, III, p. 387
SEA, p. A-19

[1]REM uses nominal costs of capital of 8.5%, 8.7%, and 16%. These real costs are derived therefrom, using (1 + real rate) = (1 + nominal rate)/(1 + inflation rate

Table 2.24

NATIONAL AVERAGE ELECTRICITY PRICES (78 mills/kwh)

1977*	34.5	
Projections	MEMM	REM
1980	--	35.58
1985	36.80	36.84
1990	38.30	40.97
1995	38.95	43.40
2000	--	48.43

*Historical national average electricity price reported in ARC-78, III, p. 269, Table 16.5

Sources: ARC-78, III/S1, Table 30
SEA, p. 20, Table 7

also gives prices for electricity delivered to the industrial, commercial, residential, and transportation sectors (see ARC-78, III/S1, Table 27), while REM reports the average fixed and variable cost of service as well as total cost (see SEA, p. 20, Table 7). A comparison of regional average prices shows the same pattern we have seen before (see Table 2.25). When the projected national average price of both models is the same in 1985, REM's prices for regions NPCC and MAAC are close to MEMM's prices for Regions 1, 2, and 3. However, REM's SERC price is lower than that of MEMM's Region 4, and REM's prices for ECAR and MAIN are both below that of MEMM's Region 5. On the other hand, REM's WSCC price is substantially above those of MEMM's Regions 8 and 10 though close to that of MEMM's Region 9. If the prices within the five groups are averaged, both models concur in projecting lowest prices for the Southeast (regions 4 and SERC) and highest prices for the Northeast (regions 1, 2, and 3 and NPCC and MAAC).

Table 2.25

AVERAGE ELECTRICITY PRICES BY REGION (78 mills/kwh)

MEMM Regions	1985 MEMM	1985 REM	1990 MEMM	1990 REM	1995 MEMM	1995 REM	REM Regions
1	46.25	49.77	49.03	54.81	48.15	61.90	NPCC
2	47.83		49.12		47.67		
3	40.43	39.71	40.54	42.59	41.29	49.15	MAAC
4	33.23	30.10	35.06	34.95	35.82	38.99	SERC
5	37.25	34.77	38.07	37.47	39.05	40.61	ECAR
		29.83		35.22		38.45	MAIN
6	38.39	42.14	42.49	44.30	42.75	48.79	ERCOT
		41.06		42.32		44.47	SPP
7	36.24	32.16	35.51	35.31	35.40	38.45	MARCA
8	32.56	39.17	30.44	46.72	30.84	43.13	WSCC
9	39.85		40.31		42.78		
10	15.55		17.56		18.29		
NAT	36.80	36.84	38.30	40.97	38.95	43.40	TOTAL NERC

Sources: ARC-78, III/S1, Table 30
SEA, p. 20, Table 7

3. Description of Computational Experiments

MEMM and REM are being compared in order to contrast the effects of alternative modeling structures and assumptions upon projections and in particular to examine generation technology and fuel use issues. Without conducting any experiments, however, it is clear that each model has the ability to address issues not found in the other. For example, MEMM offers detailed breakdowns on coal plants and sulfur content of coal which permit the model to address issues of air emissions and coal supply in a detail simply not available in REM which offers only two breakdowns of coal plants, those with scrubbers and those without. On the other hand, REM's financial submodel allows the user to vary assumptions on regulatory practice and judge the impact on rates and utility financial performance while MEMM does not permit variation in regulatory practice or output measures of utility financial health. Computational experiments are not necessary to highlight these differences, nor are they really desirable where the two models are so divergent.

Rather computational tests can elucidate the impact of modeling structures and assumptions where the models attempt to simulate the same phenomenon. Since MEMM is principally a supply-demand model, this limits productive comparisons to modeling of electricity demand, capacity expansion, and generation. Since REM considers capacity expansion as exogenous, the field of choice narrows to demand and generation.

Keeping in mind the purposes outlined above, the most fruitful field for a set of computational experiments is electricity generation and the related fuel usage; the capacity on which that generation is based and cost of service are secondary comparisons of the experiments.

Another major reason for selecting generation results as worthy of further study is that MEMM's and REM's outputs show quite contrary tendencies which may not be wholly accounted for by data differences. These noteworthy results were remarked upon in the section on Supply and Demand Assumptions of Section 2. To recapitulate briefly:

1. Although REM's coal capacity is greater than MEMM's, MEMM's coal generation is greater than REM's in all years of the forecast period.

2. By 1995, MEMM's generation from oil and gas is cut substantially while coal generation is 12% greater than in REM.

3. Between 1985 and 1995, MEMM's load factors and reserve margins rise while actual capacity factors fall.

4. Between 1985 and 1995, REM's load factors remain constant, reserve margins fall, and actual capacity factors rise.

The DOE Annual Report suggests that improved load factors are responsible for MEMM's increase in coal use, decrease in oil, and greater growth in generation than in capacity. The following related experiments were designed to test the modeling of generation in the two models and to test the adequacy of the explanation given above. This set of tests was chosen on the assumption that it would not be possible to run MEMM; therefore all data changes and runs must be made with REM and compared to MEMM output currently available.

1. <u>The Rate Reform Case (Scenario C)</u>
   MEMM's demand estimates, capacity estimates (incorporating ESECA mandated conversions and retirements), Scenario C fuel prices, and improved load factors, are used as inputs to REM. The resulting pattern of generation, fuel usage, average electricity prices, and reserve margins are compared to MEMM's for 1985, 1990, and 1995. This case corresponds to MEMM's Scenario C base case.

2. <u>No Rate Reform Case</u>
   MEMM's demand estimates, capacity estimates (incorporating ESECA mandated conversions and retirements), Scenario C fuel prices, and a national average load factor of .626 are used as inputs to REM. The resulting pattern of generation, fuel usage, average electricity prices, and reserve margins can be compared only to MEMM's 1990 outputs set forth in the <u>Annual Report</u> as the "no rate reform" case. MEMM inputs and outputs for this sensitivity test are not reported in as much detail as for MEMM's regular scenarios.

Prior to performing the computational experiments, it was not known whether or not the results would show substantial agreement between the forecasts of the two models. If results agreed, additional support would have been given to DOE's forecasts of the impact of rate reform. Another possibility was that, in comparison to MEMM results, REM's outputs might have shown inadequate reserve margins and/or less substitution of generation from coal for generation from oil and gas. In this case, the experiment's results might have indicated some disagreement with the DOE's forecast of increasing reliance on coal; such results would also have underlined an important modeling difference between MEMM and REM: the use of actual capacity factors on a yearly basis versus the use of scheduled and forced outages simulated on a monthly basis.

As the next section on results will show, the latter was the outcome of the experiment. Therefore, some additional computational runs were designed. First, coal capacity was increased so that oil and gas consumption in the Scenario C normalized REM would approximate the MEMM levels. The purpose of the run was to iteratively discover what level of coal capacity would be required to match MEMM's pattern of generation from oil and gas. (See Table 5.7 for results.) In addition, the economic impact of the additional capacity was assessed by comparing the average electricity prices for this adjusted coal capacity case and for the rate reform (Scenario C) case described above (see Table 5.8).

Turning to the topics of fuel prices and capacity expansion plans, several computational experiments were designed as follows.

3. Scenario C-High

   In this case, REM was run with data corresponding to ARC-78's Scenario C-High (called C' for convenience). Scenario C-High utilizes higher fuel prices; therefore the computation measured the two models' relative sensitivity to fuel prices and indicated which variables are most sensitive to fuel prices in each model.

4. Alternative Capacity Expansion Scenarios

It was also considered important to explore the sensitivity of economic variable to changes in the capacity expansion plans. Therefore, four computer runs were designed and performed which perturbed the amount of coal and nuclear capacity from the Scenario C levels. The four experiments included:

a. 10 gigawatts of coal capacity was added by 1990
b. 10 gigawatts of coal capacity was reduced by 1990
c. 10 gigawatts of nuclear capacity was added by 1990
d. 10 gigawatts of nuclear capacity was reduced by 1990

(see Tables 5.4 and 5.5 for results)

The results of these experiments are presented in Section 5. In Section 4, however, we discuss the data that was necessary in order to perform the computer runs.

4. Normalization of the REM Data Base

The most difficult aspect of substituting MEMM data for REM data is the use of different regional aggregates in the two models. There is no exact method of transforming MEMM regional data into REM regional data. This problem plagues the transformation of nearly all data and has been dealt with in different ways depending on the nature of the figures in question. In general, where a national total or national average is available and is a meaningful number, as is the case with capacity, then REM's national total has been set equal to MEMM's national total but this total has been divided up according to REM's regional proportions. Where a national average figure is either not available or meaningless, as is true of unit capital cost multipliers, then each of REM's regional figures has been set equal to the average for those MEMM regions that correspond most closely with the given REM region. Any method of modifying REM's regional data will doubtless have ramifications on REM's outputs which are to be compared with MEMM's predictions; it is hoped that the methods chosen here will cause the least prejudice to calculations of national generation and fuel use.

Another difficulty that affects all data changes is the use of different plant categories. While MEMM offers a detailed breakdown of coal plants, REM does not. For the normalization two coal categories are used in REM: "coal-existing" which includes all of MEMM's existing coal capacity and "coal-new" which includes MEMM's new coal capacity for all coal types. Where only one coal category is used in the following tables, this number applies to both existing and new plants. Similarly, although hydro and pumped storage are distinguished in both models, where data for hydro only is presented, it applies to both hydro and pumped storage.

MEMM outputs several tables on different emerging technologies including data on generation in million kilowatt-hours per day and the minimum acceptable price in dollars per thousand kilowatt-hours. However, the assumptions on capital costs, capacity factors and such are not presented in the Annual Report and are not available for use in REM. Rather than ignore these technologies altogether, we have combined them in the category "geothermal and other" and used REM's data on geothermal characteristics throughout the following tables to apply to the entire capacity in this category. Since geothermal capacity dominates MEMM's emerging technologies in 1985 and 1990 (92% and 88%) and remains one of the most important categories in 1995 (at 28%), this choice seems reasonable. Even if REM's data on geothermal is radically different from the assumptions behind MEMM's generation from emerging technologies, the impact will still be minimal since capacity in this category is such a small part of total capacity: less than 1% in 1985 and 1990, and 2% in 1995.

This chapter presents the adjusted REM data and the methods used for that adjustment. This material is presented under the same groupings as the comparison of the two models' original data in section 2 of this report and it builds upon the explanations offered there. REM data adjusted for the first computational experiment (the rate reform case) is presented in detail in the first section. In the next section the necessary data changes for the other suggested simulations are discussed.

Simulation 1: The Rate Reform Case (Scenario C)

Technical Data

REM uses scheduled and forced outage rates to determine plant availability and then dispatches them by economic criteria to meet the required load. MEMM, on the other hand, uses actual capacity factors and no inputs on scheduled and forced outages. To render REM's data compatible with MEMM assumptions, we have assumed that the actual capacity factors for baseload use reported in PIES-77 documentation are equivalent to maximum capacity factors; we have then used REM's existing forced outage rates and recalculated scheduled outage rates compatible with these maximum capacity factors (see Table 4.1). These rates apply to all years of the forecast period. Turbine and pumped storage scheduled outage rates have been set at zero, not because such a rate is thought to be realistic, but to be compatible with the high capacity factors used in MEMM. Because the ARC-78 does not report such data for emerging technologies, REM's data on geothermal plants is used here and throughout as the adjusted data base.

The ARC-78 reports ranges for generating plant heat rates while PIES-77 documentation reports heat rates by plant type and region. Table 4.2 presents the average of the ARC-78 ranges to be used in REM, except for combined cycle, turbines, and geothermal plants, since the ARC-78 does not report heat rates for these plants. The average of the ranges in PIES-77 data is used for combined cycle and turbines, and REM data is used for geothermal plants.

Table 4.1
ADJUSTED REM DATA
UNIT OUTAGE RATES (%)

Plant Type	MEMM's Maximum Capacity Factors	REM Scheduled Outage Rate	REM Forced Outage Rate
Nuclear	65.0	20.92	17.8
Coal	65.0	29.12	8.3
Gas	70.0	23.66	8.3
Oil	70.0	23.66	8.3
Oil/Gas-Combined Cycle	80.0	5.88	15.0
Oil/Gas-Combustion Turbine	80.0	0.0	20.0
Hydro	85.0	13.62	1.6
Pumped Storage	85.0	0.0	15.0
Geothermal*	--	13.8	9.0

* Because MEMM offers no data on Geothermal, REM's rates are used.

Note: MEMM's capacity factors for baseload use are assumed to be maximum capacity factors, REM's Forced Outage Rate remains the same, and a new Scheduled Outage Rate is calculated using:
Scheduled Outage Rate = 1 - Maximum Capacity Factor/(1 - Forced Outage Rate).

Sources: PIES-77, VI/I, pp. II-222-231
SEA, p. A-6, Table A.5
cf. Table 2.2

Table 4.2

ADJUSTED REM DATA

GENERATING PLANT HEAT RATES (btu/kwh)

Plant Type	
Nuclear	11,000
Coal	10,275
Gas	10,705
Oil	10,825
Combined Cycle*	8,725
Combustion Turbine*	14,600
Hydro	10,389
Geothermal+	21,500

* Since MEMM data is not available, this heat rate is from PIES-77 data.

+ Since MEMM data is not available, this heat rate is from REM data.

Note: These heat rates apply to 1985, 1990, and 1995 and to all regions.

Sources: ARC-78, III/S1, p. 55
PIES-77, VI/I, pp. II-268-270, Tables 14-18
SEA, p. A-5, Table A-4
cf. Table 2.3

Supply and Demand Assumptions

To duplicate the assumptions of MEMM's base case or "rate reform" case, REM's load factors and demand estimates are altered to be consistent with MEMM's data, and new peak estimates are figured. Examination of MEMM data indicates that the same rate of improvement in load factors is assumed in each region as is assumed nationally. We have, therefore, set REM's national load factors in each year equal to the national load factors used in MEMM and then figured new regional load factors by multiplying the original REM load factors for each region by the ratio of the adjusted REM national load factor to the original REM national load factor (see Table 4.3). For example, given original REM 1985 load factors of .646 for NPCC and .625 nationally, and a MEMM 1985 national load factor of .636, the new REM 1985 load factors will be (.636/.625) x .646 = .657 for NPCC and .636 nationally.

A similar method has been used to adjust demand estimates. REM's total national energy demand has been set equal to MEMM's, but total demand for a given year has been broken down into regions according to REM's original regional proportions in that year; hence, adjusted REM region X demand in 1985 = adjusted REM total national demand in 1985 x (original REM region X demand in 1985/original REM total national demand in 1985) (see Table 4.4). No attempt has been made to adjust demand figures to account for the fact that MEMM and REM both use demand data which include slightly different estimates of line losses. Since estimates of line losses are given only in PIES-77 documentation and these estimates are close to REM's (9.5% vs. 10% nationally), additional tinkering does not seem justified.

New REM regional peak estimates are based on the adjusted load factors and demand data discussed above. Table 4.5 presents the new system peaks derived using the formula, System Peak = Total Generation/(8.76 x System Load Factor).

Table 4.3

ADJUSTED REM DATA

SYSTEM LOAD FACTORS

REM Region	1985	1990	1995
NPCC	.657	.678	.699
MAAC	.605	.625	.644
SERC	.634	.654	.674
ECAR	.672	.693	.714
MAIN	.595	.614	.633
ERCOT	.611	.630	.649
SPP	.567	.585	.602
MARCA	.608	.627	.646
WSCC	.701	.723	.745
NAT.	.636	.656	.676

Sources: ARC-78, III/S1, Table 26
SEA, p. 11, Table 3
cf. Table 2.9

Table 4.4

ADJUSTED REM DATA
ENERGY DEMAND
(billions of KWH)

REM Region	1985	1990	1995
NPCC	249.91	282.32	313.57
MAAC	214.66	246.46	278.15
SERC	651.11	815.87	1004.93
ECAR	501.39	602.47	711.48
MAIN	244.56	303.05	369.12
ERCOT	213.50	265.63	324.95
SPP	289.46	371.66	469.05
MARCA	134.29	165.93	201.57
WSCC	555.32	660.82	772.87
NAT.	3054.21*	3714.21	4445.69

* number does not total due to rounding error

Sources: ARC-78, III/S1, Table 26
SEA, p. 11, Table 3
cf. Table 2.8

Table 4.5
ADJUSTED REM DATA
PEAK ESTIMATES (GWe)

REM Regions	1985	1990	1995
NPCC	43.42	47.53	51.21
MAAC	40.50	45.02	49.30
SERC	117.24	142.41	170.20
ECAR	85.17	99.24	113.75
MAIN	46.92	56.34	66.57
ERCOT	39.89	48.13	57.16
SPP	58.28	72.52	88.94
MARCA	25.21	30.21	35.62
WSCC	90.43	104.34	118.43
NAT.	548.20	646.34	750.74

Note: Figured from Total Generation and System Load Factor data given on Tables 4.3 and 4.4:
System Peak = Total Generation/(8.76 x System Load Factor)

REM's capacity data has also been changed so that national totals in each plant category equal MEMM's national totals but REM regional patterns are maintained. Table 4.6 presents MEMM national total capacity grouped in the plant categories to be used in REM. As noted before, coal-existing includes all of MEMM's capacity on line at the beginning of 1978; this category naturally declines during the forecast period. Coal-new includes all new coal plants. The geothermal category includes not only geothermal but all other emerging technologies, although it will be referred to hereafter simply as "geothermal."

These national totals for each plant type have been distributed to regions according to REM's original proportions. Hence, the adjusted REM region X nuclear capacity in 1985 = the adjusted REM total nuclear capacity in 1985 x (the original REM region X nuclear capacity in 1985/the original REM total nuclear capacity in 1985) (see Table 4.7). Only the total capacity in the geothermal and other category has been distributed in a different fashion. For this category, the capacity in a given MEMM region has been assigned to that REM region which corresponds most closely to it or divided between two or more REM regions. For example, the .06 gigawatts of capacity in MEMM region 6 in 1985 has been split, with .03 gigawatts assigned to ERCOT and .03 gigawatts assigned to SPP. The last part of Table 4.7, Installed Capacity by Region (GWe): Total, presents the actual sum of the capacities for each region derived by the above methods. The national total capacities are only slightly different than the national totals of Table 4.6 due to rounding errors.

Since REM uses data on hydro and pumped storage energy available to model hydro generation rather than dispatching hydro plants as it does other plant types, Table 4.8 gives regional generation totals for these two categories. REM's national totals are set equal to MEMM data for national generation and this total is divided into regions according to REM's original patterns for hydro and pumped storage generation.

Table 4.6
ADJUSTED REM DATA
INSTALLED CAPACITY BY PLANT TYPE (GWe): NATIONAL TOTAL

Plant Type	1985	1990	1995
Nuclear	101.69	145.84	197.43
Coal - Existing	212.20	211.01	209.14
Coal - New	72.80	187.91	308.37
Gas Fired	56.58	58.34	58.72
Oil Fired	100.30	96.98	94.14
Combined Cycle	8.14	8.09	7.99
Combustion Turbines	58.55	67.65	59.98
Hydro	66.10	70.03	72.91
Pumped Storage	20.65	28.25	32.48
Geothermal	2.84	5.14	22.95
Total	699.82*	879.21*	1064.11

* does not total due to rounding errors.

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Table 2.4

Table 4.7

ADJUSTED REM DATA

INSTALLED CAPACITY BY REGION (GWe): NUCLEAR

REM Region	1985	1990	1995
NPCC	11.232	13.489	18.974
MAAC	11.476	15.791	19.195
SERC	28.955	47.072	62.388
ECAR	10.920	14.367	21.422
MAIN	13.015	17.207	22.546
ERCOT	3.005	5.615	7.904
SPP	7.372	10.117	14.616
MARCA	3.093	3.411	4.293
WSCC	12.623	18.771	26.092
NAT.	101.690*	145.840	197.430

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA

INSTALLED CAPACITY BY REGION (GWe): COAL-EXISTING

REM Region	1985	1990	1995
NPCC	3.786	3.755	3.722
MAAC	15.585	15.457	15.320
SERC	55.109	54.657	54.173
ECAR	68.325	67.765	67.165
MAIN	28.034	27.805	27.558
ERCOT	4.235	4.201	4.163
SPP	9.139	9.064	8.984
MARCA	11.356	11.812	11.707
WSCC	16.631	16.494	16.348
NAT.	212.200	211.010	209.140

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA
INSTALLED CAPACITY BY REGION (GWe): COAL NEW

REM Region	1985	1990	1995
NPCC	1.546	3.310	4.636
MAAC	0.625	3.109	5.740
SERC	12.929	38.696	74.795
ECAR	17.227	40.065	61.396
MAIN	3.445	14.251	27.311
ERCOT	7.595	18.759	26.803
SPP	14.453	32.760	53.122
MARCA	6.137	14.328	22.013
WSCC	8.845	22.632	32.556
NAT.	72.800*	187.910	308.370*

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA
INSTALLED CAPACITY BY REGION (GWe): GAS-FIRED

REM Region	1985	1990	1995
NPCC	0.003	0.003	0.003
MAAC	--	--	--
SERC	0.079	0.058	0.058
ECAR	0.038	0.041	0.041
MAIN	0.039	0.042	0.042
ERCOT	31.663	32.152	32.361
SPP	23.315	23.842	23.998
MARCA	0.217	0.218	0.219
WSCC	1.225	1.984	1.997
NAT.	56.580*	58.340	58.720*

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA

INSTALLED CAPACITY BY REGION (GWe): OIL-FIRED

REM Region	1985	1990	1995
NPCC	24.881	24.260	23.550
MAAC	13.796	13.505	13.109
SERC	17.578	17.103	16.602
ECAR	5.665	5.438	5.278
MAIN	4.477	3.860	3.747
ERCOT	--	--	--
SPP	8.901	8.829	8.571
MARCA	0.456	0.405	0.393
WSCC	24.547	23.581	22.890
NAT.	100.300*	96.980*	94.140

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA

INSTALLED CAPACITY BY REGION (GWe): COMBINED CYCLE

REM Region	1985	1990	1995
NPCC	0.490	0.391	0.304
MAAC	0.464	0.370	0.288
SERC	0.991	0.724	0.563
ECAR	0.531	0.424	0.329
MAIN	--	--	--
ERCOT	0.163	0.130	0.101
SPP	1.016	0.810	0.630
MARCA	0.180	0.144	0.112
WSCC	4.304	5.098	5.663
NAT.	8.140*	8.090*	7.990

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA

INSTALLED CAPACITY BY REGION (GWe): COMBUSTION TURBINES

REM Region	1985	1990	1995
NPCC	7.266	7.393	5.125
MAAC	11.447	11.370	8.347
SERC	13.698	16.034	14.831
ECAR	4.716	6.781	5.662
MAIN	5.126	6.205	6.202
ERCOT	1.609	2.396	3.230
SPP	3.322	3.771	2.772
MARCA	4.466	5.130	4.155
WSCC	6.901	8.569	9.655
NAT.	58.550*	67.650*	59.980*

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA

INSTALLED CAPACITY BY REGION (GWe): HYDRO

REM Region	1985	1990	1995
NPCC	5.516	7.334	9.187
MAAC	1.194	1.175	1.308
SERC	10.314	11.640	13.434
ECAR	0.667	1.331	2.568
MAIN	0.500	0.758	1.609
ERCOT	0.233	0.314	0.515
SPP	2.501	2.489	2.361
MARCA	2.735	2.694	2.446
WSCC	42.441	42.295	39.482
NAT.	66.100*	70.030	72.910

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA

INSTALLED CAPACITY BY REGION (GWe): PUMPED STORAGE

REM Region	1985	1990	1995
NPCC	3.217	5.239	5.857
MAAC	1.564	1.846	2.063
SERC	7.106	8.487	9.487
ECAR	3.418	5.836	6.524
MAIN	0.275	0.324	0.363
ERCOT	--	--	--
SPP	0.551	0.650	0.727
MARCA	--	--	--
WSCC	4.519	5.867	7.459
NAT.	20.650	28.250*	32.480

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7

ADJUSTED REM DATA

INSTALLED CAPACITY BY REGION (GWe): GEOTHERMAL AND OTHER

REM Region	1985	1990	1995
NPCC	0.05	0.05	4.30
MAAC	0.02	0.02	2.72
SERC	0.02	0.02	3.00
ECAR	0.01	0.01	0.01
MAIN	0.01	0.01	0.01
ERCOT	0.03	0.11	0.11
SPP	0.03	0.10	0.12
MARCA	--	--	0.12
WSCC	2.66	4.81	12.54
NAT.	2.84*	5.14*	22.95*

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6

Table 4.7
ADJUSTED REM DATA
INSTALLED CAPACITY BY REGION (GWe): TOTAL

REM Region	1985	1990	1995
NPCC	57.987	65.224	75.658
MAAC	56.171	62.643	68.090
SERC	146.779	194.491	249.331
ECAR	111.517	142.058	170.395
MAIN	54.921	70.462	89.388
ERCOT	48.533	63.677	75.187
SPP	70.600	92.432	115.901
MARCA	28.640	38.142	45.458
WSCC	124.696	150.101	174.682
NAT.	699.844	879.230	1064.090

Sources: ARC-78, III/S1, Table 26
SEA, p. 12, Table 4
cf. Tables 2.5, 4.6, 4.7

Table 4.8
ADJUSTED REM DATA
GENERATION FROM HYDRO (billions of KWH)

REM regions	1985	1990	1995
NPCC	34.433	34.803	35.657
MAAC	4.314	4.346	4.453
SERC	39.619	39.903	40.882
ECAR	1.630	1.642	1.682
MAIN	2.673	2.687	2.753
ERCOT	0.354	0.357	0.366
SPP	6.093	6.137	6.288
MARCA	14.752	14.857	15.222
WSCC	183.551	186.727	191.308
NAT.	287.42*	291.46*	298.61*

* does not total due to rounding errors

Sources: ARC-78, III/S1, Table 26
SEA, pp. 16-17, Table 5
cf. Table 2.7

Table 4.8

ADJUSTED REM DATA

GENERATION FROM PUMPED STORAGE (billions of KWH)

REM regions	1985	1990	1995
NPCC	3.072	3.776	4.064
MAAC	2.484	3.118	3.356
SERC	7.100	9.416	10.133
ECAR	2.702	4.187	4.507
MAIN	0.479	0.585	0.629
ERCOT	0	0	0
SPP	0.194	0.237	0.255
MARCA	0	0	0
WSCC	1.619	2.161	2.326
NAT.	17.650	23.480	25.270

Sources: ARC-78, III/S1, Table 26
SEA, pp. 16-17, Table 5
cf. Table 2.7

Fuel Prices

REM's original fuel prices have been adjusted in a similar fashion as capacity. REM's original national average fuel prices presented in our earlier discussion are weighted averages based on the regional fuel prices and regional fuel consumption of REM's base case. These original national average fuel prices have been adjusted to equal MEMM's national average fuel prices; regional prices have been derived therefrom according to REM's original regional proportions. Hence the adjusted REM region x coal price for 1985 = the adjusted REM national coal price for 1985 x (the original REM region x coal price for 1985/ the original REM national coal price for 1985). Tables 4.9 through 4.12 present adjusted prices for coal, distillate oil, residual oil, and natural gas, all figured according to this method. On the assumption that most natural gas for electric utilities is sold on the intrastate market, REM's national average natural gas price has been set equal to MEMM's national average intrastate natural gas price when that price is given.

Nuclear fuel prices are the same in all regions in both MEMM and REM. REM's nuclear fuel prices should be adjusted accordingly:

NUCLEAR FUEL PRICES (78 mills/kwh)

1985	6.89
1990	8.77
1995	8.88

Source: ARC-78, III, p. 220, Table 12.5 and ARC-78, III/S1, Table 31

Since a detailed breakdown of the costs of the different steps in the nuclear fuel cycle used in MEMM is only available for 1990, and since the final prices are given for all three years, we suggest that REM's nuclear fuel submodel be bypassed and these prices be used directly in REM. If this approach is not

Table 4.9

ADJUSTED REM DATA

COAL PRICES (78$/mmbtu)

REM regions	1985	1990	1995
NPCC	2.22	2.25	2.32
MAAC	1.86	1.91	2.03
SERC	1.82	1.92	2.12
ECAR	1.68	1.80	1.93
MAIN	1.82	1.98	2.08
ERCOT	2.22	2.25	2.32
SPP	1.73	1.79	1.79
MARCA	1.56	1.75	2.00
WSCC	1.30	1.42	1.48
NAT.	1.74	1.84	1.96

Sources: ARC-78, III, p. 233 and ARC-78, III/S1, Table 30
SEA, p. A-7, Table A.6 and SEA, p. 10, Table 6
cf. Table 2.12

Table 4.10

ADJUSTED REM DATA

DISTILLATE OIL PRICES (78$/mmbtu)

REM regions	1985	1990	1995
NPCC	3.01	3.58	4.53
MAAC	2.90	3.47	4.39
SERC	2.59	3.12	3.94
ECAR	3.05	3.64	4.61
MAIN	2.86	3.41	4.31
ERCOT	2.43	2.90	3.67
SPP	2.75	3.26	4.13
MARCA	2.54	3.00	3.78
WSCC	2.85	3.40	4.29
NAT.	2.88	3.46	4.37

Sources: ARC-78, III/S1, Tables 30 and 31
SEA, p. A-9, Table A.8
cf. Table 2.14

Table 4.11

ADJUSTED REM DATA

RESIDUAL OIL PRICES (78$/mmbtu)

REM regions	1985	1990	1995
NPCC	2.52	2.98	3.78
MAAC	2.49	2.94	3.74
SERC	2.21	2.62	3.33
ECAR	2.54	3.00	3.81
MAIN	2.45	2.88	3.66
ERCOT	2.02	2.38	3.03
SPP	2.33	2.76	3.50
MARCA	2.10	2.32	3.15
WSCC	2.67	3.16	4.01
NAT.	2.53	3.00	3.82

Sources: ARC-78, III/S1, Tables 30 and 31
SEA, p. A-10, Table A.9
cf. Table 2.15

Table 4.12

ADJUSTED REM DATA

NATURAL GAS PRICES (78$/mmbtu)

REM regions	1985	1990	1995
NPCC	3.01	4.05	4.77
MAAC	3.04	4.09	4.81
SERC	2.98	4.03	5.14
ECAR	2.96	3.98	4.69
MAIN	2.96	3.98	4.69
ERCOT	2.01	2.70	3.18
SPP	2.74	3.70	4.35
MARCA	2.81	3.76	4.44
WSCC	2.91	3.92	5.79
NAT.	2.32	3.18	3.81

Sources: ARC-78, III/S1, Tables 30 and 31
SEA, p. A-8, Table A.7
cf. Table 2.16

desirable, the costs of the different stages in the nuclear fuel cycle can be estimated for 1985 and 1995, but these estimates will undoubtedly be inaccurate.

Capital Costs and Other Financial Data

A normalization of REM's inputs on capital costs and other financial data is considerably more suspect than dealing with capacity estimates. In part this is true because the ARC-78 does not report costs and financial data in detail. But more basically, while REM's financial/regulatory model makes explicit the financial assumptions behind cost calculations, these same assumptions are in MEMM embedded in cost estimates without explanation. For example, while MEMM reports capital costs including AFDC per unit of completed capacity, REM calculates semiannual cash flows and figures AFDC on these flows during the construction period. The ARC-78 does not explain the assumptions on lead time, typical patterns of construction cash expenditures, and AFDC rates behind its data. Other examples are more glaring: while REM's model replicates regulatory rate-setting, MEMM simply inputs revenue requirements for existing assets and capital charge rates for revenue requirements. (See PIES-77, VI/I, pp. II 264-65.) No attempt has been made in this normalization to alter REM data where the models are already so divergent.

A consequence of this problem is that it is impossible to separate the effect of different data from the effect of different modeling assumptions. The principal output affected by the difficulties in normalizing financial data in the two models is the average price of electricity. Comparisons of MEMM's and REM's projected electricity prices in the cases outlined previously are necessarily fraught with complications. This output is, for the purpose of testing model assumptions, the least reliable of the inputs and outputs,discussed thus far.

REM accepts unit capital cost data for region ECAR and fossil baseload and nuclear capital cost multipliers for all regions which indicate each region's costs relative to region ECAR. Unit capital costs for non-baseload plants are assumed to be the same in all regions. These same assumptions are being employed in this normalization despite the fact that PIES-77 documentation indicates that non-baseload unit capital costs also vary in different regions. Table 4.13 lists as unit capital costs for region ECAR the capital costs reported for DOE region 5 which corresponds fairly closely with ECAR. Costs for gas plants, hydro, and pumped storage are gleaned from PIES-77 data since these plant costs are not reported in the ARC-78. Because the ARC-78 assumes no real price escalation in capital costs, 1985 costs for these plants have been used in all three years; the REM 1985 geothermal unit capital cost has likewise been used for all three years.

Regional capital cost variation in the original REM data is considerably greater than in MEMM data. REM's original costs for region WSCC are particularly high relative to the rest of the country. For this normalization REM's pattern of regional variation has not been maintained. Rather capital cost multipliers for REM regions have been estimated from the multipliers of the MEMM regions which most closely match REM regions. Table 4.14 lists new REM regional multipliers based on the cost data and multipliers presented in Tables 2.20 and 2.21. Fossil baseload multipliers are based on PIES-77 data on coal plants since the ARC-78 only reports regional capital cost variation for nuclear plants. Where more than one MEMM region parallels a given REM region, an average of the relevant MEMM regional multipliers is reported here. For example, since cost data for DOE regions 1 and 2 indicate fossil baseload multipliers of 1.01 and 1.07, NPCC is assigned a multiplier of 1.04.

Since the ARC-78 does not report operation and maintenance costs, Table 4.15 lists these costs based on PIES-77 data. These operation and maintenance costs apply to all regions and all years. The cost for oil-fired plants is that given for residual as opposed to distillate plants; PIES-77 documentation gives a much lower operation and maintenance cost for distillate plants. (See

Table 4.13

ADJUSTED REM DATA
UNIT CAPITAL COSTS FOR REGION ECAR (78$/kw)

Plant Type	1985	1990	1995
Nuclear	970	970	970
Coal - new	655	655	655
Gas*	350	350	350
Oil	435	435	435
Combined Cycle	315	315	315
Combustion Turbines	170	170	170
Hydro*	350	350	350
Pumped Storage*	350	350	350
Geothermal+	1143.4	1143.4	1143.4

* Since ARC-78 does not report capital costs for this plant type, these unit costs are based on PIES-77 data for 1985 and no real price escalation is assumed.

+ Since capital costs are not reported for MEMM emerging technologies, REM 1985 data is used for geothermal plants and no real price escalation is assumed.

Sources: ARC-78, III/S1, p. 29 and ARC-78, III, p. 387
PIES-77, VI/I, p. II-237, Table 10
cf. Tables 2.19, 2.21

Table 4.14

ADJUSTED REM DATA
REGIONAL CAPITAL COST MULTIPLIERS

Region	Fossil Baseload*	Nuclear+
NPCC	1.04	1.04
MAAC	1.01	1.08
SERC	0.91	0.87
ECAR	1.00	1.00
MAIN	1.00	1.00
ERCOT	0.92	0.93
SPP	0.95	1.03
MARCA	0.99	1.12
WSCC	1.11	1.02

* These regional multipliers are based on the variation shown in PIES-77 data for coal plants.

+ These regional multipliers are based on ARC-78 data.

Sources: ARC-78, III/S1, p. 29 and ARC-78, III, p. 387
PIES-77, VI/I, p. II-237 and II-264, Table 10
cf. Tables 2.20, 2.21

Table 4.15

ADJUSTED REM DATA
OPERATION AND MAINTENANCE COSTS (78 mills/kwh)

Plant Type	
Nuclear	1.96
Coal - Existing	2.33
Coal - New	2.33
Gas Fired	0.60
Oil Fired	1.07
Combined Cycle	1.49
Combustion Tyrbines	3.27
Hydro	0.83
Pumped Storage	0.83
Geothermal*	0.97

* REM data is used for geothermal plants since neither ARC-78 nor PIES-77 reports costs for emerging technologies.

Sources: PIES-77, VI/I, pp. II-236 and II-263, Table 8
SEA, pp. A-3-4, Table A.3
cf. Table 2.22

Table 2.22) As usual, geothermal data is that already used in REM.

That MEMM financial assumptions are buried in a few cost figures precludes a satisfactory normalization of all of REM's financial variables. Table 4.16 presents the parameters that can be approximately altered. In order to replicate the static capital structure assumed by MEMM, REM's minimum interest coverage ratio has been dropped to zero and debt and preferred stock limits set at 55% and 10%, respectively.

REM's new costs of financing are set to be compatible with MEMM's real costs of financing previously reported in Table 2.23 and REM's assumed yearly inflation rate of 5.5%. These costs are nominal costs figured according to the formula, (1 + nominal interest rate) = (1 + real interest rate) x (1 + inflation rate).

While MEMM makes no assumptions about inflation and presents all outputs in constant dollars, REM assumes a yearly inflation rate of 5.5% from 1978 through the end of the forecast period. REM uses inputs in current dollars, its calculations are made in current dollars, and its outputs are in current dollars. The inputs presented in this section will consequently require alteration for use in the simulations. The appropriate inflators for costs presented in this section in constant 1978 dollars are:

INFLATORS FOR 1978

1985:	$(1.055)^{7} = 1.45468$
1990:	$(1.055)^{12} = 1.90121$
1995:	$(1.055)^{17} = 2.48480$

REM's adjusted data have been presented in constant 1978 dollars rather than current dollars for ease of comparison with the data reported in the ARC-78 in constant 1978 dollars.

Table 4.16

ADJUSTED REM DATA
FINANCIAL PARAMETERS

CAPITAL STRUCTURE	
Debt:	55%
Preferred:	10%
Common:	35%
Minimum Interest Coverage Ratio	0
COST OF FINANCING	
Debt:	8.67%
Preferred:	9.19%
Common:	12.36%
ASSUMED INFLATION RATE	5.50%

Sources: ARC-78, III, p. 387.
SEA, p. A-19
cf. Table 2.23

It will likewise be necessary to deflate REM's outputs, given in current dollars, in order to make comparisons with the data reported in the ARC-78 in constant 1978 dollars. The appropriate deflators for REM output are:

DEFLATORS FOR CURRENT DOLLARS

1985:	$1/(1.055)^{7}$	= 0.68744
1990:	$1/(1.055)^{12}$	= 0.52598
1995:	$1/(1.055)^{17}$	= 0.40245

The paucity of these data modifications relative to REM's many financial parameters underlines the difficulties with this part of the normalization. Unfortunately any other changes to REM data will be inherently unsatisfactory because of MEMM's different modeling structure and the ARC-78's sketchy documentation of financial assumptions.

Simulations 2, 3, and 4: Required Data Changes

For the additional simulations no changes need be made to the adjusted REM data listed under technical data and capital costs and other financial data. However, supply and demand data and fuel prices do require adjustment. Because MEMM is an equilibrium model which establishes market-clearing prices and quantities in all energy markets, a change in any major supply or demand variable alters many other variables. This factor complicates the data requirements for the proposed simulations. Although a computational experiment may be described as changing one variable, such as fuel prices, this one change will necessitate alterations to other inputs as well. In the case of higher oil prices (case 3) the necessary data is available in as much detail as for the base case (case 1). But although the ARC-78 describes the results of several sensitivity tests of electricity results, the complete data set for such tests is not available. Regional detail, particularly, is lacking. Although it is clear that other variables are changing besides the particular variable being tested, these other changes can only be guessed at.

Scenario 2: No Rate Reform Case

The no rate reform case presents these problems since this is one of the sensitivity tests that the ARC-78 covers only briefly. Since only 1990 data is reported for MEMM sensitivity tests, only changes to 1990 data are discussed. Presumably, fuel prices remain the same since there is no indication to the contrary.

The main variable being altered, the load factor, can be adjusted by the same method employed in case 1: the national load factor can be set equal to .626 and regional load factors derived according to REM's existing pattern of regional variation. Because MEMM is an equilibrium market-clearing model, however, all other supply and demand variables are also affected. Unfortunately, only national totals are given for energy demand and capacity by plant type. (See ARC-78, III, pp. 272-73) The same methods used for case 1 can be used to derive regional data from these new totals according to MEMM's pattern of regional variation. New capacity estimates need only be figured for coal, oil, natural gas, nuclear, and turbine capacity, since only these plant types are affected. Old and new coal capacity are not distinguished, but it is quite reasonable to assume that the coal-existing data for 1990 remains the same and only the estimate of coal-new need be altered to conform with the new total. New peak estimates can be derived from the new generation figures and load factors. Hydro and pumped storage generation remain the same as for case 1.

Scenario 3: Scenario C-High

Scenario C-High was designed to measure the impact of higher oil prices. As one of the regular cases studied in the ARC-78, data for this case is presented in as much detail as for Scenario C, which we have called the rate reform case. It is possible, therefore, to study this case in 1985, 1990, and 1995. Although load factors remain the same as in case 1, a higher oil price generates higher fuel prices and alters total demand, total capacity, and the capacity mix. Hence all the data reported in Tables 4.4 through 4.12 require changes for this case.

Higher oil prices not only affect national fuel prices, demand, and capacity, but also alter somewhat the regional pattern of these variables. We feel that the substantially different regional breakdowns used in MEMM and REM make it impossible to alter REM's regional proportions accurately to show this slight variation between Scenario C and Scenario C-High regional proportions. We therefore believe that the same methods used in case 1 to generate REM regional demand, capacity, and fuel prices from MEMM national averages also should be used for this case: REM's regional proportions in these variables will be maintained for both cases.

In following this plan, new regional demand data will be figured and then new peak estimates will be derived from them and from the load factors which are the same for this scenario as for case 1. New regional breakdowns must be figured for all categories except hydro and pumped storage since these two categories alone show no alteration in capacity. However, new regional breakdowns for pumped storage generation are required since national generation from pumped storage is less for this case. New fuel prices must be figured for all fuels except nuclear fuel which remains unchanged from case 1.

Scenario 4: Alternative Capacity Expansion Scenarios

Case 4 does not purport to match any of the scenarios or sensitivity tests reported in the ARC-78. The changes in nuclear and coal capacity suggested are the only variables to be altered in this test. Additional or decreased capacity can b divided up according to the usual REM proportions. The rest of the data will be the same as for case 1 or case 3, depending on whether one wishes to test the effect of additional capacity in combination with a medium or high oil price.

5. Results of Computational Experiments

Table 5.1 presents the national generation patterns by plant type for the years 1985, 1990, and 1995 for Scenario C of the ARC-78 under the column labeled MEMM, the version of REM normalized with MEMM Scenario C parameters under the column labeled REM-Normalized, and the original user version of REM under the column labeled REM-Base Case. The results presented raise some very important, but unanswered, issues. In 1985, the MEMM Scenario C and normalized version of REM demonstrate quite comparable generation patterns. Recall that the data on generation capacity configuration, maximum capacity factors, load factors, fuel costs, and electricity demands in the normalized REM case are set equal to the values in MEMM Scenario C, so this is not surprising. Nonetheless, it is true that the normalized REM results exhibit slight shortages in 1985, indicating a very marginal level of reliability given the generation and load patterns. The more substantial differences in the MEMM and normalized REM (N-REM) results in 1985 are that N-REM demonstrates slightly less coal generation than MEMM and slightly more production from the category of "Other" plant types. Through time, up to 1995, the disparity in "Other" generation in MEMM and N-REM decreases, at least on a percentage basis. The disparity in coal generation, however, increases slightly.

A more significant difference in generation trends, however, lies with oil and gas. These are the marginal sources of supply, and any differences in the simulated output of other plant types get reflected in the oil and gas generation. Whereas the MEMM generation scenario demonstrates a consistent and significant decline in output from oil and gas plants over the time period 1985 to 1995 under Scenario C assumptions, the same results do not emerge from N-REM under the same assumptions. In 1995, N-REM shows about 7 times as much generation from oil and gas plants as MEMM. Within the context of fuel use policy,

TABLE 5.1

NATIONAL TOTAL GENERATION BY PLANT TYPE

[SCENARIO C] (in billions of KWH)

Plant Type	1985 MEMM (Scenario C)	1985 REM (Normalized)	1985 REM (Base Case)	1990 MEMM (Scenario C)	1990 REM (Normalized)	1990 REM (Base Case)	1995 MEMM (Scenario C)	1995 REM (Normalized)	1995 REM (Base Case)
Nuclear	572.39	579.055	713.384	824.20	830.459	926.892	1115.39	1124.228	1078.963
Coal									
Existing	1127.90	1042.007	1072.807	1127.34	949.186	116.216	1085.46	766.287	1150.826
New	389.95	385.735	401.284	1047.19	1068.245	796.392	1706.72	1730.692	1336.556
Coal Subtotal	1517.85	1427.742	1474.091	2174.53	2017.431	1912.608	2792.18	2496.979	2487.382
Residual Oil Fired Steam	390.30	389.188	236.382	270.32	317.811	238.747	29.60	178.307	294.379
Gas Fired Steam	197.46	232.748	176.191	43.44	134.114	169.770	15.32	118.877	181.819
Hydro	287.42	284.419	235.937	291.46	291.459	237.545	298.61	298.61	237.545
Other* a.	31.51	53.349	43.173	37.05	49.550	57.579	60.54	44.265	77.753
b.	20.56	46.625	2.072	15.36	14.368	13.412	16.28	1.999	10.984
c.	17.65	17.650	15.917	23.48	23.480	19.779	25.27	25.270	17.349
d.	19.27	19.446	13.832	34.37	35.251	19.779	92.50	157.564	31.294
Other Subtotal	88.79	137.070	74.994	110.26	122.649	100.549	194.59	229.098	137.380
TOTAL	3054.21	3050.222**	2910.979	3714.21	3713.922	3583.667	4445.69	4446.094	4417.461

*Other includes the following in this table:

a. combined cycle
b. combustion turbine
c. pumped storage
d. Geothermal (hydrothermal in MEMM) plus emerging technologies. (REM does not include specific new technologies but considers them to have generating characteristics similar to geothermal; hence the REM geothermal figure reflects other emerging technologies as well. In MEMM, the specific new technologies in 1985 and 1990 include: solar thermal power, photovoltaics, wind systems, biomass-electric, and ocean thermal; in 1995 central atmospheric fluidized-bed combustors are also included.)

**Region 1	Electric Generation Energy Shortage of	2.000 MM
Region 4	Electric Generation Energy Shortage of	.244 MM
Region 5	Electric Generation Energy Shortage of	.364 MM
Region 7	Electric Generation Energy Shortage of	1.327 MM
	TOTAL	3.935 MM

particularly the Powerplant and Industrial Fuel Use Act, this discrepancy is quite significant. Compared to REM, MEMM results tend to understate the required oil and gas generation under identical assumptions, and vice versa. Because of the normalization procedures that have been employed in establishing consistent data inputs, it can also be said that the differences are attributable not to data but to differences in model structure, particularly in the way the two models simulate generation.

The same differences in the patterns of oil and gas generation exhibited in Table 5.1 carry over into the results of Table 5.2, which presents similar comparisons for Scenario C-High assumptions.

When comparing the normalized REM generation results with the original REM scenario, which differ in all those parameters and data values detailed above, the nuclear and "Other" generation disparities are traceable to differences in the capacity configurations employed. In both 1985 and 1990, the REM base case possessed more nuclear capacity than N-REM, and in 1995 possessed less than N-REM. In all three years, the N-REM has more "Other" capacity than was used in the REM base case. In both the nuclear and "Other" plant type categories the simulated generation by these plant types is consistent with the differences in capacity.

Table 5.3 presents the projected electricity prices derived from MEMM for the C and C-High scenarios, and the counterpart results from REM normalized to the same C and C-High cost assumptions. The results of the two models are actually quite close. The normalized REM results escalate slightly faster than the REM results, but this is consistent with the differences in generation pattern. More oil and gas is used in the normalized REM cases, increasing the fuel costs over the counterpart values in MEMM. *

* Table 5.3 is in constant dollars; in nominal costs by 1995 the prices would look much higher.

TABLE 5.2

NATIONAL TOTAL GENERATION BY PLANT TYPE

[SCENARIO C'] (in billions of KWH)

	1985			1990			1995		
Plant Type	MEMM (Scenario C')	REM (Normalized)	REM Base Case	MEMM (Scenario C')	REM (Normalized)	REM (Base Case)	MEMM (Scenario C')	REM (Normalized)	REM (Base Case)
Nuclear	572.39	579.055	713.384	829.12	834.900	926.892	1119.26	1127.758	1078.963
Coal									
Existing	1112.18	1029.788	1072.807	1088.54	811.249	1116.216	1067.10	727.190	1150.826
New	500.10	529.967	401.284	1278.31	1301.195	796.392	1708.48	1737.803	1336.556
Coal Subtotal	1612.28	2138.810	1474.091	2366.85	2112.444	1912.608	2775.58	2464.993	2487.382
Residual Oil Fired Steam	286.28	304.586	236.382	20.48	213.253	238.747	0	148.784	294.379
Gas Fired Steam	203.24	202.842	176.191	48.05	88.097	169.770	11.34	99.940	181.819
Hydro	287.41	284.419	235.937	291.46	291.459	237.545	298.61	298.611	237.545
Other* a.	26.26	38.049	43.173	53.60	34.260	57.579	80.33	43.599	77.753
b.	16.66	33.856	2.072	15.05	1.205	3.412	16.78	.895	10.984
c.	16.08	16.080	15.917	22.10	22.099	19.779	24.91	24.909	17.349
d.	24.22	25.012	13.832	34.37	83.351	19.779	112.06	229.096	31.294
Other Subtotal	83.22	112.997	74.994	125.12	140.915	100.549	234.08	298.499	137.38
TOTAL	3044.82	3043.653	2910.979	3681.08	3681.067	3583.667	4438.87	4438.582	4417.461

*Other includes the following in this table:

a. combined cycle
b. combustion turbine
c. pumped storage
d. Geothermal (hydrothermal in MEMM) plus emerging technologies. (REM does not include specific new technologies but considers them to have generating characteristics similar to geothermal; hence the REM geothermal figure reflects other emerging technologies as well. In MEMM, the specific new technologies in 1985 and 1990 include: solar thermal power, photovoltaics, wind systems, biomass-electric, and ocean thermal; in 1995 central atmospheric fluidized-bed combustors are also included.)

Source: MEMM: ARC-78, III/S1, Table 26, Scenario C-high; REM: MIT runs of the model

TABLE 5.3

National Average Electricity Prices (78 mills/KWH)

Projections	MEMM Scenario C	MEMM Scenario C'	REM Scenario C	REM Scenario C'
1985	36.80	38.78	36.12	38.27
1990	38.30	38.94	39.996	40.77
1995	38.95	39.06	39.561	40.21

Tables 5.4 and 5.5 present the results of normalized REM simulations in which the amount of coal and nuclear capacity is perturbed by 10,000 MWe from the original MEMM data in the years 1990 and 1995 (compare these tables with Table 5.1). The purpose was to examine the sensitivity of the oil and gas generation values to these perturbations. Of particular interest, for example, was to measure how much additional generation was provided by the additional installed capacity. An analysis of the results in Table 5.4 show that at the margin, new nuclear capacity operates at about a 65 percent capacity, near the maximum capacity factor constraint inserted as data. The results for the coal capacity perturbations, however, reveal that the marginal coal plants would operate at only about a 25 percent capacity factor. This is because the coal capacity would be load limited, according to REM, in many regions for a substantial portion of the year. This is consistent with the capacity factor of the oil and gas plants of the N-REM scenario. Why and how MEMM exhibits such a low capacity factor for the oil and gas plants under the same assumptions is not answerable, however, from the results available.

The ARC-78 states one reason that generation from oil and gas plants reduces to the extent demonstrated in the Scenario C results, and that coal generation increases as shown, is that rate reform leads to improving load factors. In Scenario C, the load factor in 1995 is 8 percent greater than the current value (0.676 vs. 0.626). To examine the sensitivity of the REM generation patterns to the load factor assumption, a case was simulated in which the load factors were not increased, but all other REM data was consistent with Scenario C. That is, the normalized REM base case assumed a load factor of .656 in 1990, while the simulation in this "no rate reform" case assumed .626. The results of this sensitivity analysis are shown in

Table 5.4

NATIONAL TOTAL GENERATION BY PLANT TYPE WITH VARYING NUCLEAR CAPACITIES
[Scenario C] (billions of kwh)

	1990	1995	1990	1995
	Additional Nuclear 10 GWe		Reduced Nuclear 10 GWe	
Nuclear	887.402	1181.170	773.515	1067.285
Coal				
a. Existing	928.128	738.440	968.905	793.096
b. New	1067.662	1725.299	1068.652	1735.239
Total	1815.53	2463.739	2037.557	2528.335
Residual Oil Fired Steam	292.155	160.197	343.024	198.214
Gas Fired Steam	129.695	115.111	138.619	122.776
Hydro	291.459	298.611	291.459	298.611
Other				
Geothermal	35.251	157.564	35.251	157.564
Combined Cycle	49.152	42.850	50.028	45.404
Combustion Turbine	9.635	1.555	20.956	2.634
Pumped Storage	23.480	25.270	23.480	25.270
Total	117.518	227.239	129.715	230.872
TOTAL	3714.018	4446.062	3713.888	4446.090
Projected Cost of Electricity (78 mills/kwh)	39.782	39.408	40.223	39.724

Table 5.5

NATIONAL TOTAL GENERATION BY PLANT TYPE WITH VARYING COAL CAPACITIES
[Scenario C] (billions of kwh)

	Additional Coal 10 GWe		Reduced Coal 10 GWe	
	1990	1995	1990	1995
Nuclear	830.459	1124.228	830.459	1124.228
Coal				
a. Existing	926.525	735.945	970.659	795.307
b. New	1124.228	1781.739	1011.914	1678.753
Total	2050.753	2517.684	1982.573	2474.06
Residual Oil Fired Steam	299.716	167.729	334.733	190.277
Gas Fired Steam	123.021	110.565	145.702	127.777
Hydro	291.459	298.611	291.459	298.611
Other				
Geothermal	35.251	157.564	35.251	157.564
Combined Cycle	49.077	43.082	50.106	45.439
Combustion Turbine	10.738	1.330	20.123	2.878
Pumped Storage	23.480	25.270	23.480	25.270
Total	118.546	227.246	128.96	231.151
TOTAL	3713.952	4446.059	3713.886	4446.098
Projected Cost of Electricity (78 mills/kwh)	39.959	39.541	40.048	39.593

TABLE 5.6

NATIONAL TOTAL GENERATION BY PLANT TYPE 1990, SCENARIO C
(No Rate Reform Case) (in billions of KWH)

	N-REM constant load factor	N-REM improved load factor
Nuclear	830.800	830.459
Coal a. Existing	956.229	949.186
New	1038.916	1068.245
Total	1995.145	2017.431
Residual Oil Fired Steam	321.412	317.811
Gas Fired Steam	137.080	134.114
Hydro	291.459	291.459
Other a. Geothermal	35.251	35.251
b. Combined Cycle	49.713	49.550
c. Combustion Turbine	14.235	14.368
d. Pumped Storage	23.480	23.480
Total	122.679	122.649
TOTAL	3698.574	3713.922
REM- Projected Cost of Electricity (78 mills/KWH)	39.993	
MEMM- Projected Cost of Electricity (78 mills/KWH)	43.8	

Table 5.6 for 1990. When compared to the corresponding generation pattern from N-REM in 1990 in Table 5.1, the results exhibit little sensitivity to the hypothesized change in load factors. For example, total coal generation decreased only 22.3 billion kWh with no rate reform. Thus, the ARC-78 reliance on the improving load factors as an explanation for reduced oil and gas generation may need to be reexamined.

Tables 5.7 and 5.8 present the results of simulation of N-REM in which sufficient coal capacity was added to yield a projected oil and gas generation value consistent with the MEMM outputs in 1995. This was accomplished by examining the REM regions to see which ones utilized large quantities of oil and gas, and adding coal capacity in a proportional fashion to those regions. This additional coal capacity figure had to be very large because the coal plants at the margin operate at a much lower capacity factor than the oil and gas plants. In fact, a total of 65,000 MWe of new coal capacity over and above the MEMM value had to be hypothesized to be in commercial operation in 1995 in order to yield oil and gas generation numbers consistent with the MEMM pattern of results. The regional price effects of the increased coal capacity are shown in Table 5.8. The projected average national electricity price is increased from 39.561 to 42.317 mills/kWh with the largest effects evident in the NPCC and ERCOT regions. Substantial increases in the cost-of-service are indicated because the additional coal plants are not operating at high enough capacity factors to yield average costs of generation below the marginal costs of generation from existing oil and gas plants.

TABLE 5.7

NATIONAL TOTAL GENERATION BY PLANT TYPE
WITH ADDITIONAL NEW COAL CAPACITY OF 65 GW* - 1995
[Scenario C] (in billions of KWH)

Nuclear		1124.228
Coal	a. Existing	711.595
	New	2039.682
	Total	2751.277
Residual Oil Fired Steam		39.691
Gas Fired Steam		19.138
Hydro		298.611
Other	a. Geothermal	157.564
	b. Combined Cycle	28.777
	c. Combustion Turbine	1.381
	d. Pumped Storage	25.270
	Total	212.992
TOTAL		4445.934

*Coal capacity had to be increased by 65 GW to bring down oil and gas consumption approximately to MEMM level.

TABLE 5.8

PROJECTED COST OF ELECTRICITY BY REGION - 1995
(in 78 mills/KWH)

Region		Normalized REM Scenario C	Normalized REM (Scenario C) with Adjusted Oil and Gas Consumption to MEMM level
1.	ECAR	41.733	41.759
2.	ERCOT	45.462	50.418
3.	MAAC	41.433	42.828
4.	MAIN	40.723	40.790
5.	MARCA	38.703	38.765
6.	NPCC	40.387	71.441
7.	SERC	40.012	40.115
8.	SPP	40.239	41.091
9.	WSCC	32.746	32.70
Projected Average National Electricity Price		39.561	42.317

From the point of view of how fuel use policy affects the electric utilities, the results obtained from the work described in this report are quite significant. Under consistent assumptions on demand and the generation capacity configuration, the REM model exhibits about 7 times as much oil and gas consumption in the year 1995 as the MEMM model. To bring the oil and gas consumption in REM down to the approximate values reported for Scenario C in ARC-78, approximately 65,000 MWe additional coal capacity must be hypothesized as installed by 1995. This is a 15 percent increase over the MEMM Scenario C coal capacity in 1995 and corresponds to about a $65 billion (in constant 1980 dollars) capital outlay by the electric utility industry between now and then.

Unresolved is exactly what structural features of the models create the differences in projected generation patterns. As stated early in this report, in MEMM the annual load duration curve is subdivided into four load categories, and generation from the alternative plant types within each of these four categories is derived from input data on historical capacity factors for plants in each load mode. In REM, the annual peak load and generation requirements are subdivided into twelve monthly load duration curves, maintenance is scheduled endogenously, energy limited plant types are fit optimally into the load duration curve for each month, and the remaining generation (after alteration of the load curve for hydro and pumped storage generation) is simulated based upon merit order operation. As a larger proportion of total installed capacity becomes coal, as it does in these scenarios, the capacity factor of incremental coal plant additions reduces because of load limits. It is possible that the data for MEMM were not correspondingly adjusted, yielding capacity factors for coal in the future that are inconsistent with the load and generation patterns. However without access to the actual capacity factor data employed by EIA, we cannot be certain that this explanation is correct. A second ancillary question is whether historical capacity factors are a reasonable basis for setting the future input data to MEMM given the prospective changes in capacity mix.

In order to test this explanation, it would be necessary to conduct simulation experiments on MEMM. One possible experiment would be to simulate MEMM with maximum capacity factor constraints consistent with the REM capacity factor outputs for 1990 and 1995. If this brought the results into alignment, it would suggest that further attention should be given to these input data items in MEMM. If further discrepancies remained, the results would provide new information from which new hypotheses could be formed.

Oil and gas are the subject of existing fuel use policy, and the Department of Energy does use computer models to project the economic impacts of existing or proposed utility oil and gas burning constraints. Since this report showed that the modeling methodology does make a significant impact on projection results, we suggest that EIA consider implementing continuing simulation experiments on MEMM.

Bibliography

Logistics Management Institute. The Integrating Model of the Project Independence Evaluation System, Vol. IV: Model Documentation. Prepared for U.S. Department of Energy, Energy Information Administration. DOE/EIA-8558-4. February 1979.

Logistics Management Institute. The Integrating Model of the Project Independence Evaluation System, Vol. VI: Data Documentation. Part I. Prepared for U.S. Department of Energy, Energy Information Administration. DOE/EIA-8558-611. February 1979.

Southwest Energy Associates. The Regional Economic Impacts on Electricity Supply of the Powerplant and Industrial Fuel Use Act and Proposed Amendments (HR6930 and S2470). Prepared for the Edison Electric Institute. April 1980.

U.S. Department of Energy. Annual Report to Congress, 1978, Vol. III: Forecasts. Energy Information Administration Report: DOE/EIA-0173/3.

U.S. Department of Energy. Annual Report to Congress, 1978, Vol. III, Supplement 1: Midterm Energy Projections for the United States. Energy Information Administration Report: DOE/EIA-0173/3-S1.

Wood, D. O. "Energy Model Evaluation & Analysis: Current Practice," Paper presented at the DOE/NBS Symposium on Validation and Assessment of Energy Models, May 19-21, 1980, Gaithersburg, MD. (forthcoming in Proceedings).