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Report To The Congress

OF THE UNITED STATES

New England Can Reduce Its Oil Dependence Through Conservation And Renewable Resource Development

Volume 2 Of Two Volumes

This volume contains our consultants' analysis of the potential impact that conservation and renewable energy could have on New England's energy situation.

UNITED STATES GENERAL ACCOUNTING OFFICE

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PREFACE

To assist us in determining the potential impact that conservation and renewable energy could have on New England's energy situation, we employed the services of an energy consulting firm. The consultants developed projections of New England's energy needs through the year 2000 under three policy options--business as usual, vigorous conservation, and increased use of renewable resources. This volume includes the results of their analysis.

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FINAL DRAFT SUMMARY

REDUCING NEW ENGLAND'S OIL DEPENDENCE THROUGH CONSERVATION AND ALTERNATIVE ENERGY
1978-2000

SUMMARY BRIEF OF THE ANALYSIS AND RESULTS CONTAINED IN TECHNICAL REPORTS I THROUGH V

Final Revision
September, 1980

Energy Systems Research Group, Inc.
Boston, Massachusetts 02109

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1. SCOPE AND ORGANIZATION OF THE STUDY

1.1 Scope of the Study

This report is an assessment of the extent to which energy conservation measures and alternative supply options that are technically feasible and economically attractive could affect the long-range consumption of oil in New England in the 1978-2000 period. In identifying a set of promising conservation measures and supply options, the attempt has been to point to areas where additional public action appears to be required in order to realize the potential benefits available to the region during the next twenty years. Our objective is to quantify the conservation and alternative supply potentials which could be attained through new institutional initiatives.

On the demand side, the study offers quantitative estimates of the reduction in electricity consumption that will occur should the measures contained in a conservation scenario be implemented. The conservation measures and levels incorporated in the scenario satisfy three criteria. They are technically feasible; their incremental costs to electricity consumers as a group will be less than the costs of additional electricity; and they appear to require the stimulus of additional public action if they are to be implemented. The quantification of the conservation scenario's potential impact was performed using the ESRG long-range load forecasting model. A "Base Case" forecast based on present trends and policies was made and compared with a "Conservation Case" forecast based on the conservation scenario. The Conservation Case forecast was used to quantify (a) utility sector oil savings and (b) buildings sector oil savings.

The additional development of the model that was used in making the forecasts that would have been required in order to quantify possible oil savings in the industry sector was not undertaken for this study. Thus, this conservation potential, which by all indications is a very real one, is not analyzed or quantified within the present report. In addition, the transportation sector was entirely outside the scope of the study.

On the supply side, the study identifies the alternative supply sources that hold most promise as technically feasible and economically attractive options for displacing a portion of the presently planned generation mix and quantifies their potential contribution during the planned period 1980-2000. Because of the study's focus on saving oil and because of the community's evident interest in avoiding environmentally problematic resources, the report focues on those alternative supply options that use renewable resources rather than fossil fuels.

With respect to oil use for heating buildings, our purpose was to quantify the reduction that could be achieved through additional conservation initiatives of the oil/gas mix in heating fuel use remained constant. While this was an analytical assumption, it is not unrealistic. At the present time, gas enjoys a price advantage, but its relative price is expected to increase in the mid-1980s. Deliberately inducing shifts from oil heat to gas heat through policy represents an option for reducing oil use that has not been analyzed in this study.

1.2 Organization of the Research

The research performed to provide input to the G.A.O. New England study is presented in a series of five technical reports. The five volumes and their contents are as follows:

Technical Report I. In this report the structure of a long-range model for forecasting electric energy consumption (and peak power requirements) is described in detail. Based on a "business-as-usual" scenario incorporating present technical, economic, and policy trends, a long-range forecast for the New England states was performed. The data inputs and forecast results are described in detail in Report I.

Technical Report II. Here, a conservation scenario is constructed to explicitly modify several of the input assumptions contained in the "business-as-usual" scenario embodied in Report I. The scenario was designed to permit quantification of economically and technically attractive conservation potential that is not likely to be realized without additional policy action. A second forecast was run based on this scenario, and the results for long-range electrical energy are presented in detail in this Report. The forecast in Report I is denoted the Base Case forecast, and that in Report II, the Conservation Case forecast.

Technical Report III. In this report the impact of implementation of the conservation scenario developed in Report II upon New England oil consumption is quantified. The quantification was limited to two types of savings: (a) oil savings from reduced electricity consumption, and (b) oil savings from reduced heating demand in buildings. Oil savings from conservation of energy in manufacturing are not quantified (except via the electricity reduction for that sector), and the transportation sector is outside the scope of the study.

Technical Report IV. In this report an alternative supply potential is identified. Available literature and data on non-conventional generating sources using non-fossil fuels was reviewed and the options that are more technically and economically attractive were identified. Quantitative estimates of the electric capacity and energy potential from windpower, solid waste, hydro and tidal power, and wood were developed. Finally, the oil savings that would be realized were these alternative sources to substitute for oil-fired generation were estimated.

Technical Report V. In this report the economic ramifications of the conservation measures embodied in the conservation scenario of Reports II and III are assessed. Specifically, an input-output approach to the analysis of the New England regional economy is used to quantify the impacts of the residential sector conservation scenario. Particular emphasis is placed upon the positive net employment changes that would ensue in New England were the residential conservation scenario fully implemented.

2. PRINCIPAL FINDINGS

2.1 Impacts of the Conservation Scenario

Oil consumed for electricity generation and buildings sector heating constituted over half of petroleum products consumed as fuel in New England in 1978 measured in terms of Btu content.* Implementation of the conservation strategy scenario developed for this study would have profound implications for utility and buildings sector oil consumption. The oil savings are quantified in the following table.

TABLE 1

OIL CONSUMPTION BY THE UTILITY AND BUILDINGS SECTORS IN 1978, 1990, AND 2000, BASE CASE AND CONSERVATION CASE WITH PERCENTAGE REDUCTIONS DUE TO CONSERVATION

	1978 Historic	1990 Forecast	2000 Forecast
Base Case (10^{12}Btu)	1148	908	921
Conservation Case (10^{12} Btu)	-	649	569
Reduction from Base to Conservation (Percent)	-	28	38

The potential for saving oil through conservation is dramatically evident from the above table. Twenty-eight percent less oil is consumed by 1990 and thirty-eight percent less by 2000, than without a push for achieving the additional conservation potential quantified in the conservation scenario. If anything like the base year sectoral breakdown holds throughout the century, these utility and buildings sector savings could in themselves represent savings of a fifth of the oil that the region would otherwise consume. (Forecasts of transportation and industry consumption were not made.)

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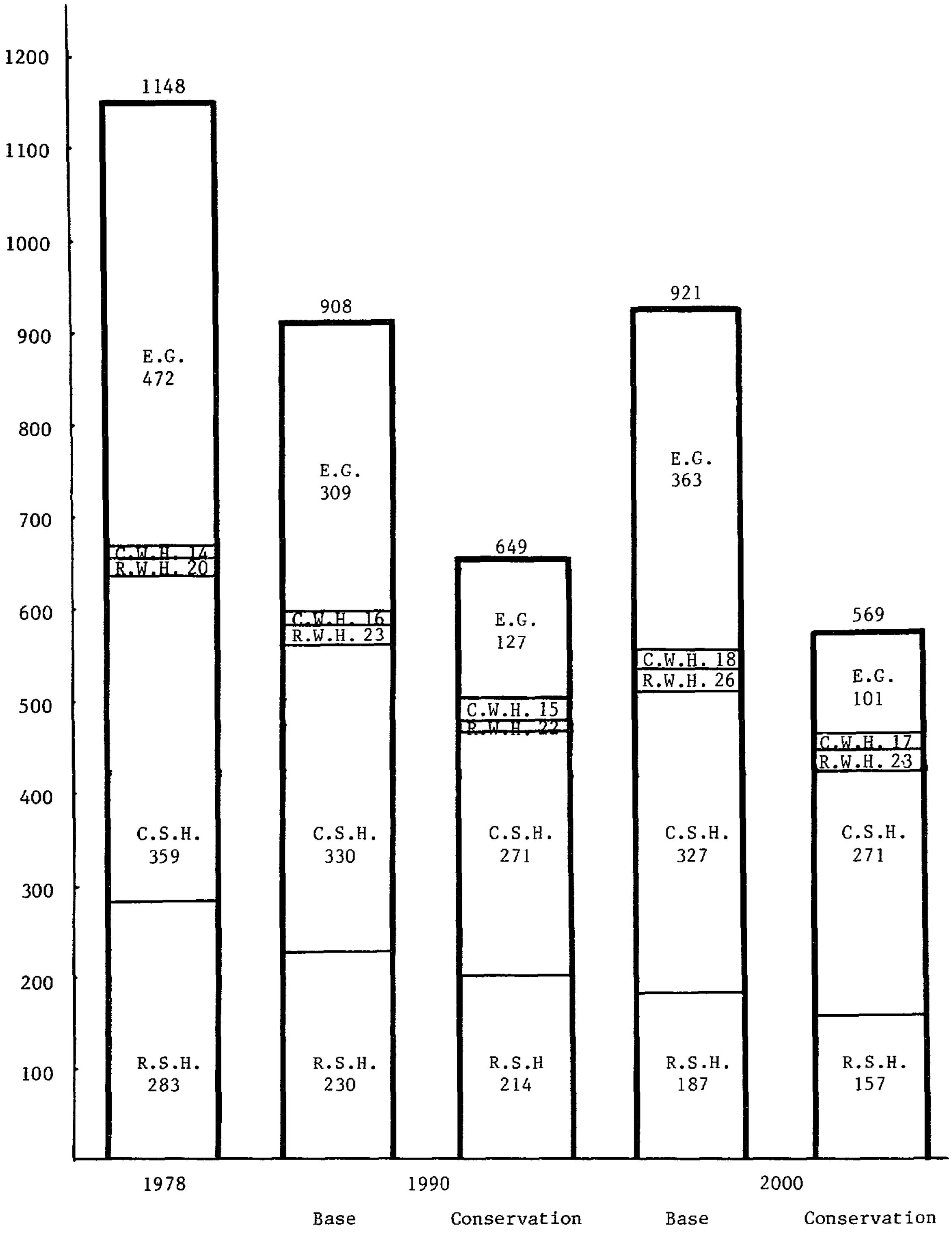
* United States Department of Energy, State Energy Data Report, Report DOE/EIA-0214(78), April 1980. The components were residential and commercial oil consumption at seventeen percent each and oil consumption for electricity generation at nineteen percent. Other uses of oil were industry, fourteen percent, and transportation, thirty-three percent. Energy Information Administration consumption data were not used to calculate base year (1978) consumption in this study. Had they been, the absolute numbers would have differed but the trends and the order of magnitude of conservation's impact would have been the same. (See Report III, Sec. 2.3).

FIGURE 1

NEW ENGLAND OIL CONSUMPTION FOR HEATING, AND ELECTRICITY GENERATION
1978, 1990, AND 2000, BASE CASE AND CONSERVATION CASE



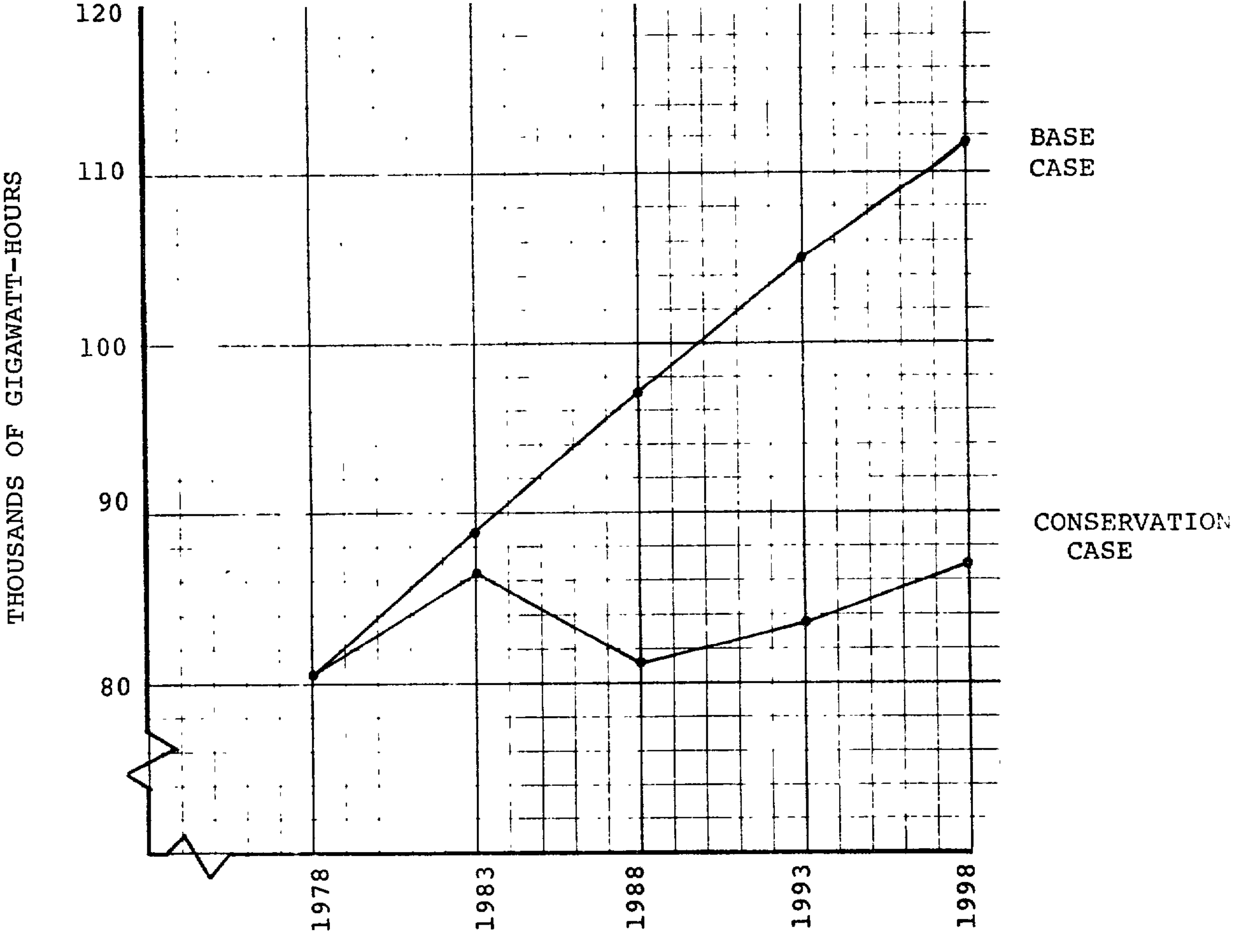
R.S.H.	Residential space heating	R.W.H.	Residential water heating
C.S.H.	Commercial-institutional space heating	C.W.H.	Commercial-institutional water heating
E.G.	Electricity generation		

Oil savings potentially attainable through additional conservation amount to sixteen percent of forecasted Base Case consumption of oil for heating by the year 2000. For electrical generation, the savings potential is greater both relatively and absolutely: over seventy percent of the year 2000 consumption is saved in the conservation scenario.

In Figure 1 the utility and buildings sector savings are represented separately. In addition, each "oil consumption bar" breaks down buildings sector consumption into the Btu content of oil used for residential and commercial space and water heating.

The utility oil savings were based on the Conservation Case long-range electric energy and demand forecast, which quantified the conservation scenario's impact on electric generation requirements. Figure 2 illustrates the impact of the conservation scenario on electric energy forecasts.

Figure 2
COMPARISON OF CONSERVATION AND BASE CASE
FORECASTS OF ENERGY, NEW ENGLAND



In addition to the growing electric energy savings from conservation as shown in Figure 2, annual summer and winter peak demand is reduced considerably. Table 2 provides figures for peak demand (and for energy) under Base Case and Conservation Case conditions. By 1998, the regionwide peak is reduced by 24 percent from the Base Case forecast.

TABLE 2

COMPARISON OF ESRG BASE CASE AND CONSERVATION FORECASTS
OF ELECTRIC DEMAND
NEW ENGLAND AGGREGATE ENERGY AND PEAK

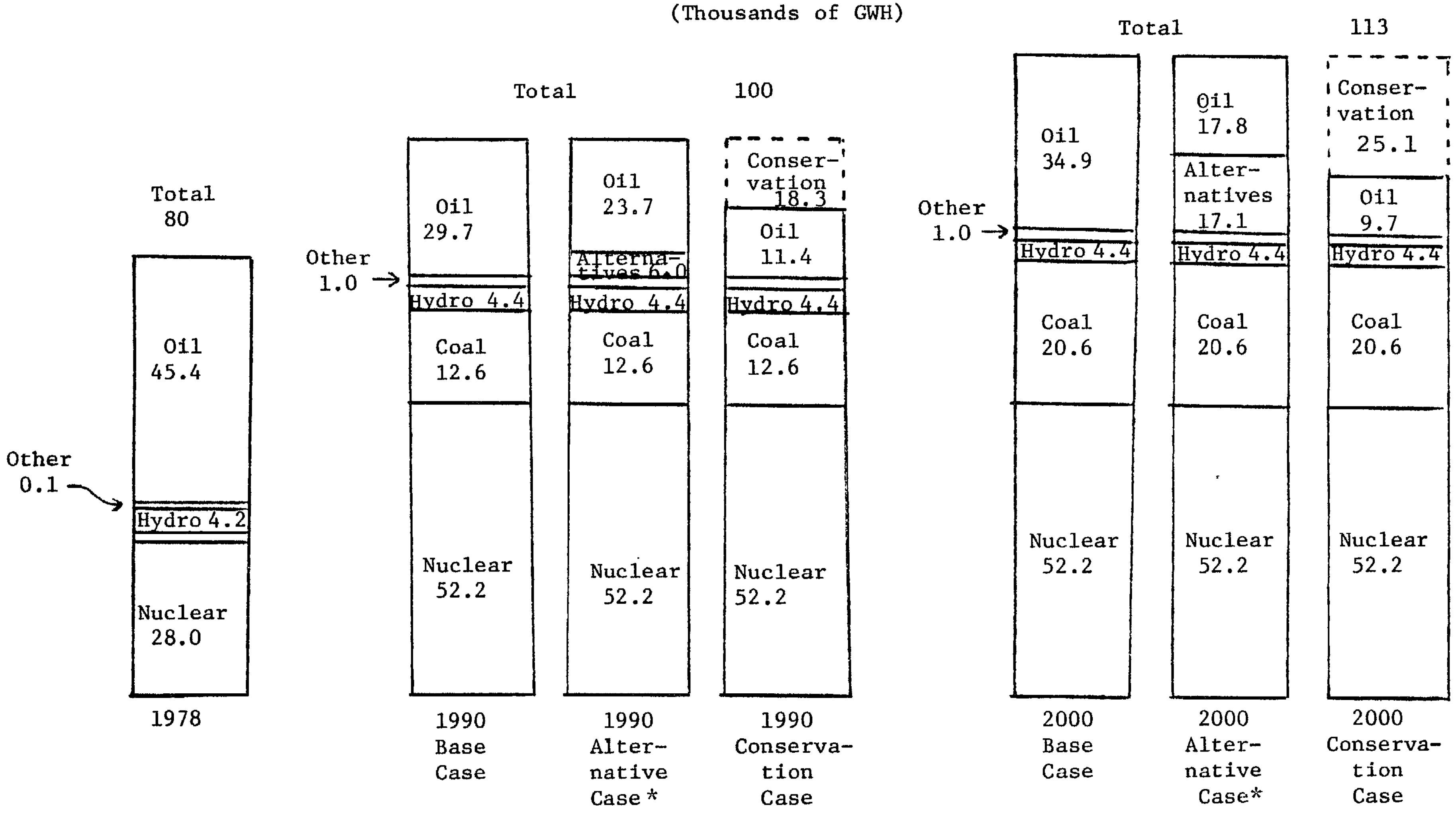
	Energy (GWH)		Summer Peak (MW)		Winter Peak (MW)	
	Base Case	Conservation	Base Case	Conservation	Base Case	Conservation
1978	80,530	80,530	14,073	14,073	14,964	14,964
1983	88,730	86,160	15,330	15,240	16,780	16,400
1988	97,080	81,090	16,600	14,240	18,650	15,550
1993	104,750	83,680	17,740	14,640	20,210	15,940
1998	111,480	86,700	18,740	15,130	21,460	16,320

The ESRG Base Case forecast is lower than NEPOOL's forecast for New England. For the period 1980-1990, the annual rate of growth of system peak is 2.17 percent in the ESRG forecast and 2.51 percent in the NEPOOL forecast. The real divergence comes after 1990, when the ESRG peak growth rate drops to 1.26 percent per year while the NEPOOL growth rate increases to 3.2 percent per year. For 1990, the NEPOOL-forecasted peak is 20,650 MW. The ESRG-forecasted peak is six percent less. By 1995, the NEPOOL forecast is for a peak of 24,170 MW. The ESRG-forecasted 1995 peak is 14 percent less. The NEPOOL forecast implies a higher "Base Case" level of oil consumption than projected in this study.

To compute the implications for utility oil consumption of the considerable conservation reduction quantified above, we first assumed completion of a contemplated New England Power Pool (NEPOOL) construction program. We then assumed that the generation displaced by conservation would be oil-fired generation, an assumption based on oil's position as the marginal (most costly) utility fuel in the generation system and on the utilities' economic dispatch practices. The generation mix implications of conservation can be by comparing the "Conservation Case" and the "Base Case" bars for 1990 and 2000 in Figure 3.

FIGURE 3

ELECTRICAL GENERATION BY FUEL TYPE
(Thousands of GWH)



* "Alternative" sources include electricity from solid waste, hydropower, tidal power, windpower, and wood. (A small amount of generation from such sources is included within "Other" fuel types for 1978 and Base Case 1990 and 2000 forecasts.)

The 2000 Conservation Case bar in Figure 3 is particularly striking. Oil-fired generation is reduced to but 9 percent of the total generation mix, within striking distance of its possible practical lower limit of a few percent for cycling and peaking functions.

The quantification of buildings sector heating oil savings due to the conservation scenario was achieved through a series of computations based on adaptations of the long-range forecasting model's residential and commercial input and output data. Although the conservation scenario's ban on unassisted new resistance heating in the buildings sector increases the number of oil-heated units more rapidly than occurs under the "business-as-usual" conditions of the Base Case forecast, this effect is far outweighed by the utility oil savings from the ban and by the other energy-saving measures in the conservation scenario.

2.2 Impacts of the Supply Scenario

Realization of the most promising alternative supply options could significantly reduce the region's oil consumption for electrical generation. In Figure 3, the impact of those options on the generation mix was illustrated. The oil consumption implications of that change in generation mix are shown in Figure 4. Figure 4 gives oil consumption in terms of trillions of Btu (left-hand scale) or millions of barrels (right-hand scale) per year.

The estimate of the contribution of alternative energy to reduced oil usage was based analytically upon an extrapolation of the NEPOOL construction program to the year 2000. Present NEPOOL plans (retirements, reratings, and additions of authorized and planned units) would yield a total capability of 27,120 MW by the end of the latest planning period (1995/96). We therefore included utility-planned generating additions still under NEPOOL study. This produces a year 2000 capability of 28,700 MW, exclusive of the Montague plant that is no longer actively planned by Northeast Utilities System. The major additions that we assumed by the year 2000 are listed in Table 3 below. Plants of under 100 MW are not individually listed.

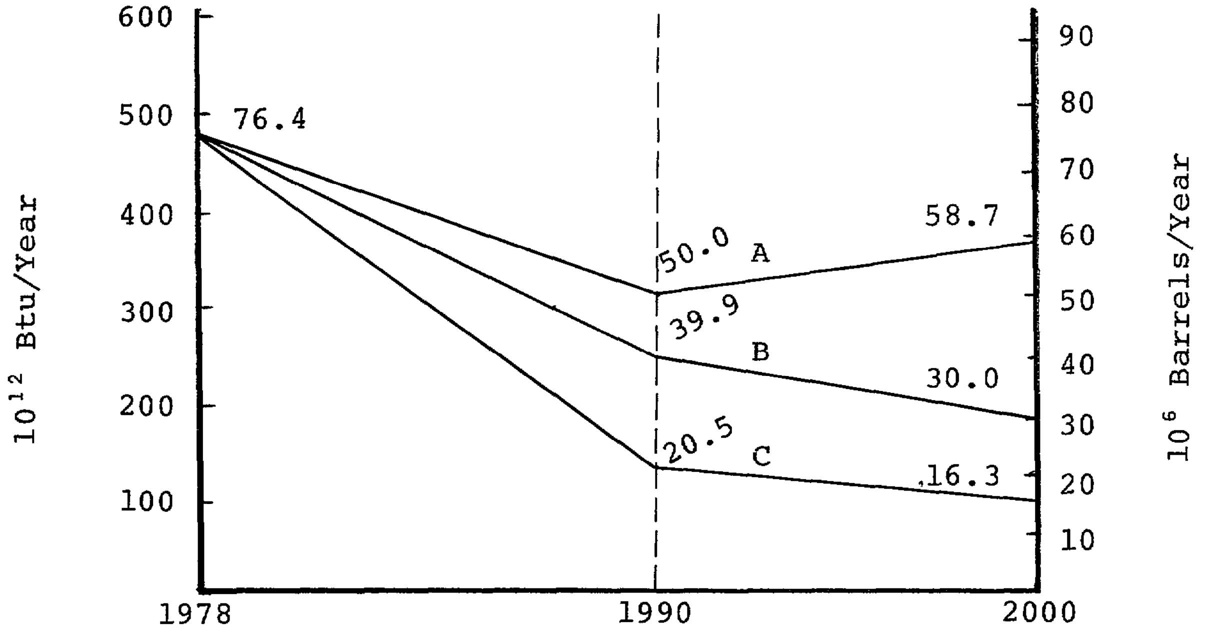
TABLE 3

NEW GENERATING CAPACITY ASSUMED ADDED IN NEW ENGLAND BY THE YEAR 2000

Plant	No. of Units	Fuel	Capacity (MW)
Stony Brook	2	Oil	510
Seabrook	2	Nuclear	2,300
Pilgrim	1	Nuclear	1,150
Millstone	1	Nuclear	1,150
Sears Island	1	Coal	570
Edgar	1	Coal	800
Canal	1	Coal	600
M.M.W.E.C.	2	Refuse	150

FIGURE 4

NEW ENGLAND OIL CONSUMPTION FOR ELECTRICAL GENERATION, 1978, 1990, AND 2000, UNDER BUSINESS AS USUAL, CONSERVATION, AND ALTERNATIVE SUPPLY SCENARIOS*



A Base Case Forecast

B Base Case Forecast and Implementation of Alternative Supply Potential

C Conservation Case Forecast

* All cases assume the NEPOOL construction program and the conversion of two generating stations from oil to coal.

The line labelled "B" represents the implementation of the alternative supply potential prioritized here relative to "A," the Base Case forecast. By 2000, oil consumption for generation would drop from 59 to 30 million barrels per year, a savings of nearly 50 percent relative to the Base Case forecast.

Note that in neither Figure 3 nor Figure 4 are the oil savings from conservation and alternative supply added together. If the conservation savings were fully realized and the full alternative supply potential identified here were also available by 2000, all oil-fired generation, save a minimum needed for peaking functions, would be eliminated. Approximately 25 to 50 percent of the generation from alternative sources would be substituting for oil. The balance would be substituting for other fuels, most likely coal. Since an oil-fired fuel cost estimate was the criterion for assessing the attractiveness of measures and options on both the conservation and the supply side, the analysis here cannot be held to confirm the direct economic desirability of full implementation of both the conservation and the alternative supply potentials.

Since the region has far to go in reducing oil dependence, however, it would clearly be rational to begin by aiming to tap the bulk of both the conservation and the alternative supply potential. Indeed, if there is reason to believe the NEPOOL construction program of new nuclear and coal capacity will not be completed, so that more oil will really be consumed than indicated in line "A" in Figure 4, then proceeding vigorously on both fronts would be completely consistent with the results of this study.

The alternative electric generation potential in New England, excluding units built, under construction, or definitely planned, is summarized below in Table 4. In the conservation scenario, we attempted to include measures which appeared to definitely require the stimulus of public action if their benefits were to be realized. Probably the bulk of the capacity listed in Table 4 also falls into this category, since for purposes of the supply scenario "Base Case" conditions are NEPOOL plans.

TABLE 4

ADDITIONAL* REGIONAL ELECTRIC GENERATION CAPACITY FROM ALTERNATIVE ENERGY SOURCES, POTENTIAL IN 1990 AND 2000 (MW)

	Wind	Solid Waste	Tidal Power	Hydroelectric Generation		Wood
				Large Scale	Small Scale	
1990	500	480	13	195	510	30
2000	2900	850	750	580	510	80

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*Increment over Base Case conditions

2.3 Overall Economic Implications of Conservation

The conservation and alternative supply scenarios were constructed on the basis of a direct economic comparison with the costs of oil-fired electricity generation. Thus, scenario components represent cost-effective energy options. Estimates of the total dollar costs and benefits of the conservation and supply scenarios have not been developed, except for the residential sector energy conservation scenario measures. For the residential sector, the energy savings from implementation of the conservation scenario between the base year and the end of the century amount to some 280 percent of the costs of the conservation investments, representing a clear economic advantage for conservation. Report V describes the derivation of these costs and benefits.

The direct economic trade-offs between conservation investments and energy production tell only part of the relevant story. The indirect economic consequences of alternative energy strategies--such as their environmental costs and their employment impacts--are of direct policymaking relevance.

In order to illustrate the relevance of the indirect economic trade-offs to evaluation of energy strategies, an input-output approach to modelling the regional economy was employed and the employment impacts of the residential measures in the conservation scenario were measured.

It was determined that after all job losses from reduced spending for energy due to the effects of conservation were accounted for, the investments in conservation that are implied in the conservation scenario would produce a net increase in employment. The increased employment was due to the direct and indirect labor and materials requirements for implementing the conservation scenario measures and to an increase in disposable consumer income from savings due to reductions in energy bills which was translated into increased spending for goods and services in the region.

The net result of the analysis was that in each state in each year between 1978 and 2000, total employment would increase as a result of the shift from the Base Case scenario to the residential conservation strategy. The relative gain would grow with time, and by the end of the century, well over 300,000 net additional jobs would have been created. This comparative benefit is modest considered against the scale of regional employment as a whole. But it is quite clearly a positive effect on balance, with the potentially positive effects of commercial and industrial conservation remaining to be explored.

3. ASSESSING THE POTENTIAL FOR CONSERVATION

3.1 The Conservation Scenario

The conservation scenario which was employed for analyzing the potential for electrical energy conservation was designed for use in conjunction with the ESRG long-range load forecasting model. The model is a detailed structure for quantifying present and future levels of electric energy consumption and peak demand. The mathematical structure and conceptual foundations of the model are specified in Technical Report I; also contained in that volume is a detailed presentation of the "Base Case" (or pre-conservation strategy) forecast produced by the model for this study. The Base Case forecast is a benchmark against which to quantify the potential for additional conservation of electric energy which would result from the policy-based conservation scenario in the region.

The forecasting model disaggregates energy use into various components within the major energy consuming sectors: residential, commercial, and industrial. Within the residential sector, detail is provided for several "end-uses," i.e., for 14 major sources of consumption, such as specific appliances, lighting, and heating. Within the commercial sector, four major end-uses are detailed in each of the five major types of buildings, such as hospitals and retail/wholesale establishments. Within the industrial sector, the consumption of electrical energy is detailed for each of twenty standard categories of manufacture. To produce a Base Case forecast, the computer sums the total yearly energy and peak demand from the many specific end-use submodels.

The Conservation Case forecast takes advantage of the detailed structure of the forecasting model. A conservation scenario is constructed by specifying changes that impact specific end-uses and groups of end-uses during the forecast period. Such demand-reducing measures as an increase in the amount of self-generation in industry, a reduction in the use of electric space heating in office buildings, and an increase in the insulation levels of single-family homes are quantified explicitly in the conservation scenario. Using these scenario inputs, the Conservation Case forecast interrupts Base Case computations to produce a second, slower growth year-by-year long-range forecast. When compared with the Base Case forecast, the Conservation Case forecast presents a quantitative estimate of the energy that can be saved (and the winter and summer peak reductions that can be attained) through a deliberate policy of implementing the measures in the conservation scenario.

As indicated in Report II, the Base Case forecast attempts to capture conservation that has occurred and is ongoing due to present trends and existing policies or policies whose implementation seems certain. The Conservation Case forecast attempts to capture additional conservation that would be attendant on more vigorous promotion of cost-effective demand reducing measures in the states. The criteria used to select additional conservation measures for inclusion in the scenario were:

- The conservation measures are technically feasible.
- The measures do not increase overall social costs for energy services.
- The measures appear to require the stimulus of additional public action for implementation.

Technical feasibility refers to the present or imminent availability of the hardware and know-how to promulgate the conservation measures. Measures in the scenario are generally based on available technology and practices. For example, increased levels of home insulation using existing building practices are included in the scenario; the use of radically new building practices, such as involved in the production of prototypical "zero energy" homes, are not. This is not to deny the possibility that it might be desirable for policymakers to strongly encourage or underwrite the development of new techniques for conserving energy.

The social cost criterion is that the benefits to society of implementing a measure exceed its cost. In this study we restrict consideration to direct cost tradeoffs; e.g., that the lifetime costs of a measure do not exceed the costs of producing the kilowatt-hours (kwh) saved by the measure during its lifetime. The avoided costs per kwh used to measure the cost attractiveness of a conservation measure are not necessarily those experienced by the individual consumer who will invest in the measure. Ideally they are the social costs of producing the incremental energy that would be required in the absence of conservation. These criteria are discussed more fully in the second Technical Report, which details the conservation scenario and the results of the Conservation Case forecast. The scenario is a cautious one, based on direct cost/benefit tradeoffs and available technologies. Indirect effects due to cost "externalities" (environmental benefits, scarce fuel preservation, capital conservation, etc.) have not been included nor have promising measures still in the development phase (industrial solar applications, total energy systems, etc.). Such scenario constraints are not meant to deny the possible value of a larger set of conservation activities and measures. Rather the scenario is designed to highlight for policymakers' consideration the most promising of those options for energy savings that otherwise may not be realized.

In the scenario, hypothetical new policy actions are linked to the specified conservation measures. In some cases a specific policy is posited -- *e.g.*, a specific appliance efficiency regulation -- and in others a range of conceivable policies is set forth. The purpose of the analysis is not to develop a precise set of policy proposals, legislation, and regulations. It is rather to provide policymaking guidance by quantifying the conservation potential from feasible and socially cost-effective measures not likely to be implemented without additional public action, and thus to serve as a basis for recommendations on new policy areas that appear to deserve active consideration at this time.

The policy measures associated with the conservation scenario developed in Technical Report II include the following elements.

Residential Sector

Appliance Efficiency Standards
Lighting Efficiency Improvements
Building Envelope Standards
Plumbing Fixture Efficiency Standards
Electric Space Heat Regulation
Voltage Regulation

Commercial Sector

Building Envelope Standards
Passive Solar Energy Requirement in New Construction
HVA/C System Equipment Efficiency Regulations
HVA/C Operations Requirements
Internal Load Requirements (lighting levels and ventilation rates)
Electric Space Heat Regulation
Voltage Regulation

Industrial Sector

Cogeneration Regulation and Incentives (utility ownership option, utility surveys, back-up rate review, etc.)
Industrial Conservation Program (services, audits, outreach)
Building Envelope Standards

The degree of detail in the Conservation Case forecast is greater in the residential sector than in other sectors. This reflects the greater degree of end-use decomposition in the basic forecasting model, itself a reflection of the relative homogeneity of the sector and the greater degree of data availability. There is in general a more precise connection between the policy specification and the resulting savings in the residential sector than in other components of the Conservation Case forecast. The greater degree of detail available for the residential sector is fortunate because public policy initiatives are probably more important in realizing the conservation potential in this sector than in other sectors. Residential sector decision-makers are largely consumers while decision-makers in the other sectors are investors or agencies better able to "front-end" direct expenditures that are commercially or socially attractive on a life-cycle cost basis. (Nevertheless, further policy initiatives are needed to realize the existing conservation potential in the commercial and industrial sectors too.)

Measures that are of doubtful or unproven direct social cost attractiveness at this time, such as active residential solar systems and utility-initiated residential load control, were not included in the scenario. Such measures may have very real mid- or long-term social value; they simply are not among the most evidently attractive at this time.

Long-range forecasting is a science that necessarily involves uncertainty. The first volume of the Technical Report, in particular, addresses the issue of uncertainty. What the Conservation Case forecast gives us cannot be an advance proof that a precise amount of energy will be saved if a given policy is implemented. What we do get is a measure of the order of magnitude of savings that appear to be attainable through purposeful new initiatives.

The value of energy conservation measures as a social investment has been increasingly noted in the energy literature. What is distinctive about the Conservation Case forecast is its quantification of the specific effects for New England of a set of conservation actions and investments holding high technical and economic promise.

3.2 Results of the Conservation Forecast

The effect of the conservation package on forecasted electricity consumption in New England is dramatic. As the measures are phased in during the 1981 to 1988 period, total energy consumption actually begins to fall. Consumption increases again as underlying demographic trends and increasing saturations of some end-uses produce net growth. Nevertheless, the "energy gap" between the Base Case and the Conservation Case grows. During each year of the forecast period, more energy is conserved than during the previous year. The two forecasts were graphed in Sec. 2 above.

Since nuclear units have lower fuel costs than fossil-fired units, and since plans for converting to coal seem to be somewhat uncertain, the primary near-term supply benefit of a conservation strategy would be avoided purchases of largely imported and increasingly costly oil. Economic generation dispatch would dictate that oil plants be the first whose output would be reduced. These issues are more fully discussed in the supply summary below.

For consumers as a group, life-styles identical to those implied in the Base Case forecast are retained, yet less is spent on the mix of services than would have been without the conservation investments incorporated in the conservation scenario.

3.3 Observations Concerning Electricity Conservation Measures

The development of the conservation scenario, summarized and detailed in Technical Report II, was a process of pointing to conservation options that appear strongly promising at the present time. Given the dramatic energy savings resulting from the implementation of the measures in the aggregate, a general observation is that the order of magnitude of potential savings that remain above and beyond recent price and policy induced conservation is sufficiently large that even policies which do not cause full implementation of additional conservation can have an important effect.

The quantification of a regional electric energy conservation potential was not, of course, based on a political analysis of the process of institutional change. Rather, it assumed or hypothesized plausible policy changes in order to enter promising options for additional conservation into the forecasting model. Now, with the results in hand, it is appropriate to consider specific areas of opportunity.

Residential Sector

The residential conservation scenario included strong efficiency standards for several appliances. Minimum standards for new appliances have a legislative precedent at the state level. California has a comprehensive set of standards and some other states have selected standards. In addition, the U.S. Department of Energy is developing standards for a number of appliances under the National Energy Conservation Policy Act of 1978 (N.E.C.P.A.). N.E.C.P.A. also authorizes the Secretary of Energy to promulgate standards for appliances not specifically named in the legislation. The federal standards will supercede state standards unless a waiver is granted pursuant to application to the Secretary of Energy.

The conservation scenario employed more demanding standards than in effect in any state at present, resulting in the energy savings for new appliances indicated below. These are beyond Base Case improvements that assume new appliances will attain voluntary efficiency levels targeted by the Federal Energy Administration a few years ago.

TABLE 5

INCREMENTAL ENERGY SAVINGS FOR PROTOTYPICAL NEW APPLIANCES (PERCENT VERSUS PRE-STANDARD LEVELS)

Appliance	1983 Standard	1988 Standard	Other
Refrigerator/Freezer	12	19	
Freezer	3	19	
Electric Range	2	2	
Electric Water Heater	5	2	
Room air conditioners*	12	2	
Central air conditioners			
Northern New England	-	6	
Southern New England	11	-	
Heat pump	-	13	
Plumbing fixtures	-	-	32**
Efficient lamps	-	-	48***

*Southern New England only

**Total effect by 1991 of standards effective in 1981

***Total effect by 1987 of promotion efforts begun in 1983

These appliance standards probably had a very strong effect on the Conservation Case forecast. A sensitivity run of the forecasts without the standards in a recent ESRG Connecticut study* produced a residential energy consumption that was almost 9 percent greater in 1988 and over 9 percent greater in 1998, than with the standards. Thus the appliance measures may account for nearly half of the conservation savings in the residential sector.

The conservation scenario employed a ban on additional unassisted resistance space heating after 1983. For a single measure, this has a strong effect on residential conservation, and its effect grows with time. In the Connecticut study, a sensitivity run without the e.s.h. ban showed Conservation Case residential energy consumption to be 3 percent higher by 1988 and 6 percent higher by 1998, than with the ban.

The conservation scenario included passive solar measures for new homes and weatherization for new and existing residential buildings, above and beyond the effects of the existing building code and Base Case weatherization retrofit trends. (A sensitivity run in the Connecticut study showed that the effects of the incremental conservation scenario weatherization grew slowly, reaching 2.4 percent of residential energy by 1998.) While there clearly is a conservation effect worth pursuing, we may have understated weatherization potential in two ways. First, we resolved all doubt in terms of the energy difference between 1978 actual weatherization on the one hand, and code-implied new-home weatherization on the other, in favor of a generous Base Case estimate of heating and cooling load reductions, in order not to overestimate conservation potential. Second, the emerging literature on residential thermal integrity suggests that practices which depart from conventional building practices (thus violating our conservation scenario "feasibility" criterion) may be highly cost-beneficial.

The conservation scenario includes a conservation voltage regulation (c.v.r.) Because it results in a direct energy savings of from 1.3 to 2.5 percent of total residential and commercial energy, depending on the state, at negligible cost to consumers, the c.v.r. is an obviously attractive measure to which too little attention has been paid. (A c.v.r. is a

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* The Potential Impact of Conservation and Alternate Supply Sources on Connecticut's Electric Energy Balance, A Report to the Power Facility Evaluation Council of the State of Connecticut. Boston, Massachusetts: Energy Systems Research Group, Draft Report ESRG 80-09/R, June 2, 1980.

regulation holding service voltage on distribution feeder circuits to the lower half of the voltage range, e.g., to 114 to 120 volts instead of 114 to 126 volts on a 120 volt circuit.)

Commercial Sector

Three of the residential sector measures also apply directly to the commercial sector. These are:

- Conservation voltage regulation.
- Resistance heating restriction.
- Heat pump improvement.

The discussion of conservation voltage reduction in the preceding section is applicable here. The effect of the e.s.h. ban (based on a commercial sector sensitivity run, in the Connecticut study referenced above), is smaller than in the residential sector. The ban may not decrease sectoral energy consumption by 1 percent until 15 years after the base year.

The conservation scenario is based on a set of measures for each building type and vintage in the model as discussed in Technical Report II. While the measures are cost-effective, the level of investment (and consequently of energy savings) is estimated to be above that occurring in the commercial sector on the basis of market forces and current policies (compare table 8.20 and accompanying text of Technical Report I with table 4.1 in Report II). Depending upon building type, the additional conservation to be induced by policy would consist of such measures as increasing the R-value of all exterior surfaces, incorporating passive solar design elements providing additional waste heat reclamation; providing automated venting and bypass systems and combustion air preheat systems; increased use of task lighting and high-efficiency lamps; and providing integrated energy management systems for optimal operations and control settings.

When customers generate all or a portion of their own electricity, the supply they provide can be treated analytically as a reduction in demand. Self-generation simply reduces requirements for electricity from the utility system. Co-generation--combined production of electric and thermal energy--also increases the overall efficiency with which energy is consumed.

It should be noted that, because the major potential for self-generation or cogeneration of electricity is in the industrial sector, the conservation scenario did not incorporate an increase in commercial-sector cogeneration. This choice was not intended to imply that this area is undeserving of further investigation; it simply reflects the significant promise of the more thoroughly investigated conservation options summarized above. Another form of cogeneration, district heating, has not been addressed here.

Industrial Sector

Big industry in the United States is improving the productivity with which it utilizes energy. There is still some shifting from fossil fuels to electricity within several industrial categories, but there seems to be little question that conservation is going on.* While New England-specific conservation data for the recent period were not yet available at this writing, the conservation scenario assumed that state efforts would be directed at the small-business sector, comprising the bulk of manufacturing establishments, except in the area of cogeneration.

In the area of cogeneration, the conservation potential is noteworthy. In the recent report Cogeneration: Its Benefits to New England, the Massachusetts Governor's Commission on Cogeneration estimated a region-wide commercial and industrial potential of nearly 1,700 megawatts of new cogeneration capacity under "Base Case" conditions which included a rate framework similar to that which has been created by the Public Utility Regulatory Policies Act of 1978 (PURPA). The bulk of the site-specific analytical work in that study was in Massachusetts, with the results extrapolated to the region on the basis of patterns of industrial (and commercial) activity.

PURPA mandates development of utility purchase rates from cogenerators based on long-run avoided energy and capacity costs of the utility. It also mandates nondiscriminatory rates for back-up electric service to cogenerators. Development of these more favorable rates is assumed in the Base Case scenario. The conservation scenario assumes that rate development is embedded in a context in which other policy initiatives occur.

One possible initiative is a systematic survey of potential cogenerators to determine the technical and economic feasibility of increased cogeneration based on the new, more favorable rate framework of PURPA. Through the survey process, potential cogenerators can be made aware of tax incentives and financial assistance available to them and industry-utility discussions can be initiated.

Because the mere identification of potential that is attractive, even if followed by such initiatives as discussed in the preceding paragraph, may not be sufficient to overcome institutional inertia and the relatively high payback requirements that many industries place on energy capital investments, Technical Report II discusses the concept of utility ownership of cogeneration systems on customer sites.

Basically, the advantages of utility ownership are economic. Utility rate of return requirements are lower than those of industry when investment in generation capacity is involved. Investment in cogeneration equipment based on an agreement between a utility and the primary industrial steam/

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*See, for example, the Annual Report on the Industrial Energy Efficiency Program for July 1977 through December 1978, issued last December by the Department of Energy. Other citations on industrial energy conservation are contained within Technical Report II.

electricity customer could permit a sharing of construction costs. In addition, utilities have appropriate skills in-house and experience with all aspects of the regulatory process. P.U.R.P.A. would probably have to be amended, as has been recommended by the Institute of Electrical and Electronics Engineers, to permit utility ownership of decentralized cogeneration systems.

Should government adopt a cogeneration policy orientation, the overall task is the development of an integrated framework for providing regulatory coherence, reviewing and establishing adequate utility/industry interface policy (particularly concerning backup charges), and creating adequate institutional mechanisms for initiating projects, raising capital, and implementing projects. State government can creatively work to develop a coherent regulatory framework for cogeneration addressing electric rates, fuels policy, and the application of environmental standards. It can develop a technical services capability to promote cogeneration by providing information and advice to would-be customers. In Report II, the conservation scenario assumed such initiatives. Production of new electricity through industrial cogeneration, based largely on historic patterns of self-generation, was estimated to attain a level twice that of the Base Case during the forecast period.

The conservation scenario also incorporated a ten percent additional gain in energy conservation for the industrial sector, attained in 1988 and maintained thereafter, due to additional industrial outreach efforts begun in 1983 and aimed primarily at medium and small businesses.

4. ASSESSING THE POTENTIAL FOR ALTERNATIVE SUPPLY

4.1 Criteria for Assessment of Electricity Supply Options

The purpose of the assessment of the potential for generation from alternative sources was to identify technologies that seem likely to be technically feasible and reasonably cost-effective over the 1978-2000 period. "Alternative sources" could encompasss a wide range of technologies other than conventional fossil fuel combustion and nuclear fission that are capable of providing electrical energy to the grid. We focussed upon technologies that utilize renewable resources (as opposed to technologies which utilize fossil fuels).

Technologies were judged likely to be technically feasible by 1990 if the underlying technology is proven and commercial-scale demonstration projects are now under way. For the purpose of judging cost-effectiveness, the cost per kwh of alternative supply options was compared to the cost of fuel for oil-fired generation. The sum of fixed and variable costs of alternative supply options were compared with only the variable fuel cost of conventional generation because the need for additional capacity in New Englnad is uncertain at this time. Of course, to the extent that alternative sources do provide additional capacity, they will be even more attractive if a need for such capacity develops. Technologies were considered likely to be cost-effective only if the best current estimates of their 1990 levelized busbar costs per kwh were in or below this range.

4.2 Technology Assessments

The technologies identified as more promising for New England were wind power, energy from municipal waste, small-site hydroelectricity ("small hydro"), large-scale hydro, tidal power, and wood. In this section, we begin by discussing these six technologies. Later we discuss other technologies that were considered but were judged to be too uncertain in their potential to receive priority at this time.

The potentials discussed below represent reasoned judgements based largely on the criteria of 1990 technical feasibility and cost-effectiveness. No systematic consideration has been given to institutional or environmental constraints that might limit the realization of the potentials. In the case of tidal power and conventional hydropower, where capacity additions have been proposed in the past and some measure of the intensity of institutional/environmental resistance has been gained, we have adjusted the potential downward from the level that would obtain on the basis of feasibility and economics alone. Such adjustments are fully described in Report IV, Sec. 2.3.

Wind Power. The extraction of energy from wind has a long history. Windmills were first used to generate electricity before 1900, and a 1.25 megawatt (mw) wind turbine was operated on Grandpa's Knob in Vermont in the 1940's. The widespread availability of cheap oil and gas, however, prevented substantial interest in wind generation until the mid-1970's.

Several sub-megawatt wind units are in use by electric utilities under D.O.E. sponsorship. The U.S. Department of Energy (D.O.E.) in conjunction with the National Aeronautics and Space Administration (N.A.S.A.), has undertaken a wind program aimed at commercialization of megawatt-size wind energy conversion systems (WECS) by the mid-1980's. Initial commercial introduction could begin around the year 1983, with large-scale production under way by 1984. Wind generation is, therefore, considered feasible for the purpose of this study. One current concept for ultimate commercialization is a "wind farm" of about fifty 2-mw units, occupying about fifty acres. Such concentration would be aimed at efficient management of operations and maintenance requirements.

The cost-effectiveness of WEC systems is somewhat uncertain. First, the cost of the machines themselves that will ultimately be in commercial use must be projected from current prototypes using some assumed "learning curve" as well as factor input escalation. Second, the cost per kwh depends on both the cost of the WECS and the wind speed at the particular site.

Sites with higher average wind speeds will, in general, have lower costs per kwh. To achieve this lower cost, the WECS must be designed for the appropriate rated wind speed. Since the cost of the WECS (per kw) depends on the rated wind speed, comparisons of different machines can be misleading if their rated wind speeds differ. A more expensive machine may produce cheaper power if its rated wind speed is higher and it operates at a windier site. It appears, however, that the sensitivity of optimum design to site characteristics is not so great as to require custom design for each site. Mass production of a high, moderate and low wind model should be possible.

Given the uncertainties, no single figure for the cost of WECS power was developed. Estimates for levellized busbar costs per kwh range from 2.5 to 8¢/kwh for the 100th unit produced, as compared to oil-fired generation costs of at least 6-8¢/kwh (1990 costs in $ 1980). Despite the breadth of this range of estimates, it seems reasonable to conclude that wind will be cost-effective by 1990.

The magnitude of wind potential in New England is difficult to estimate. Identification of suitable sites is crucial to the economics of wind power. Twelve mph is thought to be the minimum viable average wind speed. Even average wind speeds are not adequate to characterize potential sites. The distribution of wind speeds is crucial, because WECS produce most efficiently at their rated wind speeds. The fraction of wind energy that is captured declines at speeds above or below this optimum, and the machine cuts out completely at certain upper and lower speed limits.

A detailed inventory of the wind resource is necessary before the potential for wind generation can be determined. It is likely that some of the highest wind speed sites are along the coast (where land is scarce and aesthetic objections to wind machines might be abundant). Nevertheless, some estimates of the regionwide potential indicate that the wind resource is worth considering seriously. The MITRE Corporation estimated that 35 100-mw windfarms could be developed in New England as a whole by the year 2000. The New England Energy Congress estimated a regional potential of 5,400 to 10,800 mw by the year 2000. If this maximum estimate were realized, windmills would be generating about 28 million megawatt-hours (mwh) of electricity yearly, saving as much as 50 million barrels of oil. Similarly, a recent generation planning study performed by the Electric Power Research Institute (EPRI) concluded that for oil-dependent utilities wind power penetration might economically exceed 10 percent of capacity. This implies at least 2000 mw regionwide.

The increasing cost of oil for utility consumption greatly enhances the attractivenss of wind machines. Though wind provides a somewhat intermittent source of power, electricity storage devices are not required to increase its economic attractiveness. As the EPRI report showed, the cost-effectiveness of storage depends on the overall nature of the utility system and its load. At the levels of wind penetrationconsidered here, the attractiveness of WECS is fairly insensitive to the level of storage.

These substantial estimates of the wind power potential contrast with the capacity figures mentioned by the New England Power Pool (NEPOOL). NEPOOL estimates that the maximum potential for wind power by 2000 is but 71.2 mw, even though NEPOOL's capital cost figures for wind machines of $856/kw to $1177/kw indicate that wind energy at a site with an average wind speed of 15 mph or greater would fall below 9.3¢/kwh, and thus meet our cost criterion.

Municipal Solid Waste (MSW). MSW can provide fuel for electric generation in one of three ways. A refuse-derived fuel (RDF) can be burned by the utility, usually along with existing fuels; a utility can contract to purchase steam for use in an existing station from a facility that burns raw or processed MSW; or, a facility specifically designed to generate electricity from waste combustion can be constructed. In any case, the maximum potential of the resource can be estimated on the basis of the available waste steam.

The economics of a MSW facility are described by an output price in ¢/kwh (or $/MMBtu) of steam and a "tipping fee" (in $/ton refuse) paid by the waste supplier. For a given technical configuration, the output price can be lowered by raising the tipping fee, and vice-versa. To be cost effective, a facility must produce energy at a cost competitive with oil, while charging a tipping fee that is competitive with disposal costs. As noted above, electricity from oil is expected to cost 6¢ to 8¢/kwh (1980 $) in 1990.

This is based on an oil cost of $5 to $6.75/MMBtu, so refuse derived fuels would have to be priced in that range to be competitive. An equivalent price, assuming 85 percent combustion efficiency, is $7 to $9 per MMBtu. The tipping fee that would be low enough to attract a steady MSW stream will be highly dependent on local disposal practices. Our review found that recovery of energy from MSW is cost-effective where sufficient waste exists, even with relatively low tipping fees.

In the U.S. at the present time, interest in MSW is focussed principally on large (>1000 tons/day) plants. Such plants are only feasible in metropolitan areas, since they require waste from about 500,000 people and transportation of MSW any great distance is not economical. Smaller plants (100-450 tons/day) are common in Europe, and could presumably be built here if they were economically justified. Construction began last fall on a 150 tpd plant in Auburn, Maine, designed to produce steam for local industry to be sold at a price indexed to the price of oil. The plant is expected to cost $3.2 million, with an initial tipping fee of $8.50/ton.

The best estimates of energy available from MSW in numerous specific New England cities and towns remain those developed in a Brookhaven National Laboratory study of 11 years ago. By analyzing that study in the context of the current situation and likely cost trends in the region as a whole, we developed a regionwide estimate of at least 1200 mw of potential electric generation capacity.

Conventional Hydropower. Technically feasible sites for new conventional hydro-electric generation capacity exist in New England. The U.S. Corps of Engineers has identified 17 major sites with a total potential for 975 mw and 2020 gwh/year. These totals do not include the controversial Dickey-Lincoln School project in Maine; that could add 760 mw and 1540 gwh/year. However, the Corps has established favorable benefit/cost ratios for less than half this capacity, with the remainder having ratios in the range of 0.8 to 1. While the 1979/1980 oil price increases since the U.S.A.C.E. report we consulted may have pushed all this capacity over the economic justification threshold, it is also quite likely that all these sites would be subject to severe environmental, land use, and water use conflicts.

Small Scale Hydropower. Much attention has been focussed on the potential for hydroelectric power at small dam sites in New England. In January, 1980, the New England River Basin Commission published a final Report based on its three-year investigation of this potential. Carried out in conjunction with the U.S.A.C.E., the study involved detailed engineering and economic analysis of the approximately 1,750 New England dams that do not now produce power. This report showed that, while the maximum economic potential is much less than the technically feasible potential, there exists significant potential that is already economical.

The economic potential was detailed in Report IV. Depending on the required rate of return on the investment, approximately 500 mw of capacity in New England is cost-effective by our criterion, assuming the rate of return required for private investment. If the rate of return requirement were reduced through public ownership, the potential capacity would be some 700 mw.

Tidal Power. The technology for the generation of electricity from tidal action is similar to that used for hydroelectric generation, except that the direction of flow reverses with the tidal cycle, and the equipment must be designed to withstand the corrosive effects of salt water. Tidal variations on the order of 15 feet, which are generally considered necessary for tidal power generation, do occur along the upper Maine coast. Cost estimates for power produced from tidal projects in Maine range from about 7 to 8.5¢/kwh. If realized, these costs would be cost-effective by our criteria. The maximum potential for tidal power in New England is some 1200 mw. This potential consists of the Cobscook Bay area and other sites along Maine's upper coast. Development of these projects would require resolution of potential environmental conflicts.

Wood. The wood resources in New England could provide the basis for the development of the wood-electricity option in the region. Existing technology derives steam suitable for electrical generation from the combustion of green wood chips in a spreader-stoker boiler. A 17 mw wood-fired power plant is currently operated by the Burlington (Vermont) Electric Department, and planning is underway for a 50 mw facility expected to come into service November 1983. The planned facility will produce electricity at an estimated 9 to 11¢/kwh. A facility of this size requires a very large and steady supply of wood -- about 60 to 70 truckloads per day for the 50 mw plant. Since there are several competing uses for the region's forest and wood resources, it is not at this time certain that the development of a number of such facilities would entail an efficient use of these resources. Thus, the cost-benefit criterion for the development of this resource would ultimately require a more extended set of comparisons and analyses than a direct comparison with oil costs.

Other Supply Options

There are other technologies and primary energy sources that could be used to provide electricity in the New England region as part of an oil conserving strategy. Their exclusion from the foregoing discussion should not imply that they will not be viable energy supply options in the coming decades. Rather, it represents a judgement that the technologies discussed above have a sufficiently higher chance to achieve commercial status to merit priority attention. The second group of supply options are discussed briefly below.

Solar Generation. Electricity can be generated in two ways using solar radiation as the primary energy source. The direct heat of the sun can be used, with appropriate collecting and concentrating equipment, to produce steam to drive a conventional turbine generator. This is generally referred to as a solar thermal electric system because solar radiation can also produce electricity by striking arrays of photovoltaic cells fabricated from certain semiconductor materials. Because solar thermal electric systems have not yet been demonstrated commercially, it cannot be considered likely that they will be feasible until after 1990. The technical feasibility of photovoltaic electric generation has been established; the costs, though falling, remain very high.

Ocean Power. In addition to tidal power as discussed above, the possibility of generating electricity from wave action and ocean thermal gradients has received attention in the energy literature. Ocean thermal and wave energy are still at the early stage of development, and it is unlikely that the waters near New England would have sufficient temperature gradient or adequate wave energy characteristics for these sources to be suitable even if they do become technically feasible.

District Heating. District heating is a form of central-station cogeneration that reduces oil use per kwh of electricity generated due to the concurrent production of thermal energy for heating (or cooling) building complexes or neighborhoods. It does not fall within our criterion of an alternative technology, since it does not ordinarily utilize renewable resources. Nevertheless it is a promising method of increasing the efficiency of energy production. The economics of district heating are favorable due to the high cost of space heating in New England. Any city in New England that has conventional power plants situated in or around the city could probably be economically served by a district heating system at least for part of its heating requirement.

5. ASSESSING THE ECONOMIC AND EMPLOYMENT RAMIFICATIONS OF RESIDENTIAL ENERGY CONSERVATION

5.1 Approach

Regional input-output (I/O) analysis is one method of tracing the economic effects of a change in the level of activity in one industry upon the other industries with which it is associated in a regional economy. A given increase in the demand for storm windows, for example, increases in varying degrees the demand for materials and labor in all the industries involved in the chain of production leading to the fabrication of this final commodity. The spending of wages earned through this chain further spreads the effects of the change in demand through the economy.

In the current study, use of a regional I/O approach permits a complete analysis of the direct and indirect effects of specific increases in the demand for residential energy conservation goods and services.

In order to perform an I/O analysis, a regional input-output table or its equivalent is required. Regional Industrial Multipliers (RIMS) have been developed by the Bureau of Economic Analysis of the U.S. Department of Commerce. RIMS for the New England states were incorporated as one of the four major elements in the computerized employment model used for this analysis.

The employment impact analysis described in Report V is linked directly to the forecasting results described in Reports I and II. There, base and conservation case forecasts were developed for each of the New England states. Because the forecasts are end-use based, the implementation of conservation measures which impact residential consumption can be linked directly to changes in end-use consumption. For example, the conservation scenario embodies increases in the installation rate of storm windows relative to the Base Case. (In the forecast model, this is a factor in reducing the energy demand for space heating.) Comparing the base and conservation forecasts allows the identification of the annual number of added storm windows and the associated energy savings. Monetary savings which result will have a local employment impact through increased spending. Based upon this information, the model computes the economic consequences of additional demand for this number of storm windows. Analogous procedures for all conservation measures provides a stream of disaggregated conservation implementations. The I/O analysis is performed on a measure-by-measure basis, taking into account the number of yearly applications of each measure required to account for the differences between Base and Conservation Case forecasts.

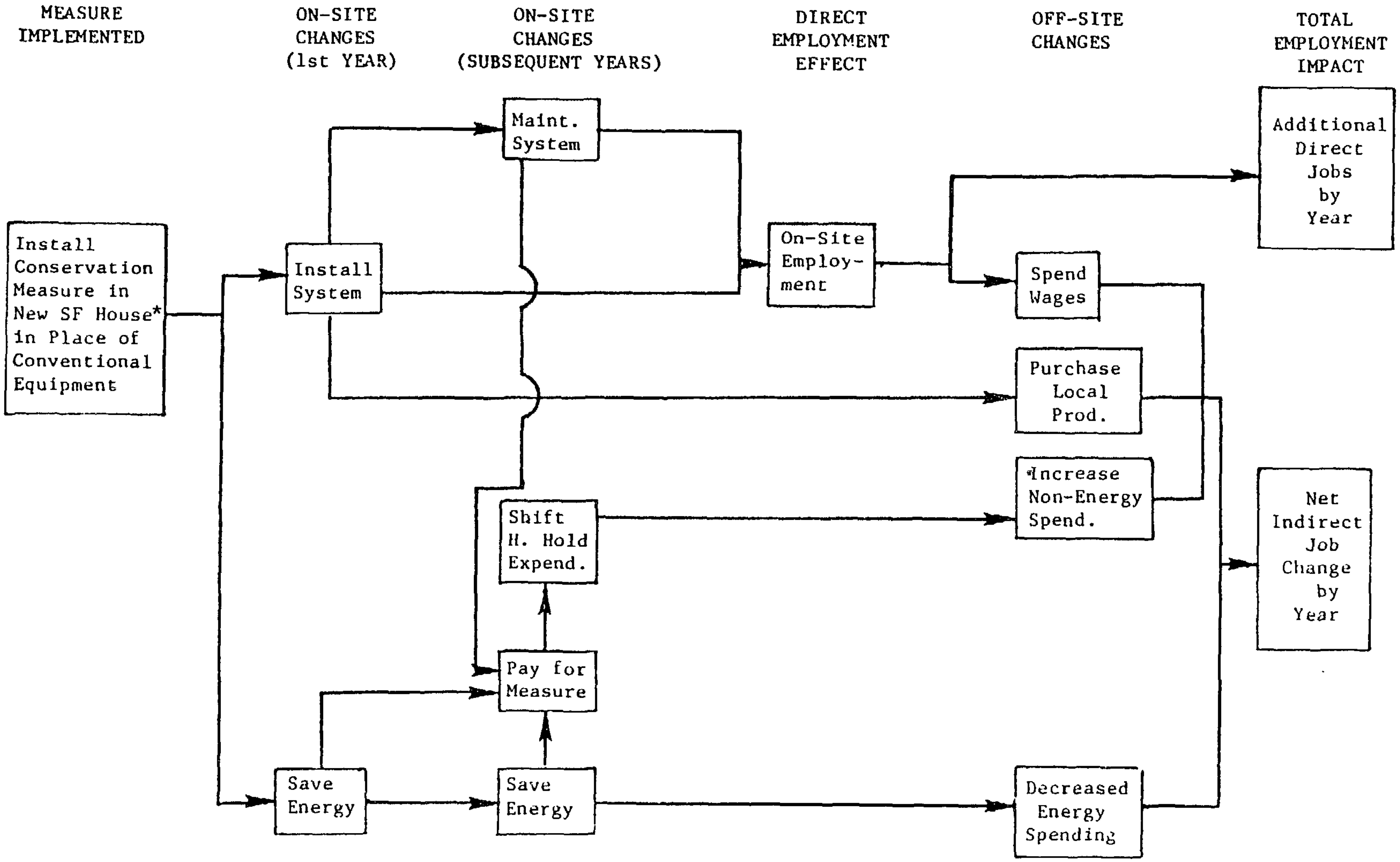
To analyze the economic consequences of an individual conservation measure, such as the addition of a storm window, it is necessary to specify labor and material requirements. ESRG has developed a data base containing such information. In the course of the current project, this data has been expanded and adjusted to reflect New England conditions. This provides a key input to the ESRG model computations. Separate data exist on measures for new vs. existing and single vs. multifamily dwellings where appropriate. The employment model receives the input data on the labor and materials required for each measure, as well as the number of applications of each measure. Based on this input data, as well as the RIMS multipliers mentioned earlier, the model estimates the changes in regional economic activity necessary to meet the demands due to the yearly installation of the assumed number of conservation measures. There are a number of distinct effects upon the regional economy. These include:

- On-site employment required to install the measures.
- Demand for materials on regional sales activity.
- Spending of wages of on-site workers on regional sales.
- Decreased energy consumption on regional energy sales.
- Indirect effects of all of the above throughout the regional economy.

Aggregation of these effects yields a profile of the impact of incremental conservation investment by state and by type of employment impact.

In Figure 5, we trace the steps involved in computing the direct and indirect economic effects of investment in the additional conservation. The installation ("measure implemented") of a conservation measure triggers a series of economic responses. In addition to the labor involved in installation, there is maintenance for certain measures. Installation and maintenance activity together constitute the "on-site" employment due to the installation of the measure. The on-site employment leads to the first off-site effect: the spending of wages which are paid to workers engaged in the installation and maintenance of the measure. This is shown in the "off-site changes" column of the diagram. Two other off-site effects are also shown. The

FIGURE 5
THE EMPLOYMENT EFFECTS OF
ONE CONSERVATION MEASURE APPLICATION



* Or any other appropriate unit as shown in Table 12.

first is the purchase of locally produced materials. Here are also included any appropriate wholesale, retail, or transportation activity associated with goods produced outside the region.

Next is shown the increases due to non-energy spending. This is the most important effect of conservation. Many conservation measures pay for themselves quite rapidly and have a useful life far beyond the period needed to repay the cost of the installation. In our analysis, we assume that consumer expenditures measures are "repaid" out of savings due to decreased energy consumption. Energy savings eventually pay for the measure, as indicated in the diagram. Once the measure is paid for, the continued savings are shifted to general household expenditures, through which they increase non-energy spending within the economy. This "responding effect" provides the largest increase in local employment among the various direct and indirect effects.

In addition to the sources of increased employment, there is one major source of decreased employment. The decreased demand for energy caused by the conservation measures leads to decreased economic activity in the energy producing sectors. These include the electric and gas utilities and the petroleum industry. Decreased demand here is translated into overall employment reductions in a manner analogous to that discussed above. Associated indirect effects are taken into account here, as in the rest of our analysis.

5.2 Results

The residential sector shift from the Base Case to the Conservation Strategy scenario produces substantial overall regional employment gains. These are the product of an overall increase in regional economic activity as a result of conservation investment. There are two dimensions to this.

First, the regional commitment to conservation produces on-site employment (e.g., storm window installation). Second, there are indirect, "off-site" effects. Here, while reduced energy expenditure does reduce regional energy-related employment, measure implementation and the "respending" of associated savings increase conservation-related employment. The latter effect overshadows the former.

As explained above and shown in Figure 5, there are three different ways in which the effects of on-site conservation-related activity are linked to the local economy. The three are: (1) through the demand for materials purchased locally and through the spending wages to on-site workers, (2) through decreased consumption of local energy services, and (3) through shifts in household income and thereby spending, made possible by the re-allocation of savings from decreased energy expenditures. Table 6 presents the total employment impact by state disaggregated according to these different effects. Also presented are the total direct employment on-site as well as the overall total employment.

An examination of Table 6 shows that indirect employment (that is, employment off-site) gives the bulk of the impact in each of the states. Further, it is clear that this employment is a composite of competing effects. Purchase of materials and the spending of wages and the effect of shifts in disposable income tend to increase local employment, while decreased spending for energy tends to decrease employment. It is particularly interesting to compare the decrease in employment due to fuel savings with the increase due to the shift in funds associated with these savings. Despite the fact that the spending of energy savings only commences after the original capital investment in conservation is paid for, the results show that the net effect of this shift is to strongly increase regional employment.

TABLE 6

TOTAL EMPLOYMENT IMPACT DISAGGREGATED BY ECONOMIC EFFECT OF CONSERVATION, 1978-2000

	ME	NH	VT	MA	RI	CT	NEW ENGLAND
On-Site	7,492	6,910	3,382	26,521	4,332	15,903	64,540
Indirect Employment Due To:							
Labor and Materials Purchases	14,490	15,171	6,248	69,356	9,266	33,718	148,249
Reduced Energy Expenditures	-39,468	-39,418	-16,613	-174,828	-24,500	-80,875	-375,702
Consumer Spending of Energy Savings	51,736	51,614	22,159	235,062	31,988	105,589	498,148
Sub-Total Indirect Employment	26,757	27,366	11,794	129,590	16,753	58,433	270,693
Total Employment	34,249	34,276	15,176	156,111	21,085	74,336	335,233

The yearly impacts of each of the basic employment factors for New England as a whole are given in Table 7. Here, as in Table 6, labor and materials impacts, together with on-site employment, are dominant in the early years. However, by the mid-point in the study period, they are overtaken by the effects of respending.

TABLE 7

TOTAL ANNUAL EMPLOYMENT IN NEW ENGLAND
DISAGGREGATED BY ECONOMIC EFFECTS OF CONSERVATION

	1983	1988	1993	1998	TOTAL
On-Site	1,534	4,440	3,703	3,245	64,540
Indirect Employment Due To:					
Labor and Material Purchases	4,002	9,207	8,383	8,591	148,249
Reduced Energy Expenditures	-2,005	-12,667	-24,039	-35,471	-375,702
Consumer Spending of Energy Savings	1,721	14,836	31,353	50,888	498,148
Sub-Total Indirect Employment	3,718	11,376	15,697	24,008	270,693
Total Employment	5,251	15,815	19,402	27,252	335,233

The details of this pattern are related to the assumption that all savings are credited toward the cost of a conservation measure until that measure is paid off. Once the measure is "paid off," these savings are treated as additional disposable income, to be spent or saved following the general pattern of residential consumers.

From the standpoint of regional employment-creation, investment in conservation is very efficient. In Table 8, yearly employment per million dollars of total investment and per million dollars of local economic activity is given. The latter is a measure of the fraction of the expenditures on conservation which remain in the local economy. Thus, for example, if the measure under consideration were insulation, the local spending would include the portion of the total cost of the measure associated with local and some inter-regional transportation, wholesale and retail, together with any on-site labor costs involved in its installation. However, if the insulation were manufactured outside New England, no manufacturing costs would affect the local economy. The data in Table 8 shows that approximately 52 percent of the total investment in conservation leads to local economic activity and thus to local employment. Despite the fact that some investment "leaks" out of the region, comparison with other expenditures, such as power plant construction, shows that investment in conservation creates more employment per dollar invested than do most alternatives.

TABLE 8

EMPLOYMENT PER MILLION DOLLARS
OF CONSERVATION INVESTMENT BY STATE

	ME	NH	VT	MA	RI	CT	TOTAL N. E.
Total Employment	34,249	34,276	15,176	156,111	21,085	74,336	335,233
Total Investment, 10^6 $	680	659	335	2,558	413	1,630	6,275
Employment Per 10^6 $ Invested	50.4	52.0	45.3	61.0	51.1	45.6	53.4
Local Spending, 10^6 $	404	414	180	1,480	236	929	3,643
Employment Per 10^6 $ Spent Locally	84.8	82.8	84.3	105.5	89.3	80.0	92.0

The total cumulative costs of conservation investment, which reach some $6.3 billion by the end of the century, are far outstripped by the stream of energy savings. During the first few years, costs exceed savings. After 1985, cumulative savings already outstrip cumulative costs. The costs of implementing and maintaining conservation measures then remain relatively constant while savings continue to mount (see Table 9). After 25 years, total cumulative savings are some $17.7 billion. The "investment" figures do not include any finance charges, and the "savings" figures do not include the tax credits for which residents qualify under existing law.

TABLE 9

YEARLY CONSERVATION INVESTMENT AND ENERGY SAVINGS IN NEW ENGLAND

(10^6 1980$)
1978 - 2000

	1978	1983	1988	1993	1998	TOTAL
Total Investment	0	161	379	366	368	6,276
Energy Savings	0	91	617	1,129	1,641	17,675

Of course, these data represent only the direct economic trade-offs. The primary purpose of the analysis described in this section has been to demonstrate the importance of also consideringthe indirect and employment impacts of alternative energy strategies.

ESRG 79-29/1
Draft Report

REDUCING NEW ENGLAND'S OIL DEPENDENCE THROUGH CONSERVATION AND ALTERNATIVE ENERGY

TECHNICAL REPORT I

BENCHMARK FORECASTS OF ELECTRIC ENERGY AND PEAK DEMAND FOR THE NEW ENGLAND STATES

A Report to the
General Accounting Office
of the
United States Congress

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David R. McAnulty

April, 1980

ENERGY SYSTEMS RESEARCH GROUP, INC.
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1. INTRODUCTION

At the request of the United States General Accounting Office, ESRG is investigating the potential for oil-use reduction in New England over the next two decades. Two broad areas are under quantitative assessment: 1) conservation and 2) alternative supply options. Those conservation measures which affect the level of electricity consumption are particularly important in New England where a large fraction of electric generation is from oil-fired power plants (57% in 1978).

The identification and quantification of electricity conservation measures is the subject of a companion volume. The object of this volume is to develop "business-as-usual" estimates (hereafter, Base Case) of the growth in electric energy requirements and peak power demands for each of the six New England states. These forecasts provide benchmark growth levels in order to provide a basis for detailing the impacts of a sharp increase in emphasis on conservation policy in New England. Conservation trends, policies, and regulations firmly in place already, of course, form part of the Base Case scenario structure. It should be emphasized that while ESRG considers the Base Case New England forecasts to be reliable approximations to future growth, they are not intended as alternative demand forecasts for Base Case electric system planning purposes. Their function lies elsewhere: the estimation of reasonable breakdowns of future electricity consumption by end-use in order to provide a basis for quantifying conservation impact potential.

Aggregate Base Case statewide electric energy and peak load forecasts are presented along with sales forecasts by major demand sectors in Table 1.1 (by state) and 1.2 (New England total) below. The Base Case is constructed as the mean of High/Low forecast bands which are presented in Appendix A in aggregate form. It should be stressed that the three forecasts -- Base, High, Low -- all refer to the non-conservation scenario; they are designed to bracket forecast uncertainty only under "business-as-usual" conditions. Table 1.3 translates the Base Case forecasts for energy and peak into growth rates, giving the High and Low Cases for comparison. Forecast decompositions by end-use component are presented in Appendix B.

Sections two through seven of this volume describe in detail the conceptual basis and mathematical structure of the forecasting model. Data and assumptions relied upon in driving the model is the subject of Sec. 8.

TABLE 1.1
(Continued)

ESRG BASE CASE FORECASTS OF ENERGY AND PEAK FOR NEW ENGLAND STATES

BASE CASE
NH

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	2456.	1771.	1523.	625.	6376.	991.	1203.
1979	2570.	1810.	1600.	650.	6630.	1030.	1260.
1980	2690.	1840.	1670.	670.	6870.	1060.	1310.
1981	2790.	1870.	1740.	700.	7100.	1090.	1370.
1982	2890.	1910.	1810.	720.	7330.	1120.	1420.
1983	2980.	1940.	1890.	740.	7550.	1150.	1470.
1984	3070.	1980.	1960.	760.	7770.	1180.	1520.
1985	3160.	2010.	2030.	790.	7990.	1210.	1570.
1986	3250.	2060.	2120.	810.	8240.	1250.	1630.
1987	3350.	2100.	2210.	840.	8500.	1280.	1690.
1988	3440.	2150.	2310.	860.	8760.	1320.	1740.
1989	3530.	2200.	2400.	890.	9020.	1350.	1800.
1990	3620.	2250.	2490.	920.	9280.	1390.	1860.
1991	3670.	2300.	2580.	940.	9490.	1420.	1900.
1992	3710.	2340.	2680.	960.	9700.	1450.	1940.
1993	3760.	2390.	2770.	980.	9910.	1480.	1980.
1994	3800.	2440.	2870.	1010.	10120.	1510.	2020.
1995	3850.	2490.	2960.	1030.	10320.	1540.	2060.
1996	3890.	2540.	3050.	1050.	10530.	1560.	2100.
1997	3930.	2590.	3150.	1070.	10740.	1590.	2140.
1998	3970.	2630.	3240.	1100.	10950.	1620.	2180.
1999	4020.	2680.	3340.	1120.	11160.	1650.	2220.
2000	4060.	2730.	3430.	1140.	11370.	1680.	2260.

BASE CASE
RI

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	1820.	1603.	1379.	513.	5315.	972.	973.
1979	1860.	1610.	1430.	520.	5420.	990.	990.
1980	1890.	1620.	1490.	530.	5520.	1010.	1020.
1981	1930.	1620.	1540.	530.	5620.	1020.	1040.
1982	1960.	1630.	1600.	540.	5720.	1040.	1060.
1983	1990.	1630.	1650.	550.	5820.	1050.	1080.
1984	2010.	1640.	1700.	550.	5910.	1070.	1100.
1985	2040.	1650.	1760.	560.	6000.	1080.	1120.
1986	2070.	1660.	1820.	560.	6110.	1100.	1140.
1987	2100.	1670.	1870.	570.	6210.	1120.	1170.
1988	2130.	1680.	1930.	580.	6320.	1130.	1190.
1989	2160.	1690.	1990.	580.	6420.	1150.	1210.
1990	2180.	1700.	2050.	590.	6530.	1160.	1230.
1991	2190.	1720.	2110.	600.	6610.	1180.	1250.
1992	2200.	1730.	2160.	600.	6690.	1190.	1260.
1993	2210.	1740.	2220.	610.	6780.	1200.	1280.
1994	2210.	1750.	2280.	610.	6860.	1220.	1290.
1995	2220.	1760.	2340.	620.	6940.	1230.	1310.
1996	2230.	1770.	2400.	620.	7020.	1240.	1320.
1997	2240.	1780.	2460.	630.	7110.	1260.	1340.
1998	2240.	1790.	2520.	630.	7190.	1270.	1350.
1999	2250.	1810.	2580.	640.	7280.	1280.	1370.
2000	2260.	1820.	2640.	650.	7370.	1300.	1380.

BASE CASE
VERMONT

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	1597.	1002.	760.	401.	3760.	572.	765.
1979	1650.	1020.	800.	410.	3880.	590.	790.
1980	1700.	1040.	850.	420.	4000.	610.	820.
1981	1750.	1050.	890.	430.	4130.	620.	850.
1982	1800.	1070.	940.	440.	4240.	640.	880.
1983	1850.	1080.	980.	450.	4360.	650.	910.
1984	1890.	1100.	1030.	450.	4480.	670.	940.
1985	1940.	1120.	1070.	460.	4590.	690.	970.
1986	1990.	1130.	1130.	470.	4730.	700.	1010.
1987	2050.	1140.	1190.	480.	4860.	720.	1040.
1988	2100.	1160.	1250.	490.	5000.	740.	1070.
1989	2150.	1170.	1310.	500.	5140.	760.	1110.
1990	2210.	1180.	1370.	510.	5280.	780.	1140.
1991	2240.	1200.	1430.	520.	5390.	790.	1160.
1992	2260.	1210.	1490.	530.	5500.	810.	1190.
1993	2290.	1220.	1560.	540.	5610.	820.	1210.
1994	2320.	1240.	1620.	540.	5720.	840.	1230.
1995	2340.	1250.	1680.	550.	5830.	850.	1250.
1996	2370.	1260.	1740.	560.	5940.	870.	1270.
1997	2390.	1280.	1810.	570.	6050.	880.	1300.
1998	2420.	1290.	1870.	580.	6160.	900.	1320.
1999	2450.	1300.	1930.	590.	6270.	910.	1340.
2000	2480.	1320.	2000.	600.	6390.	930.	1360.

TABLE 1.1

ESRG BASE CASE FORECASTS OF ENERGY AND PEAK FOR NEW ENGLAND STATES

BASE CASE CONN	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	8154.	6495.	5975.	1710.	22334.	4021.	4052.
1979	8360.	6570.	6130.	1750.	22800.	4110.	4140.
1980	8550.	6640.	6270.	1780.	23250.	4190.	4230.
1981	8750.	6710.	6420.	1810.	23690.	4270.	4320.
1982	8920.	6780.	6560.	1850.	24110.	4340.	4410.
1983	9080.	6850.	6710.	1880.	24520.	4410.	4490.
1984	9230.	6920.	6840.	1910.	24910.	4470.	4570.
1985	9380.	6990.	6980.	1940.	25290.	4540.	4650.
1986	9540.	7050.	7190.	1980.	25750.	4610.	4750.
1987	9700.	7110.	7390.	2010.	26210.	4690.	4840.
1988	9860.	7170.	7590.	2050.	26670.	4760.	4930.
1989	10020.	7230.	7790.	2090.	27130.	4840.	5030.
1990	10180.	7290.	8000.	2120.	27590.	4910.	5120.
1991	10230.	7350.	8200.	2150.	27920.	4970.	5180.
1992	10270.	7410.	8400.	2180.	28260.	5020.	5230.
1993	10310.	7470.	8600.	2210.	28590.	5070.	5290.
1994	10360.	7530.	8790.	2240.	28920.	5120.	5350.
1995	10400.	7590.	8990.	2270.	29250.	5170.	5400.
1996	10440.	7650.	9190.	2290.	29570.	5220.	5460.
1997	10480.	7710.	9390.	2320.	29900.	5270.	5510.
1998	10520.	7770.	9580.	2350.	30220.	5320.	5570.
1999	10560.	7830.	9780.	2380.	30550.	5370.	5620.
2000	10610.	7890.	9970.	2410.	30880.	5420.	5680.

BASE CASE MASS	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	11756.	11202.	8464.	3100.	34522.	6286.	6431.
1979	12020.	11250.	8650.	3160.	35080.	6380.	6550.
1980	12260.	11300.	8840.	3220.	35620.	6460.	6670.
1981	12520.	11340.	9030.	3280.	36170.	6540.	6800.
1982	12750.	11390.	9220.	3340.	36700.	6620.	6920.
1983	12980.	11430.	9400.	3400.	37210.	6700.	7040.
1984	13190.	11480.	9590.	3460.	37710.	6780.	7160.
1985	13390.	11520.	9770.	3510.	38200.	6850.	7270.
1986	13610.	11620.	9970.	3580.	38770.	6940.	7400.
1987	13840.	11710.	10160.	3640.	39340.	7030.	7530.
1988	14060.	11800.	10350.	3700.	39920.	7120.	7660.
1989	14290.	11900.	10540.	3770.	40500.	7210.	7790.
1990	14510.	11990.	10730.	3840.	41070.	7290.	7920.
1991	14580.	12080.	10920.	3900.	41490.	7360.	8000.
1992	14660.	12180.	11120.	3960.	41910.	7430.	8080.
1993	14730.	12270.	11310.	4020.	42330.	7490.	8150.
1994	14800.	12360.	11500.	4080.	42740.	7560.	8230.
1995	14870.	12450.	11690.	4140.	43160.	7630.	8310.
1996	14940.	12550.	11880.	4200.	43570.	7690.	8390.
1997	15010.	12640.	12070.	4260.	43980.	7760.	8460.
1998	15070.	12730.	12270.	4320.	44400.	7820.	8540.
1999	15150.	12830.	12460.	4380.	44820.	7890.	8620.
2000	15240.	12920.	12650.	4440.	45250.	7960.	8700.

BASE CASE MAINE	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	3014.	2014.	2460.	735.	8223.	1231.	1540.
1979	3110.	2020.	2560.	750.	8440.	1260.	1590.
1980	3190.	2030.	2660.	760.	8650.	1290.	1640.
1981	3280.	2040.	2750.	770.	8860.	1320.	1690.
1982	3370.	2050.	2850.	790.	9060.	1350.	1740.
1983	3450.	2060.	2950.	800.	9270.	1370.	1790.
1984	3530.	2070.	3050.	810.	9470.	1400.	1840.
1985	3610.	2080.	3150.	830.	9670.	1430.	1890.
1986	3700.	2100.	3270.	840.	9920.	1460.	1950.
1987	3790.	2120.	3390.	860.	10160.	1490.	2000.
1988	3870.	2150.	3520.	870.	10410.	1530.	2060.
1989	3960.	2170.	3640.	890.	10660.	1560.	2120.
1990	4060.	2190.	3760.	910.	10910.	1590.	2180.
1991	4100.	2210.	3890.	920.	11120.	1620.	2220.
1992	4150.	2230.	4010.	930.	11320.	1650.	2260.
1993	4190.	2250.	4140.	940.	11530.	1680.	2300.
1994	4230.	2270.	4270.	960.	11730.	1700.	2340.
1995	4280.	2300.	4390.	970.	11940.	1730.	2380.
1996	4320.	2320.	4520.	980.	12150.	1760.	2420.
1997	4370.	2340.	4650.	1000.	12360.	1790.	2460.
1998	4410.	2360.	4780.	1010.	12560.	1810.	2500.
1999	4460.	2380.	4910.	1020.	12770.	1840.	2540.
2000	4510.	2400.	5050.	1040.	12990.	1870.	2580.

TABLE 1.2

ESRG AGGREGATE FORECAST OF ENERGY AND PEAK IN NEW ENGLAND

New England; Base Case

	Energy (GWH)	Non-Coincident Summer Peak (MW)	Non-Coincident Winter Peak (MW)
1978	80530	14073	14964
1983	88730	15330	16780
1988	97080	16600	18650
1993	104750	17740	20210
1998	111480	18740	21460

New England; High Case

	Energy (GWH)	Non-Coincident Summer Peak (MW)	Non-Coincident Winter Peak (MW)
1978	80530	14073	14964
1983	94390	16330	17950
1988	107730	18420	20910
1993	119620	20310	23380
1998	130370	22090	25500

New England; Low Case

	Energy (GWH)	Non-Coincident Summer Peak (MW)	Non-Coincident Winter Peak (MW)
1978	80530	14073	14964
1983	83050	14350	15610
1988	86420	14710	16300
1993	89860	15210	16940
1998	92580	15410	17420

TABLE 1.3

ESRG FORECAST GROWTH RATES FOR NEW ENGLAND

	CASE	1978	%/Yr. 1978-88	1988	%/Yr. 1988-98	1998
Annual Energy (GWH)	High	80,530	2.95	107,730	1.93	130,370
	Base	80,530	1.89	97,080	1.39	111,480
	Low	80,530	.71	86,420	.69	92,580
Non-coincident Summer Peak (MW)	High	14,073	2.73	18,420	1.83	22,090
	Base	14,073	1.67	16,600	1.22	18,740
	Low	14,073	.44	14,710	.47	15,410
Non-coincident Winter Peak (MW)	High	14,964	3.40	20,910	2.00	25,500
	Base	14,964	2.23	18,650	1.41	21,460
	Low	14,964	.86	16,300	.67	17,420

2. OVERVIEW OF FORECASTING APPROACH

This section is restricted to a broad description of the forecast model characteristics. The conceptual basis and mathematical structures of the model are described in subsequent sections.

The model forecasts are based on the aggregation of separate forecasts for the major end-use components comprising system demand. This allows for explicit incorporation of the impacts of differential end-use growth, energy policy, new technology and specific conservation practices. For example, appliance efficiency improvements are integrated indirectly into the appliance submodel rather than as approximate adjustments on gross energy requirements.

The energy consumption for a given component is given by the expression:

$$\text{Energy Consumption in End-Use Category} = \text{End-Use Measure} \times \text{Energy Intensity}$$

In other words, the energy consumption by end-use is the product of the quantity of the end-use ("End-Use Measure") and the annual average energy consumed per unit of the end-use ("Energy Intensity"). The measure of an end-use activity will be in units appropriate to the sector being modelled. These are summarized in Figure 2.1.

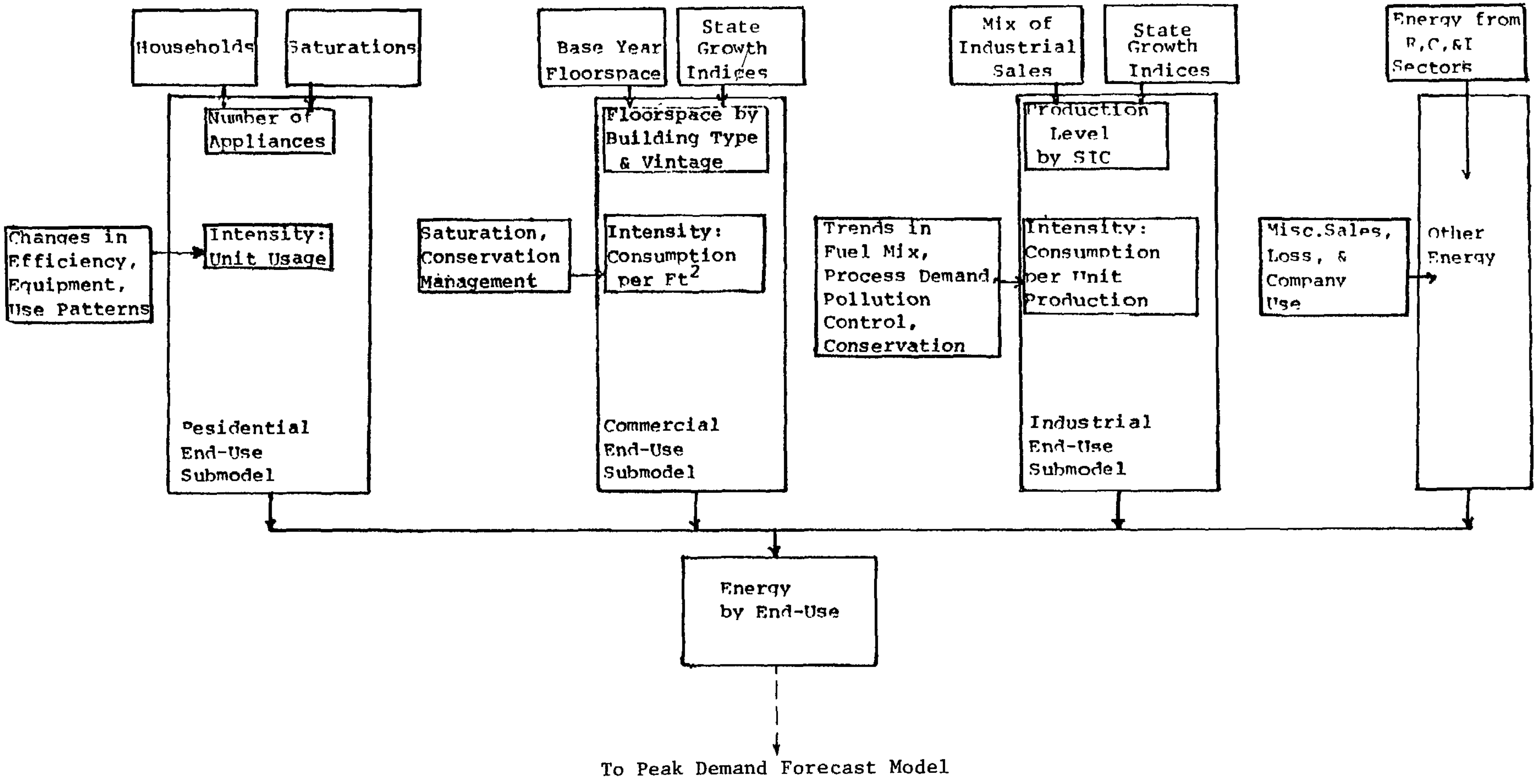
The forecasting technique consists of three fundamental steps: (1) analysis of base year energy-consuming stock in terms of average measure levels and intensities, (2) specification of growth in the end-use measures and (3) simulation of the factors affecting the intensity of unit energy use. The actual mathematical analogs chosen for energy consumption in the end-use models must be wedded to the specific character of the end-use category. Further, they must be constrained by limitations in available data. The computational procedures selected are discussed in detail in Sections 3 through 7.

The energy forecast model, schematized in Figure 2.2, is the heart of the system. It, in turn, is comprised of a series of submodels which produce forecasts of energy consumption disaggregated by end-use. These are summed to give annual energy and are input to the demand forecast model. The results for the utility are combined to output system energies and peaks. (Additionally, the energy forecasts broken down by end-use category may be outputted allowing for a clearer understanding of the structure of total consumption and sensitivity to specific assumptions.)

FIGURE 2.1
MODEL COMPONENTS

SECTOR	END-USE ACTIVITY	END-USE MEASURE	ENERGY INTENSITY
Residential	14 Appliance Categories 2 housing types	number of units	average annual consumption per unit
Commercial	5 building types 4 end-use categories 2 vintages (new & existing)	floorspace square footage	average annual consumption per square foot
Industrial	19 manufacturing subsectors	production units	average annual consumption per unit production

FIGURE 2.2
ENERGY FORECAST MODEL SCHEMATIC

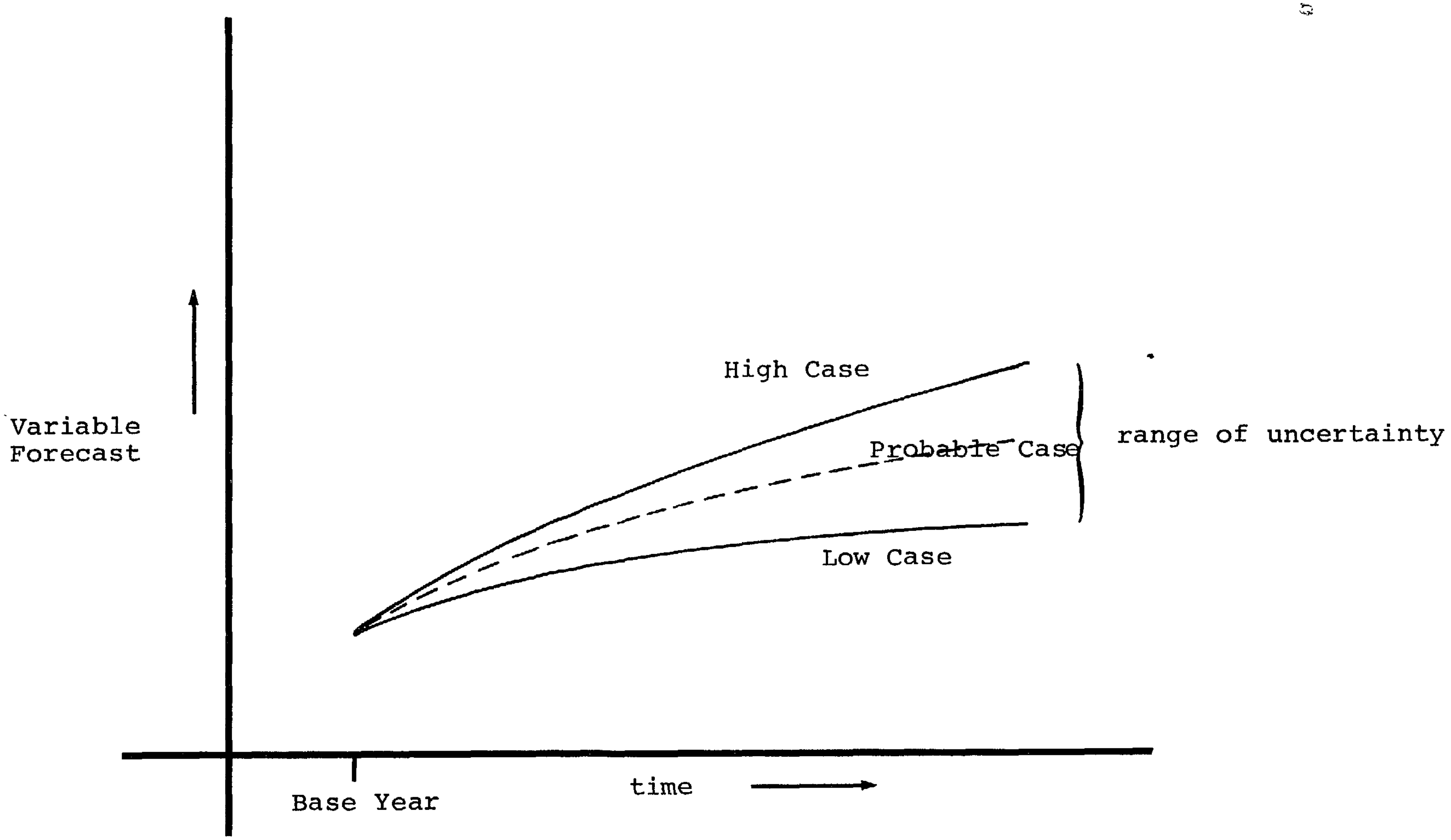


From one perspective, the model is a functional relationship between a set of independent variables (data file) and selected dependent variables (output forecasts). The computer program designed for executing this mapping accepts a user-selected data file and produces user-selected outputs. The inputs are of two types: (1) data which characterizes the actual base year experience of a given utility and (2) assumptions on future values of the independent variables which chart the changes in base year values. The first type of data is developed and updated from independent sources (utility surveys, industry load studies, census information, etc.). The second type of input defines a set of growth assumptions or "scenarios". Though one has guidelines for estimating the growth variables entering the submodels (historic patterns, independent national and state projections, policy impacts, market penetration analysis, etc.), uncertainty cannot be avoided.

This uncertainty is dealt with in the program in two ways. First, a range of growth variable values are automatically required in producing a forecast. The model is designed to accept from the outset the uncertainty in the driving variables identified by the user. The program operates from "high" and "low" data files associated with data choices for high and low cases, respectively. Though one cannot prophesize with certitude a given input item, one can with some confidence give a realistic range of possible future values. The high and low scenarios are designed to bracket the set of possible futures. The "probable" case is defined in the model as the mid-range forecast illustrated in Figure 2.3. The uncertainty in the input data set is reflected in the overall forecast uncertainty. The range of uncertainty, is, of course, an increasing function of time.

The second method for treating uncertainty is through sensitivity analysis. The program allows for temporary changes of an input item (or set of items), permitting tests of the response in forecast output to changes in data file input. The stability of output to specific input variations can be computed and utilized in assessing the validity of a given forecast.

Figure 2.3
Forecast Scenarios



3. RESIDENTIAL SECTOR

This section describes the electrical energy demand forecast model for the residential class of customers. The component end-uses of residential energy consumption are treated in fourteen separate submodels. This level of detail allows the incorporation of the central factors affecting overall demand which can be lost in methodologies which forecast aggregate demand alone.

The fourteen residential end-uses for which submodels have been developed are listed in Table 3.1.

TABLE 3.1
RESIDENTIAL END-USE SUBMODELS

Input	End-Use
1	Refrigerator
2	Freezer
3	Electric Range
4	Lighting
5	Television
6	Clothes Dryer
7	Clothes Washer
8	Dishwasher
9	Water Heater
10	Air Conditioning - Room
11	Air Conditioning - Central
12	Space Heat
13	Heating Auxiliaries
14	Miscellaneous

These submodels will be described later. At the most elementary level, annual consumption for end-use (i) in year (t) is given by the expression:

$$E_{t,i}=N_{t,i}\times C_{t,i} \tag{3.1}$$

where

$E_{t,i}$ = Total annual energy consumption of end-use (i) in year (t)

$N_{t,i}$ = Total number of corresponding units

$C_{t,i}$ = Average annual energy consumption per unit

Then the total energy consumption in the residential sector for year (t) becomes

$$\sum_i E_{t,i}$$

A glance at Equation 3.1 will show that the residential forecast for each end-use can be viewed as a combined forecast of the total number of units, on the one hand, and the average consumption per unit, on the other hand.

3.1 Number of Units

The number of units for a given end-use is computed as the product of the number of households and the end-use saturation, defined here as the average number of units per household. The number of household units is further divided into single family units (SF) and multifamily units (MF). This breakdown is desirable since appliance ownership and usage patterns may vary significantly by housing type. A shift in the mix of SF and MF in the forecast period thus affects ultimate demand.

3.2 Saturation Curves

Saturations enter the end-use submodels via the logistic growth curve. This curve has the general form:

$$SAT_{t,i,k} = \frac{C_{i,k}}{1+B_{i,k} \times e^{-(A_{i,k} \cdot T)}} \qquad (3.2)$$

for the saturation (SAT) of a given end-use (i), and housing type (k), in year (t). The parameters are constrained by:

$$B>0, \; A>0, \; 0<C<1. \qquad (3.3)$$

(The indices are suppressed for notational convenience.) (3.3)

Parameter C is called the ceiling, representing the asymptotic limit of the dependent variable; the greater the value of A, the more rapid is the approach to the ceiling. From the derivative

$$\frac{d\ SAT_t}{dt} = \frac{A}{C} \cdot SAT_t \cdot (C-SAT_t) \qquad (3.4)$$

we see that the growth rate is proportional to both the level already achieved and the increment remaining to the ceiling.

Ideally, the parameters would be estimated by fits to historic saturation data. The data, however, is not sufficient to warrant such a complete determination. Instead, we have used base year saturations (SBY) to determine one parameter, chosen values for the ceiling or terminal saturation (STERM) according to scenario assumptions, and used historic data to fit the remaining variable A.

Rewriting Equation 3.2 in terms of STERM and SBY and fixing the base year t=1 as we do throughout the model, we arrive at the form of the saturation curve as it enters the submodels:

$$\mathrm{SAT}_t = \frac{\mathrm{STERM}}{1 + \left(\frac{\mathrm{STERM-SBY}}{\mathrm{SBY}}\right) \times e^{-A \cdot (t-1)}} \qquad (3.5)$$ [*]

3.3 End-use Submodels

The second term in Equation 3.1, the average annual energy consumption for each end-use, incorporates a great deal of complexity. Once the base year energies are established, the time dependence of average energy consumption must be computed. The major factors which can impact average energy use are:

- appliance efficiency increases
- thermal integrity improvements of building shells
- new technology market penetration
- population per household decreases
- energy conservation practices induced by electricity price increases

The end-use submodels are designed to allow sensitivity to assumptions on these trends. Consequently, overall forecasts based on a range of reasonable input assumptions allow for the development of a band of possible error within which lies the "probable" forecast.

The submodels will be discussed in the sequence given in Table 3.1. In each case, we give a brief qualitative description in the text and the system of equations in an accompanying table. Although the end-uses have particular characteristics which require unique model elements, the overall strategy displayed schematically in Figure 3.1 is used throughout. The yearly increment in electrical energy consumption is calculated by (1) subtracting the energy consumption of retired units, (if any), (2) adding the energy consumption of replacements, and (3) adding the energy consumption of additonal new units due to customer and saturation growth. With this iteration technique, we can, once the base year breakdown is established, compute energy consumption for each year of the forecast under a given set of assumptions on changes in saturation, customer, technology mixes, efficiencies and use patterns.

3.3.1 Refrigerators and Freezers

The factors affecting demand for these two appliances are quite similar so that the same algorithm for modeling growth in energy consumption are employed. Variable definitions and dynamic equations are summarized in Table 3.2.

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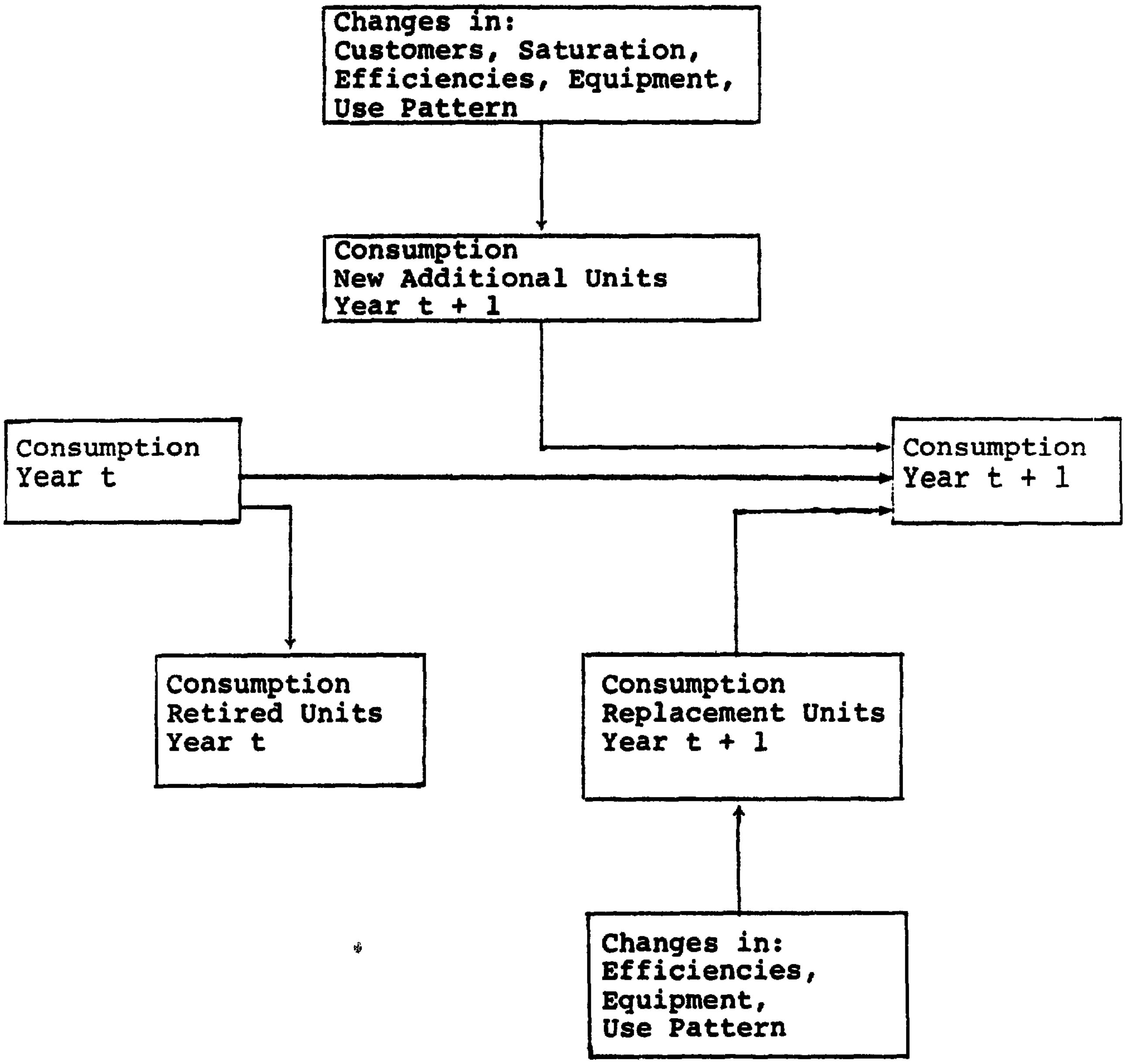
[*] In the case of decreasing saturations, the form of the curve is given by:

$$\mathrm{SAT} = \mathrm{STERM} + (\mathrm{SBY-STERM}) \times e^{-A(t-1)}$$

FIGURE 3.1

Schematic of Yearly Energy Increments by End-use



The total number of appliances by housing type is obtained by multiplication of saturation and households (Equation 3.6). The iteration procedure is initialized by computing base year consumption as the product of the number of appliances on-line in the base year and their average unit consumption (Equation 3.7). There is a great deal of variation in energy demand with brand, size and model. Therefore, average usage may vary as a function of regional appliance mix.

The iteration proceeds from year to year by subtracting out the energy consumption of retired units and adding back the energy from new units added (Equation 3.8). The retired energy is a product of the average number retired per year (the total number in the previous year divided by the average lifetime) times the average unit consumption of the retired units. This last factor must be treated with care; the 1960's saw an increase in the average size of refrigerators and freezers and a rapid penetration of the energy consuming frost-free feature. Therefore, units currently retired are from earlier, less energy consuming vintages (Equation 3.11).

New units, both replacements and net additions, are brought on-line at current energy levels (Equation 3.10), with new unit average usage according to the efficiency improvements and efficiency phase-in period assumed in a given model run (Equation 3.13).

TABLE 3.2
SUBMODEL FOR REFRIGERATORS AND FREEZERS

Variable Code

t	Year (base year = 1)
i	Appliance index (1=refrigerator and 2=freezer)
k	Housing type (SF=1 , MF=2)
TOTNUM	Total number of appliance
HSTOCK	Households
SAT	Saturation
UNNEW	Average unit usage of new appliance
UNAVBS	Average unit usage of base year stock
ALT	Average appliance lifetime
EFFIMP	Efficiency improvement over base year models
TEND	Final year of efficiency improvement phase-in
UNREP	Average unit usage of replaced units
UNOLD	UNREP for t≤ALT
NEWENI	Energy use of new units
RETENI	Energy use of retired units
ENREU	Annual appliance energy demand

Equations

Stock stream:

$$\mathrm{TOTNUM}_{t,k,i} = \mathrm{SAT}_{t,k,i} \times \mathrm{HSTOCK}_{t,k,i} \qquad (3.6)$$

Initialize:

$$\mathrm{ENREU}_{1,k,i} = \mathrm{TOTNUM}_{1,k,i} \times \mathrm{UNAVBS}_{k,i} \qquad (3.7)$$

Iterate for t>1:

$$\mathrm{ENREU}_{t,k,i} = \mathrm{ENREU}_{t-1,k,i} - \mathrm{RETENI}_{t,k,i} + \mathrm{NEWENI}_{t,k,i} \qquad (3.8)$$

where

$$\mathrm{RETENI}_{t,k,i} = \mathrm{UNREP}_{t,k,i} \times \mathrm{TOTNUM}_{t-1,k,i} / \mathrm{ALT}_i \qquad (3.9)$$

$$\mathrm{NEWENI}_{t,k,i} = (\mathrm{TOTNUM}_{t,k,i} - \mathrm{TOTNUM}_{t-1,k,i} + \mathrm{TOTNUM}_{t-1,k,i} / \mathrm{ALT}_i) \times \mathrm{UNNEW}_{t,i} \qquad (3.10)$$

and

$$\mathrm{UNREP}_{t,i} = \begin{cases} \mathrm{UNOLD}_{t,i} & t \leq \mathrm{ALT}_i \\ & \text{for} \\ \mathrm{UNNEW}_{t-\mathrm{ALT}_i} & t > \mathrm{ALT}_i \end{cases} \qquad (3.11)$$

$$\mathrm{UNNEW}_{t,i} = (1-\mathrm{EFFIMP}_t) \times \mathrm{UNNEW}_{1,i} \qquad (3.12)$$

$$\mathrm{EFFIMP}_{t,i} = \begin{cases} \left[(t-1) / (\mathrm{TEND}-1) \right] \times \mathrm{EFFIMT}_i & 1 < t \leq \mathrm{TEND} \\ & \text{for} \\ \mathrm{EFFIMT}_i & t > \mathrm{TEND} \end{cases} \qquad (3.13)$$

3.3.2 Electric Ranges

The determinants of growth for electric ranges are straightforward: saturation and customer increases, efficiency improvements in new appliances, and market penetration of the microwave oven feature which can decrease overall energy demand.

The total stock is given, as usual, as the product of saturation and housing stock (Equation 3.14). Further disaggregation by housing type is not necessary for this end-use since available saturation and energy demand data does not distinguish between single and multi-family usage patterns. The iteration process is initialized with base year data (Equation 3.15) and proceeds with the characteristic subtraction of retired units and addition of new units (Equation 3.16). Units are retired at a rate equal to the inverse of the average life time (Equation 3.17). The two sources of new units, net additions and replacements, are represented by the first and second terms of Equation 3.18, respectively. Average usage of new units is decremented by a factor derived from assumed efficiency targets and phase-in times (Equations 3.19 and 3.20).

Finally, account is taken of the decreased energy usage associated with microwave ovens used in association with electric ranges. The total energy demand is a weighted factor of usage without and with microwave ovens, the first and second terms, respectively, in Equation 3.21.

TABLE 3.3
SUBMODEL FOR ELECTRIC RANGES

Variable Code

t	Year (base year = 1)
TOTNUM	Total number
HSTOCK	Households
SAT	Saturation
ENREU1	Annual electric range energy demand w/o microwaves
ENREU	Annual electric range energy demand with microwaves
UNAVBS	Average usage base year stock
UNNEW	Average unit usage of new units
EFFIMP	Efficiency improvement
TEND	Final year of efficiency improvement phase-in
RETENI	Energy use of retired units
NEWENI	Energy use of new units
ALT	Average lifetime
MSAT	Microwave oven saturation as a fraction of electric ranges
EDF	Energy demand factor: ratio energy demand with and without microwave oven

Equations

Stock stream:

$$\mathrm{TOTNUM}_t = \mathrm{SAT}_t \times \mathrm{HSTOCK}_t \qquad (3.14)$$

Initialize:

$$\mathrm{ENREU1}_1 = \mathrm{TOTNUM}_1 \times \mathrm{HSTOCK}_1 \qquad (3.15)$$

Iterate for t>1:

$$\mathrm{ENREU1}_t = \mathrm{ENREU1}_{t-1} - \mathrm{RETENI}_t + \mathrm{NEWENI}_t \qquad (3.16)$$

where

$$\mathrm{RETENI}_t = \mathrm{ENREU1}_{t-1}/\mathrm{ALT} \qquad (3.17)$$

$$\mathrm{NEWENI}_t = (\mathrm{TOTNUM}_t - \mathrm{TOTNUM}_{t-1}) \times \mathrm{UNNEW}_t + \left(\mathrm{TOTNUM}_{t-1/\mathrm{ALT}}\right) \times \mathrm{UNNEW}_t \qquad (3.18)$$

and

$$\mathrm{UNNEW}_t = (1-\mathrm{EFFIMP}_t) \times \mathrm{UNAVBS} \qquad (3.19)$$

with

$$\mathrm{EFFIMP}_t = \begin{cases} \mathrm{EFFIMT} \times (t-1) / (\mathrm{TEND}-1) & \text{for } t<\mathrm{TEND} \\ \mathrm{EFFIMT} & \text{for } t\geq\mathrm{TEND} \end{cases} \qquad (3.20)$$

Microwave oven adjustment:

$$\mathrm{ENREU}_t = \mathrm{ENREU1}_t \times (1-\mathrm{MSAT}_t) + \mathrm{MSAT}_t \times \mathrm{EDF} \times \mathrm{ENREU1}_t \qquad (3.21)$$

3.3.3 Lighting

Lighting energy demand is represented as the product of average annual energy usage per household and the number of households (Equation 3.22). The household growth is developed outside the submodel and inputted to it. There remains the anticipated changes in lighting energy demand per household.

The model assumes that saturations are currently at 100%; i.e., all households have electric lighting and this shall remain true throughout the forecast period. However, the intensity of lighting use per household as well as the efficiency of conversion of electric to light energy has in the past, and may well in the future, vary with time. Future deviations from base year levels is taken into account by the usage factor (Equation 3.23).

In the past, several factors have contributed to increases in lighting energy demand per household: shift in housing mix toward larger SF residences, inexpensive electricity fostering purchase of decorative lighting and discouragement of household conservation practice. These trends have generally reversed: family size is gradually shrinking, MF dwellings are rising relative to SF, and rising electricity costs are encouraging conservation.

It appears likely that these shifting patterns will lead, at least to some extent, to the market penetration of energy efficient lightbulbs. These include improved incandescents and more fluorescents in the near term, followed possibly by commercialization of the screw-in fluorescent in the 1980's. Possible impacts of such technology shifts are incorporated in Equation 3.24.

TABLE 3.4
SUBMODEL FOR LIGHTING

Variable Code

t	Year (base year = 1)
HSTOCK	Households
UNAVBS	Average consumption per housing unit in the base year
UNAV	Average consumption per housing unit
UF	Usage factor
MF	Market fraction efficient bulbs
RELEFF	Efficiency improvement of nonconventional bulb
ENREU	Annual energy demand for lighting

Equations

$$\mathrm{ENREU}_t = \mathrm{UNAV}_t \times \mathrm{HSTOCK}_t \tag{3.22}$$

with

$$\mathrm{UNAV}_t = \mathrm{UF}_t \times \mathrm{UNAVBS} \tag{3.23}$$

with efficient bulb capturing market fraction:

$$\mathrm{UNAV}_t = (1-\mathrm{MF}_t) \times \mathrm{UNAVBS} + \mathrm{MF}_t \times (1-\mathrm{RELEFF}_t) \times \mathrm{UNAVBS}$$

or

$$\mathrm{UF}_t = 1-\mathrm{MF}_t \times \mathrm{RELEFF}_t \tag{3.24}$$

3.3.4 Television

The submodel for televison usage must contain sufficient complexity to allow for (1) saturation and customer growth, (2) changes in unit energy requirements, (3) changes in the mix of black and white and color televisions,and (4) decreased usage per unit in cases of multiple ownership. The last factor is due to the nonproportionality between the number of televisions and the viewing hours. That is, if, for instance, a family purchased a second television, the hours of use will not simply double since the redundant unit will be used to some extent in substitution for the first.

The dynamics of television energy demand growth are presented in Table 3.5. After defining the stock stream saturation and housing stock with inputs from outside the submodel (Equation 3.25), the iteration procedure is initialized with base year data (Equation 3.26) and proceeds from year-to-year in the usual way (Equations 3.27 to 3.31). Changing ratios of black and white to color are allowed in the weighted averages for new units in Equation 3.29. Finally, in the case of multiple average ownership, the total energy is decremented by a decreased use factor for second and third televisions (Equation 3.32).

TABLE 3.5
SUBMODEL FOR TELEVISIONS

Variable Code

t	Year (base year = 1)
k	Housing type
TOTNUM	Total number
HSTOCK	Housing units
SAT	Saturation
NEWCOL	Average unit usage of new color television
NEWBW	Average unit usage of new black and white television
EFIMCO	Efficiency improvement color units over base year
EFIMBW	Efficiency improvement black and white units over base year
TEND	Final year of efficiency improvement phase-in
FRBW	Fraction new units which are black and white
ALT	Average lifetime
RETENI	Energy use of retired units
NEWENI	Energy use of new units
UNAVBS	Average unit usage in base year
ENREU	Annual energy demand in (t,k)
DUF	Decreased use factor for multiple televisions

Equations

Stock stream:

$$\mathrm{TOTNUM}_{t,k} = \mathrm{SAT}_{t,k} \times \mathrm{HSTOCK}_{t,k} \tag{3.25}$$

Initialize:

$$\mathrm{ENREU}_{1,k} = \mathrm{TOTNUM}_{1,k} \times \mathrm{UNAVBS} \tag{3.26}$$

Iterate for t>1:

$$\mathrm{ENREU}_{t,k} = \mathrm{ENREU}_{t-1,k} - \mathrm{RETENI}_{t,k} + \mathrm{NEWENI}_{t,k} \tag{3.27}$$

where

$$\mathrm{RETENI}_{t,k} = \mathrm{ENREU}_{t-1,k} / \mathrm{ALT} \tag{3.28}$$

$$\begin{aligned} \mathrm{NEWENI}_{t,k} = {} & (\mathrm{TOTNUM}_{t,k} - \mathrm{TOTNUM}_{t-1,k} + \mathrm{TOTNUM}_{t-1,k} / \mathrm{ALT}) \\ & \times ((1-\mathrm{FRBW}_t) \times \mathrm{NEWCOL}_t + \mathrm{FRBW}_t \times \mathrm{NEWBW}_t) \end{aligned} \tag{3.29}$$

and

$$\begin{aligned} \mathrm{NEWCOL}_t &= (1-\mathrm{EFIMCO}_t) \times \mathrm{NEWCOL}_1 \\ \mathrm{NEWBW}_t &= (1-\mathrm{EFIMBW}_t) \times \mathrm{NEWBW}_1 \end{aligned} \tag{3.30}$$

with

$$\mathrm{EFIMCO}_t = \begin{cases} (t-1 / (\mathrm{TEND}-1) \times \mathrm{EFIMCOT} & \text{for } t<\mathrm{TEND} \\ \mathrm{EFIMCOT} & \text{for } t>\mathrm{TEND} \end{cases} \tag{3.31}$$

(similarly for EFIMBW_t)

Decrease usage for multiple ownership (for $\mathrm{SAT}_{t,k}>1$):

$$\mathrm{ENREU} \longrightarrow \mathrm{ENREU}_{t,k} \times (1+\mathrm{DUF} \times (\mathrm{SAT}_{t,k} -1) / \mathrm{SAT}_{t,k}) \tag{3.32}$$

3.3.5 Clothes Dryers

The submodel for clothes dryers is quite simple. Demand is primarily a function of saturation and customer growth since efficiency improvement possibilities are small and substitute technologies to conventional dryers are not on the horizon (increased use of solar drying would be reflected in lower saturations). Although predictions of changing unit usage intensity (such as loads per week) are unrealistic, qualitatively, the decreasing trend in population per household would suggest that current levels should safely overestimate demand. The equation set (Table 3.6) should by now be self-explanatory.

TABLE 3.6
SUBMODEL FOR CLOTHES DRYER

Variable Code

t	Year (base year = 1)
TOTNUM	Total number
HSTOCK	Households
SAT	Saturation
UNAVBS	Average unit usage of base year stock
ALT	Average lifetime
EFFIMP	Efficiency improvement over base year units
TEND	Final year of efficiency improvement phase-in
NEWENI	Energy demand of new units
RETENI	Energy demand of retired units
UNNEW	Average unit usage of new units year t
ENREU	Annual energy demand in year t

Equations

Stock stream:

$$\mathrm{TOTNUM}_t = \mathrm{SAT}_t \times \mathrm{HSTOCK}_t \tag{3.33}$$

Initialize:

$$\mathrm{ENREU}_1 = \mathrm{TOTNUM}_1 \times \mathrm{UNAVBS} \tag{3.34}$$

Iterate for $t>1$:

$$\mathrm{ENREU}_t = \mathrm{ENREU}_{t-1} + \mathrm{NEWENI}_t - \mathrm{RETENI}_t \tag{3.35}$$

where

$$\mathrm{RETENI}_t = \mathrm{ENREU}_{t-1} / \mathrm{ALT} \tag{3.36}$$

$$\mathrm{NEWENI}_t = (\mathrm{TOTNUM}_t - \mathrm{TOTNUM}_{t-1} + \mathrm{TOTNUM}_{t-1} / \mathrm{ALT}) \times \mathrm{UNNEW}_t \tag{3.37}$$

and

$$\mathrm{UNNEW}_t = (1-\mathrm{EFFIMP}_t) \times \mathrm{UNAVBS}$$

with

$$\mathrm{EFFIMP}_t = \begin{cases} (t-1)/(\mathrm{TEND}-1) \times \mathrm{EFFIMT} & \text{for } t<\mathrm{TEND} \\ \mathrm{EFFIMT} & \text{for } t\geq\mathrm{TEND} \end{cases} \tag{3.38}$$

3.3.6 Clothes Washer and Dishwasher

Clothes washers and dishwashers are treated together since, as we shall see, the algorithm for modeling demand is identical. Each of these end-uses requires energy in two forms: (1) electric energy to drive motors and auxiliary equipment and (2) thermal energy in the form of hot water for process functions. Technology shifts are in the offing which would effect each of these.

For the case of thermal requirements, the impact on overall electrical energy is indirect. Specifically, changes in hot water demand will "flow through" to effect the electricity demand in the cases where hot water is produced in electric hot water heaters. The submodel allows for changes in both the electrical and thermal demands, saving the latter for input into the electric water heat submodel.

Therefore, after running the usual iteration to develop direct electrical energy demand (Equations 3.39 to 3.45), average forecast hot water demand for each appliance is calculated as a function both of overall saturation growths and unit demand changes. (Equation 3.46 to 3.47). These results are incorporated into the electric hot water heater submodel.

TABLE 3.7
SUBMODEL FOR CLOTHES WASHER AND DISHWASHER

Variable Code

t	Year (base year = 1)
i	Appliance index (CW = 7, DW = 8)
TOTNUM	Total number
HSTOCK	Households
SAT	Saturation
UNAVBS	Average base year unit electric energy usage
ALT	Average appliance lifetime
CWHW	Clothes washer average hot water demand per customer
DWHW	Dishwasher average hot water demand per customer
HWRECW	Hot water reduced demand -- clothes washer
HWREDW	Hot water reduced demand -- dishwasher
UNNEW	Average unit electrical energy usage of new appliance units
NEWENI	Energy demand of new units
RETENI	Energy demand of retired units
ENREU	Annual energy demand
EFFIMP	Efficiency improvement over base year
TEND	Final year of efficiency improvement phase-in

Equations

Stock stream:

$$\text{TOTNUM}_{t,i} = \text{SAT}_{t,1} \times \text{HSTOCK}_{t,i} \tag{3.39}$$

Initialize:

$$\text{ENREU}_{1,i} = \text{TOTNUM}_{1,i} \times \text{UNAVBS}_{i} \tag{3.40}$$

Iterate for t>1:

$$\text{ENREU}_{t,i} = \text{ENREU}_{t-1,i} + \text{NEWENI}_{t,i} - \text{RETENI}_{t,i} \tag{3.41}$$

where

$$\text{RETENI}_{t,i} = \text{ENREU}_{t-1,i}/\text{ALT}_{i} \tag{3.42}$$

$$\text{NEWENI}_{t,i} = (\text{TOTNUM}_{t,i} - \text{TOTNUM}_{t-1,i} + \text{TOTNUM}_{t-1,i}/\text{ALT}_{i}) \times \text{UNNEW}_{t,i} \tag{3.43}$$

and

$$\text{UNNEW}_{t,i} = (1 - \text{EFFIMP}_{t,i}) \times \text{UNAVBS}_{i} \tag{3.44}$$

with

$$\text{EFFIMP}_{t,i} = \left\{ \begin{array}{ll} (t-1/(\text{TEND}-1) \times \text{EFFIMT} & \text{for } t<\text{TEND} \\ \text{EFFIMT} & \text{for } t\geq\text{TEND} \end{array} \right. \tag{3.45}$$

(Continued)

TABLE 3.7 (Continued)

Hot Water Demands:

New unit usage year t:

$$UCWHWI = 19 \times UNAVBS_7 \times (1-HWRECW_t)$$

$$UDWHWI = 4.6 \times UNAVBS_8 \times (1-HWREDW_t)$$

(factor 19 and 4.6 are ratios of hot water to electric energy requirements for clothes washer and dishwasher, respectively [Ref. 1])

with

$$HWRECW_t = \begin{cases} ((t-1)/(TEND-1)) \times HWRECT & \text{for } t<TEND \\ HWRECT & t \geq TEND \end{cases}$$

Average unit usage:

$$UCWHW_t = (UCWHW_{t-1} \times REM_t + (TOTNUM_t - REM_t) \times UCWHWI_t)/TOTNUM_t \quad (3.46)$$

where REM_t = remaining units from previous year = $TOTNUM_{t-1} \times (1-1/ALT_i)$

Average usage per customer:

$$CWHW_t = SAT_{t,7} \times UCWHW_t \quad (3.47)$$

And similarly for dishwasher.

3.3.7 Electric Water Heaters

The electric water heater submodel is sensitive to a number of time dependent factors affecting overall energy demand:

- saturation
- efficiencies
- average residential hot water requirement
- solar technology penetration

The number of electric water heaters is computed in Equation 3.48. First, in Equation 3.48a, the base year units are computed from input data. For subsequent years, the total number is computed as the combination of the previous year's value (first term on the right of Equation 3.48a) plus additions from two new markets. First, all new electric space heaters are assumed to also have electric water heaters. (This will slightly overstate growth.) This is reflected in the second line on the right of Equation 3.48b (penetrations of electric space heat also appear in the esh submodel, Section 3.3.9). Second, new non-electric space heated homes (Equation 3.48b, third line first bracket) are assumed to purchase electric water heaters according to base year electric water heaters saturations in base year non-electric space heated homes (Equation 3.48b, third line, second bracket).

The hot water energy demands of clothes washer and dishwasher have been developed earlier and are used in Equation 3.49 to define the demand from "other" uses. Possible reductions in this category, such as widespread adoption of slow-flow shower heads, etc., which are now on the market, are also allowed for in the last expression.

Average efficiencies of electric water heaters are expected to improve with time primarily due to minimizing stand-by losses through better insulation jackets. The iterative procedure in Equation 3.51 weights new units (first term) with existing units (second term). The unit electric energy demand is then given by the ratio of hot water output (measured in KWH's) and the average efficiency (Equation 3.52). If there is some penetration of solar equipment to assist in hot water production, this average must be properly corrected by weighting in the fraction solar assisted at reduced demand levels (Equation 3.52). The total electric energy required for this energy then follows immediately as the product of the total number on line and the average unit usage (Equation 3.53).

TABLE 3.8
SUBMODEL FOR ELECTRIC WATER HEATER

Variable Code

t	Year (base year = 1)
k	Housing type (1=SF, 2=MF)
TOTNUM	Total number
HSTOCK	Households
SBY	Base year electric water heater saturation
ESHSAT	Electric space heating saturation
UNAVBS	Average base year unit electric energy demand
UNAV	Average unit usage
ALT	Average lifetime
CWHW	Clothes washer hot water demand
DWHW	Dishwasher hot water demand
OTHW	Other hot water demand
HWREOT	Hot water reduced demand for "other"
AVEFF	Average electric water heater efficiency
NUNEFF	New unit average efficiency year t
FS	Fraction electric hot water heaters solar assisted
PCSOLW	Fraction supplied by solar in solar assisted units
ENREU	Total energy demand year t
PEN	Penetration of esh in new construction

Equations

Stock stream:

$$\mathrm{TOTNUM}_{1,k} = \mathrm{SBY}_k \times \mathrm{HSTOCK}_{1,k} \qquad (3.48a)$$

$$\begin{aligned}\mathrm{TOTNUM}_{t,k} = {} & \mathrm{TOTNUM}_{t-1,k} \qquad (3.48b)\\ & + (\mathrm{HSTOCK}_{t,k} - \mathrm{HSTOCK}_{t,1,k}) \times \mathrm{PEN}_{t,k}\\ & + \left[(\mathrm{HSTOCK}_{t,k} - \mathrm{HSTOCK}_{t-1,k}) \times (1-\mathrm{PEN}_{t,k})\right] \times \left[(\mathrm{SBY}-\mathrm{ESHSAT}_{1,k})/(1-\mathrm{ESHSAT}_{1,k})\right]\end{aligned}$$

"Other" water demand:

$$\mathrm{OTHW}_t = (\mathrm{UNAVBS} \times \mathrm{AVEFF}_1 - \mathrm{DWHW}_1 - \mathrm{CWHW}_1) \times (1-\mathrm{HWREOT}_t)$$

Where DWHW & CWHW are from previous submodel, the first term in parenthesis is the base year total hot water usage. (3.49)

By definition

$$\mathrm{NUNEFF}_t = \mathrm{AVEFF}_1/(1-\mathrm{EFFIMP}_t)$$

where

$$\mathrm{EFFIMP}_t = \begin{cases}(t-1)/(\mathrm{TEND}-1) \times \mathrm{EFFIMT} & \text{for } t<\mathrm{TEND}\\ \mathrm{EFFIMT} & \text{for } t\geq\mathrm{TEND}\end{cases} \qquad (3.50)$$

Average efficiency from:

$$\begin{aligned}\mathrm{TOTNUM}_t \times \mathrm{AVEFF}_t = {} & (\mathrm{TOTNUM}_t - \mathrm{TOTNUM}_{t-1} + \mathrm{TOTNUM}_{t-1}/\mathrm{ALT}) \times \mathrm{NUNEFF}_t\\ & + (\mathrm{TOTNUM}_{t-1} - \mathrm{TOTNUM}_{t-1}/\mathrm{ALT}) \times \mathrm{AVEFF}_{t-1} \qquad (3.51)\end{aligned}$$

then,

$$\begin{aligned}\mathrm{UNAV}_t = {} & (\mathrm{DWHW}_t + \mathrm{CWHW}_t + \mathrm{OTHW}_t)/\mathrm{AVEFF}_t \quad \text{(w/o solar)} \qquad (3.52)\\ & \times(1-\mathrm{FS}_t + \mathrm{FS}_t \times (1-\mathrm{PCSOLW})) \quad \text{(w solar)}\end{aligned}$$

Finally,

$$\mathrm{ENREU}_t = \mathrm{TOTNUM}_t \times \mathrm{UNAV}_t \qquad (3.53)$$

3.3.8 Air Conditioners

The two types of air conditioners -- room and central -- are treated as separate end-uses. For each, the final forecast is a co-mingling of saturation and customer growths, efficiency increases, and building shell-thermal integrity improvements. It is tacitly assumed that average unit size will not increase over the base year due to demographic trends toward smaller family size and the decreased cooling load requirement that accompanies improved insulation.

Energy demand is calculated by employing the usual iterative sequence (Equations 3.54 to 3.60). The model assumes that in cases of multiple room air-conditioner ownership, average energy usage is additive. This may lead to a slight overestimate of demand insofar as second and third window/wall units are used substitutively to some extent. Such an effect is, however, difficult to estimate.

The model allows for adjustments in the average thermal integrity of building shells in the housing stock (Equation 3.61). This is given as an average over changes in base year and new construction units as indicated in Equations 3.62 and 3.63. There are two likely sources for improvements here: reinsulation in the retrofit market and stricter conservation practices in new building designs relative to historic design standards. Consequently, the overall improvement over base year values depends on estimates of several factors such as current building stock average characteristics, the degree of future reinsulation, and the effects of anticipated building codes for new construction.

In addition to effects tracked here, energy requirements for air conditioners may be affected by the energy efficiency of other appliances since waste heat which arises due to appliance inefficiency becomes a part of the load that must be handled with the air conditioner. Declining number of persons per household may also affect the energy requirement for air conditioned units. With a smaller number of persons per residence, the probability increases that the building will be vacant for a significant number of hours during the day and air conditioning will not be required at least in as great amount during that time. Analagous comments apply to electric space heating.

TABLE 3.09

SUBMODEL FOR AIR CONDITIONERS

Variable Code

t	Year (base year = 1)
k	Housing type (1 = SF, 2 - MF)
i	End use index (10 = Room A/C, 11 = Central A/C)
TOTNUM	Total number on-line
ALT	Average appliance lifetime
HSTOCK	Housing units
BYHSTK	Base year housing stock surviving
HRET	Housing unit removal rate
TIIMP	Average thermal integrity improvement
TIE	Thermal integrity improvement of base year housing units
TIN	Thermal integrity improvement of new construction units
EFFIMP	Efficiency improvement over base year
TEND	Final year of efficiency phase-in
SAT	Saturation
UNAVBS	Average base year unit consumption
UNNEW	Average unit usage of new units
NEWENI	Energy demand of new units
RETENI	Energy demand of retired units
ENEUI1	Annual energy demand w/o thermal integrity improvement
ENREU	Annual energy demand

Equations

Stock stream:

$$\text{TOTNUM}_{t,k,i} = \text{SAT}_{t,k,i} \times \text{HSTOCK}_{t,k} \qquad (3.54)$$

Initialize:

$$\text{ENEUI1}_{1,k,i} = \text{TOTNUM}_{1,k,i} \times \text{UNAVBS}_{k,i} \qquad (3.55)$$

Iterate for t>1:

$$\text{ENEUI1}_{t,k,i} = \text{ENEUI1}_{t-1,k,i} + \text{NEWENI}_{t,k,i} - \text{RETENI}_{t,k,i} \qquad (3.56)$$

where

$$\text{RETENI}_{t,k,i} = \text{ENEUI1}_{t-1,k,i}/\text{ALT}_{i} \qquad (3.57)$$

$$\begin{aligned}\text{NEWENI}_{t,k,i} = {} & (\text{TOTNUM}_{t,k,i} - \text{TOTNUM}_{t-1,k,i} \\ & + \text{TOTNUM}_{t-1,k,i}/\text{ALT}_{i}) \times \text{UNNEW}_{t,k,i}\end{aligned} \qquad (3.58)$$

and

$$\text{UNNEW}_{t,k,i} = (1 - \text{EFFIMP}_{t,i}) \times \text{UNAVBS}_{k,i} \qquad (3.59)$$

with

$$\text{EFFIMP}_{t,i} = \begin{cases}((t-1)/\text{TEND}-1)) \times \text{EFFIMT} & \\ \text{EFFIMT} & \end{cases} \quad \text{for} \begin{cases} t<\text{TEND} \\ t\geq\text{TEND}\end{cases} \qquad (3.60)$$

Correct for changes in thermal integrity:

$$\text{ENREU}_{t,k,i} = (1-\text{TIIMP}_{t,k,i}) \times \text{ENEUI1}_{t,k,i} \qquad (3.61)$$

where

$$\begin{aligned}\text{TIIMP}_{t,k,i} = {} & \Big[\text{TIIMP}_{t-1,k,i} \times \text{HSTOCK}_{t-1,k} + \text{TIE}_{t,k,i} \times \text{BYHSTK}_{t,k} \\ & - \text{TIE}_{t-1,k,i} \times \text{BYHSTK}_{t-1,k} + \text{TIN}_{t,k,i} \times (\text{HSTOCK}_{t,k} \\ & - \text{HSTOCK}_{t-1,k} + \text{BYHSTK}_{t,k} - \text{BYHSTK}_{t-1,k})\Big] \\ & / \text{HSTOCK}_{t,k} \qquad \text{for } t>1\end{aligned} \qquad (3.62)$$

and

$$\text{BYHSTK}_{t,k} = \text{HSTOCK}_{1,k} \times (1-\text{HRET}_{k})\ t-1 \qquad (3.63)$$

3.3.9 Electric Space Heating

The growth in the number of electric space heated (ESH) homes is closely related to the decision on fuel use in new construction markets or in converting existing households from fossil fuel heating to electric. Consequently, it is analytically useful to introduce the concept of "penetration" in developing the number of housing units with ESH. In the model, the following definition is used:

$$\text{Penetration}_t = \frac{\Delta \text{ electric space heat customers}_t}{\Delta \text{ customers}_t}$$

where t is the year label and "Δ" signifies the change from the previous year. The historic values of the increments are readily available from utility records providing useful information in estimating future trends. With this definition, the yearly number of ESH units can be computed through the iteration procedure of Equation 3.63 of Table 3.10 with the initial number defined as the product of base year saturation and household for each housing type.

The ESH intensity (annual KWH consumption per unit) must be represented as the combination of three distinct heating systems: conventional resistance heating, electrically driven heat pump, and solar augmentation (with or without heat pumps). The key dynamic expression is the iteration formula, Equation 3.65, which increments the previous year's total ESH energy demand by the additional demand coming on-line. This additional demand is the sum of the contributions from the system options considered: conventional resistance ("direct"), heat pump and solar, respectively, in Equation 3.66. Each of these is in turn decomposed into the product of new units in the ESH subcategory and usage per unit Equations 3.67, 3.68, and 3.69. Adjustments are made for possible conservation oriented changes in building envelope designs ("thermal integrity factor") in new units relative to the base year mix of electrically heated units. Finally, the market share of each ESH option is given a broken linear time dependence over the forecast period.

TABLE 3.10
SUBMODEL FOR ELECTRIC SPACE HEATING

Variable Code

t	Year (base year = 1)
k	Building type (SF=1, MF=2)
TOTNUM	Total number
HSTOCK	Housing stock
PEN	Penetration
UNAVBS	Average usage base year resistance heating stock
NESHDI	Energy demand of new direct ESH
NESHHP	Energy demand of new ESH with heat pump
NESHSA	Energy demand of new ESH with solar assist
FHP	Fraction of new ESH units with heat pump
FHPBY	Fraction of base year ESH units with heat pump
TEHP	Time end of increasing heat pump fraction of new ESH
COP	Heat pump coefficient of performance
COPEI	COP efficiency improvement
TEFFI	End year COP efficiency improvement
FSA	Fraction of new ESH units with solar assist
TSSA	Time start of solar space heat penetration
PCSOL	Percent heating requirement due to solar in solar assisted ESH units
TIF	Thermal intergrity factor adjusting new unit demand from base year unit demand
ENREU	Annual energy demand

Equations

Stock stream:

$$\mathrm{TOTNUM}_{t,k} = \mathrm{TOTNUM}_{t-1,k} + \mathrm{PEN}_{t,k} \times (\mathrm{HSTOCK}_{t,k} - \mathrm{HSTOCK}_{t-1,k}) \qquad (3.63)$$

Initialize:

$$\mathrm{ENREU}_{1,k} = \mathrm{TOTNUM}_{1,k} \times \mathrm{UNAVBS}_{k} \times (1-\mathrm{FHPBY}+\mathrm{FHPBY}/\mathrm{COP}) \qquad (3.64)$$

Iterate:

$$\mathrm{ENREU}_{t,k} = \mathrm{ENREU}_{t-1,k} + \mathrm{NEWENI}_{t,k} \qquad (3.65)$$

where

$$\mathrm{NEWENI}_{t,k} = \mathrm{NESHDI}_{t,k} + \mathrm{NESHHP}_{t,k} + \mathrm{NESHSA}_{t,k} \qquad (3.66)$$

The subcomponents of new demand are given by:

$$\mathrm{NESHDI}_{t,k} = (1-\mathrm{FHP}_{t,k} - \mathrm{FSA}_{t,k}) \times (\mathrm{TOTNUM}_{t,k} - \mathrm{TOTNUM}_{t-1,k}) \times (\mathrm{TIF}_{k} \times \mathrm{UNAVBS}_{k}) \qquad (3.67)$$

$$\mathrm{NESHHP}_{t,k} = (\mathrm{FHP}_{t,k} \times (\mathrm{TOTNUM}_{t,k} - \mathrm{TOTNUM}_{t-1,k})) \times (\mathrm{TIF}_{k} \times \mathrm{UNAVBS}_{k}/\mathrm{COP}_{k,t}) \qquad (3.68)$$

(continued)

TABLE 3.10 (Continued)

where

$$COP_{t,k} = COP_k \times (1 + (t-1)/(TEFFI -1) \times COPEI)$$

$$NESHSA_{t,k} = (FSA_{t,k} \times (TOTNUM_{t,k} - TOTNUM_{t-1,k})) \times TIF_k \times ((1-PCSOL_k/100) \times UNAVBS_k) \qquad (3.69)$$

Phase in fractional breakdowns:

$$FHP_{t,k} = \begin{cases} ((TEHP-t)/(TEHP-1)) \times FHP_{1,k} + ((t-1)/(TEHP-1)) \times FHP_{TEHP,k} & \text{for } t<TEHP \\ FHP_{TEHP,k} & \text{for } t\geq TEHP \end{cases} \qquad (3.70)$$

$$FSA_{t,k} = \begin{cases} 0 & \text{for } t<TSSA \\ ((t-TSSA)/(21-TSSA)) \times FSA_{21,k} & \text{for } t\geq TSSA \end{cases} \qquad (3.71)$$

3.3.10 Heating Auxiliaries

Heating auxiliaries refers to the electrically driven equipment such as pumps and fans used in conjunction with oil and gas home heating systems. Energy demand is simply the number of fossil-fuel heating systems multiplied by the average unit electrical demand for auxiliaries. With the assumption that all customers have either fossil fuel or electric space heating, the heating auxiliary saturations is given simply by one minus the electric space heating saturations. This is used in developing the yearly number on-line (Equation 3.72). The expression for annual heating auxiliary energy consumption (Equation 3.75a) is composed of contributions from surviving base year households (defined in Equation 3.74) and newly constructed units. Energy requirements for these are shown, respectively, in Equations 3.73 and 3.75 where possible decrements in average units usage due to improvements in the average thermal integrity of residential buildings is account for. On the other hand, the model does not explicitly include possible decreased energy requirements due to heating system or electric motor efficiency improvements.

TABLE 3.11
SUBMODEL FOR HEATING AUXILIARIES

Variable Code:

t	Year (base year = 1)
k	Housing type (1=SF, 2=MF)
ESHSAT	Electric space heat saturation
UNAVBS	Average unit usage in base year
TIIMP	Thermal integrity improvement over base year
TIE	Thermal integrity improvement of base year housing units
TIN	Thermal integrity improvement of new construction units
HSTOCK	Housing stock
BYHSTK	Base year non-ESH housing units surviving
HRET	Housing unit removal rate
TOTK	Total number of non-ESH housing units
ENEUI	Annual energy demand
ENEUI1	Annual energy demand from base year housing stock
ENEUI2	Annual energy demand from newly constructed units

Equations:

$$TOTK_{t,k} = (1 - ESHSAT_{t,k}) \times HSTOCK_{t,k} \quad (3.72)$$

$$ENEUI1_{t,k} = BYHSTK_{t,k} \times (1-TIE_{t,k}) \times UNAVBS_k \quad (3.73)$$

where:

$$BYHSTK_{t,k} = TOTK_{1,k} \times (1-HRET_k)^{t-1} \quad (3.74)$$

$$ENEUI2_{t,k} = ENEUI2_{t-1,k} + (1-TIN_{t,k}) \times UNAVBS_k \times \left[TOTK_{t,k} - TOTK_{t-1,k} + BYHSTK_{t-1,k} - BYHSTK_{t,k}\right] \quad (3.75)$$

Finally,

$$ENEUI_{t,k} = ENEUI1_{t,k} + ENEUI2_{t,k} \quad (3.75a)$$

3.3.11 Miscellaneous Appliances

This category includes an enormous array of small appliances used in the home for food preparation, entertainment, maintenance and personal care. Since energy demand in this category consists of use in a large variety of devices, each with low annual consumption, a disaggregated computational scheme is inappropriate. Consequently, forecast energy consumption is computed simply as the product of average demand per housing unit and the number of housing units (Equation 3.76). The average unit usage deviates from base year values by a factor which is phased in linearly over the forecast period (Equations 3.76a and 3.77).

Average use per customer of miscellaneous appliances had been generally increasing prior to 1973 as part of the overall growth in energy-intensive equipment fostered by a combination of rising real per capita income, declining real electricity prices, and an explosion of small convenience devices. Current trends can be expected to moderate growth. Major factors are:

- increasing electricity costs
- substitution effects (e.g., cooking devices for ranges)
- decreased growth in disposable income
- energy conservation awareness
- smaller families
- market saturation

On the other hand, unanticipated new devices may appear in the marketplace to refuel growth in average consumption. Consequently, there is a good deal of uncertainty in use per customer trends over the twenty year forecast. Actual scenario runs of the model encompass a range of values.

TABLE 3.12
SUBMODEL FOR MISCELLANEOUS APPLIANCES

Variable Codes

t	Year (base year = 1)
HSTOCK	Total number of housing units year t
UNAVBS	Annual average usage per housing unit in base year
UPCIN	Use per customer increase
UNAV	Annual average usage per household unit
ENREU	Total annual energy consumption

Equations:

$$ENREU_t = UNAV_t \times HSTOCK_t \qquad (3.76)$$

where

$$UNAV_t = (1+UPCIN_t) \times UNAVBS_t \qquad (3.76a)$$

with

$$UPCIN_t = ((t-1)/20) \times UPCIN_{21} \qquad (3.77)$$

4. COMMERCIAL SECTOR

In modeling electrical energy consumption for the commercial sector, the degree of analytic detail is constrained by the adequacy both of the data base and current understanding of energy flows in the commercial building sector. Over the past few years, however, substantial progress has been made in quantitatively characterizing the components of commercial demand which allows for considerably more refinement than has been traditionally employed (*e.g.*, Refs. 2-6).

The importance of avoiding aggregate historical trending or correlation analysis is underscored by the reversal or diminution of the underlying factors that drove U.S. commercial energy growth at over 5% per year in the twenty years preceding the oil embargo of 1973. These factors included: rapidly increasing population, per capita income, and proportion of employment in services, combined with decreasing energy costs.

The commercial model tracks energy demand for five building types (BT), four end-uses (EU), or twenty BT/EU combinations each for existing and new buildings. These are displayed in Table 4.1 along with the commercial category allocated to each building type. Both demarcations -- "building type" and "commercial category" -- will be useful in constructing the commercial model.

4.1 Model Structure

As discussed in Sec. 2, the underlying strategies in the commercial and residential sectors are analogous. In the commercial sector, the measure of energy using activity is the magnitude of floor space while the energy intensity is expressed in average annual kwh/square foot for each end-use, building type, and utility service territory. The elements of the model are displayed schematically in Figure 4.1.

The specifications of base year floor space, average consumption per square foot of each end-use ("electrical use coefficients"), and saturations (fraction of floorspace with end-use) gives the base year breakdowns. Folding in the time dependences of floorspace, conservation, and saturations, one arrives at the yearly forecasts.

The commercial forecast model, therefore, divides conceptually into two separate submodels: one for floorspace and the other for electric intensity. These will be discussed in turn.

4.2 Commercial Floorspace

The floorspace computation is summarized in the first row of Figure 4.1. Note that the floorspace analysis is disaggregated by commercial category; these are then aggregated to building types according to the allocations of Table 4.1. The reason for this procedure is that while detailed growth forecasts are available for the 14 commercial categories (*e.g.*, Ref. 7), the latest intensity

TABLE 4.1
COMMERCIAL MODEL END-USES, BUILDING TYPES AND COMMERCIAL CATEGORY

Index i	End Use
1	Space-Heating
2	Cooling
3	Light & Power
4	Auxiliary

Index k	Building Type	Index j	Commercial Category
1	Office	1	Finance, Insurance and Real Estate
		2	Federal Government
		3	State & Local Government
		4	Professional Services
2	Retail	5	Retail and Wholesale
3	Hospitals	13	Hospitals and Health Related Establishments
4	Schools	14	Schools and Educational
5	Other	6	Trucking and Warehouse
		7	Other Transportation Services
		8	Communications
		9	Lodging & Personal Services
		10	Business & Repair Services
		11	Amusement & Recreation
		12	Railroad

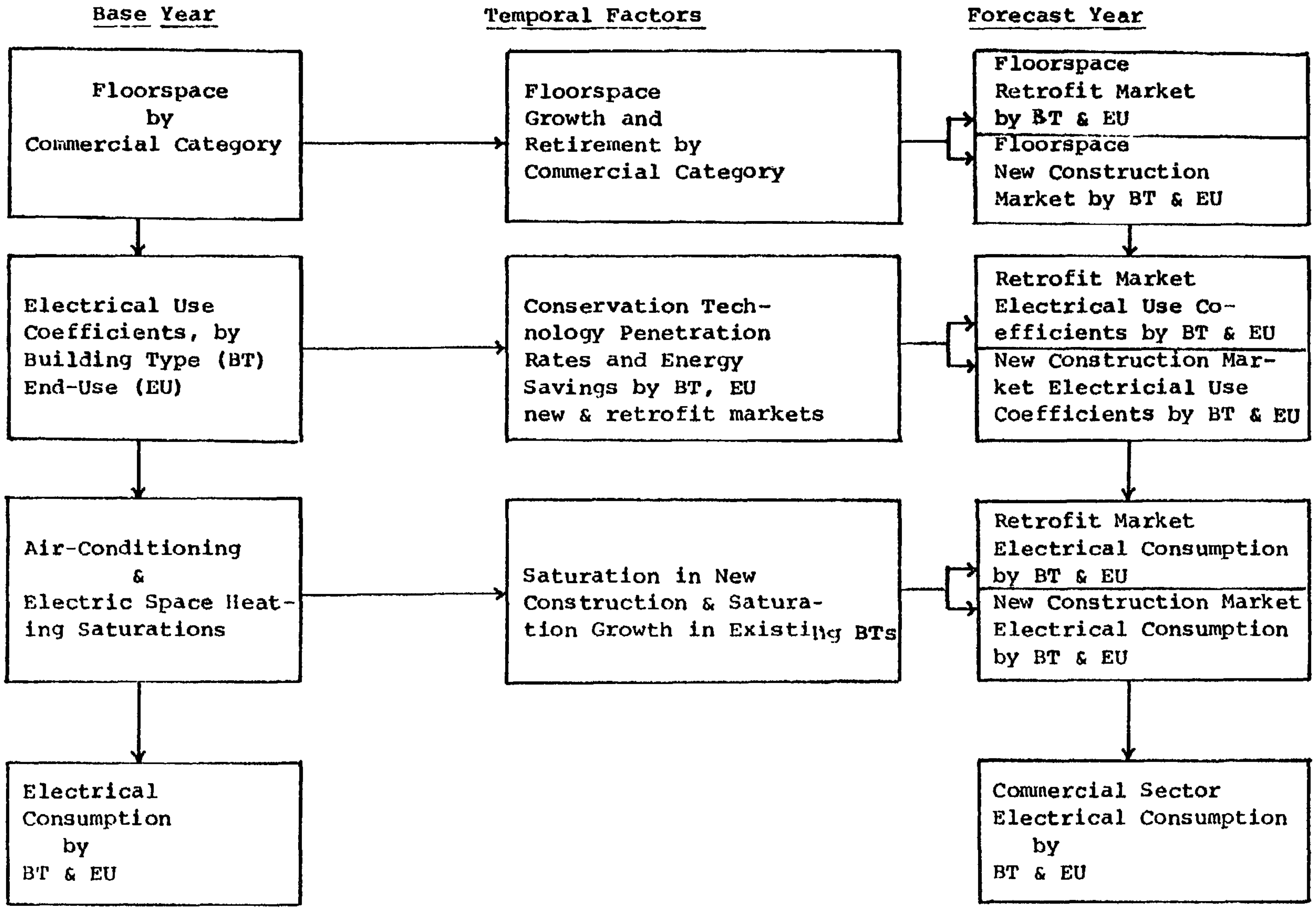


FIGURE 4.1
COMMERCIAL SECTOR MODEL SCHEMATIC

TABLE 4.2
COMMERCIAL MODEL - FLOORSPACE

Indices

$t = 1,2,\ldots$	Year (1975 = 1)
$j = 1$ to 14	Commercial category
$n = 1$ to 2	Existing or new building
$k = 1$ to 5	Building types

Variables

SQFTCC	Square footage by commercial category
SQFTBT	Square footage by building type
RSQFT	Annual retirement rate of base year floorspace
SPOP	Statewide population
UPOP	Population in forecast area
SAPOP	School age population in forecast area
PARAM	Parameter used for floorspace growth
EMP	Statewide employees
COMIND	Commercial index giving floorspace ratios in successive years
OSQFT	Pre-1976 floorspace remaining in year t
NSQFT	New floorspace
AGG	Aggregation matrix from commercial category to building type

Equations:

Growth parameters:

$$\text{PARAM}_{t,j} = \text{EMP}_{t,j} \times \text{UPOP}_t/\text{SPOP}_t \qquad (4.1)$$

for $j = 1$ to 12 and

$$\text{PARAM}_{t,13} = \text{UPOP}_t \qquad (4.2)$$

$$\text{PARAM}_{t,14} = \text{SAPOP}_t \qquad (4.3)$$

Growth indices:

$$\text{COMIND}_{t,j} = \text{PARAM}_{t,j}/\text{PARAM}_{t-1,j} \quad \text{for } t>1 \qquad (4.4)$$

Iterate:

$$\text{SQFTCC}_{t,j} = \text{COMIND}_{t,j} \times \text{SQFTCC}_{t-1,j} \text{ for } t>1 \qquad (4.5)$$

with $\text{SQFTCC}_{1,j}$ inputted.

Aggregate to building type:

$$\text{SQFTBT}_{t,k} = \sum_j \text{AGG}_{j,k} \times \text{SQFTCC}_{t,j} \qquad (4.6)$$

Breakdown to existing and new:

$$\text{SQFTBT}_{t,k} = \text{OSQFT}_{t,k} + \sum_{t'=2}^{t} \text{NSQFT}_{t',k} \qquad (4.7)$$

(continued)

TABLE 4.2 (Continued)

where

$$OSQFT_{t,k} = \begin{cases} SQFTBT_{1,k} & \text{for } t = 1 \\ (1-RSQFT_k) \times OSQFT_{t-1,k} & \text{for } t > 1 \end{cases} \quad (4.8)$$

and

$$NSQFT_{t,k} = SQFTBT_{t,k} - SQFTBT_{t-1,k} + RSQFT_k \times SQFTBT_{t-1,k} \quad (4.9)$$

data and conservation penetration analysis are available on the basis of building type (References 6 and 8). Floorspace is thus treated on the basis of commercial category and then aggregated to the building type demarcation.

The system of equations for the floorspace component of the commercial model is given in Table 4.2. The model is based on a year-to-year iteration (Equation 4.5). Two factors are involved: 1975 floorspace data to initialize the iteration and an annual growth index.

4.2.1 1975 Floorspace

A separate computation was performed to generate the 1975 floorspace data. This was required due to the paucity of data on existing commercial building stock. Initial floorspace estimates were derived by multiplying Census employment data (Reference 9) by average floorspace per employee. School and hospital estimates were taken from national floorspace estimates (Reference 6) scaled to the forecast region by the ratio of state to national pupils and hospital beds, respectively (Reference 5). The square foot multipliers, giving average footage per employee by commercial category, are displayed in Table 4.3. They are based on average values by SIC given in the literature (References 5, 10), aggregated to commercial categories by using the groupings in the table (Reference 11) and taking weighted statewide averages over the SIC's within a group.

The 1975 floorspace results are used as data in the floorspace module of the main commercial program (see Equation 4.5). Total floorspace is ultimately calibrated to the specific utility by normalizing to base year energies as discussed later.

4.2.2 Floorspace Growth Indices

The growth indices ("COMIND") give floorspace ratios in successive year (Table 4.2, Equation 4.4). The gowth indices are equivalent to:

$$\mathrm{COMIND}_{t,j} = (1 + \mathrm{GRSQFTCC}_{t,j}) \qquad (4.10)$$

where

$\mathrm{GRSQFTCC}_{t,j}$ = average annual growth rate of square footage in commercial category and year t.

For the case of hospital and health related establishments (j = 13), population growth is the proxy for floorspace growth (Equation 4.2). For the case of schools (j = 14), floorspace growth is equated to growth in school age population (Equation 4.3). For the other commercial categories, the level of employment was taken as the best measure of activity and, therefore, floorspace growth. Estimates of population and employment growth used in the current forecast are postponed to the data discussion below.

TABLE 4.3
SQUARE FOOTAGE MULTIPLIERS

Commercial Category	Corresponding SIC's	Average Square Feet Per Employee*
1. Finance, Insurance, Real Estate(FIRE)	60	155
	61	214
	62	176
	63	149
	64	149
	65	390
	66	187
	67	156
2. Federal Government	91	189
3. State and Local Government	92	183
	93	393
4. Professional Service	81	211
	83	216
	89	312
5. Retail & Wholesale	50,51	682
	52	987
	53	271
	54	509
	55	502
	56	532
	57	878
	58	270
	59	444
6. Trucking & Warehouse	42	3162
7. Other Transportation	41	280
	44	139
	45	809
	46	8050
	47	780
8. Communication	48	177
9. Lodging and Personal Service	70	837
	72	304
10. Business and Repair Service	73	275
	75	1422
	76	270
11. Amusement & Recreation Service	78	777
	79	871
	84	2000
	86	860
12. Railroad	40	187

* The Administrative and Auxiliary portions of FIRE, retail and wholesale, transportation, Communication, and Utilities are allotted 200 sq. ft. per employee. Source: Refs. 5 and 10.

4.3 Electric Energy Intensities

With floorspace estimates generated with the methodology just described, there remains the second element of the commercial forecast: average electric energy consumption per square foot. As shown in the lower two rows of boxes of Figure 4.1, the evaluation of intensities again involves two phases: first, a specification of initial values of electrical demand coefficients (defined as average annual electrical consumption of a given BT/EU/service territory combination) and end-use saturations; second, an estimation of conservation penetration and saturation growth. We shall discuss these two phases sequentially.

4.3.1 1975 Intensities

Average electrical demands by end-use and building types have been adapted from the "theoretical building loads" developed for the Department of Energy by Arthur D. Little, Inc. (Reference 8). The study combined engineering design parameters and survey research to arrive at estimates of average building requirements for each of the EU/BT combinations treated in the commercial model. The adaptation of ADL's Northeast region building loads to unit electricity demands (electrical use coefficients) by service territory requires the adjustment of weather sensitive loads to the prevailing climatic conditions.

4.3.2 Future Intensities

The computation of forecast year intensities is described in Table 4.4. Intensities are, by definition, the product of the saturation (fraction of floorspace with end-use) and the electrical use coefficients (average annual kwh/ft^2 of floorspace with end-use). This is expressed mathematically by Equation 4.13. Note that the intensities are specified by 4 end-uses and 10 building types. In practice, however, many of the inputs are trivial. (E.g., saturations are defined as 1 for i = 3 and 4).

The time dependence of the electric use coefficient ("EUC") is obtained by incrementing the 1975 values by changes in end-use demands due to conservation practices initiated in the post-1975 era. In Reference 6, three levels of efficiency improvements are considered. The levels are defined by cost-effectiveness groupings, i.e., level 1 changes have the shortest paybacks and level 3 changes the longest (though all are cost-effective). The levels incorporate bundles of design features, devices, measures and/or equipment in the following categories:

- Building thermal integrity, including passive solar measures.
- Heating, ventilating, and air conditioning systems and controls.

- Internal loads and comfort conditions.
- Operation and maintenance provisions.

Measures in the last category, O&M provisions, tend to drop out of the level 3 technology combinations, which are the most capital-intensive of the three.

The energy savings that the technology and modifications associated with each conservation level would achieve are provided in Reference 6 for each U.S. region. These savings are to be applied against the base line loads discussed above. The matrix of percentage efficiency improvements is given in Table 4.5 by level, building type and end-use. They are also broken down by new buildings and 1975 stock ("retrofit").

The overall savings are functions both of the energy requirement reductions related to the conservation level and the penetration of these levels. Here, level "penetration" is defined as the fraction of floorspace in the given year and BT/EU combination at the given level. The average savings are then given by the sum over levels of the product of level penetration ("$PEN_{t,i,k,m}$") and percent improvement ("$PIMP_{t,i,k,m}$") as given in Equation 4.12.

The time dependence of the electrical use coefficients can then be written as the initial value multiplied by a decreased demand factor (Equation 4.11). The penetration of the conservation level technology groupings is dependent on a number of factors: initial costs, consumer preference, capital availability, pay-back time and electricity costs. Using linear programming techniques, optimal energy technologies by building type (new or retrofit market) and end-use have been computed (Reference 6). The mix of penetrations which result are functions of inputted economic assumptions. Consequently, the forecast scenarios can incorporate sensitivity to a range of assumptions on, e.g., future fuel costs. The electrical intensities require, in addition to the electrical use coefficients, "saturation" estimates. (Equation 4.13).

An additional factor must be taken into account for the electric space heat end-use: the possible use of heat pumps. Penetration analysis suggests that electric space heat with heat pump is cost-effective over conventional electric resistance heating for all new construction to 1985. The model allows for a market response delay by phasing in the fraction of new electrically space heated buildings which have heat pumps to unity in 1985. Additionally, the model incorporates the cautious assumption that solar heating and air conditioning will have an insignificant impact on overall load during the forecast period. In the case of water heating, where electricity consumption is relatively insignificant, solar energy would substitute primarily for fossil fuels.

TABLE 4.4
ELECTRIC ENERGY INTENSITIES

Indices

t	Year (1975 = 1)
i	Commercial end-use (i = 1 to 4)
k	Building type (k = 1 to 5)
n	Existing or new buildings (n = 1 to 2)
m	Conservation levels (m = 1 to 3)

Variables

INTEN	Electrical intensity (average annual KWH/FT^2)
EUC	Electrical use coefficient (= INTEN with all saturations = 1)
SAT	Saturation (fraction floorspace with end-use)
PEN	Market fraction ("penetration")
PIMP	Fractional energy savings (i,k,n) at given conservation level (Table 4.5)
PENSUM	Fractional energy decrease
HPFRAC	Fraction new electrically heated buildings
COP	Heat pump coefficient of performance

Equations

From definitions:

$$\mathrm{EUC}_{t,i,k,n} = (1 - \mathrm{PENSUM}_{t,i,k,n}) \times \mathrm{EUC}_{1,i,k,n} \qquad (4.11)$$

where

$$\mathrm{PENSUM}_{t,i,k,n} = \sum_m \mathrm{PIMP}_{t,k,n,m} \times \mathrm{PEN}_{t,i,k,n,m} \qquad (4.12)$$

and

$$\mathrm{INTEN}_{t,i,k,n} = \mathrm{SAT}_{t,i,k,n} \times \mathrm{EUC}_{t,i,k,n} \qquad (4.13)$$

except for new electric space heating building where heat pumps are phased-in:

$$\mathrm{INTEN}_{t,1,k,2} = (\mathrm{HPFRAC}_t/\mathrm{COP} + (1-\mathrm{HPFRAC}_t)) \times \mathrm{SAT}_{t,1,k,2} \times \mathrm{EUC}_{t,1,k,2} \qquad (4.14)$$

where HPFRAC is given the following linear parameterization:

$$\mathrm{HPFRAC}_t = \begin{cases} \left(\frac{t-1}{10}\right) \times \mathrm{HPFRAC}_{11} & \text{for } t \le 11 \\ \mathrm{HPFRAC}_{11} & t > 11 \end{cases} \qquad (4.15)$$

TABLE 4.5
FRACTION OF LOAD SAVED

Building Type	End-Use	Conservation Level					
		Retrofit Market			New Market		
		1	2	3	1	2	3
Office	Heating	.11	.15	.23	.25	.35	.40
	Cooling	.13	.17	.34	.20	.35	.47
	L & P	.25	.50	.50	.15	.25	.25
	Aux	.17	.28	.38	.10	.16	.20
Retail	Heating	.08	.23	.25	.30	.42	.50
	Cooling	.12	.20	.20	.25	.37	.46
	L & P	.13	.25	.25	.15	.24	.30
	Aux	.18	.36	.45	.10	.16	.20
Hospital	Heating	.07	.15	.16	.20	.32	.40
	Cooling	.07	.24	.28	.15	.25	.33
	L & P	.08	.12	.17	.10	.15	.15
	Aux	.19	.25	.30	.10	.15	.15
Schools	Heating	.14	.21	.29	.30	.42	.50
	Cooling	.16	.26	.56	.25	.35	.41
	L & P	.12	.30	.42	.15	.20	.20
	Aux	.26	.33	.53	.20	.25	.30
Miscellaneous	Heating	.09	.15	.26	.30	.42	.50
	Cooling	.05	.12	.24	.25	.35	.40
	L & P	.09	.15	.24	.15	.15	.20
	Aux	.14	.23	.32	.15	.20	.20

* L & P = Light and power
Aux = Auxiliaries (e.g., fans, pumps, humidifiers, water heaters)

4.4 Energy Forecast

The computation of commercial sector energies is a straightforward exercise once the forecasts for floorspace and electrical energy intensity have been obtained. The expressions for average annual energy consumption by end-use and building types are given in Table 4.6.

Calibration to base year sales is performed on total sales:

$$\text{Commercial Energy Sales, year } t = \sum_{i,k,n} \text{ENCEU}_{t,i,k,n} \tag{4.16}$$

The model is first run from 1975 (t=1) to the base year (t = 1+base year - 1975). The total floorspace is then adjusted to normalize total sales in a given service territory to base year experience. An overall square foot adjustment factor scales each term in the energy sum (Equation 4.17). The necessity for such an adjustment is traced to the use of national average square foot per employee data. One finds, as anticipated, that such data closely approximates state averages except in service areas dominated by land-scarce urban centers.

TABLE 4.6
COMMERCIAL ENERGY FORECAST

Indices

t	Year (1975 = 1)
i	Commercial end-use (i = 1 to 4)
k	Building type (k = 1 to 5)
n	Existing or new buildings (n = 1 to 2)

Variables

ENCEU	Annual energy consumption
INTEN	Corresponding electrical energy intensity (See Table 4.4)
OSQFT	Remaining 1975 building stock floorspace (See Table 4.2)
NSQFT	New floorspace (See Table 4.2)

Equations

Retrofit market:

$$\text{ENCEU}_{t,i,k,1} = \text{INTEN}_{t,i,k,1} \times \text{OSQFT}_{t,k} \tag{4.17}$$

New Construction:

$$\text{ENCEU}_{t,i,k,2} = \sum_{t'=2}^{t} \text{INTEN}_{t',i,k,2} \times \text{NSQFT}_{t',k} \tag{4.18}$$

5. INDUSTRIAL SECTOR

As with the residential and commercial sectors, industrial energy consumption is broken down into products of energy using activities and energy intensities of those activities. The measure of activity in the case of industrial energy consumption is physical output (in units/year) for each major manufacturing subsector. The subsectors are chosen at the two-digit Standard Industrial Classification (SIC) level. Less detail would lose sensitivity to differing growth and electricity use trends among industries; more detail would require inputs beyond the capability of the current data base. The SIC's included in the forecast are given in Table 5.1.

The electric energy intensity for the industrial sector is correspondingly defined as average electricity consumption per unit of production. The growth in production is related to the level of economic growth and business activity in the state, while the electric intensity is a function of several major factors: process technology, pollution control requirements, conservation level, and fuel mix. In past decades, electrical energy growth has been driven by increases in production level, energy intensiveness in manufacturing processes, and increased fuel fraction for electricity, on the one hand, and a virtual absence of energy conservation, on the other. The job of forecasting is to adequately characterize historic experience and to incorporate a realistic range of growth in the demand-driving factors.

5.1 Model Structure

The model elements and their relationship are schematized in Figure 5.1. Growths in base year electric energy consumption by SIC are related to growths in production and electric energy intensity. The resultant electric energy demand must then be divided into the amount purchased and the amount self-generated since it is the purchased energy which is ultimately identified with utility sales. Changes in the fraction of electric energy consumption supplied by self-generated electricity must also be allowed for.

The forecast energy thus depends on the specifications of base year experience, the forecast of production growth, the trend in electric energy intensity, and the changes in fraction self-generated. These will be discussed, respectively, in Sections 5.2 to 5.5, and brought together in the energy forecast model described in Section 5.6.

TABLE 5.1
STANDARD INDUSTRIAL CLASSIFICATIONS

ESRG Index	SIC	Description
1	20	Food and Kindred Products
2	22	Textiles
3	23	Apparel and Other Textile Products
4	24	Lumber and Wood Products
5	25	Furniture and Fixtures
6	26	Paper and Allied Products
7	27	Printing and Publishing
8	28	Chemicals and Allied Products
9	29	Petroleum and Coal Products
10	33	Primary Metal
11	34	Fabricated Metal Products
12	35	Machinery (except electrical)
13	36	Electric Equipment
14	37	Transportation Equipment
15	30	Rubber and Plastics
16	31	Leather
17	32	Stone, Clay and Glass
18	38	Instruments, Related Products
19	39	Miscellaneous

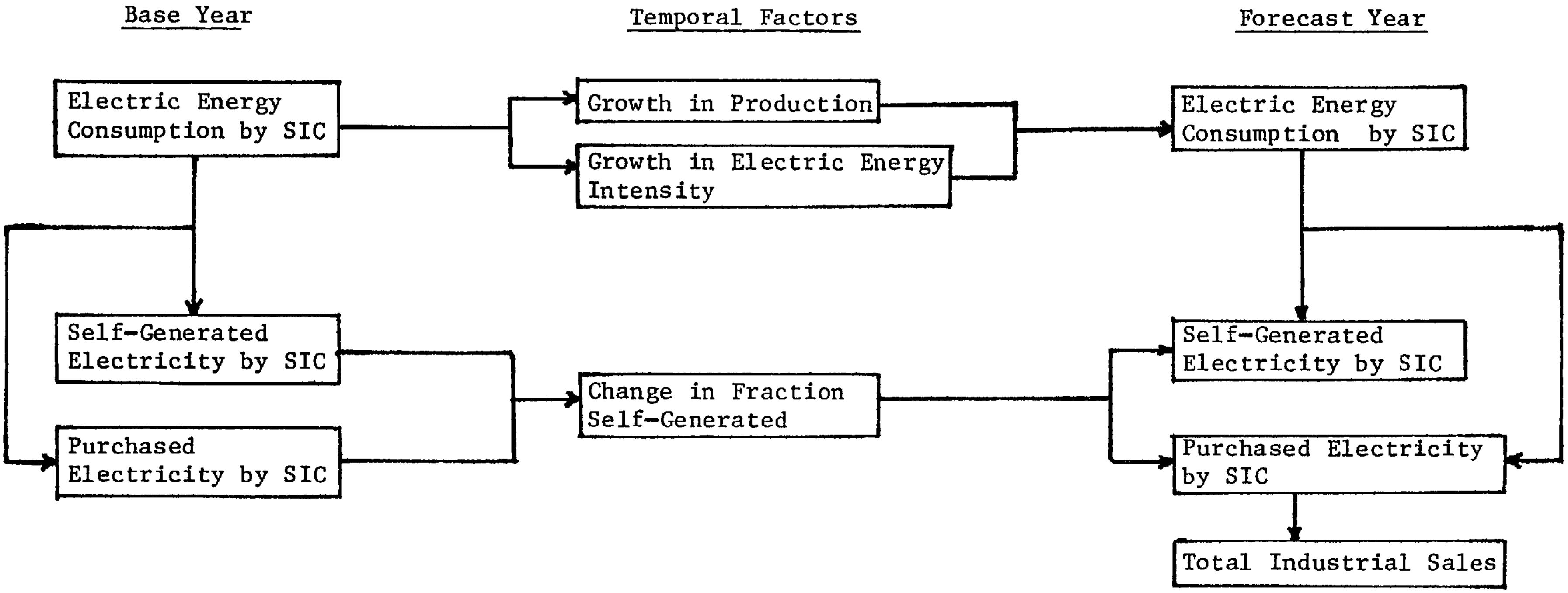


FIGURE 5.1
INDUSTRIAL SECTOR MODEL SCHEMATIC

5.2 Base Year Experience

The model requires inputs on base year industrial sales and self-generated electricity by two-digit SIC. Statewide data is available from public sources (see e.g., Reference 12). Fractional breakdowns of base year sales by service territory and SIC are generally available and may also be generated from statewide data on the basis of county employment by industrial grouping (Reference 9), and on county to service area allocation matrices. This is, of course, not necessary for statewide forecasts.

5.3 Production Growth

The measure of industrial activity which is employed in the model is the level of actual physical production. Growth in production suitably forecast is the measure of "energy using activity" in the industrial forecast. In addition, to accurately capture trends in process shifts and in fuel mix in industry, energy intensity (discussed in the next sub section) should be expressed on a KWH per unit production basis rather than, say KWH per $ value added.

The Federal Reserve Board gathers data on industrial production nationally (Reference 13). This data is reported in the form of the "national production index" which, for each SIC, is normalized to 100 for 1967. Composite forecasts of NPI's are also available (Reference 14).

To make use of the national historical and forecast information, account must be taken of deviations between state-level and national trends. Specifically, national production growth must be weighted by any changes in the fraction of the U.S. production occurring in the state. Forecasts of the ratio of state-to-national production activity are provided by the BEA (Reference 7) on the basis of earnings.

Combining these factors, one can develop an expression for state production index (SPI) given in Equation 5.1.a of Table 5.2. As we shall see in Section 5.6, the ratio of $\mathrm{SPI}_{t,i}$ for successive years alone is utilized in defining annual energy growth. Consequently, the absolute values are irrelevant to the model and any convenient normalization is acceptable. In practice, we shall follow the FRB's normalization procedure.

Alternative estimates of state production growth can be developed from combining productivity trends (measured in physical output per manhour) with state-level employment forecasts available from State planning offices. This is shown in Equation 5.1.b of Table 5.2. Both methods may be considered in estimating likely ranges of industrial production growth. We shall return to the specifics when discussing input data assumptions.

TABLE 5.2

STATE PRODUCTION INDEX FORECAST

Indices

t	Year (base year = 1)
j	Industrial grouping by 2 digit SIC (j = 1 to 19)

Variables

NPI	National production index
SPI	State production index
SNER	State to national earnings ratio
SEMP	State Employment Index
SPROD	State Productivity Index

Equation

$$SPI_{t,j} = SNER_{t,j} \times NPI_{t,j} \qquad (5.1a)$$

or

$$SPI_{t,j} = SEMP_{t,j} \times SPROD_{t,j} \qquad (5.1b)$$

5.4 Electrical Energy Intensity

Electrical energy intensity - average consumption per unit of physical output - has changed over time for three major reasons: adoption of capital intensive production technologies, changes in the mix of fuels used for thermal and process energy, and increased use of energy management practices.* The historic time series intensities may differ radically by SIC classification and by geography since the impact of these factors will be a function of particular manufacturing conditions, fuel prices and availability, employment constraints, technology vintage, and state policy climate. We shall discuss later the methods for estimating ranges of future electric intensity for industries in the state.

5.5 Fraction Self-Generated

Up to this point, industrial electricity consumption has been forecasted on the basis of the total demand for electricity on the customer's side of the meter:

Total kwh Demand = Production × Intensity

where intensity is expressed in terms of unit production requirements. Only part of this demand must be met by the utility, however, since many industries produce some of their electricity requirements in-house.

Therefore, an additional factor--the fraction of total electrical energy consumption which is self-generated--is necessary in computing forecast industrial sales. This fraction may change over present values as a result of national energy policy, developing state interest in addressing regulatory and other barriers to such investment, and renewed interest among industrial planners in combined energy systems as a result of the increasing costs of electricity. Therefore, the historic decrease in the fraction self-generated is likely to reverse. The degree will depend on scenario assumptions based on existing studies of cogeneration potential and on historic levels experienced in the state.

5.6 Energy Forecast

The basic elements required for the industrial sector have now been described. They are brought together in the energy forecast model summarized in Table 5.3. The iteration (Equation 5.5) is first initialized for the base year. The fractional breakdown of industrial sales (Equation 5.2) is used to define base year sales by SIC. Total energy is derived from purchased energy

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* Short term fluctuations related to, e.g., business cycle or large plant relocations, are not germane to the long-range forecast which depends only on secular trends.

using base year values for the fraction self-generated (Equation 5.3). The growth index of Equation 5.4 (=1 + average annual rate of growth in year t) is based on the growths in state production index (Section 5.3) and electric energy intensity (Section 5.4). Finally, forecasted total energy consumption is decreased by the self-generated component to arrive at the forecast for industrial sales (Equation 5.6).

TABLE 5.3
INDUSTRIAL ENERGY FORECAST

Indices

t	Year (base year = 1)
j	Industrial grouping by 2-digit SIC (j = 1 to 19)

Variables

TESIC	Total electric energy consumption
PENSIC	Purchased electric energy consumption
ISALES	Base year total industrial sector sales
SEI	Electric intensity
SPI	State production index
MIX	Fraction base year industrial sales breakdown
IND	Growth index
SGEN	Fraction self-generated

Equations

Initialize (t=1):

$$\mathrm{PENSIC}_{1,j} = \mathrm{MIX}_j \times \mathrm{ISALES} \qquad (5.2)$$

$$\mathrm{TESIC}_{1,j} = \mathrm{PENSIC}_{1,j}/(1 - \mathrm{SGEN}_{1,j}) \qquad (5.3)$$

For t>1, define growth index:

$$\mathrm{IND}_{t,j} = (\mathrm{SEI}_{t,j} \times \mathrm{SPI}_{t,j}) \,/\, (\mathrm{SEI}_{t-1,j} \times \mathrm{SPI}_{t-1,j}) \qquad (5.4)$$

Then,

$$\mathrm{TESIC}_{t,j} = \mathrm{IND}_{t,j} \times \mathrm{TESIC}_{t-1,j} \qquad (5.5)$$

$$\mathrm{PENSIC}_{t,j} = \mathrm{TESIC}_{t,j} \times (1-\mathrm{SGEN}_{t,j}) \qquad (5.6)$$

6. OTHER ENERGY REQUIREMENTS

The residential, commercial, and industrial sectors account for the bulk of energy consumption. The residual categories are street and highway lighting, railroads, company use, losses, and sales for resale. Of these, the last item represents KWH sales to other electric utilities. Since we are interested in only demand for electricity on the utility system (not on itself), this category can be ignored.

The category "losses" refers to electric energy lost in the transmission and distribution lines in the course of serving system customers. Utility "company use" is the energy consumed by the electric utilities themselves in business operations. These two categories - losses and company use - are accounted for in the model by a fraction of total sales ($FRLS_t$ in Table 6.1). That is

$$FRLS_t = \left(\frac{\text{losses and company use}}{\text{total sales}} \right)_t$$

Total sales includes, in addition to the three main sectors discussed in earlier sections, sales for railroad and street and highway lighting. Total energy from the "other" sector is then derived from Equation 6.1. Yearly energy sales from the three main sectors are inputed from the respective sectoral models, base year data for "other" sales, losses and company use are readily available from utility records. Deviations from base year values are provided by Company forecasts or can be independently estimated.

TABLE 6.1
OTHER ENERGY

Indices

t	Year (base year = 1)

Variables

$FRLS_t$	Losses and company use as a fraction of total sales
SUM_t	Sum of energy sales to residential, commercial and industrial sectors
$OSALES_t$	Energy sold for street and highway lighting and railroads
$OTHEN_t$	Energy sendouts in "other" category

Equation

$$OTHEN_t = OSALES_t + FRLS_t \times (SUM_t + OSALES_t) \qquad (6.1)$$

7. PEAK POWER

In the preceding sections, we have concentrated on the electrical energy forecasting model. Here, we shall turn instead to the method for translating these results into peak power demand forecasts ("demand" henceforth). Power, being the rate at which energy is expended, will be expressed in units of 1000 kwh/hour or simply mw.

In developing peak power forecasts, a compromise between a disaggregated end-use approach and gross load factor approach has been adopted. The former requires excessive data requirements on the composition of demand at peak. The latter loses the ability to track changes in the relationship between energy and peak due to shifts in the relative contribution of load components as a result of differing end-use growth rates or changes in use patterns. The system peak (summer and winter) is analyzed in terms of two components - "weather sensitive demand" and "base demand". In addition, certain impacts of load shifting are explicitly treated. In other words, changes in system load factor due to a changing mix of base to seasonal load and due to shifts of some energy-using operations off-peak are included.

The computational specifics are summarized in Table 7.1. First, the total energy is calculated by summation over the separate end-use forecasts developed in the sectoral models (Equations 7.1 to 7.4). The problem next is to group weather sensitive energies on the one hand, and base energy, on the other hand. By weather sensitive energy we mean extra electrical energy consumed as a result of seasonal climatic variation. For example, electric space heating energy is completely winter weather sensitive while energy consumed for comfort cooling is completely summer weather sensitive. Such strictly weather sensitive end-uses are grouped together in Equation 7.5 for all residential end-uses. The weather sensitive fractions (WSFR) for all residential end-uses are given in Table 7.2. On the other hand, the seasonal fluctuation in the other residential usages, defined in Equation 7.6, gives the variation of seasonal usage from average levels.

Next, weather sensitive commercial end-uses are identified in Equation 7.7. The notational convention is correctly incorporated by identifying summer (p=1) and winter (p=2) correctly with the cooling and electric space-heating end-uses, respectively. Breakdowns on weather sensitive to non-weather sensitive energy requirements in the industrial and "other" categories are not available. However, these sectors generally show minimal seasonal variation since, for example, monthly industrial process requirements are correlated to market fluctuations which, in a long term model, can be treated as temporally random. Consequently, industrial and "other" energy will be included in our "base" energy category. It is worth stressing that the division into weather sensitive and non-weather sensitive components is only necessary anyway when the relative weight of component contributions to peak change. If the shape of the annual load curve is not expected to change, a single load factor would suffice in mapping annual energy to seasonal peak.

The overall weather sensitive energy by season is formed as the summation of its sectoral components. For summer, we have the simple sum of Equation 7.10. For winter, two additional complications arise: (1) the model allows for the possibility of thermal storage in the commercial sector and (2) heat pump efficiencies (which are functions of temperature) must be reduced in calculating the winter peak. We shall discuss these in turn.

Rate differentials by time-of-day, if large enough, can make capital investment in thermal storage systems economically attractive. We have allowed for this possibility in the most promising case of commercial space heating. That fraction of usage which is shifted to off winter peak should not be included in the winter weather sensitive energy used to compute winter peak. This is taken into account explicitly in the second term of Equation 7.11 where the "fraction off-peak commercial weather sensitive" (FOPCWS) is phased in linearly from zero for the assumed start-up of time-of-use rates to a value assumed for the year 2000 (Equation 7.12). The values selected depend on scenario assumptions on the likelihood and nature of future time-of-use (TOU) rates.

The other complication in deriving the winter weather sensitive energy is the decrease in heat pump coefficient of performance at colder temperatures. If average seasonal energies were used to drive the winter weather sensitive peak, underestimates of peak demand would result since more KWH of electric input per kwh of heating output are required on colder days. The third term in Equation 7.11 corrects for this effect. Forecast annual electrical energy consumption for heat pumps, are computed in the residential and commercial energy programs (called TREHP and TCOHP, respectively). The coefficient of performance correction factors (COPCR and COPCC for residential and commercial sectors, respectively) are defined as the ratio of average to coldest day COP. The method and assumptions for estimating the corrections are discussed later.

Next, the base energy is defined by subtracting the strictly weather sensitive parts from total energy (Equation 7.8). Also subtracted is an estimate of residential "base" energy consumption that would be shifted to off-peak should TOU rates be adopted for the residential customer class. The off-peak shifted energy is paramaterized in Equation 7.9 where estimates of the start-up year and fraction of time-flexible end-use consumption shifted are required. Time-flexible end-use consumption is defined here (after Reference 15) as the energy used for clothes dryer, clothes washer, dish washer and water heater. These are the end-uses that could most conveniently be shifted in response to off-peak reduced rates and for which the customer would experience little or no life-style alteration. Additional load shifting is conceivable - e.g., timers on freezer and refrigerator automatic defrost devices and thermal storage -- but considered less probable.

Armed with the base and weather sensitive energy component, the summer and winter peaks are computed in Equation 7.15. The "coincident load factors" are defined here, for a given component of demand, as the ratio of the contribution to the utility system peak and the energy. Since energies will be expressed in 10^6 kwh (gwh) and demand will be expressed in mw, the "coincident load factors" are in units of $(10^3 \text{ hours})^{-1}$. They are derived in Equations 7.13 and 7.14 from base year experience. The base year energies are derived within the model as discussed above, while base year summer and winter peaks are those experienced in the base year (weather normalized if available.) The division into "base" and "weather sensitive" peak is derived from analysis of the variation in monthly peaks as a function of temperature as will be explicated in the data discussion.

TABLE 7.1
PEAK POWER MODEL

Indices

t	Year (base year = 1)
p	Season (1 = summer, 2 = winter)
i	End-use
j	Commercial category
k	Building/housing type
n	Existing or new buildings

Variables

BY	Base year
TOTEN	Total energy requirements
BD	Base demand in base year
AFBEU	Average seasonal fluctuations of residential "base" end-uses
BE	Base energy
WSE	Weather sensitive energy
RESSA	Residential sales
COMMSA	Commercial sales
INDSA	Industrial sales
OTHEN	"Other" energy requirements
ENREU	Energy consumption residential end-uses
ENCEU	Energy consumption commercial end-uses
PENSIC	Purchased energy industrial by SIC
CLFB	Coincident load factor--base
CLFWS	Coincident load factor--weather sensitive
RTOUY	TOU rate start-up year--residential sector
CTOUY	TOU rate start-up year--commercial sector
FOPRB	Fraction time-elastic energy consumption shifted off-peak
FOPRBT	Fraction time-elastic energy consumption shifted off-peak by 2000
OPBER	Base energy shifted to off-peak in residential sector
FOPCWS	Fraction commercial weather sensitive demand off-peak
FOPCWT	Fraction commercial weather sensitive demand off-peak by year 2000
WSFR	Weather sensitive fraction residential end-uses
COPCR	Coefficient of performance correction factor - residential
COPCC	Coefficient of performance correction factor - commercial
TRCHP	Total energy consumed by residential heat pumps
TCOHP	Total energy consumed by commercial heat pumps
PEAK	Peak

(continued)

TABLE 7.1 (Continued)

Variables (Continued)

CNWH	Fraction of residential waterheating load controlled in year t

Equations

Sectoral energies:

$$\mathrm{RESSA}_t = \sum_{i=1}^{14} \mathrm{ENREU}_{t,i} \qquad (7.1)$$

$$\mathrm{COMMSA}_t = \sum_{k=1}^{5} \sum_{i=1}^{4} \sum_{n=1}^{2} \mathrm{ENCEU}_{t,k,n,i} \qquad (7.2)$$

$$\mathrm{INDSA}_t = \sum_{j=1}^{19} \mathrm{PENSIC}_{t,j} \qquad (7.3)$$

Total energy:

$$\mathrm{TOTEN}_t = \mathrm{RESSA}_t + \mathrm{COMMSA}_t + \mathrm{INDSA}_t + \mathrm{OTHEN}_t \qquad (7.4)$$

Define intermediate sums:

$$\mathrm{RWSSUM}_{t,p} = \sum_{i=10}^{13} \mathrm{WSFR}_{i,p} \times \mathrm{ENREU}_{t,i} \qquad (7.5)$$

$$\mathrm{AFBEU}_{t,p} = \sum_{i=1}^{9} \mathrm{WSFR}_{i,p} \times \mathrm{ENREU}_{t,i} \qquad (7.6)$$

$$\mathrm{CWSSUM}_{t,p} = \sum_{k,n} \mathrm{ENCEU}_{t,k,n,3-p} \text{ (3-p is end-use label)} \qquad (7.7)$$

then

$$\mathrm{BE}_t = \mathrm{TOTEN}_t - \sum_{p=1}^{2} (\mathrm{RWSSUM}_{t,p} + \mathrm{CWSUM}_{t,p}) - \mathrm{OPBER}_t \qquad (7.8)$$

where

$$\mathrm{OPBER}_t = \begin{cases} \mathrm{CNWH}_t \times \mathrm{ENREU}_{t,8} & \text{for } t \leq \mathrm{RTOUY} \\ \mathrm{FOPRB}_t \left[\sum_{i=6,7,9} \mathrm{ENREU}_{t,i} + (1-\mathrm{CNWH}_t) \times \mathrm{ENREU}_{t,8} \right] + \mathrm{CNWH}_t \times \mathrm{ENREU}_{t,8} & \text{for } t > \mathrm{RTOUY} \end{cases}$$

and

$$\mathrm{FOPRB}_t = (t-\mathrm{RTOUY})/(2001-\mathrm{BY}-\mathrm{RTOUY}) \times \mathrm{FOPRBT} \qquad (7.9)$$

(continued)

TABLE 7.1 (Continued)

Weather sensitive energy:

$$WSE_{t,1} = RWSSUM_{t,1} + CWSSUM_{t,1} \tag{7.10}$$

$$WSE_{t,2} = RWSSUM_{t,2} + (1-FOPCWS_t) \times CWSSUM_{t,2} + TREHP_t \times (COPCR-1) + TCOHP_t \times (COPCC-1) \tag{7.11}$$

where

$$FOPCWS_t = \begin{cases} 0 \\ ((T-CTOUY) \; / \; (2001 - BY - CTOUY)) \times FOPCWT \end{cases} \quad \text{for} \quad \begin{cases} t \le CTOUY \\ t > CTOUY \end{cases} \tag{7.12}$$

Define:

$$CLFB = BD \; / \; BE_1 \tag{7.13}$$

$$CLFWS_p = (PEAK_p - CLFB \times (BE+AFBE_{1,p}))/WSE_{1,p} \tag{7.14}$$

then

$$PEAK_{t,p} = CLFB \times (BE_t + AFBE_{t,p}) + CLFWS_p \times WSE_{t,p} \tag{7.15}$$

TABLE 7.2
SEASONAL VARIATION OF RESIDENTIAL ENERGY USE

End-Use	Summer	Winter
Refrigerator	.05	-.04
Freezer	.03	-.04
Range	-.05	.03
Lighting	-.08	.05
TV	-.02	.02
Clothes Dryer	-.04	.01
Clothes Washer	-.04	.01
Dishwasher	-.04	.02
Water Heater	-.05	.05
AC-Room	1.0	0
AC-Central	1.0	0
ESH	0	1.0
Ht. Aux.	0	1.0
Misc.	0	0

Based on Reference 31.

8. DISCUSSION OF INPUT DATA AND ASSUMPTIONS

The model, as described in Secs. 3 through 7, simulates electricity demand at the point of consumption. It is a tool for mapping a set of input data (defining historic experience, equipment ownership growth, technology shifts, fuel switching, etc.) onto a set of output results (system and end-use energy requirements forecasts, peak levels, etc.). This section describes the data utilized and assumptions made in generating the High Case and Low Case forecasts for each of the New England states. The uncertainty bands in input parameters are intended to represent a reasonable range of assumptions about the future.

The computer program that ESRG has developed to implement the model allows for flexibility in the choice of both inputs and outputs. The data explication below is intended to correspond closely to the model descriptions given earlier. With cross-referencing to the discussion of the mathematical structure of the appropriate submodel, this should allow the reader to fully understand the basis for the forecasts reported in Sec. 1. The base year, which serves as the departure point for forecasting, is 1978 throughout the study since this was the most recent year of full data when the forecast was performed.

8.1 Residential Sector

Here we shall concentrate on the data inputs used to derive the residential forecast model described in Sec. 3: demographics, saturations, and factors affecting unit usage levels.

8.1.1 Demographics

Base year and projected population data were available from four basic sources: (1) U.S. Census Bureau, current Population Report Series P-25 (Ref. 15), (2) Bureau of Economic Analysis updated OBERS projections (Ref. 7), (3) the New England Power Pool documentation of the NEPOOL/Battelle Forecast Model (Ref. 16), and (4) where available, the various state planning agencies' projections (Refs. 17-21). Table 8.1 below gives the population projections used in the present forecast, along with their sources. For each state, the High and Low Cases utilize the high and low estimates from the Census series and the state agencies to best represent the range of available forecasted growth rates. In all cases, source (3) above lies in the range chosen (with the exception of Massachusetts where NEPOOL's projections lie below our Low Case.) These forecasts serve as the base for forecasting residential customers (households), as well as growth in commercial floorspace allotted to health and education.

TABLE 8.1

COMPARISON OF POPULATION FORECASTS, NEW ENGLAND STATES

STATE	ESRG CASE	FORECAST SOURCE	Ref*	1975	Population Growth 1985/1975	1990/1975	1995/1975	2000/1975
Connecticut	High	U.S. Housing Census IIA	15	1.0	1.079	1.125	1.166	1.198
	Low	U.S. Housing Census IIB		1.0	1.035	1.060	1.080	1.092
Maine	High	U.S. Housing Census IIB	15	1.0	1.130	1.203	1.270	1.328
	Low	U.S. Housing Census IIA		1.0	1.080	1.127	1.169	1.203
Massachusetts	High	U.S. Housing Census IIB	15	1.0	1.068	1.109	1.146	1.177
	Low	U.S. Housing Census IIA		1.0	1.064	1.103	1.138	1.167
New Hampshire	High	N.H. Off. of Comp. Planning	21	1.0	1.226	1.310	1.382	1.450
	Low	U.S. Housing Census IIB	15	1.0	1.152	1.234	1.307	1.371
Rhode Island	High	U.S. Housing Census IIA	15	1.0	1.077	1.033	1.164	1.199
	Low	R.I. State Planning Program	19	1.0	1.026	1.045	1.062	1.074
Vermont	High	Vt. State Planning Office	20	1.0	1.139	1.219	1.290	1.370
	Low	U.S. Housing Census IIB	15	1.0	1.095	1.151	1.200	1.242

* References are listed on pp. 107-111.

In order to translate population forecasts into housing (customer) forecasts, two further characteristics of housing stock must be defined. Projections of persons per household and trends in the mix between single-family and multifamily housing must be developed. A 1976 Census document (Ref. 22) shows persons per household grouped between 2.89 and 2.97 for the New England states. The present forecast adopted a High Case assumption that this will decrease to 2.5 by 1990, after Ref. 23, and a Low Case of 2.7 (Ref. 24). Base year housing mix was developed by modifying 1970 housing mix fractions (Ref. 25) to reflect 1970-1978 housing construction permits (Ref. 26). The projection of future housing mix takes into account recent trends toward smaller families, condominiums in the cities, and tighter money markets. The base year and projected housing mix are as follows:

	CONN.		MAINE		MASS.		N.H.		R.I.		VT.	
	SF	MF	SF	MF	SF	MF	SF	MF	SF	MF	SF	MF
Base Year	59%	41%	75%	25%	51%	49%	69%	31%	52%	48%	73%	27%
New Housing-High	59%	41%	75%	25%	51%	49%	69%	31%	52%	48%	73%	27%
(to 1995) -Low	50%	50%	65%	35%	40%	60%	60%	70%	45%	55%	65%	35%

Base year customer counts were drawn from the 1978 EEI annual report (Ref. 27) with a slight downward modification to account for seasonal/second homes based upon NEPOOL estimates (Ref. 16). The energy use of these second homes was accounted for and grown with the residential "miscellaneous" submodel.

The ESRG forecast of New England customers based upon the above assumptions are presented, by state, in Table 8.2.

8.1.2 Appliance Saturations

Appliance saturation assumptions are summarized in Tables 8.3 through 8.8 for each New England state. The symbols in parentheses refer to the terms in Eq. 3.5 for the saturation logistics curve. Electric Space Heating (ESH) and Water Heat saturations are derived using penetration rates, as described below. The end-uses not included in the table have predetermined definitional saturation values: lighting and miscellaneous are each fixed at one, while heating auxiliary saturation is defined as one minus the electric space heat saturation.

TABLE 8.2

NEW ENGLAND CUSTOMER FORECAST ($\times 10^6$)

	1978		1980				1985				1990				1995			
			HIGH		LOW		HIGH		LOW		HIGH		LOW		HIGH		LOW	
	SF	MF	SF	MF	SF	MF	SF	MF	SF	MF	SF	MF	SF	MF	SF	MF	SF	MF
CT	.632	.436	.656	.453	.642	.446	.727	.502	.674	.478	.806	.556	.709	.512	.855	.576	.721	.523
ME	.275	.092	.288	.097	.282	.095	.326	.110	.301	.105	.369	.124	.321	.116	.389	.131	.331	.122
MA	.942	.923	.974	.954	.958	.948	1.069	1.047	1.009	1.025	1.174	1.149	1.064	1.108	1.213	1.187	1.092	1.149
NH	.208	.093	.223	.100	.218	.095	.258	.116	.239	.109	.293	.131	.261	.124	.309	.138	.275	.133
RI	.163	.148	.169	.154	.165	.150	.187	.171	.171	.157	.207	.189	.177	.165	.215	.196	.180	.167
VT	.119	.044	.125	.046	.122	.046	.142	.052	.131	.051	.162	.059	.141	.057	.171	.063	.146	.060

TABLE 8.3

STATE OF CONNECTICUT
APPLIANCE SATURATION ASSUMPTIONS

Appliance		Base Year Sat. ("SBY")	1970 Sat. ("SEY")	High Case Terminal Sat ("STERM")	High Case Growth Parameter ("A")	Low Case Terminal Sat ("STERM")	Low Case Growth Parameter ("A")
Refrig.	(SF)	1.08	1.08	1.08	0.0	1.08	0.0
	(MF)	1.02	1.00	1.02	0.0	1.02	0.0
Freezer	(SF)	.38	.31	.60	0.060	.38	0.0
	(MF)	.15	.08	.30	0.126	.15	0.0
Range		.68	.56	.85	0.091	.68	0.0
TV	(SF)	2.05	1.78	2.5	0.076	2.05	0.0
	(MF)	1.00	1.00	1.00	0.0	1.00	0.0
Cl. Dryer		.55	.38	.85	0.102	.70	0.141
Cl. Washer		.79	.77	.85	0.039	.79	0.0
Dishwasher		.33	.25	.90	0.051	.70	0.059
Water Heat		.28	.24	-	-	-	-
AC/room		.756	.35	1.00	0.219	.80	0.387
AC/cen.	(SF)	.066	.024	.20	0.161	.15	0.177
	(MF)	.102	.03	.30	0.203	.20	0.237
ESH	(SF)	.066	.052	-	-	-	-
	(MF)	.135	.052	-	-	-	-

Sources: Refs. 16, 25, 28, 29

TABLE 8.6

STATE OF NEW HAMPSHIRE
APPLIANCE SATURATION ASSUMPTIONS

Appliance		Base Year Sat. ("SBY")	1970 Sat. ("SEY")	High Case Terminal Sat ("STERM")	High Case Growth Parameter ("A")	Low Case Terminal Sat ("STERM")	Low Case Growth Parameter ("A")
Refrig.	(SF)	1.09	1.00	1.15	0.125	1.09	0.0
	(MF)	1.00	1.00	1.00	0.0	1.00	0.0
Freezer	(SF)	.47	.33	.65	0.116	.47	0.0
	(MF)	.12	.08	.15	0.157	.12	0.0
Range		.70	.63	.90	0.051	.70	0.0
TV	(SF)	1.26	1.01	2.00	0.064	1.26	0.0
	(MF)	1.00	1.00	1.00	0.0	1.00	0.0
Cl. Dryer		.49	.37	.80	0.076	.60	0.127
Cl. Washer		.72	.71	.80	0.016	.72	0.0
Dishwasher		.28	.13	.90	0.123	.70	0.134
Water Heat		.318	.31	-	-	-	-
AC/room		.256	.124	.60	0.131	.40	0.172
AC/cen.	(SF)	.02	.005	.06	0.213	.03	0.288
	(MF)	.02	.005	.06	0.213	.03	0.288
ESH	(SF)	.16	.044	-	-	-	-
	(MF)	.07	.044	-	-	-	-

Sources: Refs. 16, 25, 33, 34

TABLE 8.7

STATE OF RHODE ISLAND
APPLIANCE SATURATION ASSUMPTIONS

				High Case		Low Case	
Appliance		Base Year Sat. ("SBY")	1970 Sat. ("SEY")	Terminal Sat ("STERM")	Growth Parameter ("A")	Terminal Sat ("STERM")	Growth Parameter ("A")
Refrig.	(SF)	1.10	1.04	1.15	0.106	1.10	0.0
	(MF)	1.00	1.00	1.00	0.0	1.00	0.0
Freezer	(SF)	.24	.17	.40	0.088	.24	0.0
	(MF)	.06	.04	.10	0.101	.06	0.0
Range	(MF)	.47	.44	.65	0.028	.47	0.0
TV	(SF)	2.00	1.99	2.50	0.003	2.00	0.0
	(MF)	1.00	1.0	1.00	0.0	1.00	0.0
Cl. Dryer		.30	.28	.55	0.018	.40	0.031
Cl. Washer		.69	.67	.75	0.040	.69	0.0
Dishwasher		.21	.15	.80	0.054	.60	0.060
Water Heat		.19	.14	-	-	-	-
AC/room		.22	.18	.50	0.042	.40	0.050
AC/cen.	(SF)	.017	.010	.06	0.085	.03	0.120
	(MF)	.017	.010	.06	0.085	.03	0.120
ESH	(SF)	.04	.027	-	-	-	-
	(MF)	.08	.027	-	-	-	-

Sources: Refs. 16, 25, 28, 29

TABLE 8.8

STATE OF VERMONT
APPLIANCE SATURATION ASSUMPTIONS

Appliance		Base Year Sat. ("SBY")	1970 Sat. ("SEY")	High Case		Low Case	
				Terminal Sat("STERM:)	Growth Parameter("A")	Terminal Sat("STERM")	Growth Parameter("A")
Refrig.	(SF)	1.01	1.0	1.10	1.014	1.01	0.0
	(MF)	1.00	1.0	1.00	0.0	1.00	0.0
Freezer	(SF)	.53	.39	.80	0.091	.53	0.0
	(MF)	.14	.10	.20	0.106	.14	0.0
Range		.74	.59	.95	0.096	.74	0.0
TV	(SF)	1.60	1.37	2.25	0.057	1.60	0.0
	(MF)	1.00	1.0	1.00	0.0	1.00	0.0
Cl. Dryer		.51	.39	.90	0.067	.70	0.095
Cl. Washer		.80	.79	.90	0.013	.80	0.0
Dishwasher		.29	.17	.90	0.089	.70	0.099
Water Heat		.50	.48	-	-	-	-
AC/room		.18	.046	.40	0.230	.30	0.264
AC/cen.	(SF)	.015	.007	.060	0.116	.030	0.149
	(MF)	.015	.007	.060	0.116	.030	0.149
ESH	(SF)	.12	.059	-	-	-	-
	(MF)	.12	.059	-	-	-	-

Source: Refs. 16, 25, 33

Appliance data were drawn where possible from appliance surveys or forecast documents of the several utilities (Refs. 28-34) as well as state agencies' data, with NEPOOL data (Ref. 16) providing some state specific and regionwide assumptions. Saturations for 1970 were obtained from the Census of Housing (Ref. 25). For each appliance, the growth index "A" is computed by fitting the logistic curve (Sec. 3.2) to 1970 and 1978 saturation data. Guidance in estimating the terminal saturation levels was derived from econometric relationships between appliance saturation and price/income variables. Specifically, lower bounds on saturation growths to the year 2000 were calculated using the econometric relationships given in Refs. 68 and 69 driven by the following annual real growth rates.

	Income	Electricity Price	Oil Price	Natural Gas Price
High Case	1.5%	1.0%	4.0%	4.0%
Low Case	.5%	2.5%	2.0%	2.5%

Increases in the number of electric space heating customers were formulated in terms of penetration rates as described in Sec. 3.3.9. The penetration rates are modeled to increase linearly from initial year to 1990 values, as shown in Table 8.9. These ranges generally reflect the range of values experienced during the 1970's.

Historic penetration rates have been dependent on a complex mix of factors including construction financing practices which have tended to emphasize first cost natural gas availability, and utility promotion. Given the rebound in gas availability, the trend towards life-cycle costing, and the termination of promotion, the assumed continuation of recent historic levels may somewhat overestimate ESH growth.

Electric water heater penetration is dependent on the electric space heating penetration as described in Sec. 3.3.7. All new electric space heating customers are assumed to have electric water heating, and all new non-electric space heating customers are assumed to have a penetration level for electric water heating equal to the base year saturation level of non-electric space heating customers.

8.1.3 Unit Electricity Usage

The demographic and saturation computations generate the number of units by end-use. There remains the description of input data to derive the electricity usage per unit submodels (the "C" in Eq. 3.1). Average unit usage for the base year is

TABLE 8.9

ELECTRIC SPACE HEAT PENETRATION*

		Penetration Assumptions			
		High Case		Low Case	
State	Housing Type	1979	1990	1979	1990
Connecticut	Single family	.30	.30	.15	.15
	Multifamily	.50	.50	.30	.30
Massachusetts	Single family	.30	.30	.15	.15
	Multifamily	.50	.50	.30	.30
Maine	Single family	.30	.30	.15	.15
	Multifamily	.50	.50	.30	.30
New Hampshire	Single family	.60	.60	.40	.40
	Multifamily	.40	.40	.20	.20
Rhode Island	Single family	.10	.10	.20	.20
	Multifamily	.30	.30	.40	.40
Vermont	Single family	.60	.60	.40	.40
	Multifamily	.40	.40	.20	.20

*Average ratio of change in ESH customers to change in total customers

Refs. 16, 25, 28-34

given in Table 8.10 along with the efficiency improvements assumed in the forecast runs. The latter require some clarifying comments:

- The efficiency improvements are at FEA target levels (Ref. 35). These targets could possibly be exceeded in the forecast period; the Secretary of Energy is mandated, under the National Energy Conservation Policy Act (Title IV, §422) to prescribe "standards for each type (or class) of covered products *** [which] shall be designed to achieve the maximum improvement in energy efficiency which the Secretary determines is technologically feasible and economically justified" (Ref. 36).
- The achievement date in the FEA program was 1980. The forecasts assume 1982 and 1985 for the Low and High Cases, respectively.
- Though not shown on the tables, decreases in hot water requirements have also been included at FEA-targeted levels (3.7% for clothes washers, 17% for dishwashers, with 1981 and 1985 phase-in dates for the Low and High Cases, respectively). Though such increased thermal efficiencies do not directly affect electrical consumption, they will impact indirectly on electric hot water requirements (see Sec. 3.3.7).

TABLE 8.10

BASE YEAR APPLIANCE USE DATA (KWH/YR)

Appliance	Connecticut			Massachusetts			Maine			Forecast Unit Energy Reduction
	SF	Comb. SF/MF	MF	SF	Comb. SF/MF	MF	SF	Comb. SF/MF	MF	(percent)
Refrigerator*	1810	---	1360	1810	---	1360	1810	---	1360	28
Freezer*	1530	---	1150	1530	---	1150	1530	---	1150	22
Range	---	700	---	---	700	---	---	700	---	3
Television**	---	325	---	---	325	---	---	325	---	23/14***
Clothes Dryer	---	993	---	---	993	---	---	993	---	4
Clothes Washer	---	103	---	---	103	---	---	103	---	0
Dishwasher	---	363	---	---	363	---	---	363	---	20
Water Heater	4000	---	3000	4000	---	3000	4000	---	3000	15
Room A/C	---	425	---	---	400	---	---	175	---	22
Central A/C	1660	---	1250	1595	---	1196	---	640	---	17
Space Heater	15640	---	7820	16000	---	8000	15100	---	7550	0
Heating Auxil.	500	---	250	500	---	250	500	---	250	0
Lighting	---	700	---	---	700	---	---	700	---	(see text)

Appliance	New Hampshire			Rhode Island			Vermont			Forecast Unit Energy Reduction
	SF	Comb. SF/MF	MF	SF	Comb. SF/MF	MF	SF	Comb. SF/MF	MF	(percent)
Refrigerator*	1810	---	1360	1810	---	1360	1810	---	1360	28
Freezer*	1530	---	1150	1530	---	1150	1530	---	1150	22
Range	---	700	---	---	700	---	---	700	---	3
Television**	---	325	---	---	325	---	---	325	---	23/14***
Clothes Dryer	---	993	---	---	993	---	---	993	---	4
Clothes Washer	---	103	---	---	103	---	---	103	---	0
Dishwasher	---	363	---	---	363	---	---	363	---	20
Water Heater	4000	---	3000	4000	---	3000	4000	---	3000	15
Room A/C	---	275	---	---	350	---	---	250	---	22
Central A/C	1040	---	780	1400	---	1050	875	---	875	17
Space Heater	14200	---	7100	15580	---	7790	15000	---	7500	0
Heating Auxil.	500	---	250	500	---	250	500	---	250	0
Lighting	---	700	---	---	700	---	---	700	---	(see text)

[*] Weighted over frost-free and standard units

[**] Weighted averages for B & W, Color, tube, and solid state

[***] B & W and color respectively

Sources: Refs. on Usage: 16, 28, 31, 33, 37, 38

Refs. on Reductions: 35, 58

- Energy reductions for television sets are not assumed to be as large as the government targets; the forecasts assume 23% and 14% for black-and-white and color sets respectively, while the corresponding FEA levels are 52% and 28%. The improvements are due to a phase-out of tube-type models in favor of solid state models. Current usage levels are approximately (Ref. 37):

	Black-and-White	Color
Tube	220 kwh/unit	528
Solid State	100 kwh/unit	320

  We have assumed the 1978 units at 75 percent of the 1972 to 1980 improvements which works out to 372/kwh/unit and 130/kwh/unit for the base year vintage of color and black-and-white types, respectively. The efficiency improvements are then computed to allow for ultimate switch-over to 100% solid state.

- For certain end-uses, consumption levels for single family and multifamily homes were adjusted to capture the effects of variations in the size of the living space and the number of inhabitants. The averages were disaggregated over housing types based on the following typical SF to MF unit use relationships: 4 to 3 for refrigerators, freezers and water heaters, and 2 to 1 for central air conditioning and space heat.

8.1.4 Thermal Integrity Impacts

The building envelope characteristics of single family and multifamily dwelling units determine the final demand for three temperature sensitive end-uses: electric space heating, air conditioning, and electrically driven auxiliaries associated with non-electric heating. This final demand is to be distinguished from the electricity demand which of course would embody other efficiency factors associated with the conversion devices themselves (e.g., air conditioner COP, heat pump COP, etc.) and which are treated separately and additively by the model.

Prototypical heating savings levels for single and multifamily units were computed from the study of housing stock weatherization conducted for the New England Energy Congress (Ref. 39). The model used in that study was the New England

Energy Congress/New England Regional Commission/Massachusetts Audubon Society Housing Stock Profile (NEEC/MERCOM/MAS). ESRG researchers met with scientists who developed the NEEC/NERCOM/MAS housing stock model and scrutinized the raw data inputs and outputs. From this review it was determined that the 1978 housing stock characteristics (Ref. 39, page 238) were an acceptable basis for comparison with the characteristics of new units subject to the Massachusetts Energy Conservation Building Code. The NEEC/NERCOM/MAS raw data showed that the weatherization levels implied by the Massachusetts code were just above the "option 4" level of weatherization used in the NEEC *Final Report*. Using figures shown in the *Report*, we determined that the average percentage heating reduction produced by going from average 1978 weatherization to above "option 4" weatherization was about 35 percent in both single and multifamily units, except units with electric space heat (ESH). Since this is an electricity forecasting model, the overall heating reduction percentage of 35 is applied to the electrically-driven auxiliaries associated with a fossil heating system (fans, ignitions, etc.).

The reduction for homes with ESH was 15 percent, a smaller figure on account of their higher average 1978 weatherization level (approximately "option 2" in the NEEC *Report*.)

These heating reductions from base year usage were applied to all new housing units constructed during the forecast period. Cooling load reductions due to code-induced weatherization improvements were also estimated, based on the relationship between heating and cooling load reductions found in previous studies (Refs. 40, 41). These cooling reductions amounted to 20 percent for non-ESH units and 10 percent for units with ESH.

Since the housing code affects all new units, forecasting unit heating and cooling reductions is relatively straightforward. To project the amount of weatherization that will occur in units remaining in the housing stock, however, is more judgemental and involves greater uncertainty. For the Low Case, we assume that by the end of the forecast period, 40 percent of the existing multifamily units and 75 percent of the single family units are retrofit to code levels. The disparity between the single and multifamily units is based on the historic weatherization lag of the latter, which are not primarily owner-occupied units. In the High Case, we assume that only ten percent of the remaining multifamily housing stock and 25 percent of the single family stock are retrofit to code weatherization levels during the forecast period. Applying these scenario retrofit assumptions to the heating and cooling load reductions for new units yields the following unit energy reductions:

		Heating	Cooling
High Case	SF	.10	.05
	MF	.05	.05
Low Case	SF	.25	.15
	MF	.15	.10

All reductions are rounded to avoid the implication that they are precise projections. The retrofit reductions are phased in linearly from zero in the base year to the full unit reduction at the end of the forecast period.

8.1.5 Additional Data Requirements

The basic model structure utilizes base year and forecast counts of residential customers' saturations of various end-uses, and usages per unit to derive sectoral energy demand. However, there are a number of additional factors peculiar to each appliance type which influence usage and thus overall demand. The following provides a brief discussion of each of these factors, by end-use.

Refrigerators and Freezers

The refrigerator/freezer submodel (Sec. 3.3.1) requires input data on average annual usage for new units in the base year and for old units (defined as units which come on-line one average appliance lifetime prior to the base year). This was necessary to account for the phenomenon of increasing unit usage over time which implies that retired units will, in the first part of the forecast period, require less energy than their replacement. Also, efficiency improvements need to be incorporated from new unit -- not average -- stock levels to avoid under-estimating energy demand growth.

For refrigerators, we need an estimate of unit usage for the 1962 vintage. According to Ref. 42, the average size for 1962 was $.38M^3$ which, at 40×10^6 joules/dayM^3 for average frost-free refrigerator usage for that year, implies 1540 kwh/year for frost-free units. Frost-free sales in 1962 were 27% of the total. Removing the frost-free feature decreases energy consumption by about 29% (Ref. 43, p. 15). Combining we have for the 1962 vintage units:

$$\text{Refrigerator UNOLD} = 1540 \times .27 + 1540 \times .73 \times (1-29) =$$

$$1215 \text{ kwh/unit/year}$$

Similarly, for the 1961 freezer vintage, based on data in Ref. 43, average size was about $14 ft^3$, usage was at .33 $kwh/ft^3/day$ and .20 $kwh/ft^3/day$ for frost-free and non-frost-free units, respectively, and about 30% of freezer sales were frost-free. Combining, we have:

Freezer UNOLD = 1220 kwh/unit/year

Average unit usage for new units is based on shipment data. Mean capacities and annual energy requirements across size and models are (Ref. 44):

	Mean Capacity (ft^3)	Energy Use (kwh/year)
Refrigerators	16.67	1510
Freezers	16.48	1300

Electric Range

The electric range submodel (Sec. 3.3.2) required input data to simulate the effects of microwave oven penetration. There are two issues: what fraction have microwaves and what is the effect of those that do on energy use? The latter is straightforward; field studies (Ref. 44) indicate that electric ranges with microwave ovens require 84% of the electric energy which would otherwise be consumed. The energy demand factor ("EDF") in Table 3.3 is thus set at 0.84 in the forecasts.

The NEPOOL/Battelle model description (Ref. 16) provides historic and projected saturations of microwave ovens on a national level. These were compared with New England electric range saturations and projections of saturations to produce a base year fraction of .073 growing linearly to .215 by 1995.

Lighting

There are a number of reasons to suspect that lighting energy demand may moderate: smaller family size, trend in housing mix toward smaller units, conservation induced by increasing prices, more efficient fluorescent bulbs and new lighting technology. Furthermore, recent energy legislation allows the Secretary of Energy to develop efficiency standards for end-uses consuming more than 150 kwh per year per household, a criterion which includes lighting.

Energy savings are targeted to be at levels consistent with the more efficient bulb being developed by the Duro-Test Corporation under contract with the Massachusetts Institute of Technology (Ref. 46). This bulb is being developed now for marketing within a year (Ref. 47). It will replace a conventional 100 watt bulb and consume approximately 50 percent of the energy (i.e., it will be rated at 40 to 60 watts). The net incremental cost of the bulb (over the three shorter-lifetime conventional bulbs it would replace) is anticipated to be $2.25. The cost of saving the electrical energy comes out to about 2¢ per kwh over bulb lifetime. It should be stressed that the target is reasonable since a promotion policy would also tend to stimulate interest in higher-priced but longer-lifed and even more highly energy conserving lamps, such as the General Electric "Electronic Halarc" or "Circlite" lamps (Ref. 48).

For the present forecast, we have included the possibility of market penetration of improved light bulbs. Such bulbs can be about 50% more efficient than current incandescent bulbs. Cost-benefit analysis indicates that 22% of the residential market is currently capturable by a bulb such as a new screw-in fluorescent (Ref. 49). In the Low Case, it is thus assumed that penetration levels reach 20% by the end of the forecast period. That is, "MF" in Table 3.4 is phased linearly from zero in the base year to .20 in 1998 while "RELEFF" is phased linearly from 0 to .50, a ten percent average effect after 20 years. No improvements are assumed in the High Case.

Televisions

The television submodel (Sec. 3.3.4) requires two additional items of data. The first is a use factor for redundant sets ("DUF" in Table 3.5). This refers to the ratio of energy consumption of second and third sets to the primary set. Estimates in the literature vary widely. The forecasts incorporate a typical range of 80% in the High Case and 25% in the Low Case. The second item is the mix between black-and-white and color of future television sales. The market fraction of black-and-white television sales historically was (Ref 50):

1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
.51	.49	.47	.48	.44	.49	.43	.43	.43	.403

The model runs use 39% for 1979. Regression against time on the above data leads to a value of .33 in 1998. Consequently, the forecast spans this value by assuming that the fraction of black-and-white diminishes to 20% in the High Case and holds at 39% in the Low Case, for each New England state.

Water Heaters

In addition to the inputs already discussed, the electric water heater submodel (Sec. 3.3.7) requires some additional data inputs. The first characterizes the change in home hot water requirements for end-uses other than dishwashers and clothes washers. (These are discussed above.) This factor ("HWREOT" in Table 3.8) is capable of reflecting the effects of slow-flow shower devices and energy-conserving faucets. Such plumbing fixtures can save on the order of 36% of energy for hot water (Ref. 59). In the High Case, we assume no move to such fixtures. In the Low Case, we project an ultimate market factor of 25% for hot water savings (.25 × .36) of nine percent. The present DOE campaign to encourage the use of these devices supports this modest assumption. The model phases up to these full savings over a twenty-year period beginning in 1979.

The other inputs concern the range of likely impact of solar hot water devices. To gain an heuristic understanding of the possibilities, consider the following penetration analysis. First define payback (in years) by:

$$PB_t - C \times (1-TI) \times (1-D)^t / E \times F \times P \times (1+1)^t$$

where

PB = payback
C = first cost
TI = tax incentive
D = cost deflation
E = kilowatthour demand
F = fraction served by solar
P = electric price
I = electric price increase
t = year

Substituting a realistic range of values:

	C	TI	D	E	F	P	I
High	$2500	.2	.01	4000	.5	.05	.01
Low	$1500	.3	.02	4000	.5	.05	.02

we have

	PB-1978	PB-1998
High	19 years	12.8
Low	10	4.5

Based on 30% penetration at payback of seven years (Ref. 45) and zero penetraton at twenty-year payback, the above assumptions lead to:

	Penetration	
	1978	1998
High	0	.17
Low	.18	.53

or average penetrations over the forecast period of about 9% and 35% for the two cases. To be cautious, the forecasts have been based on zero penetration of solar hot water in the High Case and penetration phased linearly from zero in the base year to 20% in 1998 in the Low Case.

Electric Space Heat

There are three elements in the submodel (Sec. 3.3.9) that need to be specified relating to solar heating, heat pump penetration, and heat pump coefficients of performance. These will be discussed in turn.

- In estimating the penetration of solar assist technology, we first calculate a range of possible paybacks. The methodology is analogous to the computation of solar hot water paybacks described earlier. Here, we substitute first costs ranging from $6,000 to $8,000, real cost deflation at 3% in the Low Case after Ref. 52. These lead to penetration estimates defined here as the fraction of the additional electric space heat units that come on-line in 1998 with the solar assist feature at approximately 25% in the Low demand case and 5% in the High demand case. In the forecasts, we have used more pessimistic assumptions to allow for possible institutional impediments and errors in the range of input parameters. These are:

High Case	Zero solar space heating in the forecast period.
Low Case	Zero solar space heating to 1985. Penetrations increase linearly from zero to 25% and 5% in 1998 for single family and multifamily units, respectively.

- Heat pumps have been capturing an increasing fraction of the electric space heat market. The fundamental reason is that heat pump-assisted electric space heat appears to have superior economics to resistance heating. Estimates of relative costs for New England are contained in Table 8.11.

TABLE 8.11

RELATIVE ECONOMICS OF ALTERNATIVE HEATING SYSTEMS

	First Cost*	Capital+	Heating Fuel++	Total
Electric Resistance	$1300	$170	$600	$770
Natural Gas	2200	290	200	490
Electric Heat Pump	2950	390	300	690

* Estimates for single family units in 1979 dollars Refs. 8, 53, and 54.

+ Assumed financed at 12% over twenty years.

++ Fuel costs based on 5¢/kwh electricity, 12,000 kwh per household, gas boiler efficiency at 0.8, gas cost at 40¢/therm, heat pump COP = 2.0, and comparable insulation levels in new homes.

The figures indicate that gas heating is the most cost-effective option considering heating costs alone, though heat pump costs are also lower than resistance electric costs. However, remembering that heat pumps are year-round devices, it appears that they may be more nearly competitive with gas heating. They are superior to resistance heating. Consequently, it is assumed that the increase in saturation of electric heating is assoiated with increasing fractions of new electrically heated homes which use heat pumps. However, the cautious assumption used in this submodel was that the present heat pump fraction of electric space heat is zero (after Ref. 55) initially having a zero penetration rate, growing to .25 in the High Case and .75 in the Low Case, using trend values from Ref. 55.

- Heat pump coefficient of performance (COP) is defined as the ratio of kwh heating output to kwh electric input (for operating the compressor and fans). Data on unitary air-to-air heat pumps is taken from a recent evaluation performed at Argonne National Laboratory (Ref. 55) for typical models. COP varies both with size and outdoor temperature. The model requires average and low temperature values in order to estimate average COP over the heating season in forecasting energy, and the lower COP operating at the lower temperatures of the winter peak. We have assumed capacities of approximately three tons and fifteen tons for the residential and commercial sectors, respectively.

Performance data is summarized in terms of a "nominal" COP given at Air Conditioning and Refrigeration Institute's test standards* and an adjustment factor for outdoor temperature. The adjustment factor is parameterized as follows:

$$Y = A+B\cdot T+C\cdot T^2$$

where

A,B, and C are coefficients
T is outdoor temperature in ^{0}F
Y is percentage of nominal COP at temperature T.

Table 8.12 summarizes the data.

TABLE 8.12
HEAT PUMP PERFORMANCE DATA

	Nominal COP	Temperature Range (^{O}F)	A	B	C
Residential	2.4	$-10\leq T\leq 20$	61.6	1.26	-0.030
		$+20\leq T\leq 70$	44.66	1.855	-0.014
Commercial	2.7	$-10\leq T\leq 20$	56.75	0.875	0.007
		$+20\leq T\leq 70$	65.32	0.531	0.004

For the forecast states, an average and low temperature must be defined in order to estimate average COP and COP at peak. The method devised for computing regional temperature characteristics is summarized in Table 8.13.

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*47^{0}F. outdoor dry-bulb, 43^{0}F. outdoor wet-bulb and 70^{0}F. indoor dry-bulb temperature.

TABLE 8.13

HEAT PUMP COP TEMPERATURE VARIATION CALCULATION

Indices

m	Month (m=1 to 12)
l	Locality
s	Sector (1≡residential; 2≡commercial)

Variables

A_s, B_s, C_s	Coefficients (See Table 8.12)
$STNDRD_s$	Nominal COP (See Table 8.12)
$TEMPL_{m,l}$	Mean monthly temperature, month "m", locality "l"
$TEMP_m$	Mean monthly temperature, month "m" in forecast area
$LOTEMl_l$	Low temperature in locality "l"
LOTEMP	Low temperature in forecast area
POP_l	Population in locality "l"
DAY_m	Number of days in month "m"
HDD_m	Heating degree days in month "m"
$PCCOPM_{s,m}$	Percent of nominal COP in sector "s", month "m"
$PCCOPA_s$	Percent of nominal COP - average
$PCCOPL_s$	Percent of nominal COP - low
$COPA_s$	Average COP in sector "s"
$COPL_s$	Low COP in sector "s"

Equations

$$TEMP_m = (\Sigma TEMPL_{m,l} \times POP_l) \ / \ (\sum_l POP_l) \tag{8.1}$$

$$HDD_m = \begin{cases} 1 \\ (65 - TEMP_m) \times DAY_m \\ 0 \end{cases} \quad \text{for} \begin{cases} TEMP_m \leq 65 \\ TEMP_m > 65 \end{cases} \tag{8.2}$$

$$PCCOPM_{s,m} = A_s + B_s \times TEMP_m \div C_s \times TEMP^2{}_m \tag{8.3}$$

$$PCCOPA_s = (\sum_m HDD_m \times PCCOPM_{s,m}) \ / \ \sum_m HDD_{s,m} \tag{8.4}$$

$$LOTEMP = (\sum_l LOTEML_l \times POP_l) \ / \ \sum_l POP_l \tag{8.4}$$

$$PCCOPL_s = A_s + B_s \times LOTEMP + C_s \times LOTEMP^2 \tag{8.5}$$

$$COPA_s = PCCOPA_s \times STNDRD_s \ / \ 100 \tag{8.6}$$

$$COPL_s = PCCOPL_s \times STNDRD_s \ / \ 100 \tag{8.7}$$

For each New England state, locations throughout the state, weighted by population density were used to compute the statewide mean monthly temperatures. These temperatures were used in Eq. 8.3 (which is a rewrite of the equation above in model code) to define percentage of nominal COP on a monthly sectoral and service area basis. Mean monthly temperature data is taken from Ref. 56. The coefficients are from Table 8.12. These monthly values are in turn weighted by monthly heating degree days (a measure of monthly usage) to arrive at the annual percentage of nominal COP (Eq. 8.4). The heating degree days are computed by subtracting the average monthly temperatures (when they are less than 65^0F) from 65^0F and multiplying by the number of days in the month (Eq. 8.2). The low temperature is construed as the average temperature on the day of the winter peak. Finally, average and low COP are computed in Eqs. 8.6 and 8.7. The resultant COP's are given in Table 8.14.

TABLE 8.14

HEAT PUMP COP's

	Heat Pump COP's			
	Residential		Commercial	
STATE	Average	Low	Average	Low
Connecticut	2.189	1.664	2.443	1.712
Massachusetts	2.181	1.608	2.437	1.647
Maine	2.060	1.343	2.324	1.436
New Hampshire	2.080	1.440	2.348	1.502
Rhode Island	2.204	1.695	2.459	1.754
Vermont	2.034	1.160	2.285	1.334

As with other appliances, efficiency improvements are anticipated for heat pumps. The forecasts assume improvements of 4% and 13% by 1988 for the High and Low Cases, respectively.

Miscellaneous Usage

There are a number of structural factors contributing to the moderation of the historic growth in miscellaneous appliance usage:

- slightly decreasing population per household
- approach to market saturation
- increased efficiencies
- price-induced conservation
- substitutional effects (e.g., small kitchen appliances precluding use of others)

Consequently, the use per customer has been essentially constant--or slightly decreasing over the past five years in many utility service territories. The present forecast is nonetheless conservative, assuming for the high case a 50% increase in miscellaneous use per customer during the forecast period while assuming no increase in the low case.

8.1.6 Appliance Lifetimes

Actual appliance lifetimes have been used rather than the commonly-employed United States Department of Agriculture figures for average year of appliance possession by the first owner.

TABLE 8.15

APPLIANCE LIFETIMES IN YEARS

Appliance	Lifetime
Refrigerator	20
Freezer	24.9
Range	16.9
Lighting	NA
Television	14.7
Clothes Dryer	15.3
Clothes Washer	12.3
Dishwasher	13.5
Water Heater	10
Room A/C	11
Central A/C	11
Space Heat	NA
Heating Auxiliary	NA
Miscellaneous	NA

NA = not applicable
Source: Ref. 57

8.2 Commercial Sector

The discussion below of commercial forecast input assumptions parallels the model description in Sec. 4.

8.2.1 1975 Floorspace

Initial estimates of the 1975 New England states commercial floorspace are needed as input to the floorspace submodel which is summarized in Table 4.2. The computational methodology is explained in Sec. 4.2.1. The results are given in Table 8.16.

TABLE 8.16

NEW ENGLAND COMMERCIAL FLOORSPACE ESTIMATES

	1975 Floorspace ($10^6 ft^2$)					
Commercial Category	Conn.	Mass.	Maine	N.H.	R.I.	Vt.
1. F.I.R.E.	13.67	20.645	2.079	2.124	2.846	.975
2. Federal Government	3.637	11.213	2.114	1.493	1.752	.690
3. State, Local Government	15.408	38.883	5.416	6.761	5.175	2.297
4. Professional Services	4.345	13.174	1.563	.951	1.551	.627
5. Wholesale & Retail	100.425	211.609	28.945	24.674	28.769	15.329
6. Trucking, Warehousing	24.438	50.823	6.679	4.641	5.609	4.029
7. Other Transportation	4.575	11.432	1.541	.517	1.008	.380
8. Communications	2.620	5.623	.709	.645	.602	.369
9. Lodging, Personal Services	7.973	19.472	3.867	3.710	1.947	3.744
10. Business & Repair Services	14.678	32.996	2.637	2.834	3.840	.991
11. Amusement, Recreation	19.171	30.338	3.764	3.421	5.489	3.513
12. Railroad	.511	.785	.416	.079	.095	.070
13. Health Services	22.813	56.520	8.58	6.320	9.229	3.942
14. Schools, Education	79.599	155.618	27.293	20.890	24.146	12.697

8.2.2 Floorspace Growth Indices

As indicated in Sec. 4.2.2, employment growth is used as the proxy for floorspace growth for the first twelve commercial categories. The growth factors used in the forecast are summarized below in Tables 8.17 and 8.18. For each state, the High Case is based on national employment forecasts of the Bureau of Labor Statistics (Ref. 59) in conjunction with the ratio of state to national earnings projected by the Bureau of Economic Analysis (Ref. 7). Each Low Case forecast was drawn from employment forecasts done by the respective state planning agencies (Refs. 60-65).

TABLE 8.17

HIGH CASE EMPLOYMENT GROWTH INDICES

	CONNECTICUT		MASSACHUSETTS		MAINE		NEW HAMPSHIRE		RHODE ISLAND		VERMONT	
	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975
1. F.I.R.E.	1.33	1.62	1.28	1.63	1.27	1.63	1.59	2.35	1.25	1.50	1.52	2.07
2. Fed. Gov.	1.33	1.66	1.14	1.23	1.00	.96	1.40	1.94	1.19	1.23	1.36	1.73
3. St.&Loc.Gov.	1.31	1.48	1.16	1.24	1.37	1.44	1.36	1.66	1.05	1.10	1.25	1.35
4. Prof. Serv.	1.36	1.61	1.30	1.59	1.50	1.75	1.45	2.03	1.19	1.35	1.36	1.64
5. Ret. & Whole.	1.39	1.64	1.27	1.43	1.21	1.34	1.43	1.86	1.28	1.42	1.39	1.63
6. Trucking	1.33	1.38	1.30	1.24	1.14	1.17	1.48	1.80	1.27	1.29	1.19	1.29
7. Other, Trans.	1.40	1.80	1.19	1.42	1.16	1.42	1.83	2.99	1.07	1.16	1.39	1.81
8. Communic.	1.28	1.50	1.16	1.31	1.11	1.23	1.25	1.62	1.21	1.39	1.23	1.41
9. Lodg/Pers.Ser.	1.14	1.24	1.10	1.17	1.18	1.36	1.36	1.74	1.06	1.11	1.55	2.16
10. Bus/Rep.Serv.	1.52	2.22	1.43	1.93	1.54	2.46	1.87	3.53	1.62	2.41	1.60	2.56
11. Amuse/Rec.Ser.	1.54	1.88	1.49	1.92	1.32	1.52	1.55	2.40	1.42	1.64	1.53	2.25
12. R.R.Trans.	.91	.52	.85	.47	.82	.46	1.07	.81	.79	.45	.99	.66

TABLE 8.18

LOW CASE EMPLOYMENT GROWTH INDICES

	CONNECTICUT		MASSACHUSETTS		MAINE		NEW HAMPSHIRE		RHODE ISLAND		VERMONT	
	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975	EMP 1985 / EMP 1975	EMP 2000 / EMP 1975
1. F.I.R.E.	1.24	1.67	1.10	1.26	1.25	1.69	1.37	1.92	1.10	1.26	1.23	1.35
2. Fed. Gov.	1.11	1.32	1.07	1.19	.82	.59	1.04	1.09	1.10	1.26	1.11	1.17
3. St.&Loc.Gov.	1.11	1.32	1.08	1.20	1.35	1.99	1.35	1.87	1.10	1.26	1.26	1.42
4. Prof.Serv.	1.14	1.31	1.08	1.21	1.19	1.52	1.36	1.90	1.10	1.26	1.33	1.50
5. Ret.& Whole.	1.17	1.35	1.10	1.26	1.12	1.31	1.20	1.50	1.10	1.26	1.26	1.39
6. Trucking	1.08	1.21	1.10	1.27	1.01	1.04	1.26	1.64	1.07	1.18	1.21	1.33
7. Other, Trans.	1.08	1.21	1.03	1.08	1.19	1.51	1.26	1.64	1.07	1.18	1.29	1.45
8. Communic.	1.08	1.21	1.0	1.0	.98	.94	1.26	1.64	1.07	1.18	.98	.96
9. Lodg/Pers.Ser.	1.14	1.31	.96	.91	1.10	1.26	1.29	1.73	1.07	1.18	1.13	1.19
10. Bus/Rep.Serv.	1.14	1.31	1.08	1.22	1.17	1.46	1.36	1.90	1.07	1.18	1.22	1.33
11. Amuse/Rec. Ser.	1.14	1.31	1.08	1.22	1.22	1.59	1.36	1.90	1.07	1.18	1.70	2.23
12. R.R.Trans.	1.08	1.21	.81	.59	.66	.28	1.26	1.64	1.07	1.18	.87	.82

The partition of projected commercial floorspace into "new" and "existing" requires appropriate building retirement rates (refer to Sec. 4.2.2, Eqs. 4.8 and 4.9). Regional data for these rates were taken from Ref. 6. For the forecast period, the following rates were used:

1)	Office	.00647
2)	Retail	.00757
3)	Hospital	.00757
4)	School	.00647
5)	Other	.00611

8.2.3 1975 Electric Intensities

Electric intensity estimates are required to initialize the commercial sector energy growth iteration as described in Sec. 4.3.1 and Table 4.4. Given our 1975 commercial estimates, we developed overall energy intensities (kwh/Year/ft^2). The intensities appropriate to building type and end-use were developed by pro-rating Northeast electric use coefficients from Ref. 8 (as quoted in Ref. 6), with weather sensitive usage scaled, as appropriate, by heating and cooling degree days (Ref. 56). Weighted values for these are as follows:

State	Degree Days Heating	Cooling
Connecticut	6012	573
Massachusetts	6147	583
Maine	7867	253
New Hampshire	7391	573
Rhode Island	5984	512
Vermont	7845	340

Table 8.19 below provides the electricity use intensities used for the New England states, not adjusted for degree day differences, but based upon the Ref. 6 regional standard of Norwalk, Connecticut, which has averaged 5470 heating and 573 cooling degree days annually.

TABLE 8.19

COMMERCIAL ELECTRIC USE COEFFICIENTS (KWH/YEAR/FT^2)

Building Type	Existing ESH	Existing Cooling	Existing Lt&Power	Existing Aux.	New ESH	New Cooling	New Lt&Power	New Aux.
Office	9.1	4.6	7.0	5.3	12.9	3.2	7.0	4.4
Retail	4.1	5.2	18.2	6.4	6.4	3.5	18.2	5.9
Hospital	9.7	5.9	17.6	9.4	15.8	2.7	17.6	8.8
Schools	8.2	3.9	7.6	4.4	11.7	2.7	7.6	3.5
Other	4.7	5.2	10.0	6.4	7.0	2.0	10.0	5.9

Very little published source data from utilities or state agencies exists on commercial saturations. 1975 saturations are based on estimates in Ref. 16 (p. 1-10), the NEPOOL/Battelle Model, and are the source for the following assumptions used by ESRG in the present study.

State	ESH Sat.	A/C Sat.
Connecticut	.047	.60
Massachusetts	.023	.60
Maine	.031	.45
New Hampshire	.062	.45
Rhode Island	.021	.60
Vermont	.049	.45

8.2.4 Future Intensities

The methodology for incorporating future adjustments to electric intensities is described in Sec. 4.3.2. Penetration of the conservation levels has been computed in Ref. 6 for the North Eastern region based on cost optimization analysis of commercial investments in equipment and building modification; fuel cost annual average escalations of 1.3%, 2.1%, and 3.8% for electricity, oil and natural gas, respectively, to 2000, and National Energy Act incentives. The penetration levels derived from this analysis are relatively optimistic, and so were used only for the Low Case in estimating penetrations. For the High Case, the very cautious assumption that no conservation would occur in the commercial sector was made. (See Table 8.20.) Consult Table 4.4 for definitions. Note that separate penetration matrices are developed for the Electric space heat end-use. These represent fractions of floorspace at these conservation levels; the remainder, when the sum is less than one, have no conservation above base year levels.

TABLE 8.20

CONSERVATION LEVEL PENETRATION FRACTIONS (LOW CASE)

		Electric Space Heat						Other End-Uses					
		Existing			New			Existing			New		
Year	Building Type	Level 1	2	3	1	2	3	1	2	3	1	2	3
1985	Office	1	--	--	--	1	--	1	--	--	--	1	--
	Retail	--	--	--	--	.92	.08	--	.99	--	.40	.60	--
	Hospitals	--	--	--	.90	.10	--	--	--	--	.41	.59	--
	Schools	--	--	--	1	--	--	.99	--	--	1	--	--
	Other	--	--	--	1	--	--	--	--	--	1	--	--
2000	Office	--	1	--	--	1	--	--	--	1	--	.89	.11
	Retail	--	1	--	--	--	1	--	1	--	--	--	1
	Hospitals	--	1	--	--	1	--	--	1	--	--	1	--
	Schools	1	--	--	.57	.43	--	.22	--	.78	.44	.56	--
	Other	--	--	--	1	--	--	.78	--	--	.90	.10	--

Growth in electric space heat saturation is based on a range of market penetrations for both the new building and retrofit markets. Specifically, electric space heat is assumed, depending on the state, to capture 10-15% of the space heat markets in the Low Case and 20-25% for the High Case. Similar penetrations are used for the existing stock where the size of the ESH retrofit market is based on a thirty-five year lifetime for existing equipment. Projected residential saturations and the growth parameters given in the NEPOOL/Battelle Model (Ref. 16) were the primary sources used to estimate commercial saturations. The saturation assumptionsare summarized in Table 8.21.

TABLE 8.21

COMMERCIAL ELECTRIC SPACE HEAT SATURATIONS

		High Case		Low Case	
State	Year	Existing	New	Existing	New
Connecticut	Base	.047	.20	.047	.10
	2000	.15	.20	.10	.10
Massachusetts	Base	.023	.20	.023	.10
	2000	.12	.20	.07	.10
Maine	Base	.031	.20	.031	.15
	2000	.13	.20	.10	.15
New Hampshire	Base	.062	.25	.062	.15
	2000	.20	.25	.15	.15
Rhode Island	Base	.021	.20	.021	.10
	2000	.12	.20	.07	.10
Vermont	Base	.049	.25	.049	.10
	2000	.20	.25	.08	.10

The use of heat pumps is expected to increase over the forecast period although the Southern New England states are anticipated to experience the largest share of the growth. (See discussion for residential sector.) For the three Southern New England states, it was assumed that heat pumps will constitute 50% of electric space heat penetration in the High Case and 75% in the Low by the year 2000, phased in linearly from 0% in the base year. For the Northern New England states, where the COP can be expected to be less advantageous, it was assumed that there will be no heat pumps in the High Case and only 25% in the Low Case by 2000. Refer to Sec. 8.1 for a discussion of heat pump COP assumptions.

Air conditioning penetrations for new commercial buildings were taken as 90% in the High Case and 70% in the Low Case for the Southern New England states, and 70% in the High Case and 55% in the Low Case for the north. These are given in Table 8.22 below. Again, future saturations are estimated using residential saturations and NEPOOL (Ref. 16) estimates as inputs.

TABLE 8.22

COMMERCIAL AIR CONDITIONING SATURATION

State	Year	High Case Existing	High Case New	Low Case Existing	Low Case New
Southern New England	Base	.60	.90	.60	.70
	2000	.80	.90	.60	.70
Northern New England	Base	.45	.70	.45	.55
	2000	.60	.70	.45	.55

8.3 Industrial Sector

The industrial sector model is described in Sec. 5. Data requirements are of three kinds: base year experience, production growth, and electric intensity. These are discussed below sequentially.

8.3.1 Base Year Experience

Figures for base year energy sales by sector (residential, commercial, industrial, and other sales) were developed from data given by the Electric Council of New England (ECNE) in Ref. 66 Sales data on residential and "other" sales were accepted as given; sales for the commercial and industrial sectors were first cross-referenced with NEPOOL statistics for those sectors, given in Ref. 16. The categorization of commercial/industrial by a number of utilities is based upon level of energy use rather than stricter definitions of industrial as manufacturing and commercial as nonmanufacturing. The ESRG demand model requires energy sales by this stricter delineation, as does the NEPOOL/Battelle model. Therefore, NEPOOL and ECNE industrial sales data for each state for the years 1970-1976 were compared. For the southern New England states, the sources were roughly comparable over time, while in the northern states, the NEPOOL sales in industry averaged a fraction of ECNE sales data. These fractions (.866 for Maine, .655 for New Hampshire, .676 for Vermont) were used to revise the 1978 industrial sales figures given by ECNE for these three states, the remainder being assigned to the commercial category. The resultant industrial sales figures are included in Table 8.23 below.

Data for sales by Industrial SIC were also available from NEPOOL (Ref. 16). These data were the sources of the industrial mix figures given in Table 8.23.

TABLE 8.23

INDUSTRIAL SALES MIX, NEW ENGLAND STATES

SIC	Conn.	Maine	Mass.	N.H.	R.I.	Vt.
20	.026	.099	.076	.068	.032	.052
22	.027	.053	.045	.062	.153	.008
23	.007	.010	.008	.001	.031	.001
24	.002	.055	.003	.037	.001	.058
25	.003	.004	.004	.018	.001	.018
26	.053	.462	.105	.252	.030	.140
27	.027	.002	.028	.030	.023	.043
28	.070	.118	.083	.086	.041	.011
29	.003	.003	.006	0	.003	.001
30	.046	.018	.098	.045	.117	.064
31	.001	.040	.012	.043	.002	.007
32	.041	.030	.023	.032	.057	.035
33	.146	.009	.051	.035	.183	.009
34	.126	.028	.063	.026	.059	.021
35	.098	.005	.071	.070	.038	.094
36	.078	.029	.169	.148	.075	.310
37	.170	.023	.045	.030	.043	.049
38	.038	0	.073	.011	.019	.009
Mining & Misc.	.038	.012	.037	.006	.092	.070
Total 1978 Sales (GWH)	5975	2460	8464	1522	1379	760

8.3.2 Production Growth

The model requires growth estimates of "State Production Indices" as indicated in Table 5.3, Eq. 5.4. The mechanism for weighting National Production Indices to the state level is described in Table 5.2. That methodology, with National Production Index forecasts from Ref. 14 and earnings projections from Ref. 7, is used to establish production growth. Alternatively, productivity trends were developed by SIC (defined as the ratio of state production index to employees) for the 1967-77 period. Regression fits were used to project productivity. These were multiplied by state planning agency provided employment forecasts.* The two methodologies were used to define the high/low band for industrial production levels. These assumptions are summarized in Tables 8.24 and 8.25.

8.3.3 Electric Energy Intensity

Industrial electric intensity is defined as the average consumption of electricity per unit of physical output by two-digit manufacturing SIC. Changes in electrical intensity are incorporated in the energy forecast. (See Table 5.3, Eq. 5.4).

We begin by investigating the historic trend in the electrical intensities for each New England state. Linear regression is used to develop time trends for the 1963-1976 period. The computation is summarized in Table 8.26. The historic production index is derived from national production index data (Ref. 13) and state-to-national earnings ratios (Ref. 7) as discussed in Sec. 5.3 (Eq. 8.8). The intensities are then formed as the ratio of total electrical energy consumption (purchased and self-generated) from Ref. 12, and state production indices for each historic year and SIC (Eq. 8.9).

The time axis is then shifted so that the resultant intercept is automatically based on the base year = 1 (Eq. 8.10). This assures consistency with the convention adopted in the model, thus allowing for direct input of the regression analysis results into the main program. The number of historic years is allowed to vary (Eq. 8.11). Finally, after defining some intermediate summations, the slopes and intercepts are computed.

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*This procedure was not possible for Rhode Island where employment forecasts broken down by industrial category were not available.

TABLE 8.24

PRODUCTION GROWTH (HIGH CASE)

	Conn.		Maine		Mass.		N.H.		R.I.		Vt.	
SIC	SPI85/SPI78	SPI90/SPI78	SPI85/SPI78	SPI90/SPI78	SPI85/SPI78	SPI90/SPI78	SPI85/SPI78	SPI90/SPI78	SPI85/SPI78	SPI90/SPI78	SPI85/SPI78	SPI90/SPI78
20	1.20	1.37	1.23	1.41	1.15	1.26	1.39	1.69	1.15	1.21	1.15	1.25
22	.99	.99	.99	.94	.95	.88	1.25	1.44	.95	.89	1.31	1.55
23	.93	.91	1.43	1.77	1.07	1.10	1.30	1.54	1.22	1.38	1.26	1.46
24	1.14	1.21	1.14	1.19	1.09	1.22	1.06	1.10	1.24	1.37	1.03	1.05
25	1.15	1.27	1.15	1.26	1.10	1.18	1.38	1.68	1.25	1.45	1.38	1.72
26	1.25	1.47	1.18	1.31	1.08	1.14	1.33	1.60	1.25	1.45	1.26	1.47
27	1.27	1.47	1.29	1.56	1.26	1.51	1.37	1.69	1.20	1.35	1.29	1.54
28	1.51	1.97	1.75	2.55	1.38	1.70	1.55	2.00	1.72	2.46	1.53	2.03
29	1.47	2.08	1.66	2.23	1.22	1.34	1.25	1.39	1.51	1.94	1.13	1.20
30	1.39	1.72	1.18	1.34	1.24	1.45	1.60	2.12	1.46	1.89	1.63	2.28
31	1.02	1.02	1.06	1.10	.92	.86	.84	.72	1.08	1.12	.92	.86
32	1.13	1.20	.97	1.12	1.02	1.01	1.28	1.50	1.19	1.32	1.05	1.07
33	1.08	1.10	1.74	2.40	1.11	1.12	1.39	1.69	1.21	1.29	1.40	1.78
34	1.28	1.47	1.25	1.39	1.22	1.36	1.40	1.73	1.19	1.30	1.22	1.42
35	1.15	1.29	1.54	2.00	1.28	1.47	1.44	1.80	1.25	1.43	1.28	1.51
36	1.30	1.54	1.81	2.68	1.28	1.50	1.39	1.71	1.38	1.69	1.79	2.62
37	1.18	1.37	1.32	1.63	1.12	1.23	1.44	1.80	1.50	1.99	1.56	2.13
38	1.31	1.52	.93	1.18	1.18	1.28	1.28	1.50	1.38	1.68	1.07	1.12
39*	1.39	1.59	1.18	1.24	1.25	1.34	1.50	1.91	1.46	1.75	1.34	1.62

* Includes Miscellaneous Manufacturing and Mining

TABLE 8.25

PRODUCTION GROWTH (LOW CASE)

	Conn.		Maine		Mass.		N. H.		R. I.		Vt.	
SIC	$\frac{SPI85}{SPI78}$	$\frac{SPI90}{SPI78}$	$\frac{SPI85}{SPI78}$	$\frac{SPI90}{SPI78}$	$\frac{SPI85}{SPI78}$	$\frac{SPI90}{SPI78}$	$\frac{SPI85}{SPI78}$	$\frac{SPI90}{SPI78}$	$\frac{SPI85}{SPI78}$	$\frac{SPI90}{SPI78}$	$\frac{SPI85}{SPI78}$	$\frac{SPI90}{SPI78}$
20	1.20	1.37	1.21	1.36	1.00	.98	1.34	1.62	1.15	1.27	1.06	1.10
22	.99	.99	1.22	1.37	1.10	1.16	1.04	1.02	.95	.89	1.14	1.21
23	.93	.91	1.48	1.89	1.03	1.04	1.30	1.52	1.22	1.38	1.14	1.25
24	1.14	1.21	.95	.91	.87	.78	1.12	1.17	1.23	1.37	1.13	1.18
25	1.15	1.27	1.14	1.20	1.13	1.21	1.13	1.24	1.24	1.45	1.14	1.25
26	1.25	1.47	1.17	1.29	1.06	1.10	1.25	1.46	1.25	1.45	1.22	1.40
27	1.27	1.47	1.17	1.31	1.15	1.27	1.35	1.65	1.20	1.35	1.30	1.57
28	1.51	1.97	1.44	1.82	1.25	1.43	1.80	2.66	1.72	2.46	1.65	2.30
29	1.47	2.08	1.66	2.23	1.14	1.25	1.25	1.39	1.51	1.94	1.13	1.20
30	1.39	1.72	1.50	1.93	1.24	1.40	1.27	1.48	1.46	1.89	1.35	1.69
31	1.02	1.02	1.06	1.10	.80	.68	.94	.88	1.08	1.12	1.00	1.00
32	1.13	1.20	1.33	1.61	1.20	1.36	1.03	1.03	1.19	1.32	1.11	1.18
33	1.08	1.10	1.10	1.17	.99	.98	1.56	1.94	1.21	1.29	1.17	1.22
34	1.28	1.47	1.30	1.56	1.08	1.13	1.60	2.06	1.19	1.30	1.50	1.86
35	1.15	1.29	1.26	1.47	1.18	1.31	1.40	2.74	1.25	1.42	1.24	1.41
36	1.30	1.54	1.68	2.34	1.25	1.43	1.56	1.93	1.38	1.68	1.47	1.90
37	1.18	1.37	1.13	1.23	1.29	1.53	1.60	2.20	1.50	1.99	1.58	2.06
38	1.31	1.52	.93	1.18	1.16	1.28	1.20	1.31	1.38	1.68	1.28	1.50
39*	1.39	1.59	1.19	1.32	1.19	1.32	1.27	1.37	1.46	1.75	1.36	1.56

*Includes Miscellaneous Manufacturing and Mining

TABLE 8.26

ELECTRICAL INTENSITY REGRESSION ANALYSIS

Indices

BY	Base year
j	Industrial grouping by two-digit SIC (j=1 to 19)
r	Labels historic year (r=1 to N)

Variables

$YR1_r$	Historic year (calendar)
YR_r	Historic year (scale shifted to BY=1)
START	First historic year used in regression
END	Last historic year used in regression
N	Number of historic years in regression
$SPIH_{r,j}$	State Production Index for historic year "r", SIC "j"
$NPIH_{r,j}$	National Production Index for historic year "r", SIC "j"
$SNER_{r,j}$	State-to-national earnings ratio for year "r", SIC "j", in %
$SEI_{r,j}$	Electric intensity in year "r", SIC "j"
BI_j	Intercept, SIC "j"
$SLOPEI_j$	Slope, SIC "j"
$SPROSH_{r,j}$	State process energy in year "r", SIC "j"

Equations

$$SPIH_{r,j} = NPIH_{r,j} \times SNER_{r,j} / 100 \tag{8.8}$$

$$SEI_{r,j} = SPROSH_{r,j} / SPIH_{r,j} \tag{8.9}$$

$$YR_r = YR1_r - BY + 1 \tag{8.10}$$

$$N = END - START + 1 \tag{8.11}$$

$$SLOPEI_j = \left(N \times \sum_{r=1}^{N} YR_r \times SEIH_{r,j} - \left[\sum_{r=1}^{N} YR_r\right] \times \sum_{r=1}^{N} SEI_{r,j}\right) / \left(N \times \sum_{r=1}^{N} YR_r^{2} - \left[\sum_{r=1}^{N} YR_r\right]^{2}\right) \tag{8.12}$$

$$BI_j = \left(\sum_{r=1}^{N} SEI_{r,j} - SLOPEI_j \times \sum_{r=1}^{N} YR_r\right) / N \tag{8.13}$$

$$SEI_j = BI_j + SLOPEI_j \times (t-1) \tag{8.14}$$

In addition to the state-specific trends in electric energy intensity, we have also investigated the trend on a national basis. These two trends formed the basis for estimating the time behavior of electric energy intensity. Specifically, the forecasts reflect the choice which maximizes or minimizes growth for the High and Low forecasts, respectively. The specific choice, given in the terminology of Table 8.26, is given below in Table 8.27.

TABLE 8.27

STATE ENERGY INTENSITY INDEX

STATE	Conn.		Maine		Mass.		N. H.		R. I.		Vt.	
SIC	High Case	Low Case	High Case	Low Case	High Case	Low Case	High Case	Low Case	High Case	Low Case	High Case	Low Case
20	1.0	1.0	1.3	1.0	1.4	1.0	1.5	1.0	1.0	1.0	1.0	1.0
22	1.0	1.0	1.0	.9	1.0	.8	1.0	.9	1.0	1.0	1.5	1.0
23	1.4	1.0	1.4	1.0	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0
24	1.0	1.0	1.5	1.0	1.0	1.0	1.4	1.0	1.6	1.0	1.6	1.0
25	1.	.9	1.0	1.0	1.0	1.0	1.3	1.0	1.0	1.0	1.3	1.0
26	1.1	.9	1.2	.9	1.1	.9	1.1	.9	.9	.9	1.2	.9
27	1.2	1.0	1.0	1.0	1.3	1.0	1.4	1.0	1.0	.9	1.2	1.0
28	.7	.7	1.0	1.0	.9	.9	.8	.8	.9	.9	.8	.8
29	1.0	1.0	1.0	1.0	1.0	.8	1.0	1.0	1.0	1.0	1.0	1.0
30	1.0	1.0	1.0	1.0	1.0	.8	1.0	.9	1.0	1.0	1.0	1.0
31	1.8	1.4	1.5	1.4	1.5	1.4	1.4	1.4	1.5	1.4	1.4	1.4
32	1.1	1.1	1.1	1.0	1.1	1.1	1.1	.9	1.1	1.0	1.1	1.0
33	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.1	1.2	1.1	1.1	1.0
34	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.0	1.3	1.0
35	1.0	1.0	1.2	1.0	1.4	1.0	1.0	.9	1.0	1.0	1.0	1.0
36	1.1	.9	1.1	.9	1.0	.9	1.1	.9	.9	.9	1.1	.9
37	1.2	1.0	1.3	1.2	1.2	1.2	2.0	1.2	1.2	1.2	1.2	1.2
38	1.0	.9	1.0	1.0	1.0	.9	1.0	.8	1.6	1.0	1.0	1.0
39*	1.3	1.0	1.0	1.0	1.2	1.0	1.3	1.0	1.0	1.0	1.0	1.0

* Includes Miscellaneous Manufacturing and Mining.

8.3.4 Fraction Self-Generated

Recent studies have indicated that a significant increase in industrial cogeneration is likely with or without government action. The primary reason is the increasing cost of electricity. To estimate the range of likely effects we assume, in the High Case, that by the year 2000 the fraction of industrial energy which is self-generated will equal its highest historic state level (Ref. 12). For the Low Case, we assume historic state levels re-achieved by 1985, or the lowest level 1985 potential for the New England region as given in Ref. 67 for SICs 26 and 28 (steam turbines, no government action) achieved by the year 2000. The input data assumptions for fraction self-generated (SGEN in Table 5.3) are shown in Table 8.28.

TABLE 8.28

FRACTION SELF GENERATED BY TWO-DIGIT SIC, NEW ENGLAND

	Conn.			Maine			Mass.			N. H.			R. I.			Vt.		
		85			85			85			85			85			85	
SIC	76	High	Low	76	High	Low	76	High	Low	76	High	Low	76	High	Low	76	High	Low
20	0	0	0	.12	.12	.12	.14	.14	.14	.027	.027	.027	0	0	0	0	0	0
22	.023	.135	.042	.23	.25	.28	.02	.03	.05	.046	.126	.259	.02	.05	.07	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	.01	.03	.06	0	0	0	.015	.015	.015	0	0	0	0	0	0
25	0	0	0	0	0	0	0	06	.15	0	0	0	0	0	0	.06	.08	.11
26	.334	.365	.62	.64	.64	.64	.24	.27	.63	.481	.481	.62	.25	.36	.63	.25	.27	.30
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	.069	.16	.16	0	0	.16	0	01	.16	0	0	.16	0	0	.16	0	0	.16
29	0	0	0	0	0	0	0	0	0	0	0	.21	0	0	0	0	0	0
30	.029	.071	.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	.01	.023	.20	.20	.20	0	0	0	0	0	0	0	0	0
32	0	0	0	0	.005	.011	.11	.12	.15	0	0	0	.006	.006	.006	.46	.50	.55
33	.071	.173	.109	0	0	0	0	0	0	0	0	0	0	.02	.06	0	0	0
34	.013	.102	.046	0	0	0	.08	.09	.11	.013	.015	.018	0	0	0	0	0	0
35	0	0	0	0	0	0	.10	.13	.18	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	.01	.01	.01	0	0	0	.006	.006	.006	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	.11	.14	.19	0	0	0	0	0	0	0	0	0
39*	.048	.062	.062	0	0	0	0	0	0	0	0	0	.006	.008	.01	0	0	0

* Includes Miscellaneous Manufacturing and Mining

61. Massachusetts Division of Employment Security Employment Requirements for Massachusetts by Occupation, by Industry 1970-1985, July 1976.

62. Maine Department of Manpower Affairs, Maine Occupational Outlook to 1985, Employment Security Commission, February, 1977.

63. New Hampshire Department of Employment Security. New Hampshire Employment by Occupations to 1985, Economic Analysis and Reports, April, 1978 (with nonagricultural and salary employment forecast dated February 9, 1979).

64. Rhode Island Department of Employment Security. Rhode Island Occupational Projections to 1985, Research and Statistics Unit,no date.

65. Vermont Department of Employment Security. Vermont Employment Projections to 1985, Research and Statistics Section, April, 1979.

66. Electric Council of New England, Electric Utility Industry in New England, Statistical Bulletin 1978, August, 1979.

67. Thermo Electron Corporation, A Study of Inplant Electric Power Generation in the Chemical Petroleum Refining, and Paper and Pulp Industries, prepared for FEA, June 1976.

68. Hirst, E., et al., Fuel Choices in the Household Sector, Oak Ridge National Laboratory, ORNL/CON-3, October 1973.

69. Data Resources, Inc., The Residential Demand for Energy Electric Power Research Institute, EPRI, EA-235, Vol. I, January, 1977.

8.5 Peak Power

The peak power computations are summarized in Sec. 7. Careful scrutiny of Table 7.1 will reveal that this part of the model is driven by outputs from the other submodels with the exception of two kinds of data: (1) characterization of base year peak and (2) forecasts of load management impact. These will be discussed in turn.

For each New England state, three items of load data are required by the model; winter peak, summer peak, and base peak. Such data aren't typically characterized at the state level, but rather at the level of utility or power pool. Thus, standardized load factors given by NEPOOL (Ref. 16) for each state were used to gain an estimate of winter and summer peaks, using the load factor equation

$$LF = \frac{\text{Sales} \times (1.09)}{\text{Peak} \times (8{,}760)} \quad \text{where,}$$

Sales = MWH sales to ultimate customers by state given by ECNE (Ref. 66)
Peak = MW Peak demand for each state
1.09 = accounts for company use and losses
8760 = hours in 1 year

The following peaks are derived via this equation (Table 8.30), for each state.

TABLE 8.30

1978 PEAKS AND LOAD FACTORS, NEW ENGLAND

	Winter 1978-79		Summer 1978	
State	Load Factor	Peak	Load Factor	Peak
Connecticut	64.2%	4052	64.7%	4021
Massachusetts	62.6%	6431	64.1%	6280
Maine	62.2%	1540	77.8%	1231
New Hampshire	60.3%	1203	73.2%	991
Rhode Island	63.6%	973	63.7%	972
Vermont	57.3%	765	76.6%	572

The base peak is defined in Sec. 7 as the non-weather-sensitive portion of the peak. Analysis of monthly load data for utilities in New England led to estimates of the ratio of base to winter peak of 80% in the three Southern New England states and Maine, and 70% in the other states. These were used to calculate base peak in the load factor analysis of Table 7.1.

The final data requirements concern the possible impact of load management in the forecast period. In particular, the possibility of some load shifting is included as indicated in Table 7.1. Sec. 7 provides a discussion of the underlying load management mechanisms modeled to shift peak demand. In the Low Case, residential sector time-of-use rates are expected to influence the patterns of time-flexible appliances (dishwashers, clothes washers, clothes dryers, and uncontrolled water heaters). In addition, some commercial sector usage shifting is anticipated to influence time-of-use in the Low Case. Residential storage, commercial use shift and industrial load management have not been assumed to have any impact during the forecast period, possibly a conservative input in terms of peak shaving. Forecast assumptions are summarized in Table 8.31.

TABLE 8.31

LOAD MANAGEMENT

		Impact Year 1990				
Case	Year Impact Begins	Ind.	Res. Use Shift*	Res. Thermal Storage	Comm. Use Shift**	Comm. Thermal Storage
High	2000+	0	0%	0	0	0
Low	1983	0	10%	0	0	2%

* FOPRB in Table 7.1

** FOPCWS in Table 7.1

Finally, in driving peak demand and establishing base and weather-sensitive load factors, the effects of controlled water heaters must be removed as indicated in Sec. 7. The fraction of electric water heaters which are controlled in the base year is given in Ref. 16 for each New England state. These fractions are assumed to remain constant in the forecast period, with the exception of Low Case assumptions for Maine and New Hampshire, where increases to current New England levels (60%)

have been assumed. Unit usage of controlled heaters is taken at two-thirds the unit usage from uncontrolled heaters, a typically observed ratio.

TABLE 8.32

CONTROLLED WATER HEATERS

State	Residential % Water Heaters Controlled
Connecticut	.69
Massachusetts	.62
Maine	0
N.H.	.18
R.I.	.63
Vt.	.60

REFERENCES

1. "Appliance Energy Efficiencies," Appliance Manufacturer News, March, 1977.

2. General Electric, Commercial Sector Energy Consumption, Data Base Development Project, for United States Department of Energy, June, 1978.

3. Jackson, J., et al., Commercial Energy Use: A Disaggregation by Fuel, Building Type and End Use, Oak Ridge National Laboratory, ORNL/CON-14, February, 1978.

4. __________, The Commercial Demand for Energy: A Disaggregated Approach, ORNL/CON-15, April, 1978.

5. Kaufman, H., et al., Energy Consumption in Commercial Industries by Census Division - 1974, Jack Faucett Associates, March, 1977, PB-268851.

6. Carhart, S., et al., The Brookhaven Building Energy Conservation Optimization Model, Brookhaven National Laboratory, Formal Report, January, 1978.

7. U.S. Department of Commerce, Bureau of Economic Analysis. OBERS Projections of Economic Activity in the United States, revised update 1978.

8. Glesk, M., et al., Residential/Commercial Market for Energy Technologies, a report to U.S. Department of Energy by Arthur D. Little, Inc.

9. United States Bureau of the Census, County Business Patterns, 1975, (New England states).

10. Ide, Edward, Estimating Land and Floor Area Implicit in Employment Projections, for US/DOT, July, 1970, PB200-069.

11. United States Bureau of the Budget, SIC Classification Manual, 1967.

12. United States Bureau of the Census, Survey of Manufactures and Census of Manufactures, "Fuels and Electric Energy Consumed."

13. Board of Governors of the Federal Reserve System, Industrial Production, Monthly Statistical Business.

14. Predicasts, Inc., Predicasts, Number 78, January, 1980.

15. U.S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P-25, No. 796, March 1979.

16. NEPOOL Load Forecasting Task Force and Battelle-Columbus Laboratories, Report on Model for Long-Range Forecasting of Electric Energy and Demand to the New England Power Pool. West Springfield, Massachusetts: New England Power Planning, June 30, 1977 (including subsequent NEPOOL model documentation).

17. Personal Communication, quoted from forthcoming planning document, Connecticut State Office of Policy and Management.

18. Maine State Planning Office, Population Projection Series PPS-4, Maine Population Projections 1978-1983, December, 1978.

19. Rhode Island Statewide Planning Program, Rhode Island Population Projections by County, City, and Town, Technical Paper 83, April, 1979.

20. Personal Communication, quoted from forthcoming The People Book, Vermont State Planning Office.

21. New Hampshire Office of Comprehensive Planning, New Hampshire Population Projections for Towns and Cities to the Year 2000, August, 1977.

22. U.S. Department of Commerce, Bureau of the Census, Demographic, Social, and Economic Profile of States: Spring, 1976, Current Population Reports Series P-20, No. 334, January, 1979.

23. U.S. Bureau of the Census, Projections of the Number of Households and Families 1979 to 1995, Current Population Reports Series P-25, No. 805, May, 1979.

24. Energy Policy Project of the Ford Foundation Time to Choose America's Energy Future, Ballinger.

25. U.S. Bureau of the Census, Census of Housing, 1970 Vol. I Housing Characteristics for States, Cities, and Counties, Part I, United States Summary, December, 1972.

26. U.S. Department of Commerce, Bureau of the Census, Housing Units Authorized by Building Permits and Public Contracts, Annually 1970-1978.

27. Edison Electric Institute, Statistical Year Book of the Electric Utility Industry for 1978, Number 46, November, 1979.

28. Northeast Utilities System Electrical Energy Demand 1979-1988, Vol. 3, Economic and Load Forecasting Section, March, 1979.

29. Report to the Power Facility Evaluation Council, The United Illuminating Company, New Haven, Connecticut, January 1, 1978.

30. Peters, J. G., Residential Appliance Saturation Survey, Central Maine Power Company, 1976, January 1977.

31. Boston Edison Company, Long-Range Forecast of Electric Power Needs and Requirements, Annual Supplement 1-C, Vol. 1; April 1, 1979.

32. Wills, J., Residential Demand for Electricity in Massachusetts, Massachusetts Institute of Technology, June 1977.

33. Testimony of Dr. Caroline M. Smith, before the Federal Energy Regulatory Commission, Docket Nos. EL78-15 and ER78-339, September, 1978.

34. Long Range Forecast of Electric Energy and Demand in New Hampshire, Energy Systems Research Group, Inc., Boston, Mass., March 1, 1979.

35. U.S. FEA/Department of Energy, Energy Efficiency Improvement Targets for Nine Types of Appliances, Federal Register, Vol. 43, No. 70, April 11, 1978, pp. 15138-15147.

36. National Energy Conservation Policy Act, Public Law 95-619.

37. Edison Electric Institute, Annual Energy Requirements of Electric Household Appliances, EEI Pub. #75-61 Revised.

38. Edison Electric Institute, Air Conditioning Usage Study, EEI Publ. #76-2.

39. New England Energy Congress, A Blueprint for Energy Action, Final Report. Somerville, Massachusetts, May 1979.

40. Steven Buchsbaum, et al., Jobs and Energy, The Employment and Economic Impacts of Nuclear Power, Conservation, and Other Energy Options, Council on Economic Priorities, 1979.

41. Paul D. Raskin, et al., Electricity Requirements in New York State, Vol. II, State Conservation Policy Case Forecast, ESRG 79-12/2, Energy Systems Research Group, July, 1979.

42. Hoskins, R.A., et al, Energy and Cost Analysis of Residential Refrigerators, Oak Ridge National Laboratory, ORNL/CON-6, January 1977.

43. Tansil, J., Residential Consumption of Electricity 1950-1970, Oak Ridge National Laboratory, ORNL-NSF-EP-51, July 1973.

44. Liepens, G., et al., Building Energy Use Data Book, Oak Ridge National Laboratory, ORNL 53-63, April, 1978.

45. Scott, J., Solar Water Heating - Economic Feasibility, Capture Potential and Incentives, NSF, APR 75-18330, February 1977.

46. "Light Dawns -- And a Better Bulb Emerges," Science Digest, March, 1978.

47. Communication from Paul Wasdyke, Sales Engineering Manager, Duro-Test Corporation, North Bergen, N.J., July 5, 1979.

48. General Electric Company, promotional material on "Halarc" and "Circlite," 1979.

49. Stanford Research Institute, Business Development Strategy and Market for a New General Purpose Lamp, December 1976.

50. Statistical and Marketing Report, Merchandising, Vol. 2, No. 3, March 1977.

51. California Energy Commission, Appliance Efficiency Program, Revised Staff Report Relating to Space Heaters, Storage Type Water Heaters, and Plumbing Fixtures, Sacramento, C.E.C. Report 100-6, November 1977.

52. U.S. Department of Energy, quoted in Business Week, No. 2555, October 9, 1978, The Coming Boom in Solar Energy.

53. Helmich, James, Efficient Heating Systems: A Life-Cycle Cost (Staff Draft), California Energy Commission, November 1976.

54. Battelle-Columbus Laboratories and NEPOOL Load Forecasting Task Force, Model for Long Range Forecasting of Electric Energy and Demand, Report to New England Power Pool, June 1977.

55. Christian, J., Unitary Air-to-Air Heat Pumps, Argonne National Laboratory, ANL/CES/TE 77-10, July 1977.

56. U.S. Department of Commerce, Monthly Normals of Temperature Precipitation and Heating and Cooling Degree Days, 1941-1970, August, 1973.

57. California Energy Commission, Analysis of Residential Energy Uses, 1977.

58. U.S. FEA/Department of Energy, Final Energy Efficiency Improvement Targets for Water Heaters, Home Heating Equipment (Not Including Furnaces), Kitchen Ranges and Ovens, Clothes Washers, and Furnaces, Federal Register, Vol. 43, No. 198, October 12, 1978, pp. 47117-47127.

59. United States Department of Labor, Bureau of Labor Statistics Employment Projections for the 1980's, Bulletin 2030, June 1979.

60. Connecticut Labor Department, Annual Planning Information, FY80, Employment Security Division, no date.

61. Massachusetts Division of Employment Security Employment Requirements for Massachusetts by Occupation, by Industry 1970-1985, July 1976.

62. Maine Department of Manpower Affairs, Maine Occupational Outlook to 1985, Employment Security Commission, February, 1977.

63. New Hampshire Department of Employment Security. New Hampshire Employment by Occupations to 1985, Economic Analysis and Reports, April, 1978 (with nonagricultural and salary employment forecast dated February 9, 1979).

64. Rhode Island Department of Employment Security. Rhode Island Occupational Projections to 1985, Research and Statistics Unit, no date.

65. Vermont Department of Employment Security. Vermont Employment Projections to 1985, Research and Statistics Section, April, 1979.

66. Electric Council of New England, Electric Utility Industry in New England, Statistical Bulletin 1978, August, 1979.

67. Thermo Electron Corporation, A Study of Inplant Electric Power Generation in the Chemical Petroleum Refining, and Paper and Pulp Industries, prepared for FEA, June 1976.

68. Hirst, E., et al., Fuel Choices in the Household Sector, Oak Ridge National Laboratory, ORNL/CON-3, October 1973.

69. Data Resources, Inc., The Residential Demand for Energy Electric Power Research Institute, EPRI, EA-235, Vol. I, January, 1977.

APPENDIX A

High and Low Case Forecasts
of Demand and Peak,
by New England State

HIGH CASE

CONN	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	8154.	6495.	5975.	1710.	22334.	4021.	4052.
1979	8470.	6670.	6180.	1760.	23080.	4160.	4200.
1980	8770.	6840.	6390.	1820.	23810.	4290.	4340.
1981	9090.	7020.	6590.	1870.	24560.	4430.	4490.
1982	9390.	7190.	6790.	1920.	25290.	4560.	4630.
1983	9670.	7360.	6990.	1980.	26000.	4680.	4780.
1984	9930.	7530.	7200.	2030.	26680.	4800.	4920.
1985	10180.	7700.	7400.	2070.	27350.	4920.	5050.
1986	10450.	7810.	7650.	2120.	28040.	5030.	5190.
1987	10720.	7930.	7910.	2180.	28730.	5150.	5340.
1988	11000.	8040.	8170.	2230.	29430.	5270.	5480.
1989	11270.	8150.	8430.	2280.	30120.	5380.	5630.
1990	11540.	8260.	8680.	2330.	30820.	5500.	5770.
1991	11650.	8370.	8950.	2370.	31340.	5590.	5870.
1992	11760.	8490.	9210.	2410.	31870.	5680.	5970.
1993	11870.	8600.	9470.	2450.	32390.	5770.	6060.
1994	11970.	8710.	9730.	2490.	32910.	5860.	6160.
1995	12080.	8820.	10000.	2540.	33430.	5960.	6260.
1996	12180.	8930.	10260.	2580.	33950.	6050.	6360.
1997	12280.	9040.	10530.	2620.	34470.	6140.	6460.
1998	12390.	9160.	10790.	2660.	34990.	6230.	6550.
1999	12490.	9270.	11060.	2700.	35520.	6320.	6650.
2000	12600.	9380.	11330.	2740.	36050.	6410.	6750.

LOW CASE

CONN	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	8154.	6495.	5975.	1710.	22334.	4021.	4052.
1979	8260.	6470.	6070.	1730.	22520.	4050.	4090.
1980	8330.	6440.	6160.	1740.	22680.	4080.	4120.
1981	8400.	6410.	6250.	1760.	22820.	4100.	4150.
1982	8450.	6380.	6340.	1770.	22930.	4120.	4180.
1983	8490.	6340.	6420.	1780.	23040.	4130.	4200.
1984	8540.	6310.	6490.	1800.	23140.	4140.	4220.
1985	8580.	6280.	6570.	1810.	23240.	4140.	4230.
1986	8630.	6290.	6720.	1830.	23470.	4170.	4280.
1987	8680.	6290.	6870.	1850.	23690.	4210.	4310.
1988	8730.	6300.	7020.	1870.	23920.	4240.	4350.
1989	8770.	6310.	7160.	1890.	24140.	4260.	4390.
1990	8820.	6320.	7310.	1910.	24360.	4290.	4430.
1991	8800.	6330.	7450.	1930.	24500.	4310.	4450.
1992	8780.	6340.	7590.	1950.	24650.	4330.	4470.
1993	8760.	6350.	7720.	1960.	24790.	4350.	4490.
1994	8740.	6350.	7860.	1980.	24930.	4360.	4510.
1995	8720.	6360.	7990.	2000.	25070.	4380.	4530.
1996	8700.	6370.	8120.	2010.	25200.	4390.	4550.
1997	8670.	6380.	8250.	2030.	25330.	4410.	4570.
1998	8650.	6390.	8380.	2040.	25450.	4420.	4590.
1999	8630.	6390.	8500.	2060.	25580.	4430.	4610.
2000	8620.	6400.	8620.	2070.	25710.	4450.	4630.

HIGH CASE

MAINE	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	3014.	2014.	2460.	735.	8223.	1231.	1540.
1979	3150.	2050.	2590.	760.	8550.	1280.	1620.
1980	3290.	2090.	2720.	780.	8870.	1320.	1690.
1981	3430.	2120.	2860.	800.	9210.	1370.	1770.
1982	3570.	2160.	3000.	820.	9540.	1410.	1850.
1983	3700.	2200.	3140.	840.	9870.	1460.	1930.
1984	3830.	2230.	3280.	860.	10200.	1500.	2010.
1985	3950.	2270.	3420.	880.	10520.	1550.	2090.
1986	4090.	2300.	3590.	900.	10890.	1590.	2170.
1987	4240.	2330.	3760.	930.	11250.	1640.	2260.
1988	4380.	2360.	3930.	950.	11620.	1690.	2350.
1989	4530.	2390.	4110.	970.	12000.	1740.	2440.
1990	4670.	2420.	4290.	1000.	12380.	1800.	2530.
1991	4750.	2450.	4460.	1020.	12690.	1840.	2590.
1992	4830.	2480.	4650.	1040.	13000.	1890.	2660.
1993	4920.	2510.	4830.	1060.	13320.	1930.	2720.
1994	5000.	2540.	5010.	1080.	13630.	1980.	2790.
1995	5080.	2570.	5200.	1100.	13950.	2020.	2860.
1996	5160.	2600.	5390.	1120.	14280.	2070.	2920.
1997	5240.	2630.	5580.	1140.	14600.	2120.	2990.
1998	5320.	2660.	5780.	1160.	14930.	2160.	3060.
1999	5410.	2690.	5980.	1180.	15260.	2210.	3130.
2000	5490.	2720.	6170.	1200.	15600.	2260.	3190.

LOW CASE

MAINE	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	3014.	2014.	2460.	735.	8223.	1231.	1540.
1979	3060.	2000.	2520.	740.	8330.	1250.	1560.
1980	3100.	1980.	2590.	750.	8420.	1260.	1590.
1981	3140.	1970.	2650.	750.	8510.	1270.	1610.
1982	3170.	1950.	2710.	760.	8590.	1280.	1630.
1983	3200.	1930.	2770.	760.	8660.	1290.	1650.
1984	3230.	1910.	2830.	770.	8740.	1290.	1660.
1985	3260.	1900.	2880.	770.	8820.	1300.	1680.
1986	3300.	1910.	2960.	780.	8940.	1320.	1710.
1987	3330.	1920.	3030.	790.	9070.	1330.	1730.
1988	3370.	1930.	3100.	800.	9200.	1350.	1760.
1989	3400.	1950.	3170.	800.	9320.	1360.	1790.
1990	3440.	1960.	3240.	810.	9450.	1380.	1810.
1991	3450.	1970.	3310.	820.	9550.	1390.	1830.
1992	3460.	1980.	3380.	830.	9640.	1400.	1850.
1993	3460.	1990.	3450.	830.	9740.	1420.	1860.
1994	3470.	2010.	3520.	840.	9830.	1430.	1880.
1995	3480.	2020.	3590.	840.	9930.	1440.	1900.
1996	3490.	2030.	3650.	850.	10020.	1450.	1910.
1997	3490.	2040.	3720.	850.	10110.	1460.	1930.
1998	3500.	2050.	3790.	860.	10200.	1470.	1950.
1999	3510.	2070.	3850.	870.	10290.	1480.	1960.
2000	3520.	2080.	3920.	870.	10380.	1490.	1980.

HIGH CASE

MASS		ENERGY IN GWH				PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	11756.	11202.	8464.	3100.	34522.	6286.	6431.
1979	12140.	11430.	8760.	3200.	35530.	6460.	6640.
1980	12510.	11660.	9070.	3290.	36520.	6630.	6850.
1981	12910.	11890.	9370.	3390.	37560.	6800.	7070.
1982	13300.	12110.	9680.	3480.	38570.	6970.	7290.
1983	13660.	12340.	9990.	3580.	39560.	7130.	7500.
1984	14000.	12560.	10300.	3670.	40530.	7300.	7710.
1985	14330.	12780.	10610.	3760.	41480.	7450.	7920.
1986	14690.	12940.	10930.	3850.	42410.	7600.	8130.
1987	15050.	13100.	11250.	3940.	43340.	7750.	8340.
1988	15410.	13260.	11570.	4030.	44270.	7900.	8550.
1989	15770.	13420.	11900.	4130.	45220.	8050.	8760.
1990	16140.	13570.	12220.	4240.	46170.	8200.	8970.
1991	16280.	13730.	12550.	4330.	46890.	8330.	9110.
1992	16420.	13890.	12890.	4410.	47610.	8450.	9250.
1993	16560.	14050.	13220.	4500.	48330.	8580.	9390.
1994	16700.	14200.	13550.	4590.	49050.	8710.	9530.
1995	16840.	14360.	13890.	4680.	49770.	8840.	9670.
1996	16980.	14510.	14230.	4770.	50500.	8970.	9820.
1997	17130.	14670.	14570.	4860.	51220.	9090.	9960.
1998	17270.	14830.	14910.	4950.	51950.	9220.	10100.
1999	17420.	14980.	15260.	5040.	52700.	9350.	10250.
2000	17590.	15140.	15600.	5130.	53450.	9490.	10400.

LOW CASE

MASS		ENERGY IN GWH				PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	11756.	11202.	8464.	3100.	34522.	6286.	6431.
1979	11900.	11070.	8540.	3130.	34640.	6290.	6470.
1980	12010.	10930.	8620.	3150.	34710.	6290.	6500.
1981	12120.	10800.	8690.	3180.	34790.	6290.	6530.
1982	12210.	10660.	8760.	3200.	34830.	6280.	6550.
1983	12290.	10530.	8820.	3220.	34860.	6270.	6570.
1984	12370.	10400.	8880.	3250.	34890.	6250.	6590.
1985	12450.	10260.	8940.	3270.	34920.	6240.	6600.
1986	12540.	10290.	9000.	3300.	35140.	6260.	6650.
1987	12630.	10320.	9060.	3340.	35350.	6280.	6700.
1988	12720.	10350.	9120.	3370.	35560.	6310.	6740.
1989	12800.	10380.	9180.	3410.	35770.	6330.	6780.
1990	12890.	10400.	9240.	3440.	35980.	6350.	6830.
1991	12890.	10430.	9290.	3480.	36100.	6370.	6850.
1992	12900.	10460.	9350.	3510.	36220.	6380.	6870.
1993	12900.	10490.	9400.	3540.	36330.	6390.	6890.
1994	12900.	10520.	9450.	3570.	36440.	6400.	6910.
1995	12900.	10550.	9490.	3610.	36540.	6410.	6930.
1996	12890.	10580.	9540.	3640.	36650.	6410.	6950.
1997	12890.	10610.	9580.	3670.	36740.	6420.	6960.
1998	12880.	10640.	9620.	3700.	36840.	6430.	6980.
1999	12880.	10670.	9660.	3730.	36940.	6440.	7000.
2000	12900.	10700.	9690.	3760.	37060.	6450.	7020.

HIGH CASE
NH

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	2456.	1771.	1523.	625.	6376.	991.	1203.
1979	2620.	1840.	1620.	660.	6750.	1040.	1290.
1980	2790.	1920.	1720.	700.	7110.	1100.	1370.
1981	2930.	1990.	1810.	730.	7470.	1150.	1450.
1982	3080.	2070.	1910.	760.	7820.	1200.	1520.
1983	3220.	2140.	2010.	790.	8170.	1250.	1600.
1984	3350.	2210.	2120.	830.	8510.	1300.	1680.
1985	3480.	2290.	2220.	860.	8850.	1350.	1750.
1986	3610.	2350.	2340.	890.	9190.	1400.	1830.
1987	3740.	2420.	2460.	930.	9540.	1440.	1910.
1988	3870.	2490.	2580.	960.	9890.	1490.	1980.
1989	4000.	2550.	2700.	990.	10240.	1540.	2060.
1990	4130.	2620.	2820.	1030.	10600.	1590.	2140.
1991	4200.	2680.	2950.	1060.	10890.	1640.	2200.
1992	4260.	2750.	3070.	1090.	11170.	1680.	2250.
1993	4330.	2810.	3200.	1120.	11460.	1720.	2310.
1994	4390.	2880.	3330.	1150.	11750.	1770.	2370.
1995	4460.	2950.	3460.	1170.	12040.	1810.	2420.
1996	4520.	3010.	3590.	1200.	12330.	1860.	2480.
1997	4580.	3080.	3730.	1230.	12620.	1900.	2540.
1998	4640.	3150.	3860.	1260.	12910.	1940.	2600.
1999	4700.	3210.	4000.	1290.	13210.	1990.	2660.
2000	4770.	3280.	4140.	1320.	13510.	2030.	2710.

LOW CASE
NH

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	2456.	1771.	1523.	625.	6376.	991.	1203.
1979	2530.	1770.	1570.	640.	6510.	1010.	1230.
1980	2590.	1760.	1620.	650.	6630.	1020.	1260.
1981	2650.	1750.	1670.	670.	6740.	1040.	1290.
1982	2690.	1750.	1710.	680.	6840.	1050.	1310.
1983	2740.	1740.	1760.	690.	6930.	1060.	1340.
1984	2790.	1740.	1800.	700.	7030.	1070.	1360.
1985	2850.	1730.	1840.	710.	7120.	1070.	1390.
1986	2900.	1760.	1900.	730.	7290.	1100.	1420.
1987	2950.	1790.	1970.	750.	7460.	1120.	1460.
1988	3010.	1820.	2030.	770.	7630.	1140.	1490.
1989	3060.	1850.	2100.	780.	7790.	1160.	1530.
1990	3110.	1880.	2160.	800.	7960.	1180.	1560.
1991	3140.	1910.	2220.	820.	8090.	1190.	1590.
1992	3160.	1940.	2280.	840.	8220.	1210.	1610.
1993	3190.	1970.	2340.	850.	8360.	1230.	1640.
1994	3210.	2000.	2400.	870.	8480.	1240.	1660.
1995	3240.	2030.	2460.	880.	8610.	1260.	1690.
1996	3260.	2060.	2520.	900.	8740.	1270.	1710.
1997	3280.	2090.	2570.	910.	8860.	1290.	1740.
1998	3300.	2120.	2630.	930.	8980.	1300.	1760.
1999	3330.	2150.	2680.	940.	9100.	1320.	1780.
2000	3350.	2180.	2730.	960.	9220.	1330.	1810.

HIGH CASE
RI

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	1820.	1603.	1379.	513.	5315.	972.	973.
1979	1880.	1640.	1440.	520.	5480.	1000.	1010.
1980	1940.	1670.	1500.	530.	5640.	1030.	1040.
1981	2000.	1700.	1560.	540.	5810.	1060.	1080.
1982	2060.	1730.	1620.	560.	5970.	1080.	1110.
1983	2120.	1760.	1690.	570.	6130.	1110.	1150.
1984	2170.	1800.	1750.	580.	6290.	1140.	1180.
1985	2220.	1830.	1810.	590.	6440.	1160.	1220.
1986	2270.	1850.	1880.	600.	6600.	1190.	1250.
1987	2330.	1870.	1950.	610.	6750.	1210.	1280.
1988	2380.	1900.	2010.	620.	6900.	1240.	1320.
1989	2430.	1920.	2080.	630.	7060.	1260.	1350.
1990	2490.	1940.	2150.	640.	7210.	1290.	1390.
1991	2510.	1960.	2220.	640.	7330.	1310.	1410.
1992	2530.	1980.	2280.	650.	7450.	1330.	1430.
1993	2550.	2010.	2350.	660.	7570.	1350.	1460.
1994	2570.	2030.	2420.	670.	7690.	1370.	1480.
1995	2590.	2050.	2490.	670.	7810.	1400.	1500.
1996	2620.	2070.	2560.	680.	7930.	1420.	1530.
1997	2640.	2090.	2630.	690.	8050.	1440.	1550.
1998	2660.	2110.	2700.	700.	8170.	1460.	1570.
1999	2680.	2140.	2770.	710.	8290.	1480.	1600.
2000	2700.	2160.	2840.	710.	8420.	1500.	1620.

LOW CASE
RI

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	1820.	1603.	1379.	513.	5315.	972.	973.
1979	1830.	1580.	1430.	520.	5360.	980.	980.
1980	1840.	1560.	1470.	520.	5400.	980.	990.
1981	1850.	1540.	1520.	520.	5430.	990.	1000.
1982	1850.	1520.	1570.	520.	5470.	990.	1010.
1983	1850.	1510.	1610.	520.	5500.	990.	1010.
1984	1860.	1490.	1660.	530.	5530.	990.	1020.
1985	1860.	1470.	1700.	530.	5560.	1000.	1020.
1986	1860.	1470.	1750.	530.	5620.	1000.	1030.
1987	1870.	1470.	1800.	540.	5670.	1010.	1040.
1988	1870.	1470.	1850.	540.	5730.	1020.	1050.
1989	1880.	1470.	1900.	540.	5780.	1030.	1060.
1990	1880.	1470.	1950.	550.	5840.	1030.	1070.
1991	1870.	1470.	1990.	550.	5890.	1040.	1080.
1992	1870.	1470.	2040.	550.	5930.	1050.	1090.
1993	1860.	1470.	2090.	560.	5980.	1050.	1090.
1994	1860.	1470.	2140.	560.	6030.	1060.	1100.
1995	1850.	1470.	2190.	560.	6070.	1070.	1110.
1996	1840.	1470.	2240.	560.	6120.	1070.	1120.
1997	1830.	1470.	2290.	570.	6170.	1080.	1120.
1998	1830.	1470.	2340.	570.	6210.	1080.	1130.
1999	1820.	1470.	2390.	570.	6260.	1090.	1140.
2000	1820.	1480.	2440.	580.	6310.	1100.	1150.

HIGH CASE
VERMONT

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	1597.	1002.	760.	401.	3760.	572.	765.
1979	1670.	1030.	820.	410.	3940.	600.	810.
1980	1750.	1060.	870.	430.	4120.	620.	850.
1981	1830.	1100.	930.	440.	4300.	650.	900.
1982	1910.	1130.	990.	460.	4480.	670.	940.
1983	1980.	1160.	1050.	470.	4660.	700.	990.
1984	2060.	1190.	1110.	480.	4840.	720.	1030.
1985	2120.	1220.	1170.	500.	5010.	740.	1080.
1986	2210.	1240.	1250.	510.	5210.	770.	1130.
1987	2290.	1260.	1340.	530.	5420.	800.	1180.
1988	2370.	1290.	1420.	540.	5620.	830.	1230.
1989	2460.	1310.	1500.	560.	5830.	850.	1280.
1990	2540.	1330.	1590.	570.	6040.	880.	1330.
1991	2590.	1360.	1680.	590.	6210.	910.	1370.
1992	2630.	1380.	1760.	600.	6380.	930.	1400.
1993	2680.	1400.	1850.	620.	6550.	960.	1440.
1994	2720.	1420.	1940.	630.	6720.	980.	1480.
1995	2770.	1450.	2030.	640.	6890.	1010.	1510.
1996	2820.	1470.	2120.	660.	7070.	1030.	1550.
1997	2860.	1490.	2220.	670.	7240.	1060.	1590.
1998	2910.	1520.	2310.	680.	7420.	1080.	1620.
1999	2950.	1540.	2400.	700.	7590.	1110.	1660.
2000	3000.	1560.	2500.	710.	7770.	1140.	1700.

LOW CASE
VERMONT

	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	1597.	1002.	760.	401.	3760.	572.	765.
1979	1630.	1000.	790.	410.	3830.	580.	780.
1980	1650.	1010.	820.	410.	3890.	590.	800.
1981	1680.	1010.	850.	410.	3950.	600.	810.
1982	1690.	1010.	880.	420.	4010.	610.	820.
1983	1710.	1010.	920.	420.	4060.	610.	840.
1984	1730.	1010.	950.	420.	4120.	620.	850.
1985	1750.	1010.	980.	430.	4170.	620.	860.
1986	1780.	1020.	1010.	430.	4240.	630.	880.
1987	1800.	1020.	1050.	440.	4310.	640.	890.
1988	1830.	1030.	1080.	440.	4380.	650.	910.
1989	1850.	1030.	1120.	440.	4450.	660.	930.
1990	1880.	1030.	1160.	450.	4510.	670.	940.
1991	1880.	1040.	1190.	450.	4560.	670.	950.
1992	1890.	1040.	1230.	450.	4610.	680.	960.
1993	1900.	1050.	1260.	460.	4660.	680.	970.
1994	1910.	1050.	1300.	460.	4710.	690.	980.
1995	1910.	1050.	1330.	460.	4760.	700.	990.
1996	1920.	1060.	1360.	470.	4810.	700.	1000.
1997	1930.	1060.	1400.	470.	4860.	710.	1010.
1998	1930.	1070.	1430.	470.	4900.	710.	1010.
1999	1940.	1070.	1460.	480.	4950.	720.	1020.
2000	1950.	1070.	1500.	480.	5000.	720.	1030.

APPENDIX B

Disaggregated End-Use Energy Forecasts by Sector, by New England State

CONN HIGH CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	1840.	2017.	2087.	2064.	1970.
2: FREEZERS	443.	535.	607.	653.	673.
3: RANGES	502.	591.	679.	739.	775.
4: LIGHTING	748.	827.	916.	974.	1008.
5: TELEVISIONS	183.	196.	217.	247.	286.
6: CLOTHES DRYERS	583.	745.	904.	1021.	1099.
7: CLOTHES WASHERS	87.	97.	109.	117.	122.
8: DISH WASHERS	128.	158.	186.	214.	240.
9: WATER HEATERS	1074.	1215.	1282.	1342.	1391.
10: ROOM A/C	343.	419.	448.	459.	462.
11: CENTRAL A/C	128.	214.	292.	346.	375.
12: SPACE HEATERS	1113.	1519.	1953.	2219.	2375.
13: HEATINGAUXILIARY	389.	398.	408.	412.	411.
14: MISCELLANEOUS	593.	737.	908.	1062.	1199.

CONN HIGH CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	30.	50.	65.	78.	90.
2: COOLING	109.	131.	148.	163.	177.
3: LT & POWER	254.	291.	317.	338.	359.
4: AUXILIARIES	189.	211.	227.	239.	251.
2: RETAIL					
1: HEATING	41.	71.	92.	109.	125.
2: COOLING	337.	412.	467.	508.	549.
3: LT & POWER	1828.	2147.	2362.	2506.	2652.
4: AUXILIARIES	637.	739.	807.	853.	898.
3: HOSPITALS					
1: HEATING	16.	24.	31.	38.	45.
2: COOLING	77.	84.	90.	95.	101.
3: LT & POWER	368.	382.	397.	413.	429.
4: AUXILIARIES	196.	203.	210.	217.	225.
4: SCHOOLS					
1: HEATING	35.	42.	55.	72.	89.
2: COOLING	83.	78.	81.	89.	97.
3: LT & POWER	506.	447.	440.	466.	493.
4: AUXILIARIES	293.	259.	252.	262.	273.
5: OTHER					
1: HEATING	34.	59.	77.	92.	106.
2: COOLING	250.	307.	351.	385.	418.
3: LT & POWER	742.	875.	968.	1034.	1100.
4: AUXILIARIES	470.	548.	602.	640.	678.

CONN HIGH CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	155.	178.	202.	229.	255.
22: TEXTILES	161.	150.	145.	145.	145.
23: APPAREL	42.	46.	51.	56.	61.
24: LUMBER	12.	13.	14.	15.	16.
25: FURNITURE	18.	20.	22.	24.	26.
26: PAPER PRODUCTS	317.	379.	457.	550.	649.
27: PRINTING & PUBL.	161.	208.	262.	321.	385.
28: CHEMICALS	418.	472.	517.	541.	522.
29: PETROLEUM & COAL	18.	24.	33.	44.	55.
33: PRIMARY METALS	872.	937.	1014.	1106.	1201.
34: FABRICAT. METALS	753.	857.	974.	1107.	1240.
35: MACHINERY	586.	648.	723.	805.	887.
36: ELECTRIC EQUIP.	466.	589.	729.	883.	1046.
37: TRANSPORTATION	1016.	1242.	1533.	1884.	2267.
30: RUBBER & PLASTIC	275.	343.	422.	509.	597.
31: LEATHER	6.	8.	10.	12.	14.
32: STONE,CLAY,GLASS	245.	279.	311.	342.	375.
38: INSTRUMENTS	227.	277.	326.	374.	421.
39: MISC. MANUFACT.	227.	324.	422.	521.	629.

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CONN          LOW  CASE - RESIDENTIAL SECTOR - ENERGY IN GWH
                             1978   1983   1988   1993   1998
  1: REFRIGERATORS           1840.  1900.  1899.  1841.  1735.
  2: FREEZERS                 443.   451.   454.   447.   434.
  3: RANGES                   502.   522.   545.   558.   564.
  4: LIGHTING                 748.   784.   814.   816.   792.
  5: TELEVISIONS              222.   211.   205.   202.   201.
  6: CLOTHES DRYERS           583.   682.   761.   808.   833.
  7: CLOTHES WASHERS           87.    92.    97.   100.   102.
  8: DISH WASHERS             128.   146.   164.   181.   197.
  9: WATER HEATERS           1074.  1014.   964.   933.   907.
 10: ROOM A/C                 343.   340.   327.   315.   304.
 11: CENTRAL A/C              128.   178.   210.   224.   227.
 12: SPACE HEATERS           1113.  1214.  1299.  1342.  1363.
 13: HEATINGAUXILIARY         389.   377.   367.   352.   335.
 14: MISCELLANEOUS            554.   584.   619.   640.   652.
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CONN          LOW  CASE - COMMERCIAL  SECTOR - ENERGY IN GWH
                         1978   1983   1988   1993   1998
 1: OFFICES
 1:   HEATING             22.    28.    32.    36.    40.
 2:   COOLING            106.   106.   103.   100.    98.
 3:   LT & POWER         252.   244.   238.   236.   234.
 4:   AUXILIARIES        193.   192.   190.   188.   187.
 2: RETAIL
 1:   HEATING             29.    38.    42.    44.    46.
 2:   COOLING            316.   305.   302.   306.   309.
 3:   LT & POWER        1784.  1744.  1766.  1828.  1884.
 4:   AUXILIARIES        604.   555.   551.   576.   598.
 3: HOSPITALS
 1:   HEATING             14.    18.    20.    21.    22.
 2:   COOLING             81.    82.    77.    71.    64.
 3:   LT & POWER         405.   419.   415.   402.   390.
 4:   AUXILIARIES        216.   222.   215.   199.   185.
 4: SCHOOLS
 1:   HEATING             34.    33.    36.    43.    49.
 2:   COOLING             84.    68.    59.    53.    49.
 3:   LT & POWER         540.   447.   404.   394.   385.
 4:   AUXILIARIES        299.   227.   195.   187.   179.
 5: OTHER
 1:   HEATING             23.    30.    35.    39.    43.
 2:   COOLING            244.   255.   259.   258.   258.
 3:   LT & POWER         764.   816.   838.   843.   849.
 4:   AUXILIARIES        486.   516.   524.   520.   517.
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CONN          LOW  CASE - INDUSTRIAL  SECTOR - ENERGY IN GWH
                         1978   1983   1988   1993   1998
20: FOOD                 155.   174.   195.   217.   238.
22: TEXTILES             161.   158.   158.   159.   159.
23: APPAREL               42.    47.    51.    56.    60.
24: LUMBER                12.    13.    15.    17.    19.
25: FURNITURE             18.    18.    18.    18.    18.
26: PAPER PRODUCTS       317.   263.   254.   283.   308.
27: PRINTING & PUBL.     161.   188.   208.   224.   240.
28: CHEMICALS            418.   484.   516.   519.   486.
29: PETROLEUM & COAL      18.    22.    26.    32.    38.
33: PRIMARY METALS       872.   875.   905.   954.  1001.
34: FABRICAT. METALS     753.   792.   853.   929.  1001.
35: MACHINERY            586.   652.   735.   829.   923.
36: ELECTRIC EQUIP.      466.   546.   608.   658.   701.
37: TRANSPORTATION      1016.  1074.  1170.  1292.  1414.
30: RUBBER & PLASTIC     275.   303.   365.   447.   528.
31: LEATHER                6.     7.     9.    11.    13.
32: STONE,CLAY,GLASS     245.   284.   344.   421.   502.
38: INSTRUMENTS          227.   258.   280.   295.   307.
39: MISC. MANUFACT.      227.   259.   306.   364.   420.
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CONN BASE CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	1840.	1958.	1993.	1952.	1852.
2: FREEZERS	443.	493.	531.	550.	554.
3: RANGES	502.	557.	612.	649.	669.
4: LIGHTING	748.	805.	865.	895.	900.
5: TELEVISIONS	202.	203.	211.	225.	244.
6: CLOTHES DRYERS	583.	713.	832.	914.	966.
7: CLOTHES WASHERS	87.	94.	103.	109.	112.
8: DISH WASHERS	128.	152.	175.	198.	219.
9: WATER HEATERS	1074.	1114.	1123.	1137.	1149.
10: ROOM A/C	343.	379.	387.	387.	383.
11: CENTRAL A/C	128.	196.	251.	285.	301.
12: SPACE HEATERS	1113.	1366.	1626.	1781.	1869.
13: HEATINGAUXILIARY	389.	387.	388.	382.	373.
14: MISCELLANEOUS	573.	661.	763.	851.	926.

CONN BASE CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	26.	39.	49.	57.	65.
2: COOLING	107.	118.	126.	132.	137.
3: LT & POWER	253.	267.	278.	287.	296.
4: AUXILIARIES	191.	201.	208.	214.	219.
2: RETAIL					
1: HEATING	35.	55.	67.	77.	85.
2: COOLING	326.	358.	385.	407.	429.
3: LT & POWER	1806.	1946.	2064.	2167.	2268.
4: AUXILIARIES	620.	647.	679.	714.	748.
3: HOSPITALS					
1: HEATING	15.	21.	26.	30.	33.
2: COOLING	79.	83.	83.	83.	83.
3: LT & POWER	387.	401.	406.	407.	409.
4: AUXILIARIES	206.	212.	212.	208.	205.
4: SCHOOLS					
1: HEATING	34.	37.	45.	57.	69.
2: COOLING	84.	73.	70.	71.	73.
3: LT & POWER	523.	447.	422.	430.	439.
4: AUXILIARIES	296.	243.	223.	225.	226.
5: OTHER					
1: HEATING	28.	45.	56.	65.	74.
2: COOLING	247.	281.	305.	322.	338.
3: LT & POWER	753.	845.	903.	939.	975.
4: AUXILIARIES	478.	532.	563.	580.	597.

CONN BASE CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	155.	176.	199.	223.	247.
22: TEXTILES	161.	154.	152.	152.	152.
23: APPAREL	42.	46.	51.	56.	61.
24: LUMBER	12.	13.	15.	16.	17.
25: FURNITURE	18.	19.	20.	21.	22.
26: PAPER PRODUCTS	317.	321.	355.	416.	479.
27: PRINTING & PUBL.	161.	198.	235.	272.	313.
28: CHEMICALS	418.	478.	516.	530.	504.
29: PETROLEUM & COAL	18.	23.	30.	38.	47.
33: PRIMARY METALS	872.	906.	960.	1030.	1101.
34: FABRICAT. METALS	753.	824.	914.	1018.	1120.
35: MACHINERY	586.	650.	729.	817.	905.
36: ELECTRIC EQUIP.	466.	568.	669.	771.	873.
37: TRANSPORTATION	1016.	1158.	1352.	1588.	1841.
30: RUBBER & PLASTIC	275.	323.	393.	478.	562.
31: LEATHER	6.	8.	9.	11.	14.
32: STONE,CLAY,GLASS	245.	282.	328.	382.	439.
38: INSTRUMENTS	227.	268.	303.	334.	364.
39: MISC. MANUFACT.	227.	291.	364.	442.	525.

MAINE HIGH CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	628.	701.	737.	741.	720.
2: FREEZERS	197.	240.	272.	292.	302.
3: RANGES	152.	179.	209.	232.	249.
4: LIGHTING	257.	291.	329.	356.	375.
5: TELEVISIONS	48.	55.	66.	81.	102.
6: CLOTHES DRYERS	171.	217.	263.	299.	325.
7: CLOTHES WASHERS	25.	29.	32.	35.	37.
8: DISH WASHERS	32.	47.	64.	81.	97.
9: WATER HEATERS	495.	577.	633.	687.	734.
10: ROOM A/C	8.	15.	20.	23.	24.
11: CENTRAL A/C	2.	3.	3.	4.	4.
12: SPACE HEATERS	242.	421.	623.	767.	866.
13: HEATINGAUXILIARY	152.	157.	163.	167.	168.
14: MISCELLANEOUS	604.	769.	967.	1151.	1323.

MAINE HIGH CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	11.	21.	29.	34.	40.
2: COOLING	12.	15.	17.	18.	19.
3: LT & POWER	88.	100.	107.	111.	115.
4: AUXILIARIES	66.	73.	77.	79.	81.
2: RETAIL					
1: HEATING	12.	23.	31.	38.	45.
2: COOLING	36.	41.	46.	49.	52.
3: LT & POWER	579.	636.	675.	701.	727.
4: AUXILIARIES	202.	221.	233.	240.	248.
3: HOSPITALS					
1: HEATING	8.	14.	20.	26.	32.
2: COOLING	11.	12.	13.	14.	15.
3: LT & POWER	162.	172.	183.	194.	205.
4: AUXILIARIES	86.	91.	96.	102.	107.
4: SCHOOLS					
1: HEATING	14.	19.	29.	44.	58.
2: COOLING	10.	11.	12.	13.	15.
3: LT & POWER	207.	195.	199.	215.	230.
4: AUXILIARIES	120.	113.	114.	120.	127.
5: OTHER					
1: HEATING	9.	18.	25.	31.	38.
2: COOLING	24.	28.	32.	35.	38.
3: LT & POWER	217.	240.	259.	275.	291.
4: AUXILIARIES	138.	151.	162.	172.	181.

MAINE HIGH CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	244.	319.	407.	508.	620.
22: TEXTILES	130.	128.	122.	114.	106.
23: APPAREL	25.	38.	54.	73.	95.
24: LUMBER	135.	178.	219.	260.	302.
25: FURNITURE	10.	11.	12.	13.	14.
26: PAPER PRODUCTS	1137.	1390.	1668.	1972.	2300.
27: PRINTING & PUBL.	5.	6.	7.	8.	10.
28: CHEMICALS	290.	446.	647.	880.	1112.
29: PETROLEUM & COAL	7.	11.	15.	19.	23.
33: PRIMARY METALS	22.	35.	51.	70.	89.
34: FABRICAT. METALS	69.	81.	92.	102.	111.
35: MACHINERY	12.	18.	26.	35.	45.
36: ELECTRIC EQUIP.	71.	117.	180.	257.	339.
37: TRANSPORTATION	57.	78.	107.	141.	180.
30: RUBBER & PLASTIC	44.	50.	57.	64.	71.
31: LEATHER	98.	123.	150.	177.	206.
32: STONE,CLAY,GLASS	74.	75.	84.	100.	116.
38: INSTRUMENTS	0.	0.	0.	0.	0.
39: MISC. MANUFACT.	30.	33.	36.	38.	39.

MAINE LOW CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	628.	656.	664.	651.	623.
2: FREEZERS	197.	203.	206.	205.	202.
3: RANGES	152.	161.	171.	178.	183.
4: LIGHTING	257.	274.	290.	295.	291.
5: TELEVISIONS	65.	62.	62.	62.	63.
6: CLOTHES DRYERS	171.	201.	228.	247.	260.
7: CLOTHES WASHERS	25.	27.	29.	31.	32.
8: DISH WASHERS	32.	42.	53.	63.	71.
9: WATER HEATERS	495.	486.	480.	479.	477.
10: ROOM A/C	8.	12.	13.	14.	14.
11: CENTRAL A/C	2.	3.	3.	4.	4.
12: SPACE HEATERS	242.	293.	344.	379.	403.
13: HEATINGAUXILIARY	152.	149.	146.	142.	136.
14: MISCELLANEOUS	587.	630.	679.	714.	739.

MAINE LOW CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	9.	14.	18.	22.	27.
2: COOLING	12.	12.	12.	12.	12.
3: LT & POWER	86.	84.	83.	86.	89.
4: AUXILIARIES	66.	66.	66.	68.	71.
2: RETAIL					
1: HEATING	10.	15.	18.	21.	24.
2: COOLING	34.	32.	31.	32.	33.
3: LT & POWER	567.	528.	530.	560.	588.
4: AUXILIARIES	192.	167.	164.	176.	187.
3: HOSPITALS					
1: HEATING	7.	10.	13.	15.	17.
2: COOLING	12.	12.	11.	10.	10.
3: LT & POWER	173.	179.	180.	180.	181.
4: AUXILIARIES	92.	95.	93.	89.	86.
4: SCHOOLS					
1: HEATING	13.	15.	20.	26.	32.
2: COOLING	10.	8.	7.	7.	6.
3: LT & POWER	214.	185.	171.	167.	164.
4: AUXILIARIES	118.	94.	83.	79.	76.
5: OTHER					
1: HEATING	7.	11.	14.	17.	21.
2: COOLING	24.	25.	25.	25.	26.
3: LT & POWER	225.	234.	241.	247.	253.
4: AUXILIARIES	144.	149.	151.	152.	154.

MAINE LOW CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	244.	280.	317.	353.	390.
22: TEXTILES	130.	139.	149.	158.	166.
23: APPAREL	25.	33.	42.	53.	63.
24: LUMBER	135.	127.	120.	115.	110.
25: FURNITURE	10.	11.	12.	12.	13.
26: PAPER PRODUCTS	1137.	1221.	1294.	1354.	1404.
27: PRINTING & PUBL.	5.	6.	6.	7.	8.
28: CHEMICALS	290.	346.	422.	518.	614.
29: PETROLEUM & COAL	7.	11.	15.	19.	23.
33: PRIMARY METALS	22.	25.	27.	30.	33.
34: FABRICAT. METALS	69.	84.	100.	118.	136.
35: MACHINERY	12.	15.	17.	20.	22.
36: ELECTRIC EQUIP.	71.	102.	136.	171.	202.
37: TRANSPORTATION	57.	67.	79.	91.	105.
30: RUBBER & PLASTIC	44.	60.	78.	97.	116.
31: LEATHER	98.	118.	140.	163.	187.
32: STONE,CLAY,GLASS	74.	91.	110.	130.	151.
38: INSTRUMENTS	0.	0.	0.	0.	0.
39: MISC. MANUFACT.	30.	34.	37.	41.	45.

MAINE BASE CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	628.	679.	700.	696.	671.
2: FREEZERS	197.	221.	239.	249.	252.
3: RANGES	152.	170.	190.	205.	216.
4: LIGHTING	257.	283.	309.	326.	333.
5: TELEVISIONS	56.	59.	64.	72.	82.
6: CLOTHES DRYERS	171.	209.	246.	273.	293.
7: CLOTHES WASHERS	25.	28.	31.	33.	34.
8: DISH WASHERS	32.	45.	58.	72.	84.
9: WATER HEATERS	495.	532.	556.	583.	605.
10: ROOM A/C	8.	13.	16.	18.	19.
11: CENTRAL A/C	2.	3.	3.	4.	4.
12: SPACE HEATERS	242.	357.	484.	573.	634.
13: HEATINGAUXILIARY	152.	153.	155.	154.	152.
14: MISCELLANEOUS	595.	700.	823.	933.	1031.

MAINE BASE CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	10.	17.	23.	28.	33.
2: COOLING	12.	13.	14.	15.	16.
3: LT & POWER	87.	92.	95.	99.	102.
4: AUXILIARIES	66.	69.	72.	74.	76.
2: RETAIL					
1: HEATING	11.	19.	25.	30.	34.
2: COOLING	35.	36.	38.	41.	43.
3: LT & POWER	573.	582.	603.	630.	657.
4: AUXILIARIES	197.	194.	198.	208.	218.
3: HOSPITALS					
1: HEATING	7.	12.	16.	21.	24.
2: COOLING	12.	12.	12.	12.	12.
3: LT & POWER	168.	176.	182.	187.	193.
4: AUXILIARIES	89.	93.	95.	96.	97.
4: SCHOOLS					
1: HEATING	13.	17.	24.	35.	45.
2: COOLING	10.	10.	10.	10.	10.
3: LT & POWER	210.	190.	185.	191.	197.
4: AUXILIARIES	119.	103.	98.	100.	102.
5: OTHER					
1: HEATING	8.	14.	20.	24.	29.
2: COOLING	24.	27.	28.	30.	32.
3: LT & POWER	221.	237.	250.	261.	272.
4: AUXILIARIES	141.	150.	157.	162.	167.

MAINE BASE CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	244.	300.	362.	431.	505.
22: TEXTILES	130.	133.	135.	136.	136.
23: APPAREL	25.	35.	48.	63.	79.
24: LUMBER	135.	152.	170.	187.	206.
25: FURNITURE	10.	11.	12.	13.	13.
26: PAPER PRODUCTS	1137.	1305.	1481.	1663.	1852.
27: PRINTING & PUBL.	5.	6.	7.	8.	9.
28: CHEMICALS	290.	396.	535.	699.	863.
29: PETROLEUM & COAL	7.	11.	15.	19.	23.
33: PRIMARY METALS	22.	30.	39.	50.	61.
34: FABRICAT. METALS	69.	82.	96.	110.	124.
35: MACHINERY	12.	17.	22.	27.	34.
36: ELECTRIC EQUIP.	71.	109.	158.	214.	270.
37: TRANSPORTATION	57.	73.	93.	116.	143.
30: RUBBER & PLASUKC	44.	55.	67.	80.	93.
31: LEATHER	98.	121.	145.	170.	197.
32: STONE,CLAY,GLASS	74.	83.	97.	115.	133.
38: INSTRUMENTS	0.	0.	0.	0.	0.
39: MISC. MANUFACT.	30.	33.	37.	39.	42.

MASS HIGH CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	3131.	3435.	3547.	3503.	3338.
2: FREEZERS	410.	505.	576.	619.	636.
3: RANGES	568.	638.	716.	774.	816.
4: LIGHTING	1305.	1429.	1568.	1658.	1712.
5: TELEVISIONS	361.	376.	405.	448.	504.
6: CLOTHES DRYERS	537.	609.	688.	752.	802.
7: CLOTHES WASHERS	142.	158.	175.	187.	194.
8: DISH WASHERS	156.	183.	207.	232.	256.
9: WATER HEATERS	1111.	1300.	1410.	1488.	1542.
10: ROOM A/C	204.	227.	242.	259.	275.
11: CENTRAL A/C	60.	75.	91.	108.	124.
12: SPACE HEATERS	1790.	2427.	3109.	3529.	3776.
13: HEATINGAUXILIARY	646.	656.	670.	673.	669.
14: MISCELLANEOUS	1334.	1643.	2004.	2331.	2625.

MASS HIGH CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	37.	68.	93.	114.	135.
2: COOLING	204.	235.	262.	284.	306.
3: LT & POWER	466.	512.	547.	575.	603.
4: AUXILIARIES	348.	375.	396.	412.	428.
2: RETAIL					
1: HEATING	48.	92.	123.	147.	171.
2: COOLING	584.	686.	761.	817.	872.
3: LT & POWER	3112.	3506.	3759.	3918.	4077.
4: AUXILIARIES	1086.	1212.	1291.	1340.	1390.
3: HOSPITALS					
1: HEATING	22.	38.	53.	67.	81.
2: COOLING	162.	173.	184.	195.	205.
3: LT & POWER	758.	783.	811.	840.	869.
4: AUXILIARIES	404.	415.	428.	442.	456.
4: SCHOOLS					
1: HEATING	34.	47.	72.	107.	141.
2: COOLING	139.	131.	137.	152.	168.
3: LT & POWER	826.	730.	731.	797.	863.
4: AUXILIARIES	478.	423.	417.	445.	473.
5: OTHER					
1: HEATING	41.	79.	106.	128.	149.
2: COOLING	426.	512.	576.	625.	673.
3: LT & POWER	1241.	1424.	1547.	1629.	1711.
4: AUXILIARIES	788.	894.	965.	1012.	1059.

MASS HIGH CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	643.	831.	1043.	1279.	1540.
22: TEXTILES	381.	365.	342.	313.	285.
23: APPAREL	68.	80.	92.	104.	117.
24: LUMBER	25.	27.	30.	33.	36.
25: FURNITURE	34.	35.	36.	38.	39.
26: PAPER PRODUCTS	889.	957.	1030.	1106.	1183.
27: PRINTING & PUBL.	237.	316.	418.	541.	679.
28: CHEMICALS	703.	851.	1002.	1148.	1274.
29: PETROLEUM & COAL	51.	59.	66.	72.	78.
33: PRIMARY METALS	432.	485.	522.	547.	572.
34: FABRICAT. METALS	533.	613.	686.	755.	822.
35: MACHINERY	601.	826.	1075.	1348.	1644.
36: ELECTRIC EQUIP.	1430.	1716.	2020.	2334.	2649.
37: TRANSPORTATION	381.	448.	527.	617.	714.
30: RUBBER & PLASTIC	829.	972.	1133.	1307.	1481.
31: LEATHER	102.	116.	127.	136.	142.
32: STONE,CLAY,GLASS	195.	204.	211.	214.	217.
38: INSTRUMENTS	618.	684.	737.	781.	823.
39: MISC. MANUFACT.	313.	400.	476.	546.	620.

MASS BASE CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	3131.	3344.	3408.	3347.	3185.
2: FREEZERS	410.	462.	499.	519.	523.
3: RANGES	568.	616.	671.	711.	739.
4: LIGHTING	1305.	1404.	1506.	1560.	1575.
5: TELEVISIONS	390.	389.	400.	420.	450.
6: CLOTHES DRYERS	537.	599.	667.	723.	769.
7: CLOTHES WASHERS	142.	154.	168.	178.	184.
8: DISH WASHERS	156.	178.	199.	222.	245.
9: WATER HEATERS	1118.	1191.	1230.	1260.	1281.
10: ROOM A/C	204.	218.	228.	239.	249.
11: CENTRAL A/C	60.	72.	84.	97.	108.
12: SPACE HEATERS	1790.	2213.	2642.	2903.	3060.
13: HEATINGAUXILIARY	646.	642.	642.	634.	621.
14: MISCELLANEOUS	1299.	1493.	1719.	1915.	2086.

MASS BASE CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	30.	50.	65.	80.	93.
2: COOLING	201.	212.	220.	227.	233.
3: LT & POWER	463.	465.	468.	473.	479.
4: AUXILIARIES	351.	355.	357.	359.	362.
2: RETAIL					
1: HEATING	38.	66.	85.	100.	114.
2: COOLING	567.	597.	629.	662.	693.
3: LT & POWER	3071.	3146.	3265.	3411.	3553.
4: AUXILIARIES	1056.	1046.	1074.	1124.	1174.
3: HOSPITALS					
1: HEATING	20.	32.	42.	51.	60.
2: COOLING	166.	171.	173.	172.	171.
3: LT & POWER	797.	820.	836.	848.	860.
4: AUXILIARIES	424.	435.	437.	433.	430.
4: SCHOOLS					
1: HEATING	32.	40.	57.	80.	102.
2: COOLING	140.	122.	118.	122.	126.
3: LT & POWER	853.	730.	702.	736.	771.
4: AUXILIARIES	483.	397.	371.	382.	394.
5: OTHER					
1: HEATING	31.	55.	72.	87.	101.
2: COOLING	421.	467.	500.	525.	549.
3: LT & POWER	1257.	1365.	1435.	1481.	1529.
4: AUXILIARIES	800.	862.	898.	919.	940.

MASS BASE CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	643.	769.	900.	1037.	1187.
22: TEXTILES	381.	347.	312.	276.	243.
23: APPAREL	68.	78.	87.	95.	103.
24: LUMBER	25.	25.	25.	25.	26.
25: FURNITURE	34.	36.	39.	41.	44.
26: PAPER PRODUCTS	889.	780.	755.	786.	818.
27: PRINTING & PUBL.	237.	297.	364.	440.	523.
28: CHEMICALS	703.	808.	932.	1068.	1186.
29: PETROLEUM & COAL	51.	54.	57.	60.	62.
33: PRIMARY METALS	432.	456.	462.	453.	442.
34: FABRICAT. METALS	533.	613.	678.	733.	787.
35: MACHINERY	601.	743.	893.	1055.	1228.
36: ELECTRIC EQUIP.	1430.	1705.	1937.	2140.	2334.
37: TRANSPORTATION	381.	460.	539.	621.	708.
30: RUBBER & PLASTIC	829.	912.	994.	1072.	1143.
31: LEATHER	102.	108.	111.	109.	103.
32: STONE,CLAY,GLASS	195.	205.	210.	211.	212.
38: INSTRUMENTS	618.	643.	656.	663.	668.
39: MISC. MANUFACT.	313.	364.	399.	423.	449.

NH HIGH CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

		1978	1983	1988	1993	1998
1:	REFRIGERATORS	537.	625.	665.	670.	650.
2:	FREEZERS	162.	204.	232.	247.	252.
3:	RANGES	146.	178.	208.	231.	247.
4:	LIGHTING	211.	248.	283.	306.	323.
5:	TELEVISIONS	44.	50.	57.	66.	77.
6:	CLOTHES DRYERS	146.	194.	242.	281.	311.
7:	CLOTHES WASHERS	22.	26.	30.	33.	35.
8:	DISH WASHERS	31.	50.	69.	88.	104.
9:	WATER HEATERS	356.	474.	555.	624.	679.
10:	ROOM A/C	21.	31.	40.	47.	51.
11:	CENTRAL A/C	6.	11.	16.	19.	20.
12:	SPACE HEATERS	519.	820.	1110.	1306.	1439.
13:	HEATINGAUXILIARY	109.	112.	115.	116.	116.
14:	MISCELLANEOUS	147.	194.	246.	294.	337.

NH HIGH CASE - COMMERCIAL SECTOR - ENERGY IN GWH

		1978	1983	1988	1993	1998
1:	OFFICES					
1:	HEATING	19.	36.	51.	65.	78.
2:	COOLING	17.	21.	25.	29.	32.
3:	LT & POWER	91.	111.	128.	143.	158.
4:	AUXILIARIES	67.	79.	90.	99.	108.
2:	RETAIL					
1:	HEATING	20.	39.	55.	69.	83.
2:	COOLING	40.	52.	62.	70.	79.
3:	LT & POWER	516.	633.	730.	812.	896.
4:	AUXILIARIES	179.	217.	248.	274.	301.
3:	HOSPITALS					
1:	HEATING	9.	16.	22.	28.	33.
2:	COOLING	11.	12.	13.	14.	15.
3:	LT & POWER	118.	131.	141.	150.	158.
4:	AUXILIARIES	63.	69.	74.	78.	82.
4:	SCHOOLS					
1:	HEATING	18.	24.	36.	52.	67.
2:	COOLING	10.	11.	12.	14.	16.
3:	LT & POWER	156.	151.	159.	176.	193.
4:	AUXILIARIES	90.	87.	90.	98.	105.
5:	OTHER					
1:	HEATING	15.	31.	45.	59.	74.
2:	COOLING	26.	35.	44.	52.	60.
3:	LT & POWER	187.	238.	285.	331.	378.
4:	AUXILIARIES	118.	148.	176.	203.	230.

NH HIGH CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

		1978	1983	1988	1993	1998
20:	FOOD	103.	160.	230.	314.	412.
22:	TEXTILES	94.	106.	117.	126.	133.
23:	APPAREL	2.	2.	2.	3.	3.
24:	LUMBER	57.	70.	83.	97.	111.
25:	FURNITURE	27.	39.	53.	70.	89.
26:	PAPER PRODUCTS	384.	494.	620.	760.	909.
27:	PRINTING & PUBL.	46.	67.	95.	129.	168.
28:	CHEMICALS	131.	167.	199.	223.	237.
29:	PETROLEUM & COAL	0.	0.	0.	0.	0.
33:	PRIMARY METALS	53.	74.	98.	125.	154.
34:	FABRICAT. METALS	40.	51.	63.	76.	89.
35:	MACHINERY	107.	140.	176.	215.	253.
36:	ELECTRIC EQUIP.	225.	300.	386.	482.	584.
37:	TRANSPORTATION	46.	85.	139.	207.	289.
30:	RUBBER & PLASTIC	68.	98.	131.	167.	202.
31:	LEATHER	65.	68.	67.	64.	58.
32:	STONE,CLAY,GLASS	49.	61.	74.	89.	105.
38:	INSTRUMENTS	17.	20.	24.	27.	31.
39:	MISC. MANUFACT.	9.	14.	20.	27.	35.

NH LOW CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	537.	575.	593.	592.	575.
2: FREEZERS	162.	172.	178.	181.	181.
3: RANGES	146.	159.	174.	185.	194.
4: LIGHTING	211.	232.	253.	263.	266.
5: TELEVISIONS	57.	56.	57.	59.	61.
6: CLOTHES DRYERS	146.	176.	203.	223.	239.
7: CLOTHES WASHERS	22.	25.	27.	30.	31.
8: DISH WASHERS	31.	44.	58.	70.	79.
9: WATER HEATERS	356.	375.	393.	411.	424.
10: ROOM A/C	21.	26.	29.	31.	32.
11: CENTRAL A/C	6.	8.	8.	9.	9.
12: SPACE HEATERS	519.	640.	761.	852.	921.
13: HEATINGAUXILIARY	109.	108.	107.	106.	104.
14: MISCELLANEOUS	134.	149.	165.	178.	188.

NH LOW CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	14.	19.	24.	29.	35.
2: COOLING	16.	16.	16.	17.	17.
3: LT & POWER	90.	88.	90.	96.	102.
4: AUXILIARIES	69.	69.	71.	75.	80.
2: RETAIL					
1: HEATING	13.	18.	21.	25.	27.
2: COOLING	37.	35.	35.	37.	39.
3: LT & POWER	495.	463.	479.	527.	574.
4: AUXILIARIES	168.	147.	149.	167.	185.
3: HOSPITALS					
1: HEATING	8.	12.	14.	17.	18.
2: COOLING	12.	12.	11.	11.	10.
3: LT & POWER	133.	142.	147.	150.	154.
4: AUXILIARIES	71.	75.	76.	75.	74.
4: SCHOOLS					
1: HEATING	18.	20.	26.	34.	42.
2: COOLING	10.	9.	8.	8.	8.
3: LT & POWER	171.	154.	152.	160.	169.
4: AUXILIARIES	94.	78.	73.	75.	78.
5: OTHER					
1: HEATING	10.	15.	19.	24.	28.
2: COOLING	26.	28.	30.	32.	34.
3: LT & POWER	194.	212.	232.	255.	279.
4: AUXILIARIES	123.	134.	144.	156.	168.

NH LOW CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	103.	129.	156.	185.	214.
22: TEXTILES	94.	81.	73.	68.	63.
23: APPAREL	2.	2.	2.	3.	3.
24: LUMBER	57.	62.	66.	69.	72.
25: FURNITURE	27.	30.	33.	36.	39.
26: PAPER PRODUCTS	384.	365.	377.	414.	447.
27: PRINTING & PUBL.	46.	57.	70.	84.	97.
28: CHEMICALS	131.	171.	220.	272.	307.
29: PETROLEUM & COAL	0.	0.	0.	0.	0.
33: PRIMARY METALS	53.	78.	103.	130.	158.
34: FABRICAT. METALS	40.	51.	64.	80.	96.
35: MACHINERY	107.	131.	157.	181.	203.
36: ELECTRIC EQUIP.	225.	302.	368.	424.	473.
37: TRANSPORTATION	46.	71.	104.	146.	192.
30: RUBBER & PLASTIC	68.	78.	88.	96.	104.
31: LEATHER	65.	73.	79.	83.	86.
32: STONE,CLAY,GLASS	49.	48.	46.	44.	42.
38: INSTRUMENTS	17.	18.	18.	17.	17.
39: MISC. MANUFACT.	9.	11.	12.	13.	14.

NH	BASE CASE - RESIDENTIAL SECTOR - ENERGY IN GWH	1978	1983	1988	1993	1998
1:	REFRIGERATORS	537.	600.	629.	631.	612.
2:	FREEZERS	162.	188.	205.	214.	216.
3:	RANGES	146.	169.	191.	208.	221.
4:	LIGHTING	211.	240.	268.	285.	294.
5:	TELEVISIONS	50.	53.	57.	62.	69.
6:	CLOTHES DRYERS	146.	185.	222.	252.	275.
7:	CLOTHES WASHERS	22.	26.	29.	31.	33.
8:	DISH WASHERS	31.	47.	64.	79.	92.
9:	WATER HEATERS	356.	425.	474.	518.	551.
10:	ROOM A/C	21.	29.	34.	39.	42.
11:	CENTRAL A/C	6.	9.	12.	14.	15.
12:	SPACE HEATERS	519.	730.	936.	1079.	1180.
13:	HEATINGAUXILIARY	109.	110.	111.	111.	110.
14:	MISCELLANEOUS	140.	171.	206.	236.	263.

NH	BASE CASE - COMMERCIAL SECTOR - ENERGY IN GWH	1978	1983	1988	1993	1998
1:	OFFICES					
1:	HEATING	16.	28.	38.	47.	57.
2:	COOLING	16.	19.	21.	23.	25.
3:	LT & POWER	90.	100.	109.	119.	130.
4:	AUXILIARIES	68.	74.	80.	87.	94.
2:	RETAIL					
1:	HEATING	16.	28.	38.	47.	55.
2:	COOLING	39.	43.	48.	54.	59.
3:	LT & POWER	505.	548.	605.	670.	735.
4:	AUXILIARIES	173.	182.	199.	221.	243.
3:	HOSPITALS					
1:	HEATING	9.	14.	18.	22.	26.
2:	COOLING	11.	12.	12.	12.	13.
3:	LT & POWER	126.	136.	144.	150.	156.
4:	AUXILIARIES	67.	72.	75.	76.	78.
4:	SCHOOLS					
1:	HEATING	18.	22.	31.	43.	55.
2:	COOLING	10.	10.	10.	11.	12.
3:	LT & POWER	163.	152.	155.	168.	181.
4:	AUXILIARIES	92.	83.	82.	86.	91.
5:	OTHER					
1:	HEATING	13.	23.	32.	42.	51.
2:	COOLING	26.	31.	37.	42.	47.
3:	LT & POWER	190.	225.	259.	293.	328.
4:	AUXILIARIES	121.	141.	160.	179.	199.

NH	BASE CASE - INDUSTRIAL SECTOR - ENERGY IN GWH	1978	1983	1988	1993	1998
20:	FOOD	103.	144.	193.	250.	313.
22:	TEXTILES	94.	93.	95.	97.	98.
23:	APPAREL	2.	2.	2.	3.	3.
24:	LUMBER	57.	66.	74.	83.	92.
25:	FURNITURE	27.	35.	43.	53.	64.
26:	PAPER PRODUCTS	384.	429.	498.	587.	678.
27:	PRINTING & PUBL.	46.	62.	82.	106.	132.
28:	CHEMICALS	131.	169.	209.	247.	272.
29:	PETROLEUM & COAL	0.	0.	0.	0.	0.
33:	PRIMARY METALS	53.	76.	100.	127.	156.
34:	FABRICAT. METALS	40.	51.	64.	78.	92.
35:	MACHINERY	107.	136.	167.	198.	228.
36:	ELECTRIC EQUIP.	225.	301.	377.	453.	529.
37:	TRANSPORTATION	46.	78.	122.	177.	241.
30:	RUBBER & PLASTIC	68.	88.	109.	131.	153.
31:	LEATHER	65.	70.	73.	73.	72.
32:	STONE,CLAY,GLASS	49.	54.	60.	67.	74.
38:	INSTRUMENTS	17.	19.	21.	22.	24.
39:	MISC. MANUFACT.	9.	12.	16.	20.	25.

RI HIGH CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	526.	582.	605.	600.	574.
2: FREEZERS	70.	86.	98.	106.	109.
3: RANGES	101.	115.	129.	140.	147.
4: LIGHTING	218.	241.	267.	283.	294.
5: TELEVISIONS	59.	59.	59.	60.	61.
6: CLOTHES DRYERS	93.	106.	120.	132.	141.
7: CLOTHES WASHERS	22.	25.	28.	30.	31.
8: DISH WASHERS	24.	30.	37.	44.	52.
9: WATER HEATERS	208.	241.	259.	275.	288.
10: ROOM A/C	24.	27.	30.	33.	36.
11: CENTRAL A/C	7.	9.	12.	14.	17.
12: SPACE HEATERS	194.	278.	367.	423.	457.
13: HEATINGAUXILIARY	112.	115.	119.	121.	120.
14: MISCELLANEOUS	163.	203.	250.	292.	331.

RI HIGH CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	4.	8.	11.	14.	16.
2: COOLING	25.	28.	30.	33.	35.
3: LT & POWER	65.	69.	72.	75.	77.
4: AUXILIARIES	48.	51.	53.	54.	55.
2: RETAIL					
1: HEATING	7.	13.	17.	20.	24.
2: COOLING	73.	86.	95.	102.	108.
3: LT & POWER	443.	500.	535.	556.	576.
4: AUXILIARIES	155.	173.	184.	190.	197.
3: HOSPITALS					
1: HEATING	4.	6.	9.	11.	14.
2: COOLING	24.	26.	28.	30.	31.
3: LT & POWER	130.	135.	140.	145.	151.
4: AUXILIARIES	69.	71.	74.	76.	79.
4: SCHOOLS					
1: HEATING	5.	8.	12.	18.	24.
2: COOLING	20.	20.	21.	24.	26.
3: LT & POWER	137.	127.	129.	140.	151.
4: AUXILIARIES	79.	74.	74.	78.	83.
5: OTHER					
1: HEATING	5.	10.	14.	17.	20.
2: COOLING	48.	58.	66.	72.	78.
3: LT & POWER	160.	186.	203.	216.	228.
4: AUXILIARIES	102.	116.	127.	134.	141.

RI HIGH CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	44.	49.	54.	59.	65.
22: TEXTILES	211.	200.	187.	174.	161.
23: APPAREL	43.	49.	56.	63.	70.
24: LUMBER	1.	2.	3.	4.	4.
25: FURNITURE	1.	2.	2.	2.	2.
26: PAPER PRODUCTS	41.	43.	43.	42.	39.
27: PRINTING & PUBL.	32.	36.	41.	46.	50.
28: CHEMICALS	57.	82.	112.	144.	172.
29: PETROLEUM & COAL	4.	6.	7.	9.	11.
33: PRIMARY METALS	252.	311.	362.	406.	453.
34: FABRICAT. METALS	81.	112.	145.	181.	221.
35: MACHINERY	52.	62.	71.	80.	89.
36: ELECTRIC EQUIP.	103.	126.	148.	169.	188.
37: TRANSPORTATION	59.	87.	124.	169.	220.
30: RUBBER & PLASTIC	161.	214.	277.	348.	418.
31: LEATHER	3.	4.	4.	5.	6.
32: STONE,CLAY,GLASS	79.	93.	108.	123.	140.
38: INSTRUMENTS	26.	42.	61.	85.	113.
39: MISC. MANUFACT.	127.	168.	207.	244.	281.

RI LOW CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	526.	537.	530.	510.	479.
2: FREEZERS	70.	71.	70.	69.	67.
3: RANGES	101.	103.	106.	108.	108.
4: LIGHTING	218.	225.	230.	228.	220.
5: TELEVISIONS	69.	64.	62.	60.	59.
6: CLOTHES DRYERS	93.	99.	105.	110.	114.
7: CLOTHES WASHERS	22.	23.	24.	25.	25.
8: DISH WASHERS	24.	28.	32.	36.	40.
9: WATER HEATERS	208.	195.	185.	178.	173.
10: ROOM A/C	24.	25.	25.	26.	27.
11: CENTRAL A/C	7.	8.	8.	9.	9.
12: SPACE HEATERS	194.	211.	226.	233.	237.
13: HEATINGAUXILIARY	112.	108.	104.	99.	94.
14: MISCELLANEOUS	153.	159.	166.	170.	173.

RI LOW CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	3.	4.	5.	6.	7.
2: COOLING	25.	24.	23.	22.	21.
3: LT & POWER	65.	60.	56.	54.	52.
4: AUXILIARIES	50.	48.	46.	44.	43.
2: RETAIL					
1: HEATING	4.	5.	7.	7.	8.
2: COOLING	68.	63.	62.	63.	64.
3: LT & POWER	431.	398.	396.	414.	432.
4: AUXILIARIES	146.	126.	122.	130.	137.
3: HOSPITALS					
1: HEATING	3.	4.	5.	5.	6.
2: COOLING	26.	25.	24.	22.	20.
3: LT & POWER	141.	142.	141.	137.	134.
4: AUXILIARIES	75.	76.	73.	68.	64.
4: SCHOOLS					
1: HEATING	5.	5.	6.	7.	9.
2: COOLING	20.	17.	14.	12.	10.
3: LT & POWER	144.	121.	107.	98.	90.
4: AUXILIARIES	80.	61.	52.	47.	43.
5: OTHER					
1: HEATING	3.	4.	5.	6.	7.
2: COOLING	47.	47.	48.	48.	48.
3: LT & POWER	164.	168.	171.	172.	173.
4: AUXILIARIES	104.	107.	107.	106.	106.

RI LOW CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	44.	49.	54.	59.	65.
22: TEXTILES	211.	197.	161.	114.	71.
23: APPAREL	43.	49.	56.	63.	70.
24: LUMBER	1.	2.	2.	2.	2.
25: FURNITURE	1.	2.	2.	2.	2.
26: PAPER PRODUCTS	41.	32.	29.	32.	34.
27: PRINTING & PUBL.	32.	35.	38.	40.	42.
28: CHEMICALS	57.	74.	98.	125.	149.
29: PETROLEUM & COAL	4.	6.	7.	9.	11.
33: PRIMARY METALS	252.	292.	328.	362.	397.
34: FABRICAT. METALS	81.	93.	102.	111.	120.
35: MACHINERY	52.	62.	71.	80.	89.
36: ELECTRIC EQUIP.	103.	126.	148.	169.	188.
37: TRANSPORTATION	59.	87.	124.	169.	220.
30: RUBBER & PLASTIC	161.	214.	277.	348.	418.
31: LEATHER	3.	3.	4.	5.	5.
32: STONE,CLAY,GLASS	79.	89.	100.	110.	120.
38: INSTRUMENTS	26.	33.	41.	49.	57.
39: MISC. MANUFACT.	127.	168.	207.	244.	281.

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RI            BASE CASE - RESIDENTIAL SECTOR - ENERGY IN GWH
                            1978   1983   1988   1993   1998
 1: REFRIGERATORS           526.   559.   567.   555.   526.
 2: FREEZERS                 70.    78.    84.    87.    88.
 3: RANGES                  101.   109.   118.   124.   128.
 4: LIGHTING                218.   233.   248.   256.   257.
 5: TELEVISIONS              64.    62.    61.    60.    60.
 6: CLOTHES DRYERS           93.   102.   113.   121.   127.
 7: CLOTHES WASHERS          22.    24.    26.    27.    28.
 8: DISH WASHERS             24.    29.    34.    40.    46.
 9: WATER HEATERS           208.   218.   222.   227.   231.
10: ROOM A/C                 24.    26.    28.    29.    31.
11: CENTRAL A/C               7.     8.    10.    11.    13.
12: SPACE HEATERS           194.   245.   296.   328.   347.
13: HEATINGAUXILIARY        112.   112.   111.   110.   107.
14: MISCELLANEOUS           158.   181.   208.   231.   252.
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RI            BASE CASE - COMMERCIAL  SECTOR - ENERGY IN GWH
                           1978   1983   1988   1993   1998
 1: OFFICES
 1:   HEATING                4.     6.     8.    10.    12.
 2:   COOLING               25.    26.    27.    27.    28.
 3:   LT & POWER            65.    64.    64.    64.    65.
 4:   AUXILIARIES           49.    49.    49.    49.    49.
 2: RETAIL
 1:   HEATING                5.     9.    12.    14.    16.
 2:   COOLING               71.    75.    79.    82.    86.
 3:   LT & POWER           437.   449.   466.   485.   504.
 4:   AUXILIARIES          150.   149.   153.   160.   167.
 3: HOSPITALS
 1:   HEATING                3.     5.     7.     8.    10.
 2:   COOLING               25.    26.    26.    26.    26.
 3:   LT & POWER           135.   139.   140.   141.   143.
 4:   AUXILIARIES           72.    74.    73.    72.    71.
 4: SCHOOLS
 1:   HEATING                5.     6.     9.    13.    16.
 2:   COOLING               20.    18.    18.    18.    18.
 3:   LT & POWER           140.   124.   118.   119.   121.
 4:   AUXILIARIES           80.    68.    63.    63.    63.
 5: OTHER
 1:   HEATING                4.     7.     9.    11.    13.
 2:   COOLING               47.    53.    57.    60.    63.
 3:   LT & POWER           162.   177.   187.   194.   201.
 4:   AUXILIARIES          103.   112.   117.   120.   123.
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RI            BASE CASE - INDUSTRIAL  SECTOR - ENERGY IN GWH
                            1978   1983   1988   1993   1998
20: FOOD                     44.    49.    54.    59.    65.
22: TEXTILES                211.   199.   174.   144.   116.
23: APPAREL                  43.    49.    56.    63.    70.
24: LUMBER                    1.     2.     2.     3.     3.
25: FURNITURE                 1.     2.     2.     2.     2.
26: PAPER PRODUCTS           41.    37.    36.    37.    37.
27: PRINTING & PUBL.         32.    35.    39.    43.    46.
28: CHEMICALS                57.    78.   105.   134.   161.
29: PETROLEUM & COAL          4.     6.     7.     9.    11.
33: PRIMARY METALS          252.   302.   345.   384.   425.
34: FABRICAT. METALS         81.   102.   124.   146.   170.
35: MACHINERY                52.    62.    71.    80.    89.
36: ELECTRIC EQUIP.         103.   126.   148.   169.   188.
37: TRANSPORTATION           59.    87.   124.   169.   220.
30: RUBBER & PLASTIC        161.   214.   277.   348.   418.
31: LEATHER                   3.     3.     4.     5.     6.
32: STONE,CLAY,GLASS         79.    91.   104.   117.   130.
38: INSTRUMENTS              26.    37.    51.    67.    85.
39: MISC. MANUFACT.         127.   168.   207.   244.   281.
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VERMONT HIGH CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	277.	310.	327.	330.	322.
2: FREEZERS	104.	127.	145.	157.	163.
3: RANGES	83.	102.	121.	135.	145.
4: LIGHTING	114.	129.	147.	160.	169.
5: TELEVISIONS	22.	24.	28.	32.	38.
6: CLOTHES DRYERS	83.	106.	132.	155.	174.
7: CLOTHES WASHERS	13.	15.	18.	19.	20.
8: DISH WASHERS	17.	24.	32.	40.	48.
9: WATER HEATERS	304.	354.	387.	422.	454.
10: ROOM A/C	7.	12.	15.	17.	18.
11: CENTRAL A/C	2.	3.	5.	6.	8.
12: SPACE HEATERS	254.	389.	542.	649.	720.
13: HEATINGAUXILIARY	62.	63.	64.	65.	65.
14: MISCELLANEOUS	254.	324.	409.	490.	565.

VERMONT HIGH CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	6.	11.	16.	19.	23.
2: COOLING	6.	8.	9.	10.	10.
3: LT & POWER	33.	38.	41.	44.	46.
4: AUXILIARIES	24.	27.	29.	31.	32.
2: RETAIL					
1: HEATING	10.	19.	27.	32.	37.
2: COOLING	24.	29.	33.	35.	38.
3: LT & POWER	286.	336.	369.	389.	409.
4: AUXILIARIES	100.	116.	126.	132.	139.
3: HOSPITALS					
1: HEATING	5.	8.	12.	15.	18.
2: COOLING	6.	7.	7.	8.	9.
3: LT & POWER	66.	71.	76.	80.	85.
4: AUXILIARIES	35.	37.	40.	42.	44.
4: SCHOOLS					
1: HEATING	9.	12.	18.	26.	34.
2: COOLING	6.	6.	6.	7.	8.
3: LT & POWER	85.	80.	82.	88.	95.
4: AUXILIARIES	49.	46.	47.	49.	52.
5: OTHER					
1: HEATING	10.	19.	28.	35.	43.
2: COOLING	20.	25.	30.	34.	38.
3: LT & POWER	135.	160.	182.	202.	221.
4: AUXILIARIES	86.	100.	113.	124.	136.

VERMONT HIGH CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	40.	44.	48.	52.	56.
22: TEXTILES	6.	9.	13.	17.	22.
23: APPAREL	1.	1.	1.	1.	1.
24: LUMBER	44.	56.	69.	82.	95.
25: FURNITURE	14.	19.	26.	35.	44.
26: PAPER PRODUCTS	106.	135.	167.	203.	242.
27: PRINTING & PUBL.	33.	43.	55.	69.	85.
28: CHEMICALS	8.	11.	13.	15.	16.
29: PETROLEUM & COAL	1.	1.	1.	1.	1.
33: PRIMARY METALS	7.	9.	12.	15.	19.
34: FABRICAT. METALS	16.	21.	27.	34.	42.
35: MACHINERY	71.	86.	101.	118.	134.
36: ELECTRIC EQUIP.	236.	384.	584.	826.	1085.
37: TRANSPORTATION	37.	56.	83.	115.	151.
30: RUBBER & PLASTIC	49.	71.	98.	130.	161.
31: LEATHER	5.	6.	6.	7.	7.
32: STONE,CLAY,GLASS	27.	27.	28.	29.	29.
38: INSTRUMENTS	7.	7.	8.	8.	8.
39: MISC. MANUFACT.	53.	66.	80.	95.	110.

VERMONT LOW CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	277.	292.	297.	292.	280.
2: FREEZERS	104.	107.	110.	110.	108.
3: RANGES	83.	89.	95.	100.	103.
4: LIGHTING	114.	123.	131.	134.	133.
5: TELEVISIONS	29.	29.	29.	29.	29.
6: CLOTHES DRYERS	83.	98.	114.	126.	134.
7: CLOTHES WASHERS	13.	15.	16.	17.	17.
8: DISH WASHERS	17.	22.	28.	33.	37.
9: WATER HEATERS	304.	298.	295.	296.	297.
10: ROOM A/C	7.	10.	11.	11.	11.
11: CENTRAL A/C	2.	3.	3.	4.	4.
12: SPACE HEATERS	254.	301.	350.	384.	406.
13: HEATINGAUXILIARY	62.	60.	59.	57.	55.
14: MISCELLANEOUS	247.	267.	290.	307.	319.

VERMONT LOW CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	4.	5.	5.	6.	6.
2: COOLING	6.	6.	6.	6.	5.
3: LT & POWER	32.	31.	30.	29.	28.
4: AUXILIARIES	25.	25.	24.	23.	23.
2: RETAIL					
1: HEATING	6.	8.	9.	9.	9.
2: COOLING	22.	22.	22.	22.	22.
3: LT & POWER	281.	279.	284.	294.	303.
4: AUXILIARIES	95.	89.	89.	93.	97.
3: HOSPITALS					
1: HEATING	3.	4.	5.	5.	6.
2: COOLING	6.	6.	6.	6.	5.
3: LT & POWER	72.	74.	76.	76.	77.
4: AUXILIARIES	38.	39.	39.	38.	37.
4: SCHOOLS					
1: HEATING	7.	7.	8.	9.	11.
2: COOLING	6.	5.	4.	4.	3.
3: LT & POWER	89.	78.	72.	72.	71.
4: AUXILIARIES	50.	39.	35.	34.	33.
5: OTHER					
1: HEATING	6.	8.	10.	11.	12.
2: COOLING	20.	22.	23.	24.	24.
3: LT & POWER	143.	162.	171.	176.	182.
4: AUXILIARIES	91.	102.	106.	108.	110.

VERMONT LOW CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	40.	41.	43.	44.	46.
22: TEXTILES	6.	7.	7.	8.	8.
23: APPAREL	1.	1.	1.	1.	1.
24: LUMBER	44.	48.	51.	53.	56.
25: FURNITURE	14.	15.	16.	17.	19.
26: PAPER PRODUCTS	106.	114.	123.	133.	142.
27: PRINTING & PUBL.	33.	40.	48.	57.	65.
28: CHEMICALS	8.	10.	12.	15.	16.
29: PETROLEUM & COAL	1.	1.	1.	1.	1.
33: PRIMARY METALS	7.	8.	8.	9.	9.
34: FABRICAT. METALS	16.	22.	27.	33.	39.
35: MACHINERY	71.	84.	96.	108.	120.
36: ELECTRIC EQUIP.	236.	302.	373.	445.	508.
37: TRANSPORTATION	37.	57.	81.	109.	140.
30: RUBBER & PLASTIC	49.	61.	76.	92.	109.
31: LEATHER	5.	6.	7.	8.	9.
32: STONE,CLAY,GLASS	27.	26.	26.	28.	30.
38: INSTRUMENTS	7.	8.	10.	11.	13.
39: MISC. MANUFACT.	53.	67.	79.	89.	100.

VERMONT BASE CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	277.	301.	312.	311.	301.
2: FREEZERS	104.	117.	127.	133.	135.
3: RANGES	83.	95.	108.	117.	124.
4: LIGHTING	114.	126.	139.	147.	151.
5: TELEVISIONS	26.	26.	28.	30.	34.
6: CLOTHES DRYERS	83.	102.	123.	140.	154.
7: CLOTHES WASHERS	13.	15.	17.	18.	19.
8: DISH WASHERS	17.	23.	30.	36.	42.
9: WATER HEATERS	304.	326.	341.	359.	375.
10: ROOM A/C	7.	11.	13.	14.	14.
11: CENTRAL A/C	2.	3.	4.	5.	6.
12: SPACE HEATERS	254.	345.	446.	516.	563.
13: HEATINGAUXILIARY	62.	62.	62.	61.	60.
14: MISCELLANEOUS	250.	295.	350.	399.	442.

VERMONT BASE CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	5.	8.	11.	13.	15.
2: COOLING	6.	7.	7.	8.	8.
3: LT & POWER	32.	35.	36.	36.	37.
4: AUXILIARIES	24.	26.	27.	27.	27.
2: RETAIL					
1: HEATING	8.	14.	18.	21.	23.
2: COOLING	23.	25.	27.	29.	30.
3: LT & POWER	284.	308.	326.	341.	356.
4: AUXILIARIES	97.	102.	107.	113.	118.
3: HOSPITALS					
1: HEATING	4.	6.	8.	10.	12.
2: COOLING	6.	7.	7.	7.	7.
3: LT & POWER	69.	73.	76.	78.	81.
4: AUXILIARIES	37.	38.	39.	40.	41.
4: SCHOOLS					
1: HEATING	8.	9.	13.	18.	22.
2: COOLING	6.	5.	5.	6.	6.
3: LT & POWER	87.	79.	77.	80.	83.
4: AUXILIARIES	50.	43.	41.	42.	43.
5: OTHER					
1: HEATING	8.	14.	19.	23.	27.
2: COOLING	20.	24.	26.	29.	31.
3: LT & POWER	139.	161.	177.	189.	201.
4: AUXILIARIES	88.	101.	110.	116.	123.

VERMONT BASE CASE - INDUSTRIAL SECTOR - ENERGY IN GWH

	1978	1983	1988	1993	1998
20: FOOD	40.	42.	45.	48.	51.
22: TEXTILES	6.	8.	10.	12.	15.
23: APPAREL	1.	1.	1.	1.	1.
24: LUMBER	44.	52.	60.	68.	75.
25: FURNITURE	14.	17.	21.	26.	32.
26: PAPER PRODUCTS	106.	124.	145.	168.	192.
27: PRINTING & PUBL.	33.	41.	51.	63.	75.
28: CHEMICALS	8.	10.	13.	15.	16.
29: PETROLEUM & COAL	1.	1.	1.	1.	1.
33: PRIMARY METALS	7.	8.	10.	12.	14.
34: FABRICAT. METALS	16.	21.	27.	33.	40.
35: MACHINERY	71.	85.	99.	113.	127.
36: ELECTRIC EQUIP.	236.	343.	479.	636.	797.
37: TRANSPORTATION	37.	57.	82.	112.	146.
30: RUBBER & PLASTIC	49.	66.	87.	111.	135.
31: LEATHER	5.	6.	7.	7.	8.
32: STONE,CLAY,GLASS	27.	27.	27.	28.	30.
38: INSTRUMENTS	7.	8.	9.	10.	10.
39: MISC. MANUFACT.	53.	66.	79.	92.	105.

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Final Draft

REDUCING NEW ENGLAND'S OIL DEPENDENCE THROUGH CONSERVATION AND ALTERNATIVE ENERGY

TECHNICAL REPORT II

THE CONSERVATION SCENARIO

A Report to the
General Accounting Office
of the
United States Congress

David Nichols
Paul D. Raskin

May, 1980
Revised February, 1981

ENERGY SYSTEMS RESEARCH GROUP, INC.
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1. INTRODUCTION AND SELECTED RESULTS

1.1 Purpose of the Conservation Scenario

The general objective of the conservation scenario developed here is to illustrate the order of magnitude of potential oil consumption savings that can be realized through policies that promote or mandate conservation practices. Specifically, the scenario is a selection of conservation measures and levels that could be implemented for homes and buildings in order to reduce oil consumption for electricity generation and for heating homes and buildings. In order to compute oil savings for electricity using the ESRG electric load forecasting model, estimates of industrial energy conservation potential are also included in the scenario. The scenario analysis does not, however, include conservation of oil consumed in industrial processes or conservation of gasoline.

All of the conservation measures and levels selected in this scenario are feasible and cost-effective. A "feasible" measure is one which is on the market now or whose technical viability has been demonstrated in U.S. Department of Energy tests or by commercial developers planning to market the measure. A "cost-effective" measure is one whose life-cycle costs are less than the marginal costs of the energy it displaces.

The conservation measures and levels included in this scenario go beyond those presently being implemented through market forces and public policy. The scenario is entitled the "Conservation Strategy Scenario" precisely in order to emphasize its dependence upon additional or new policy measures. Hypothetical new policies are linked to the conservation measures selected herein. In some cases a specific policy is posited -- e.g., a specific appliance efficiency regulation -- and in others a range of conceivable policies is set forth. The purpose of the technical analysis described here is not to develop a precise set of policy proposals. It is, rather, to provide policymaking guidance by quantifying the conservation potential from feasible and socially cost-effective measures not likely to be implemented without additional public action.

Since both energy markets and the energy policies with which markets are inextricably intertwined are in a state of flux at the present time, it is impossible to precisely forecast the degree of conservation that will be occurring if present trends continue; present trends are themselves difficult to discern. The conservation strategy scenario necessarily computes savings relative to conservation that is occurring under present trends: a "Base Case" forecast of energy consumption, including some conservation, is required. For the case of electric energy, Report I presented a long range Base Case forecast of consumption for New England. For heating oil, the Base Case forecast is incorporated in Report III.

This appendix contains all of the conservation assumptions used to derive heating oil savings in Report III. However, while several of the conservation elements apply to both heating oil and electricity consumption, many apply only to electricity. Thus, the comparative comments in the text of this appendix relate elements of the conservation strategy scenario to the electric energy forecast presented in Report I. Indeed, section 1.2 below selects the electricity consumption results for comparison with the Base Case electricity forecast. The electric energy forecast based on the conservation strategy scenario is denoted the Conservation Case.

A final introductory note: While the Conservation Strategy Scenario illustrates the substantial conservation potential that could be realized through a deliberate policy commitment to increasing the productivity of energy use, it by no means necessarily exhausts the potential for conservation. Certain sectors, like transportation and industrial oil burning, are beyond the scope of the scenario. Even within the focus on oil for electricity and heating oil, the analysts have not been able to be precise in every detail; policy options and conservation measures worthy of consideration have been excluded because more information is needed about them or because their effects are less certain at this point than those of the included elements. Finally, conservation technologies that are unlikely to attain technical viability or economic attractiveness during the scenario period have been excluded from consideration; the conservation strategy scenario is intended to constitute a "here and now" set of options.

1.2 Selected Results: Electric Energy

Results of the Conservation Case are presented in aggregate and disaggregate form, respectively, in Tables 1.1 and 1.2. For contrast, Conservation and Base Case results are shown together in Table 1.3 and in Figure 1.1.

It should be stressed that the conservation measures focus on cost-effective energy conservation. Load management programs -- load limiting devices, time-of-use rates, interruptible rates, and the like -- have not been included beyond the Base Case levels in this analysis. Consequently, Conservation Case peak load decrements reflect only the flow-through of the overall increases in end-use efficiency assumed in the Base/Conservation transition.

Nevertheless, the forecasted effects of conservation are strong. By 1988, after most conservation measures are introduced into the model, the forecasted peak is 17 percent under the base forecast. By 1998 the reduction is 24 percent. This is indicative of the magnitude of capacity for which a conservation strategy might substitute, and as such underlines the opportunity for both utilities and policymakers to actively investigate the possibility of pursuing conservation measures as a supply option. The energy reduction of over 21 percent by 1998, relative to the Base Case, implies the possibility of very substantial oil savings, as documented in Appendix III and discussed in the Report.

Figure 1.1
COMPARISON OF CONSERVATION AND BASE CASE
FORECASTS OF ENERGY, NEW ENGLAND

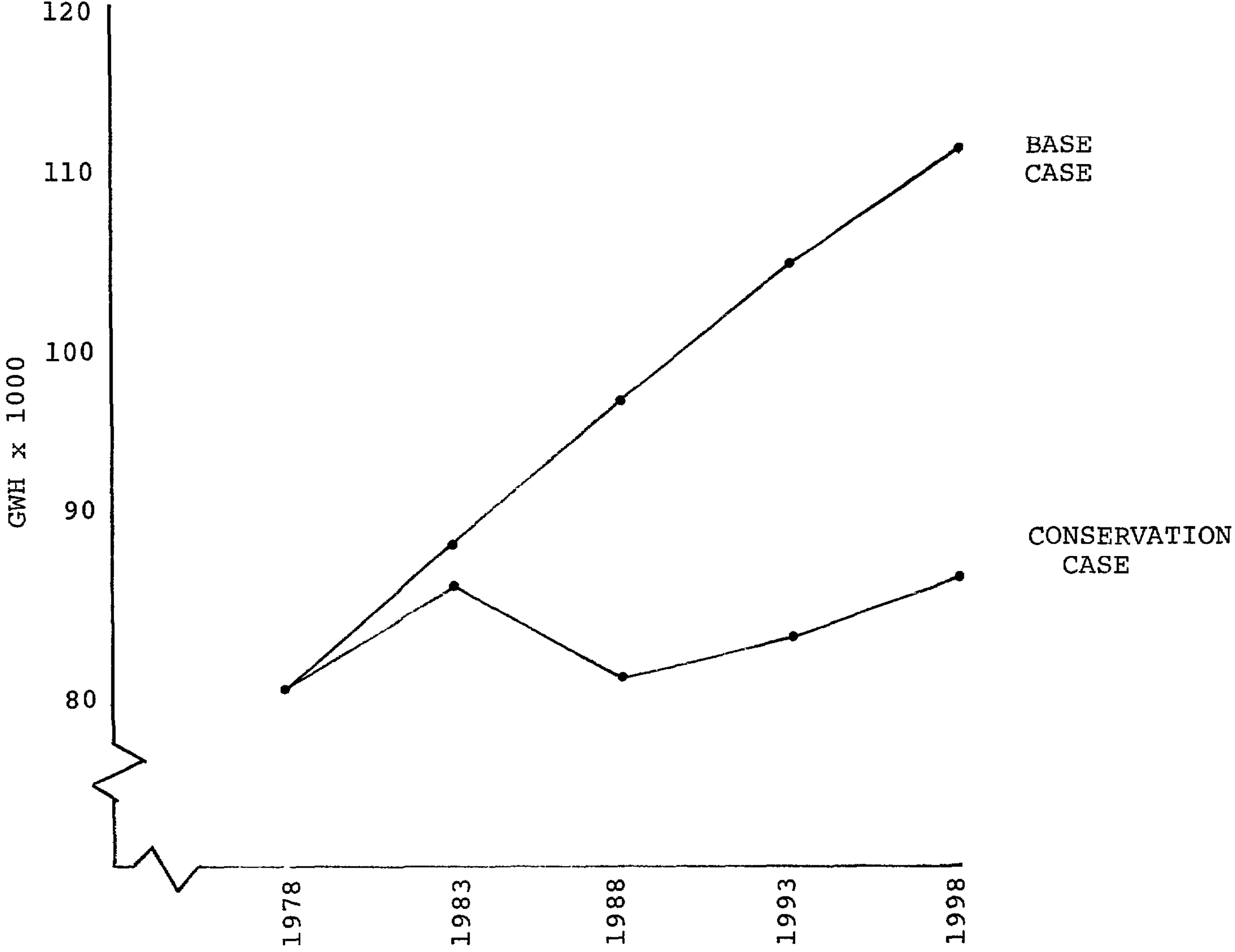

TABLE 1.1

COMPARISON OF ESRG BASE CASE AND CONSERVATION FORECASTS, NEW ENGLAND AGGREGATE ENERGY AND PEAK

	Energy (GWH)		Summer Peak (MW)		Winter Peak (MW)	
	Base Case	Conservation	Base Case	Conservation	Base Case	Conservation
1978	80530	80530	14073	14073	14964	14964
1983	88730	86160	15330	15240	16780	16400
1988	97080	81090	16600	14240	18650	15550
1993	104750	83680	17740	14640	20210	15940
1998	111480	86700	18740	15130	21460	16320

TABLE 1.2

COMPARISON OF GROWTH RATES IN ENERGY AND PEAK, ESRG BASE CASE AND CONSERVATION FORECASTS FOR NEW ENGLAND

	Case	1978	% Year 1978-88	1988	% Year 1988-93	1998
Annual Energy (GWH)	Base	80,530	1.89	97,080	1.39	111,480
	Conservation	80,530	.07	81,090	.67	86,700
Summer Peak (MW)	Base	14,073	1.67	16,600	1.22	18,740
	Conservation	14,073	.12	14,240	.73	15,130
Winter Peak (MW)	Base	14,964	2.23	18,650	1.41	21,460
	Conservation	14,964	.38	15,550	.48	16,320

TABLE 1.3
ESRG CONSERVATION FORECASTS OF ENERGY AND PEAK FOR NEW ENGLAND STATES

CONSERVATION SCENARIO

CONN		ENERGY IN GWH				PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	8154.	6495.	5975.	1710.	22334.	4021.	4052.
1979	8360.	6570.	6130.	1750.	22800.	4110.	4140.
1980	8530.	6640.	6270.	1780.	23230.	4180.	4230.
1981	8710.	6710.	6420.	1810.	23660.	4260.	4320.
1982	8480.	6540.	6560.	1840.	23430.	4310.	4360.
1983	8530.	6600.	6710.	1860.	23700.	4370.	4410.
1984	8450.	6620.	6660.	1860.	23590.	4350.	4390.
1985	8360.	6420.	6600.	1840.	23220.	4280.	4320.
1986	8280.	6210.	6590.	1830.	22900.	4220.	4270.
1987	8320.	5990.	6570.	1820.	22700.	4180.	4240.
1988	8370.	5780.	6540.	1810.	22500.	4140.	4200.
1989	8420.	5570.	6660.	1820.	22460.	4120.	4200.
1990	8460.	5620.	6780.	1840.	22710.	4170.	4240.
1991	8450.	5680.	6900.	1860.	22890.	4200.	4260.
1992	8440.	5730.	7020.	1880.	23070.	4230.	4280.
1993	8430.	5790.	7130.	1900.	23250.	4260.	4310.
1994	8420.	5840.	7240.	1920.	23420.	4290.	4330.
1995	8410.	5900.	7350.	1930.	23590.	4320.	4350.
1996	8400.	5950.	7450.	1950.	23760.	4340.	4370.
1997	8390.	6010.	7550.	1970.	23920.	4370.	4390.
1998	8370.	6060.	7650.	1990.	24070.	4390.	4410.
1999	8370.	6110.	7750.	2000.	24230.	4420.	4440.
2000	8370.	6170.	7840.	2020.	24400.	4440.	4460.

CONSERVATION SCENARIO

MASS		ENERGY IN GWH				PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	11756.	11202.	8464.	3100.	34522.	6286.	6431.
1979	12010.	11250.	8650.	3160.	35080.	6370.	6550.
1980	12240.	11300.	8840.	3220.	35600.	6460.	6670.
1981	12480.	11340.	9030.	3280.	36130.	6540.	6790.
1982	12260.	11100.	9220.	3330.	35900.	6600.	6850.
1983	12320.	11120.	9400.	3370.	36220.	6660.	6910.
1984	12140.	11110.	9300.	3380.	35940.	6610.	6860.
1985	11950.	10700.	9190.	3360.	35200.	6460.	6730.
1986	11770.	10310.	9070.	3340.	34480.	6310.	6620.
1987	11810.	9920.	8940.	3340.	34010.	6210.	6540.
1988	11860.	9540.	8800.	3330.	33520.	6100.	6470.
1989	11910.	9160.	8880.	3350.	33300.	6030.	6440.
1990	11950.	9250.	8960.	3400.	33570.	6080.	6480.
1991	11920.	9340.	9040.	3450.	33760.	6120.	6510.
1992	11910.	9430.	9120.	3500.	33950.	6150.	6530.
1993	11890.	9520.	9190.	3540.	34150.	6190.	6560.
1994	11880.	9610.	9260.	3590.	34340.	6220.	6590.
1995	11860.	9710.	9320.	3630.	34530.	6260.	6610.
1996	11850.	9800.	9380.	3680.	34710.	6290.	6640.
1997	11830.	9890.	9440.	3730.	34880.	6320.	6660.
1998	11810.	9980.	9500.	3770.	35060.	6350.	6680.
1999	11810.	10070.	9550.	3820.	35240.	6390.	6710.
2000	11820.	10160.	9590.	3860.	35440.	6420.	6740.

CONSERVATION SCENARIO

MAINE		ENERGY IN GWH				PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMFR	WINTER
1978	3014.	2014.	2460.	735.	8223.	1231.	1540.
1979	3110.	2020.	2560.	750.	8440.	1260.	1590.
1980	3190.	2030.	2660.	760.	8640.	1290.	1640.
1981	3280.	2040.	2750.	770.	8850.	1320.	1690.
1982	3240.	2000.	2850.	780.	8870.	1340.	1710.
1983	3270.	2000.	2950.	790.	9020.	1360.	1730.
1984	3260.	2000.	2890.	790.	8930.	1350.	1720.
1985	3240.	1920.	2820.	780.	8750.	1320.	1690.
1986	3220.	1850.	2750.	770.	8590.	1300.	1660.
1987	3260.	1780.	2680.	760.	8470.	1280.	1640.
1988	3290.	1710.	2600.	750.	8350.	1260.	1620.
1989	3320.	1640.	2640.	750.	8350.	1260.	1620.
1990	3350.	1660.	2670.	760.	8440.	1270.	1630.
1991	3360.	1680.	2710.	760.	8510.	1280.	1640.
1992	3380.	1690.	2740.	770.	8580.	1290.	1650.
1993	3390.	1710.	2770.	770.	8640.	1300.	1660.
1994	3410.	1730.	2790.	770.	8710.	1310.	1660.
1995	3430.	1750.	2820.	780.	8770.	1320.	1670.
1996	3440.	1770.	2840.	780.	8830.	1320.	1680.
1997	3460.	1790.	2860.	790.	8890.	1330.	1680.
1998	3470.	1800.	2880.	790.	8940.	1340.	1690.
1999	3490.	1820.	2890.	790.	9000.	1350.	1700.
2000	3510.	1840.	2900.	800.	9050.	1350.	1700.

TABLE 1.4

ESRG CONSERVATION FORECASTS OF ENERGY AND PEAK FOR NEW ENGLAND STATES

CONSERVATION SCENARIO

NH	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	2456.	1771.	1523.	625.	6376.	991.	1203.
1979	2570.	1810.	1600.	650.	6620.	1030.	1260.
1980	2680.	1840.	1670.	670.	6870.	1060.	1310.
1981	2780.	1870.	1740.	700.	7090.	1090.	1370.
1982	2760.	1860.	1810.	710.	7150.	1120.	1390.
1983	2790.	1890.	1890.	730.	7290.	1150.	1410.
1984	2780.	1900.	1870.	730.	7290.	1150.	1410.
1985	2760.	1850.	1850.	730.	7200.	1140.	1400.
1986	2750.	1810.	1850.	730.	7130.	1130.	1380.
1987	2770.	1770.	1840.	730.	7110.	1120.	1380.
1988	2790.	1730.	1820.	730.	7070.	1110.	1370.
1989	2820.	1690.	1850.	730.	7100.	1120.	1380.
1990	2840.	1730.	1890.	750.	7200.	1130.	1390.
1991	2840.	1770.	1920.	760.	7280.	1150.	1410.
1992	2850.	1800.	1950.	770.	7370.	1160.	1420.
1993	2860.	1840.	1970.	780.	7450.	1180.	1430.
1994	2870.	1880.	1990.	800.	7530.	1190.	1440.
1995	2870.	1910.	2020.	810.	7610.	1200.	1450.
1996	2880.	1950.	2040.	820.	7680.	1210.	1460.
1997	2890.	1990.	2050.	830.	7760.	1230.	1470.
1998	2890.	2020.	2070.	840.	7820.	1240.	1480.
1999	2900.	2060.	2080.	850.	7890.	1250.	1490.
2000	2910.	2100.	2090.	860.	7960.	1260.	1500.

CONSERVATION SCENARIO

RI	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	1820.	1603.	1379.	513.	5315.	972.	973.
1979	1860.	1610.	1430.	520.	5420.	990.	990.
1980	1890.	1620.	1490.	530.	5520.	1000.	1020.
1981	1920.	1620.	1540.	530.	5610.	1020.	1040.
1982	1900.	1610.	1600.	540.	5640.	1030.	1050.
1983	1910.	1610.	1650.	540.	5710.	1050.	1060.
1984	1880.	1610.	1670.	540.	5690.	1040.	1060.
1985	1840.	1550.	1680.	530.	5600.	1020.	1040.
1986	1810.	1490.	1690.	530.	5510.	1000.	1030.
1987	1810.	1430.	1700.	530.	5460.	990.	1020.
1988	1810.	1370.	1700.	520.	5410.	980.	1010.
1989	1820.	1310.	1750.	520.	5390.	970.	1010.
1990	1820.	1320.	1790.	520.	5460.	980.	1020.
1991	1810.	1340.	1830.	530.	5510.	990.	1030.
1992	1800.	1350.	1870.	530.	5560.	1000.	1030.
1993	1800.	1360.	1920.	530.	5610.	1010.	1040.
1994	1790.	1370.	1960.	540.	5660.	1020.	1050.
1995	1790.	1380.	2000.	540.	5710.	1030.	1050.
1996	1780.	1390.	2040.	540.	5760.	1030.	1060.
1997	1780.	1410.	2080.	550.	5810.	1040.	1070.
1998	1770.	1420.	2120.	550.	5860.	1050.	1070.
1999	1770.	1430.	2160.	550.	5910.	1060.	1080.
2000	1760.	1440.	2200.	560.	5960.	1070.	1090.

CONSERVATION SCENARIO

VERMONT	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1978	1597.	1002.	760.	401.	3760.	572.	765.
1979	1650.	1020.	800.	410.	3880.	590.	790.
1980	1700.	1040.	850.	420.	4000.	610.	820.
1981	1750.	1050.	890.	430.	4120.	620.	850.
1982	1730.	1040.	940.	430.	4140.	640.	870.
1983	1740.	1050.	980.	440.	4220.	650.	880.
1984	1740.	1060.	1000.	440.	4240.	650.	880.
1985	1730.	1030.	1020.	440.	4220.	650.	880.
1986	1730.	1000.	1040.	440.	4220.	650.	880.
1987	1750.	970.	1070.	450.	4230.	650.	880.
1988	1770.	930.	1090.	450.	4240.	650.	880.
1989	1790.	900.	1140.	450.	4280.	660.	890.
1990	1810.	910.	1190.	460.	4370.	670.	900.
1991	1810.	920.	1230.	460.	4440.	680.	910.
1992	1820.	930.	1280.	470.	4510.	690.	930.
1993	1830.	940.	1330.	480.	4580.	700.	940.
1994	1850.	960.	1370.	480.	4660.	710.	950.
1995	1860.	970.	1420.	490.	4730.	730.	960.
1996	1870.	980.	1470.	500.	4810.	740.	970.
1997	1880.	990.	1520.	500.	4880.	750.	980.
1998	1890.	1000.	1560.	510.	4950.	760.	990.
1999	1900.	1010.	1610.	510.	5030.	770.	1000.
2000	1910.	1020.	1660.	520.	5100.	780.	1010.

2. The Conservation Scenario

2.1 Overview of the Scenario

Scenario analysis is widely used in energy studies. In general, scenarios are quantitative projections of alternative futures. They are derived from assumptions about such physical, economic, political, or other trends as are relevant to the problem under study and are capable of being treated as interrelated variables in a mathematical model. Scenarios are analytical tools. They assist policymakers in planning for contingencies and in anticipating some of the future consequences of alternative public choices.

In most long-range electric load forecasting to date, the effort of the analysts has been to incorporate, explicitly or implicitly, a "business-as-usual" scenario, i.e., to posit a future which does not differ sharply from the present. The "Base Case" scenario referred to on page 2 is such a scenario: it attempts to incorporate the effects of trends and policies now in place. However, instead of being designed for utility planning purposes, our Base Case load forecast is designed to provide a state-specific benchmark for assessing the potential for additional conservation in New England.

The "Conservation Case" forecast, on the other hand, is based on a different scenario. It presents a possible energy conservation future for consideration. The difference between the two scenarios lies in the key conservation scenario assumption that new initiatives can result in the development and implementation of additional conservation. The criteria used to select additional measures for inclusion in the scenario were:

- The conservation measures are technically feasible.
- The measures do not increase overall social costs for energy services.
- The measures require the stimulus of additional institutional action for implementation.

Technical feasibility refers to the present or imminent availability of the hardware and know-how to effect the conservation measures, and is discussed further at the beginning of Section 3.1 below. The social cost criterion is that the benefits of implementing a measure for consumers as a group are not exceeded by the costs, and is discussed in Section 2.2

following. The institutional action criterion means that new federal, state or other initiatives appear necessary to implement the measure even though it is socially cost-effective on a life-cycle basis. Included within the scope of "state initiatives" are policies or actions deliberately undertaken to induce conservation by a regulated public utility, the utility commission, the legislature, or any other state agency. Because the purpose of this scenario analysis is to inform the assessment of the oil conservation potential developed by the Energy and Minerals Division, GAO, new policy initiatives sketched or suggested here are included only as aids in the analysis of conservation potential. While some policy discussion is interspersed throughout this report, the summary analysis of policy options is reserved for and developed by the EMD in its report.

2.2 The Direct Social Cost Criterion

The direct expenditures by New England consumers for energy conservation measures can be compared with expenditures that would be required for the additional electricity that would be used in the absence of the implementation of the given conservation measures. This is a social cost-benefit criterion, for it addresses the direct trade-offs for regional electricity customers on an aggregate rather than an individual basis.

This criterion is an ideal beginning point for an analysis of conservation potential designed to inform the regional policy-making process. But in practice, it has been necessary to construct a conservation scenario without directly applying this conceptually appropriate criterion. The reason is that a number of sophisticated financial analyses are needed to measure the trade-offs in an accurate way, the chief of which is an analysis of the long-run marginal costs of production of electricity. Development of accurate long-run marginal costs requires the application of a generation planning model. The utilities are only beginning to develop such analyses themselves, and in fact independent analyses would be a useful check on such utility analyses as emerge.

Two things are clear. First, long-run marginal or incremental costs are the appropriate yardstick for measuring the value of investments in conservation measures that will last five, ten, twenty or more years. Second, marginal costs have been and will be rising for the forseeable future. Beyond using a working estimate that the cost of production of baseload electricity from oil will be in the range of six to eight cents per kwh (1980 $) for fuel alone by 1990, we have developed no data on long-run marginal costs. (See Report IV, page 4.)

For this reason, we have developed a conservation scenario that incorporates measures of relatively low cost, so low that the precise financial treatment of the cost-benefit tradeoffs cannot significantly affect their attractiveness. The considerable potential that we have identified is certainly less than the full potential that is now cost-effective based upon the social cost criterion that is appropriate to assessing direct economic trade-offs.

Even when one develops the data required to fully apply the social cost criterion, which is discussed in more detail below, there are three relevant dimensions that require further exploration. First, regional direct cost/benefit tradeoffs may impact differentially upon consumer and investor subgroups or upon geographic locations within New England. Second, there are important indirect economic effects of pursuing one strategy -- e.g., conservation investment -- instead of another -- e.g., importing and burning oil. These dimensions are not captured in the direct cost-benefit analysis. One of them -- the employment impacts of alternative energy strategies -- is treated in Report V where, in order to determine some of the likely effects, we assess the indirect impacts of implementation of the residential portion of our conservation scenario. Last but decidedly not least, there are effects that are often regarded as non-economic because they are so hard to incorporate accurately within the framework of conventional economic analysis. Here we refer to several effects of energy strategy choices. These effects must be taken into account in policy-making whether or not they are (or even can be) accurately quantified within an economic analytical framework. They include:

- Direct and indirect health effects on workers and residents.
- Effects on the viability of natural ecosystems.
- Effects on the aesthetic environment.
- Equity considerations.
- National security considerations.

The conservation measures generally appear to have more benign "external" impacts than the energy supply alternative used in this study, so that the narrow direct social cost/benefit assessments should be seen as merely suggestive of lower bounds on conservation measure attractiveness.

In assessing the relative social costs of the two scenarios under consideration (Base and Conservation Case), the direct economic tradeoffs are conceptually straightforward. The cost associated with saving energy relative to Base Case levels is charged to the Conservation Case, while the cost of producing the equivalent amount of energy is charged to the Base Case. In the parlance of cost/benefit analysis, one evaluates the net benefits of the Conservation Case by computing the difference between the streams of costs and savings, brought back to common dollars (present value) by a social discount rate. Specifically, we have the expression:

$$\text{PVIC} = \sum_{i} \sum_{t} \frac{\left(I_t^i - C_t^i\right)}{(1 + d)^t}$$

where:

PVIC = present value of incremental benefits minus costs of achieving conservation scenario;

I_t = incremental cost of "saved" energy and capacity;

C_t = incremental costs of implementing conservation resources;

i = conservation measure;

t = year;

d = social discount rate reflecting time value of money.

This gives the relative savings of the conservation scenario over the non-conservation scenario. The word "incremental" signifies the <u>extra</u> costs and savings in making the transition to the conservation case. Costs incurred in both cases "wash," cancelling out in taking the differences in the stream of costs.

While conceptually straightforward, full and detailed computation of the stream of direct cost differences is quite complex. The costs would include the incremental capital investment to achieve the conservation measure, any conservation program administration costs, maintenance costs, possible property tax increases and income tax credits, and so on. The savings would include the energy savings in the adjustment of utility power plant dispatch to meet the reduced load, possible deferral of capacity additions and related costs, fuel saved from on-site boilers, avoided utility operation and maintenance costs, etc. These computations further depend on assumed escalation rates for fuel prices, costs, load growth, and so on.

Nevertheless, it is possible to use the benefit/cost criterion for purposes of illustration. The set of conservation measures comprising the conservation scenario are meant to represent plausible targets for a real world conservation effort. Thus, while they should be cost justified to society and technologically available, they are not selected to exhaust the cost effective potential for conservation.* Therefore, a rigorous cost analysis establishing the outer limits of cost effective conservation is not appropriate here. Rather, we wish to establish a useful "rule-of-thumb" test to measure economic acceptability.

For example, in comparing the cost of delivering an extra kilowatt-hour of electricity with the cost of saving a kilowatt-hour of electricity, let

P_t = incremental cost of producing electricity

Δkwh = kwhs saved annually by a given conservation measure.

Then, assuming an investment C_0 is made in year "0" in a conservation measure, we have

$$PVIC = \sum_{t=1}^{T_L} \frac{P_t \times \Delta kwh}{(1 - d)^t} - C_0$$

where the limits on the first sum run over the lifetime of the measure T_L. For illustration, we may simplify these relationships by assuming that escalation in the marginal electricity rate is roughly at the level of the discount rate, d.** Proceeding, we arrive at:

$$PVIC/(\Delta kwh \times T_L) = P_0 - C_0/(\Delta kwh \times T_L)$$

where it is seen that the relevant measure of the benefits of investing C_0 dollars in conservation equipment (or policy initiatives) lasting T_L years and saving Δkwh kilowatt-hours of electricity annually is the difference between the cost per kwh or adding an additional kwh, P_0, versus the costs per kwh of saving a kwh.

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* The appliance efficiency levels used here are, for example, lower than the cost-effective levels identified by the Pacific Gas and Electric Company in PG and E Assessment of Achieving Energy Conservation Potential 1980-2000, September 1980.

** Real discount and fuel escalation rates are typically assumed to be in the 3 to 4% range in current long-range planning. In addition, one would need to consider avoided capital costs for construction in accurately estimating marginal electric cost escalation.

A numerical example may be useful. Suppose we are looking at the costs and benefits of adopting appliance efficiency standards (beyond those assumed in the Base Case) for the year 1983. Typically, the incremental costs of producing a refrigerator 25 percent more efficient will be about $50. Assuming further a lifetime of 20 years and Base Case annual refrigerator consumption of electricity at 1500 kwh/unit, we have for the cost of saving electricity with the approximations above:

$$C_0/(T_L \times \Delta kwh) = 0.7¢/kwh$$

or less than a penny per kwh. On the other hand, the cost of delivering the extra energy depends on the specifics of the utility generation mix. If capacity is below reliability levels, the cost of construction of new generation and transmission facilities as well as added fuel costs must be charged to the incremental demand. If overcapacity exists in the system, the extra fuel costs of otherwise idle capacity constitute the incremental cost. Assuming the latter, a realistic assumption for the region in the year of our example, and ignoring additional customer and demand charges for the moment, the incremental cost for generating a kwh of electricity from, say, an oil-fired unit with a heat rate of 13,000/kwh and fuel costs of $6.00 per million BTU would be:

$$P_0 = 8¢/kwh$$

For this example, the cost of saving the kwh, 0.7¢, is far less than the cost of delivering it, 8¢. Extra investment in even more efficient units would be justified in this case -- and in fact are so justified for the bulk of the actual measures in the conservation scenario.

A comprehensive analysis of the comparative total social costs of the Base Case versus the Conservation Case is beyond the scope of this forecasting effort. However, it is important to emphasize that the specific measures incorporated in the conservation scenario are all cost beneficial in the above sense, often decreasing social costs dramatically. To reiterate, however, these direct economic estimates are but one dimension to consider in weighing the alternatives. In addition to reducing costs, the Conservation Case scenario tends to have other important benefits: fuel savings, pollution reduction, and employment increases. Some of the positive regional employment impacts that could be expected are modelled and reported in Technical Report 5 of this series.

2.3 Policy Framework

The measures constituting the conservation policy package will be described qualitatively in this section. Quantification of conservation measure impacts is the subject matter of Secs. 3 through 5 of this report.

The selections are not intended to exhaust the universe of technologically available and social cost reducing energy policy interventions. They are intended to represent a set of strong yet implementable measures for managing energy demand growth over the next two decades. In formulating the scenario, policy options have been discarded which involve technologies of problematic economies in the forecast timeframe (*e.g.*, industrial solar applications and photovoltaics), which are not clearly social cost beneficial (*e.g.*, various load management approaches, extreme equipment efficiency standards, and heavy investment in active solar systems), or are of minor overall importance (railroad conservation potential, street lighting improvements, etc.). Exclusion of items from the conservation policy package is not intended to imply, necessarily, a negative assessment of their potential. Rather, the policies selected for this initial investigation of conservation policy potential in the region have been limited to those which are currently most demonstrably promising.

Furthermore, it should be understood that the policy choices under consideration are modelled as changes above and beyond present state and federal policies. Existing federal and state policy initiatives are to be considered as the background for *both* the Base Case (Report I) and Conservation Case forecast scenarios.* Thus, the only difference between the two scenarios is the insertion, in the latter, of new policy measures. In other words, the question we are asking is: what would be the direct impact on electric energy requirements of development and implementation of the

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*Thus as the federal government takes new conservation policy steps, the assumptions underlying the Base Case forecast are altered. The Base Case forecast is based on federal conservation regulations actually in place at the time of forecasting (April 1980).

Conservation Case measures? Once this question is answered, the desirability of such an increase in policy efforts can be assessed in terms of its relative effects on energy demands, environmental quality, the state economy, employment, and so on.

The conservation policy actions included in this scenario are listed in Table 2.1. All listed actions go beyond Base Case conservation levels. Thus, where "building envelope standards" are listed, we refer to building shell standards more stringent than those embodied in existing state or federal laws and regulations. Existing regulations and programs are already included in the scenario definition for the Base Case. The "policy package" embodied in Table 2.1 would affect almost all uses of electricity in New England.

To model the Conservation Case, a "shadow" model was added to the end-use simulation and forecast model described in Report I. When the Conservation Case is operative, the Base Case computations are interrupted and the incremental effects of each of the conservation measures are computed. The disaggregated ESRG end-use model thus proves an ideal vehicle for assessing the effect of specific conservation policies. For each measure, the year of initiation and the quantitative impact on building characteristics, energy-use practices, and equipment characteristics must be specified. The following sections of this volume describe and quantify the effects of scenario conservation policy elements in the residential, commercial, and industrial sectors respectively.

TABLE 2.1
CONSERVATION POLICY AREAS

Sector	Measure
Residential	Appliance Efficiency Standards Lighting Efficiency Improvement Building Envelope Standards Plumbing Fixture Efficiency Standards Electric Space Heat Regulation Voltage Regulation
Commercial	Building Envelope Standards Passive Solar Energy Requirement in New Construction HVA/C System Equipment Efficiency Regulations HVA/C Operations Requirements Internal Load Requirements (lighting levels and ventilation rates) Electric Space Heat Regulation Voltage Regulation
Industrial	Cogeneration Regulation and Incentives (utility ownership option, utility surveys, back-up rate review, etc.) Industrial Conservation Program (services, audits, outreach) Building Envelope Standards

3. CONSERVATION POLICY ELEMENTS: RESIDENTIAL SECTOR

3.1 Equipment Efficiency

An important component of the residential part of the conservation scenario is a set of measures to improve the efficiency of operation of home appliances. In most cases, a set of appliance efficiency standards are specified and the savings that would result from the legislation of such standards is quantified. In other cases, specific standards are not proposed, but policy options for achieving technically feasible efficiency improvement targets are indicated and the level of energy savings computed.

For each appliance efficiency improvement incorporated, conservative criteria of technical feasibility have been used. The improvement must meet one or more of these criteria:

- The improvement is already embodied in appliances on the market.
- The improvement has been demonstrated in tests for the U.S. Department of Energy (DOE).
- The improvement is under active commercial development for near-term marketing.

Consequently, additional savings beyond those quantified in the conservation scenario may well be attainable through additional residential sector appliance efficiency improvement. Furthermore, adoption of policies to implement improvements now technically and economically feasible should encourage additional technical progress in residential appliances.

The concept of mandatory minimum efficiencies for appliances sold in a given jurisdiction has a precedent in both federal and state legislation. The first federal program was a voluntary one. This was the "energy conservation program for appliances," or "targets program," developed by the old Federal Energy Administration (FEA) pursuant to the Energy Policy and Conservation Act of 1976 (Ref. 1). The FEA analysis of "energy efficiency improvement targets" and associated energy savings is utilized in the base case residential forecast (Report I).

The FEA "targets program" demonstrated the technical and economic feasibility of improvements in appliance energy efficiency. This program is now essentially defunct, having been superceded by the National Energy Conservation Policy Act of 1978 (NECPA). Under NECPA the DOE is developing mandatory standards for a number of appliances (Ref. 2). NECPA permits states to retain appliance efficiency standards if they have them or to implement them subject to DOE approval if they do not. At this time, only California has a comprehensive state program of energy efficiency standards for appliances (Ref. 3).

The standards we propose here are technically more stringent than California's, which were developed a few years ago. However, they all satisfy the social cost-benefit criterion discussed in Sec. 2, i.e., the additional costs per kwh of electrical energy saved must be lower than the cost per kwh that would otherwise be provided by the utility. Most of the California standards are implemented in two steps, an intermediate and a final standard. We utilize this format for New England, with implementation of intermediate standards in 1983 and final standards in 1988. Policies are proposed for the following appliances:

- Refrigerators and refigerator-freezers
- Freezers
- Electric ranges
- Electric water heaters
- Room air-conditioners
- Central air-conditioners
- Heat Pumps
- Lighting
- Plumbing fixtures

This section discusses each appliance in turn. Applicable policies or policy options are discussed. The energy savings realizable through policy implementation are quantified. Technical justification is presented. The average costs per unit for adoption of technical changes to attain the indicated efficiency levels are estimated. The cost tradeoffs of "purchasing" energy savings through more efficient appliances are analyzed. All dollar figures are constant (1980) unless otherwise indicated.

Refrigerators-Freezers

We employ a minimum efficiency standard for new refrigerator-freezers of all types. The standard is designed for automatic-defrost refrigerators, but would also apply to the minority of refrigerators sold that do not fall into that category. The standard, energy savings, and costs are as follows:

TABLE 3.1
REFRIGERATOR STANDARD

	Year of Initiation	
	1983	1988
Standard (kwh/year)	400+(36×volume)*	400+(24×volume)
Energy Savings Increment (%)	12	19
Unit Cost Increment ($)	22	26

*In ft^3

For a 16 cubic foot refrigerator-freezer, the 1983 standard translates to a maximum energy consumption of 976 kwh per year or (assuming constant, 365 day operation) 2.7 kwh per day. The energy savings of 12 percent for the 1983 standards are calculated with respect to the FEA targets. The 19 percent savings is then relative to the reduced energy consumption level attained through the 1983 standards. Percentage savings is defined in the same way for the other standards discussed below. The conservation forecast computer runs use the minimum standards developed in this section as average standards. Should some new appliances exceed the minimal levels, the conservation impacts would be correspondingly more stringent. In this report, we have, in the interest of forecast caution, assumed this not to be the case.

The 1980 FEA target efficiency is already attained by specific appliances on the market, such as the Amana ESFR-16 ft^3 refrigerator-freezer which consumes 3 kwh/day (Ref. 4). DOE's Division of Buildings and Community Systems has a program to develop and commercialize new energy-saving technologies (Ref. 5). The program, in conjunction with Amana and Arthur D. Little, has developed a prototype 16 ft^3 refrigerator-freezer that consumes 1.8 kwh/day and is cost-effective (Ref. 6). The prototype thus consumes somewhat less than our 1988 standard requires (2.15 kwh/day for a 16 ft^3 model).

The costs of the energy savings that can be achieved through refrigerator improvement are relatively low. FEA's estimated unit cost in 1977 for improvements producing the change from the 1972 (FEA base year) to 1980 energy efficiency (entailing a shift in the energy factor from 3.8 to 5.28 cubic feet per kwh per day) was about \$40. In 1980 durable goods prices, this is \$50. In Table 3.1 and in the text in this section, all costs hereinafter will be given in current 1980 dollars.

Hoskins and Hirst, in developing a model for energy and cost analysis of a refrigerator (Ref. 7), had estimated about \$100 per unit to take a 16 ft^3 unit from 4.6 kwh/day (somewhat "worse" than the FEA 1972 base) to 2.2 kwh/day. Examination of Hoskins and Hirst's detailed component costing suggests taking the difference of \$44 as the cost of the FEA 1980-ESRG 1988 improvement, broken down as indicated in Table 3.1. The new Amana refrigerator is estimated to cost the consumer \$61 relative to the Amana ESFR-16 (Ref. 6, Vol. 2, p. 56). This estimate is quite consistent with our estimated incremental unit costs of meeting the 1988 standard proposed.

Refrigeration is the single most energy-consuming household electricity application (Report I). Implementation of this standard will thus be an important conservation step. For refrigerators, standards presume the retention of the popular and energy-expensive automatic defrosting feature. Energy savings from the 1980 FEA target to 1988 ESRG are 29 percent. For a 16 ft^3 unit with a lifetime of 20 years, the cost per kwh (according to the social cost-benefit estimating procedure of Sec. 2) of energy saved through the purchase of equipment embodying the 1983 standard is about eight mills, or considerably less than the 1980 residential cost of electricity. The cost per kwh of achieving the 1988 standard (relative to 1983) is about seven mills for a 16 ft^3 unit. The economic attractivesness of the improvements may vary with unit size, but their overall economic advantage is clear.

Freezers

Efficiency standards are proposed for freezers of all types. The standard is designed for chest freezers. The minority of freezers sold that do not fall into that category would in effect need to be improved more than chest freezers. The standard, energy savings, and cost are as follows:

TABLE 3.2
FREEZER STANDARD

	Year of Initiation	
	1983	1988
Standard (kwh/year)	425+(36×volume)*	425+(24×volume)
Energy Savings Increment (%)	3	19
Unit Cost Increment ($)	6	38

*In ft^3

From a technical standpoint, the FEA 1980 per-unit energy consumption implied by the 1972-1980 EEI (energy efficiency improvement) is already attained by certain models on the market. ESRG's 1988 standard is attained by certain models, such as Franklin's Signature models FFT-8948 and 8949, manually defrosted 20.8 ft^3 chest freezers (Ref. 10).

Freezers have not been studied in as much detail as refrigerator-freezers, although many of the technical and economic factors for freezers are treated in the relevant portions of refrigerator studies. FEA estimated $43 per unit for a smaller EEI than for refrigerators.

Overall energy savings from 1980 FEA to 1988 ESRG are 21 percent for freezers compared to 29 percent for refrigerators. Estimated dollar costs for further improvements are based on FEA figures and technical similarities between freezers and refrigerators. The cost per saved kwh in achieving the 1983 standards for a 15 ft^3 unit with a 24.9 year lifetime was less than nine mills, well under the present average per kwh price of electricity. The incremental unit cost of achieving the 1988 standards is also under one cent per kwh.

Electric Ranges

The FEA adopted only 40 percent of the potential per-unit energy savings found cost-effective by Science Applications, Inc. (SAI). SAI developed an analystical model and tested several units (Ref. 11). Of six feasible and cost-effective measures identified by SAI, FEA adopted two. Electric range standards are employed which would, in effect, compel incorporation of the other four measures.

The standard could be an overall performance standard, as with the previous two appliances, or it could consist of component requirements. "Range" is a mix of standard, self-cleaning oven, and microwave oven categories. Estimated energy savings from achieving some of the FEA-omitted steps by 1983 and the balance by 1988 are as follows:

TABLE 3.3
ELECTRIC RANGE STANDARD

	Year of Initiation	
	1983	1988
Energy Savings Increment (%)	2	2
Unit Cost Increment ($)	negligible	negligible

In its studies for the FEA, SAI found that feasible changes for ranges without self-cleaning ovens would result in negligible unit cost increases and that the improvements in ranges with self-cleaning ovens would reduce unit costs. Thus the overall cost is "negligible" and may even be negative. Improving the efficiency of ranges in the feasible ways produces only economic benefits.

Electric Water Heaters

The electricity consumed by electric water heaters is a function both of the efficiency of the system and of the amount of hot water it must heat. In the conservation scenario two changes influence electricity consumption:

- Increased efficiency of conventional hot water heaters
- Decreased hot water usage.

The first of these changes is described here. Mandatory standards are proposed for electric hot water heaters. Such standards could be formulated in terms of standby loss, as they are in California and New York. However, for purposes of this analysis, the standards indicate specific steps, as follows:

TABLE 3.4
ELECTRIC WATER HEATER STANDARD

	Year of Initiation	
	1983	1988
Standard	Reduce factory setting on thermostat to 130°F	Insulate jacket with 4 inches of foam and distribution pipe with 1 inch of fiberglass
Energy Savings Increment (%)	5	2
Unit Cost Increment ($)	0	37

New York and California have legislated hot water efficiency standards entailing a maximum electric heater jacket loss of 4 watt-hours per square foot of tank surface area per hour. California's staff analysis estimates an energy savings of 16 percent under the standard (Ref. 16), which is virtually the same as the FEA's 15 percent.

The FEA target for water heaters, however, does not include a reduced thermostat setting. In their energy and cost analysis of hot water heaters, Hoskins and Hirst found that a 10 degree reduction in temperature yielded a 5 percent energy savings (Ref. 12). Since the FEA test temperature for hot water heaters is 145^0 while Hoskins and Hirst's is 140^0 it is reasonable to simply apply the whole energy savings estimate here. There is no cost for this measure.

FEA did include increased insulation in its efficiency improvement target. For the 1988 level, a change in jacket insulation from 4 inches of fiberglass to 4 inches of polyurethene foam and an increase in pipe insulation to one inch of fiberglass are included. From the social cost point of view, the price of saving a kwh through these measures is about 4¢, less than the average cost of electricity and much less than the marginal cost of delivering new electrical energy.

The heat pump water heater is an example of a promising development beyond changes used in the conservation scenario. It has been developed with DOE support. Due to high first cost and the need for an interior winter heat source it has not been introduced here as part of the conservation scenario, but could be considered at some point in the future.

Room Air-Conditioners

Mandatory minimum efficiency standards are proposed for both room and central air-conditioners. The former follow:

TABLE 3.5
ROOM AIR-CONDITIONER STANDARDS

	Year of Initiation	
Southern New England:	1983	1988
Standard (E.E.R.)	9	9.2
Energy Savings Increment (%)	12	2
Unit Cost Increment ($)	36	7

The standards are expressed in terms of the overall energy efficiency ratio (E.E.R.), which is defined as the unit's cooling capacity (Btu/hour) divided by its power requirements (watts). The standards are for 115 volt room air-conditioners, the kind typical of regional residences. Units with an E.E.R. of 11.6 are on the market now (Ref. 22). The current state-of-the-art limit has been estimated at an E.E.R. of 13.5 (Ref. 23). Production-weighted FEA per-unit costs associated with target EEI were $60, or $35 per unit E.E.R. This embodied a change from the 1975 average E.E.R. of 6.2 to the 1980 FEA target E.E.R. of 7.94. Inspection of recent advertisements for units available at retail suggests as little as $20 per incremental E.E.R., with wide E.E.R. variations for units with the same cooling capacity. The use of $35 per unit E.E.R. appears to be a choice that does not understate conservation costs.

For southern New England average annual unit usage in the base year 1978 was some 400 kwh per year. The Base Case forecast (Report I) assumes that none of the FEA-targeted improvements actually occurred until after 1978. Thus, the full FEA-targeted improvement (involving an energy savings of 22 percent) must be deducted before we evaluate the attractiveness of additional conservation through appliance efficiency standards. The resulting adjusted usage is some 310-315 kwh per year. Implementation of the 1983 conservation standard for the three southern states would reduce annual unit consumption further (by about 12 percent). With a consumption reduction of about 37 kwh per unit per year and an appliance lifetime of 11 years, the social cost of the standard would be about 8.5 cents per kwh of energy saved. Implementation of the 1988 standard would further reduce consumption by 2 percent per year at a cost of 10.5 cents per kwh.

The lifetime cost of energy saved through these air conditioner standards may exceed the average cost per kwh of electricity. Remember, however, that average cost is not the criterion used in the social cost-benefit analysis in Sec. 2.2. The relevant yardstick is the cost of producing the energy that would be required in the absence of the conservation measure, a cost that diverges considerably from average cost when air-conditioning is considered. We estimate that at the present time the New England cost of production of electricity for air-conditioning is at least 10 cents per kwh. Our estimate is based on the assumption that oil cyclers and peakers are the generating plants called into play to supply this weather-sensitive end-use. It is based on fuel costs operations and maintenace costs only. If oil costs over $6/MMBTU and the heat rate of a typical cycler/peaker is 15,000 Btu/kwh, the fuel cost is 9 cents per kwh; operations and maintenance costs for such plants, in addition, are typically over one cent/kwh.

The average annual energy consumption of room air-conditioner units in Northern New England was only some 235 kwh per year. With this low usage, any increase beyond the F.E.A.-targeted E.E.R. might not be in conformity with our social cost criterion. To be cautious, therefore, we propose no standard for the northern three states. On a region-wide basis, only the 1983 standard is clearly cost-justified.

(Thermal integrity improvements in homes affect the cooling load for average single- and multifamily dwellings. In the Conservation Case forecasts, these improvements in building envelope quality are greater than in the Base Case (see Sec. 3.2 below). The improvement in the quality of the housing stock occurs gradually throughout the forecast period. At the present time, we do not take account of the resulting decreasing annual kwh use in computing the costs of air-conditioner efficiency improvements).

Central Air-Conditioners

The standards proposed are as follows:

TABLE 3.6
CENTRAL AIR-CONDITIONING STANDARDS

	Year of Initiation	
	1983	1988
Southern New England:		
Standard (E.E.R.)	9.0	-
Energy Savings (%)	11	-
Unit Cost Increment ($)	110	-
Northern New England:		
Standard (E.E.R.)	-	8.5
Energy Savings (%)	-	6
Unit Cost Increment ($)	-	55

An E.E.R. of 8.0 was targeted by the FEA for 1980 and was incorporated in the California standards effective November, 1979. Unitary air-conditioner efficiencies currently range up to an E.E.R. of 11 (Ref. 23). The FEA calculation of the production-weighted improvement cost for moving from the 1975 base E.E.R. to the 1980 target E.E.R. of 8.0 implies a cost of $58 per E.E.R. Discussions with the manufacturers suggest that the incremental cost of going from the FEA target to an E.E.R. of 9.0 is about $110 per unit E.E.R. Further increases are likely to be more costly. SAI found that "the evidence seems to indicate that it is more difficult and more expensive to increase the E.E.R. of high capacity products" (Ref. 32). Thus, increases in central air-conditioner E.E.R.s much above 9 would be increasingly costly.

Because usage levels vary considerably in New England, we have divided the southern and northern states again. Beginning from an attained FEA target unit usage of 1285 kwh per year for the southern three states, the cost of saving electricity through the 1983 standards is 7 cents per kwh. The cost per saved kwh for the 1988 standard for the northern states is 10 cents per kwh.

Heat Pumps

In the past, competitive pressures in heat pump marketing have led to decreases in initial costs, but at the expense of lower efficiencies. The current energy price-induced interest in conservation has led to a reversal of this trend with manufacturers now introducing units at significantly higher efficiencies (Ref. 24).

Over the past several years, high efficiency heat pumps with improved compressor efficiencies, larger heat exchanges, lower balance point, and new defrost control, have become available which increase coefficients of performance (COPs) by 15 to 25 percent over conventional systems (Ref. 25). Related COPs are available at over 3.0, compared to the nominal value of 2.4 used in the non-conservation case of Report I. The Conservation Case incorporates an efficiency improvement of 25 percent, while the Base Case incorporates an improvement of some 8-9 percent (Report I, page 85). The incremental Conservation Case energy savings is 13 percent per unit.

TABLE 3.7
ELECTRIC HEAT PUMP STANDARD

	Year of Initiation
	1988
Standard (C.O.P.)	3.0
Energy Savings (%)	13
Cost Increment ($)	300

The unit cost increment is the cost beyond a conventional heat pump with a COP of 2.6 to 2.7 at the standard testing conditions. The measure results in an incremental electric space heat energy savings of approximately 690 kwh per unit. Assuming a ten year lifetime, the social cost is estimated at about 4 1/2¢ per saved kwh. This adequately satisfies the criterion of being cost-competitive with the no policy alternative of producing the extra electricity where average costs are over 5¢/kwh and long-run marginal costs are higher.

Lighting

Lighting is treated somewhat differently from the other appliances in the Conservation Scenario. Due to the rapid turnover in electric lamps, especially in the incandescent market, energy efficiency improvements can rapidly begin to substantially reduce electricity demanded for lighting.

More energy-efficient lamps, especially incandescents or those intended to replace incandescents, tend to cost from three to ten times as much as conventional bulbs. They are, and/or are expected to be, cost-effective over their lifetimes with respect to replaced bulbs. Thus an efficiency standard for electric lamps -- in the form of minimum lumens per watt at different size levels -- are likely to be cost-justifiable. However, mandatory efficient bulb purchase may be burdensome on low-income groups unless connected with measures to subsidize first cost. We shall assume rather that other measures are developed to promote efficiency in lighting. A vigorous promotion of low-energy electric lamps, by state programs and/or through mandated utility information dissemination, can produce rapid penetration of new low-energy lamps.

Energy savings are targeted to be at levels consistent with the more efficient bulb being developed by the Duro-Test Corporation under contract with the Massachusetts Institute of Technology (Ref. 13). This bulb is being developed now for marketing within a year (Ref. 14). It will replace a conventional 100 watt bulb and consume approximately 50 percent of the energy (<u>i.e.</u>, it will be rated at 40 to 60 watts). The net incremental cost of the bulb (over the three shorter-lifetime conventional bulbs it would replace) is anticipated to be about $5. The cost of saving the electrical energy comes out to about 2¢ per kwh over bulb lifetime. The Conservation Scenario assumes a vigorous promotion campaign beginning in 1983 and building toward a target of a fifty percent reduction with respect to base year levels due to efficient bulb penetration. It should be stressed that the target is reasonable since a promotion policy would also tend to stimulate interest in higher-priced but longer-life energy conserving lamps, such as the General Electric "Electronic Halarc" or "Circlite" lamps (Ref. 15).

Plumbing Fixtures

Plumbing fixture standards for new fixtures are assumed implemented in the Conservation Scenario. They apply to faucets and showerheads. The standards implemented are those now in effect in California.

According to the California Energy Commission (CEC) substantial hot water demand reductions will be achieved (Ref. 16). Forty-four percent of hot water for showers will be saved and twenty-nine percent of faucet hot water. Daily use will be reduced from 26.8 to 17.1 gallons per day, or thirty-six percent overall.

Cost increments are minimal, at about $3.00 more per fixture. CEC estimated the present worth of life energy savings (in 1976 dollars with electricity costs well under current New England levels) at $120 for showerheads and $42 for faucets with electric water heaters. They were also found to be cost beneficial for gas hot water heaters. From the perspective of social cost tradeoffs, the energy is saved at under 1¢/kwh, far less than the cost of producing the equivalent amount of energy. With such an advantage in California, it is unlikely that fixture improvements could fail to be cost beneficial for New England.

The model uses resultant hot water savings to reduce electricity for heating hot water. Approximately ten percent of plumbing fixtures are replaced each year. Standards are assumed to be effective in 1981 with new fixtures phased in over the subsequent ten years toward a net energy savings of 32%.

Other Appliances

Due to insufficient analysis being available to date, implementation of mandatory minimum standards for the remaining appliances (clothes washer, clothes dryer, dishwasher, TV) is not included in this study. Socially cost-effective options may exist, but it is premature to identify them. The status of these additional appliance operational efficiency potentials should be reviewed periodically, especially as the DOE appliance efficiency program unfolds.

3.2 Building Envelope Quality

A second important component of the residential conservation scenario is improvement in the thermal integrity of dwelling units. Both the federal government and the states have already begun the process of promoting improved thermal integrity through building legislation. The effects on electricity consumption arising from such existing codes and from current and forseeable "business-as-usual" building practices are utilized in the Base Case forecast of Vol. I. Here, we explore the effects of further efforts to improve the thermal integrity of residential buildings. (However, the computations of "business-as-usual" savings are also discussed here.)

There are two principal targets for possible further efforts to improve the thermal integrity of residences: new structures, which could be subject to additional code regulation; and existing structures, which could be "retrofitted." Retrofitting can be accomplished through a variety of approaches. Regulation can be relied on, as in the case of the new municipal ordinance in Portland, Oregon, requiring upgrading of homes to minimum standards as a condition of sale (Ref. 17). Or, the state might provide encouragement, support, or regulations to ensure that utilities go beyond minimum NECPA standards in developing the Residential Conservation Service home energy audit program. Low-interest or no-interest utility loan programs can effectively reduce the "first-cost" barriers to conservation investment. Financial assistance in the form of tax credits and loan funds is another possibility.

Our conservation scenario is based on two assumptions regarding governmental action. One is that such policies as more stringent state-wide building codes can produce improved thermal integrity for all new residential units up to new, high-conservation levels. These levels are specified for four composite New England building types. Building codes in the several states are at varying stages of development, with none at all existing in Vermont. "Code" levels represent weatherization levels for new buildings as implied by the codes on the average. As the codes in general do not vary substantially from ASHRAE 90-75, the "code" level of weatherization characteristics is a reasonable representation for all the states save perhaps Vermont. The "conservation" level is assumed to apply to all states beginning in 1983. All new units are assumed to be at the new conservation code level each year of the forecast from 1984 on.

The Department of Energy is in the process of developing energy performance standards for new buildings. The "Notice of Proposed Rulemaking" was issued late in 1979 (Ref. 26). Additional supporting documents have been issued. The rule is in the process of evolution and a complete technical analysis of its energy implications was not available when this conservation strategy scenario was devised. Such limited comparisons of the impact of the proposed standards as are available suggest that, if not significantly diluted, they would be capable of producing the energy savings we have attributed to new conservation codes. (See, for example, Ref. 26, pages 3-6.)

A second assumption in the conservation scenario is that policy measures are taken to produce retrofitting of existing non-e.s.h. homes remaining in the housing stock up to conservation code levels. This entails a linear phase-in from zero to 50 percent of the remaining stock by 1998 for SF units and to 25 percent for MF units, as in Report I, Sec. 8.1.4. Table 3.8 summarizes the code level, the conservation level, and the reduction in fractional heat and cooling energy requirements resulting from the latter. Data sources are discussed in Report I, Sec. 8.1.4.

TABLE 3.8
INSULATION DIFFERENCES BETWEEN
HOUSING UNITS AT ASHRAE 90
AND NEW CONSERVATION CODE LEVELS,
AND RESULTING FRACTIONAL ENERGY
DEMAND REDUCTIONS

Housing Type	R Value of Insulation						Fractional Energy Savings	
	Current Code			Conservation Code				
	Walls	Ceilings	Floors	Walls	Ceilings	Floors	Heating	Cooling
SF F	11	20	12.5	14	38	18.5	.1	.05
SF E	11	20	12.5	14	38	20	.15	.1
MF F	5.5	14	12.5	14	38	13.5	.15	.1
MF E	5.5	14	12.5	14	38	13.5	.15	.1

SF F = Single family non electrically heated unit

SF E = Single family electrically heated unit

MF F = Multifamily non-electrically heated unit

MF E = Multifamily electrically heated unit

The fractional energy savings in Table 3.8 are rounded to the nearest .05 to avoid the implication that the data available permit precise quantification of energy savings. All the insulation improvements are cost-effective over equipment lifetimes, based on weatherization costs gathered for the NEEC/NERCOM/MAS study described in Sec. 8.1.4 of Report I. However, we do not conceptualize the fractional conservation energy savings as necessarily due only to the insulation changes summarized above. Some combination of passive solar building practices and improved insulation can be combined in new "performance" type building code, for example.

Current building codes imply virtually 100 percent double-glazing and weatherstripping, but additional cost-effective conservation is possible. Heat exchangers, high-R sheathing, and triple glazing are examples of possible measures which promise positive net benefits, especially in northern New England. Our thermal integrity improvements thus would produce substantial benefits without exhausting the potential for improvement.

3.3 Electric Space Heat Regulation

In New England, the percentage of residential units heated by electric resistance ranges from four percent (Rhode Island) to 16 percent (New Hampshire). Electric space heating (e.s.h.) is likely to represent a significant amount to growth in residential energy consumption and thus a larger fraction of residential class contribution to winter peak demand growth. This can be seen by reviewing the tables in Report 1, Appendix B, in which Base Case forecast figures show e.s.h. increasing its fractional contribution to sectoral energy use during the forecast period even with the penetrations of heat pumps and solar energy assumed in the Base Case. This implies that direct resistance heating alone will be contributing even more to demand growth unless steps are taken to limit its use. Here, we propose a ban on additional direct resistance heating.

There are two major alternatives for the customer who otherwise would have selected electric resistance heating: heat pump or conventional fossil-fuel heating systems. Indeed, the conservation model is designed to allocate the new resistance e.s.h. customers proportionately to these alternatives starting in 1983. The two-year delay serves a dual purpose: (1) it allows for completion of new housing units already structurally committed to resistance heating and (2) it allows for deliberative development of the appropriate regulatory and enforcement mechanisms.

The justification for the resistance heat ban, as with all conservation policies, rests with the likelihood of substantially decreasing state energy consumption costs. Let us consider these in turn.

The energy consumption tradeoffs in substituting a heat pump or fossil fuel system for direct electric resistance heat are quite favorable. For the case of the heat pump substitution, energy consumption is more than halved. This is traced to the "pumping" property of heat pumps in which delivered in-door heat is composed of both thermal energy transferred from outdoor air (or water) and the electricity delivered to run the pump. The ratio of heat delivered to electrical energy consumed is called the coefficient of performance (COP), a measure of the efficiency. In New England, the seasonally averaged COPs have a value ranging from 2 to 2.2 (Report I, Table 8.14) implying an electrical energy saving of over 50 percent.

The energy savings in substituting fossil fuel for resistance heating are comparable. This is illustrated schematically in Table 3.9. Primary energy requirements for delivering a unit of end-use heating energy more than double if a resistance rather than fossil fuel system is employed. This is due to the large conversion losses inherent in the thermodynamics of electricity production. The conversion losses in the table are based on a 33 percent plant efficiency (electrical energy out to primary energy in) and another 6-10 percent electric energy loss in delivering the electricity through the transmission and distribution grid.* On the other hand, for the fossil fuel system (oil or natural gas), boiler efficiencies are on the order of 60 to 70 percent (the latter is assumed in Table 3.9) and could be up to 80 percent in newer units with improved maintenance practices.

TABLE 3.9
RESISTANCE/FOSSIL FUEL PRIMARY ENERGY COMPARISON
(Arbitrary Units)

	Primary Energy	Conversion Loss	Delivered Heating Energy
Resistance Heating	3.3	2.3	1
Fossil Fuel Heating	1.5	0.5	1

In other words, compared to both the heat pump and fossil fuel alternatives, pure resistance heating represents a substantial energy penalty for the states. The decision to install a direct resistance heating system is a decision to increase necessary energy consumption for the end-use by a factor greater than two. The policy of banning resistance heating satisfies the criterion of substantial energy savings. Let us briefly look at the social cost rule-of-thumb, using the following data to estimate costs and savings in new single family homes.

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*The assumption of 33 percent efficiency (heat rate of 10,200 Btu per kwh) may substantially underestimate primary fuel consumption for resistance heating. The incremental production of electricity to supply the extra resistance heating in the region, especially near winter peak demand conditions, may involve the dispatching of plants of considerably lower efficiencies.

3. EFFECTS OF CONSERVATION AND ALTERNATIVE SUPPLY OPTIONS ON THE NEW ENGLAND GENERATING MIX

Figure 2 illustrates the current electricity generation fuel mix in New England, and the future mixes that might be expected, assuming implementation of a projected NEPOOL construction program (See Sec. 2.2 of Summary Brief for list of plants). In 1978, about 58% of the region's electrical energy was generated with oil. Under the ESRG Base Case demand forecast, this would decline to about 30% in 1990, primarily because of increased nuclear capacity and conversion of the Brayton Point plant from oil to coal. (Mt. Tom and Brayton Point are the only conversions assumed here.) This percentage would stay roughly constant between 1990 and 2000, though the absolute quantity of oil burned would increase, until by 2000 the region would be burning almost 80% as much oil for generation as it did in 1978, despite the addition of almost 7000 MW of additional non-oil capacity.

The analysis below assumes that oil is the marginal fuel for the generation system at all times. That is, all non-oil facilities are assumed to operate to the maximum of their capacity, with oil plants operated only as much as needed to meet the remaining demand. Nevertheless, some oil is burned every hour of the year. This assumption is consistent with the focus of this report -- minimizing oil consumption -- and is also consistent with the economic dispatch practices of the utilities, since the cost of oil makes oil-fired plants the most expensive to operate. There is, however, some minimum amount of oil that would be needed to operate peaking and cycling plants necessary to follow daily and seasonal load variations in the absence of storage facilities. This minimum amount could be up to about 5% of total delivered energy. Neither conservation nor alternative sources can be used to reduce oil consumption below some such minimum.

Because of the position of oil as the marginal fuel, the effect of electricity conservation is to reduce oil-based generation by the full amount of the energy saved. Each GWH of electricity saved reduces the region's oil consumption by about 1700 barrels of oil. Under the conservation strategy case, oil would be needed for only 15% of electrical generation in 1990 without any alternative supply options. This would be further reduced to about 11% in 2000, at which time the region would be burning about 25% as much oil as it did in 1978, if the "NEPOOL construction program" is carried out.

Figure 2 also illustrates the potential for reduction of oil consumption by use of alternative supply sources. As long as oil is the marginal generating fuel, alternative sources also displace oil; each GWH hour generated saves the same 1700 barrels. Under the 1990 oil-based generation to 23.7 thousand GWH, or about 24% of all generation. By the year 2000, alternative sources could reduce oil-based generation to 17.8 thousand GWH, or about 16% of all generation.

fashion. It may appear, on the other hand, that for the case of substituting fossil fuels for electricity that another energy planning goal -- minimizing scarce fuel consumption -- may be violated. There is, however, no a priori reason to believe that this would be the case. We have already shown that substantially more primary fuel must be fired at generating stations to produce electric resistance heating than would be required in directly using the fuel in conventional decentralized boilers. Given that primary energy demand would be reduced through substituting fossil fuel heating for resistance e.s.h., the remaining question is what fuel types would be saved. Though detailed generation plant dispatch simulation runs with and without additional resistance e.s.h. would be required to precisely confirm it, the probability is that the primary fuel saved would be oil. The reason is that economic dispatch of the utility generating system mandates minimizing overall operating costs. Plant-types with the lowest operating costs (nuclear, coal) are generally run to the limit consistent with planned and forced outage characteristics. Demand not met by these are then supplied by higher cost oil-generated electricity. For the forseeable future, a reduction in demand due to direct resistance heating flows through as saved oil at the point of electricity generation. In other words, substituting even oil-fired home boilers (natural gas appears to be the probable alternative to e.s.h.) for electric resistance heating in new units promises to cut oil consumption for heating by roughly one-half.

The e.s.h. regulation thus appears justified on several grounds -- energy conservation, social cost reduction, and scarce fuel management.

3.4 Voltage Regulation

Electrical utilities in the United States widely observe the national voltage standards of the American National Standard Institute (A.N.S.I.). The A.N.S.I. standards prescribe a service voltage range to be provided around a nominal voltage. For example, the minimum service voltage on a 120 volt line is 114 volts and the maximum is 126 volts for the type of service provided most residences.

Since 1974 there have been several studies and experiments designed to explore the potential for saving energy through voltage reduction. A number of these analyses are summarized in a report on voltage regulation issued by the Energy Conservation Branch of the California Public Utility Commission (Ref. 8). The energy conservation potential suggested by pertinent studies and experiments led the California P.U.C. to begin implementing voltage regulations keeping allowable service voltage on the lower half of conventional voltage ranges. Thus, on 120 volt circuits, allowable customer service voltage would be between 120 and 114 volts rather than between 126 and 114 volts. This program is referred to as the conservation voltage regulation (c.v.r.) program. We shall use the abbreviation c.v.r. here to refer to regulations keeping service voltage on the lower half of the acceptable (usually A.N.S.I.) range and the nominal voltage, as in California.

Studies carried out at the behest of that P.U.C. showed that energy would be saved and that appliance performance would be enhanced through decreased maintenance, longer lifetime, and, in the case of 1/4 to 1/2 horsepower electric motors, greater efficiency and a higher power factor (Refs. 8, 9, and 45).

The first phase of the California program is limited to distribution feeder circuits serving primarily residential and commercial customers and requiring no significant capital expenditures. The regulation is being implemented on a utility-by-utility basis. The P.U.C. staff estimated that full implementation of all regulations promulgated in 1978 would have produced over 1.7 percent electrical energy savings statewide, and extension of the regulations to all utilities would result in an energy savings of up to 3 percent. The savings are not distributed evenly along the system load curve. Off-peak, they may be 5 percent or more; at daily peak, more like 1 to 2 percent. At annual system peak, where many circuits may be loaded at or near capacity, the P.U.C. engineers expect very small savings.

Ideally, the specific responses of major commercial and residential end-uses to a voltage reduction would be separately quantified. For most appliances, including thermostatically controlled ones, energy is reduced; for some, it is not. Examples of the latter include air-conditioners operating in the hottest weather and certain small resistance loads like toasters (Ref. 45). Logically, thermostatically controlled electric water heaters and resistance space heaters would not experience energy reductions, either.

The second phase of the California program involves the implementation of the c.v.r. on circuits where significant capital expenditures may be necessary for reconductoring, installation of shunt capacitors, or installation of substations to form shorter circuits. Where it is cost-effective the regulation is to be implemented. The P.U.C. criterion of cost-effectiveness is the same as that used in this scenario generally, namely, "the value of the energy saved on a life cycle basis must equal or exceed the life cycle cost of the measures necessary to achieve the savings." (Ref. 9, p. 15). Marginal costs are the measure for the value of energy saved. The precise energy savings portion of full implementation of cost-effective voltage regulation in California will not be known until all circuits have been assessed, but P.U.C. staff anticipate possible total program additional savings of two percent or more.

In neither Phase I nor Phase II does the California CVR program presently contemplate significant voltage changes on distribution feeder circuits serving primarily agricultural or industrial loads. Industrial reduction potential exists, but some customers require no change in voltages, others regulate their high voltages internally, and in any case, more testing of the effects of industrial voltage reduction need to be undertaken.

Among the New England states, only Connecticut has adopted a new voltage regulation in order to conserve energy (Ref. 49). The state's utilities had operated with a voltage range of +5 to -3 percent of nominal voltage; the regulation changed this to +3 to -5 percent of service voltage. Thus, for a 120 volt circuit, the range is being changed from 126 to 116.4 volts to one of 123.6 to 114 volts. This two percent voltage reduction regulation, while it will not realize quite as great an ultimate savings as will the c.v.r. in California, was directly influenced by the California P.U.C.'s data and regulations (Ref. 50). By April of 1980, virtually all of the circuits of Connecticut's largest utility had been converted, as had most of those of the other major utility. Thus the bulk of the conversions have been effected. No definitive report of energy savings from this new program is available but the experience of the California tests and c.v.r. suggest that the energy savings will be at least as great as the two percent voltage reduction being implemented in Connecticut. The Connecticut order permits temporary waivers from conversion of circuits based on technical need (e.g., a very specific voltage need) or economic hardship. At this writing, some technical waivers had been granted, but no economic ones had been requested. Apparently, the voltage regulation in Connecticut is not requiring major utility expenditures.

If a true conservation voltage regulation is implemented for all residential and commercial distribution feeder circuits in New England, energy savings will result in each state. Additional savings would be realized in Connecticut, for c.v.r. is defined here as limiting service voltage to the lower portion of the normal range, from the minimum to the nominal voltages. In Connecticut this would change the acceptable range on a nominal 120 volt circuit from the recently developed 114-123.6

range to one of 114-120 volts. While energy savings are well documented, the reduction at the time of annual system peak is much more problematic. Consequently, our conservation scenario model only estimates a nominal peak shaving of one tenth of one percent due to residential and commercial sectoral c.v.r. energy savings.

C.v.r. savings vary by state as a function of voltage range at present. The Massachusetts, Maine, and Vermont ranges are the same as California's pre-c.v.r. range. The Connecticut, New Hampshire, and Rhode Island ranges are lower.* The state specific energy savings, annual and for system peak, are listed in Table 3.11. Table 3.11 is based on the assumption that the reduction in energy savings will be the same as the reduction in the mid-point of the acceptable range, even though the California P.U.C. estimates greater savings in that state. This margin of caution thus allows for some erosion in energy savings due to appliance mix changes during the forecast time period. The forecasting model of course projects end-use saturations, but appliance test data do not yet permit incorporating voltage reduction effects in end-use detail. Our scenario assumes that conservation voltage regulations are promulgated in 1981 and their energy savings are realized in 1982 and each successive year of the forecast. The model reduces sectoral consumption accordingly.

Unlike most measures discussed in Sec. 3, the c.v.r. does not simply direct increases in consumer expenditures for appliances or housing.

3.5 Solar Energy

Residential solar applications may be subdivided into two categories -- passive and active. Passive solar strategies are based on architectural techniques for advantageously coupling building interfaces and insolation environment. These considerations include building orientation, materials choices, fenestration, and shading design. Active solar, on the other hand, generally includes the solar collector, working fluid for heat transport, heat storage device, and supporting pumps and fans. By incorporating passive solar measures in new building design, significant fractions of heating and cooling loads may be saved. See, for example, Ref. 18. Some passive solar measures are assumed incorporable in a conservation residential building code like that proposed in Sec. 3.2, resulting in energy conservation. In not explicitly quantifying further energy reductions due to passive solar design features in the residential and commercial sectors, our conservation scenario may be too cautious.

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*For A.N.S.I. 120 volt service (of class A, the most common type), for example, the N.H. range is 110-125 volts and the R.I. range is 113-123 volts.

TABLE 3.11
FRACTIONAL REDUCTION IN COMMERCIAL AND RESIDENTIAL ENERGY CONSUMPTION FROM CONSERVATION VOLTAGE REGULATION

State	Annual Energy	Energy for Peak
Connecticut	.015	.001
Maine	.025	.001
Massachusetts	.025	.001
New Hampshire	.021	.001
Rhode Island	.013	.001
Vermont	.025	.001

The role for policy in increasing the market penetration of active solar systems is unclear. There are a number of areas for initiatives: tax inducements, encouragement of solar-related business, low-cost financing schemes, development of marginally costed rates for back-up electricity (see Ref. 19), etc. At current costs for solar systems the capital investment does not lead to compelling social benefits. Assuming that 30 to 50 percent of annual hot water and/or heating loads would be met by a typical system with costs in the neighborhood of $2000 and $7000, respectively, the solar investment costs from 8¢-12¢ per saved kwh. These borderline economies imply that policy priority must be given to developing a market demand sufficient to lower real first costs. At this point no new policy initiatives to increase the penetration of active solar energy systems in New England are assumed in the Conservation Strategy Scenario.

3.6 Load Management.

The economics of load management options -- either through time differentiated rate design or direct load control -- depends on the trade-offs between the costs of implementation (either special meters or direct control hardware) and the savings to the electric system. These latter include possible avoided costs for new construction and increased economic dispatch flexibility (e.g., using plants at higher capacity factors with lower operating costs). Where there is a very large reserve of capacity, potential reductions in capital investment are problematic.

Load management is not primarily aimed at conserving energy. It is aimed at improving load factors by shaving peaks and filling valleys in a utility system load duration curve. Some forms of load management may decrease energy consumption (e.g., interlocks which prevent the functioning of major appliances simultaneously). Others may increase it (e.g., storage heating, which stores energy drawn off-peak for on-peak use). The non-inclusion of load management reflects the fact that the primary focus of the conservation scenario is on energy and oil savings. In a more comprehensive analysis, including supply-side generation planning modelling, load management measures might well be found to be attractive options.

3.7 Wood Stoves.

Wood stove usage has increased rapidly over the past several years and has significantly affected fossil fuel and electric space heating requirements, reducing overall heating requirements (Ref. 51). There are two major uncertainties concerning additional growth of this fuel source: resource availability and environmental impacts. Insufficient information currently exists to adequately assess either the likely costs as easily available woodlots are exhausted or the air quality deterioration due to increased uncontrolled usage. At any rate, there seems to be very little policy leverage available to encourage wood heating beyong that triggered by the market itself.

4. CONSERVATION POLICY ELEMENTS: COMMERCIAL SECTOR

Three areas of policy action are included in the conservation strategy scenario: equipment efficiency and operational improvements, building property standards, and electric space heat regulation. As with the residential sector, additional policies to induce the purchase of solar equipment are not included at this point.

The commercial sector consists of a considerably more heterogeneous set of consumers than does the residential sector. It is thus necessary to treat the commercial sector on a more aggregated basis. We shall follow the procedures of the Base Case forecasting model, where the analysis focuses on five building types (office, retail, school, hospital and miscellaneous) and two vintages (1975 stock and new construction).

For each of the building types, we wish to identify a package of cost-effective, technologically available conservation measures to indicate the possible impacts of commercial sector conservation policies. These may affect the physical properties of buildings, internal loads/comfort conditions, and heating, ventilating, and air-conditioning (HVAC) components and operations. Three levels of conservation have been identified in Report I, Sec. 4.3 (see especially Table 4.5) based on the work in Refs. 27 and 28. The first level is based on readily available "quick fix" items. The second level adds a set of established, basic techniques. The third level includes some capital-intensive modifications requiring considerable engineering support. The measures affect the physical building properties (e.g., sealing, caulking, insulation), HVAC systems and controls (forty separate items), internal loads/comfort conditions (lighting intensity levels, ventilation characteristics), and operation and maintenance practices.

Commercial sector modelling approach and data assumptions are discussed in Secs. 4 and 8 of Report I. In the Conservation Case, it is assumed that mandated commercial building standards will be designed at the equivalent of Level 3 discussed in Report I. The percent reductions in electricity requirements and associated costs are presented in Table 4.1. These energy savings and initial costs estimates are with respect to 1975 consumption levels (see Report I, Sec. 8.2.4). New building is designed to be above and beyond current energy conservation standards such as ASHRAE Standard 90-75.

The nonconservation scenario (the Base Case) already includes considerable post-1975 conservation in the commercial sector with the penetration levels varying with building-type and end-use. This is related to market responsiveness to price-induced quick payback conservation practices already at play under business-as-usual assumptions. Again, the Conservation Case savings and costs are relative to Base Case assumptions which already include some post-1975 conservation penetration.

The improvement levels summarized in Table 4.1 appear to be reasonable targets for policy analysts. Other investigations of conservation potential, based on conventional technologies, give analogous results. For example, using an analogous end-use/engineering approach, recent studies suggest achievable conservation levels of over 40 percent relative to 1975 usage (Refs. 29, 30).

Based on the cost data in Table 4.1 and a nominal equipment lifetime of 10 years, the cost of achieving conservation technology level appears quite acceptable, often less than 1¢ per saved kwh. However, it should be emphasized that data limitations require that the commercial sector analysis be dealt with on a generic basis of the present time. The quantification of savings and costs are meant to be suggestive of the cost-effective potential for policy intervention.

Recent work dwelling on the engineering details of the transition to more efficiency in commercial consumption should contribute to a more precise specification of the possibilities. The potential for feasible conservation in appliances, for example, is detailed in a recent Thermo-Electron report (Ref. 31). The potential for conservation through building design is a major analytical thrust of the work being performed in conjunction with the Department of Energy's proposed energy performance standards for new buildings (Ref. 26). When the DOE's work has progressed further it should be possible to use its technical analysis to quantify feasible energy savings through the upgrading of commercial structures. Such information as is available on the new standards suggests that they may save as much energy as is summarized in Table 4.1. At this point, however, the analytical basis for the conservation strategy scenario's fractional electrical energy reduction is the work described in Report I, Sec. 8.2.4.

In the Conservation Case forecasts, it is assumed that new commercial sector standards do not begin impacting until 1985. In the retrofit market, the conservation policy level is phased in over a five year period from 1985. States or their regulated utilities can develop building envelope and equipment efficiency regulations. State energy agencies could also play a useful role in the dissemination of design and technical information to the professionals in the building industry. The long lead time to standard initiation could be used to generate sufficient institutional readiness for their implementation.

Electric space heat regulation. A commercial sector space heat regulation identical to that proposed for the residential sector in Sec. 3 is incorporated in the conservation strategy scenario. The basis for the banning of additional direct electric resistance heating is the positive comparative social costs of the energy conservation the regulation will produce. The regulation is assumed to be legislated in 1981 and affects the Conservation Case forecast from 1982 on.

There is precedent for a ban on electric heating in the case of California. For both residential and commercial buildings, California prohibits the use of direct resistance heating for more than 10 percent of total requirements unless such resistance heating can be shown to be cost-effective on a life-cycle cost basis in comparison with specified alternatives (Ref. 21). Since the number of cost-effective applications for unassisted resistance e.s.h. is likely to be very small, the inclusion of the California criteria in a space heating regulation is not likely to materially reduce the energy conservation resulting from the straight ban that is programmed into the conservation strategy scenario here in both residential and commercial sectors.

Another measure that is included in the commercial sector conservation scenario is the heat pump efficiency standard described in Sec. 3. It involves the same incremental energy savings and is effective from 1988 on.

in overall industrial electric energy intensity* relative to that in the Base Case. Like other economic variables, industrial output is the same in both scenarios.

The ten percent statewide industrial electrical energy efficiency improvement appears to be a comfortably realistic target for the substantially increased governmental effort characterizing the conservation scenario. First of all, the effects of more stringent standards on the building consumption component, using the office category of the commercial sector as a guide, will yield this level. Second, investigation elsewhere has found electricity conservation potential applicable to industry of up to 20 percent (Refs. 34, 35).

The Low Case in Report I incorporates the progress made by major industries toward meeting energy conservation goals and established under the DOE's voluntary industrial energy efficiency program. Conceptually these ten percent savings are additional conservation produced due to state efforts, especially efforts to reach out to small businesses that might not otherwise have the awareness or expertise to undertake cost-effective conservation measures. Such programs could be conducted by full-fledged energy extension services. These would build on the concept of the state energy extension service (E.E.S.) as currently being promoted by the federal DOE. The only New England jurisdiction in the pilot E.E.S. program was Connecticut which aided a very small number of small businesses during the initial phase of the program (Ref. 33).

DOE's evaluation of the pilot 10-state E.E.S. program surveyed 2,375 clients (and 2,500 non-clients in a "comparison survey"), who were interviewed during the year in which they received assistance. It was found that the average cost for the small business client served was $158 per contact in current (largely 1978) dollars (Ref. 33).

Assume a doubling of the contact cost to (in 1980 dollars) $365 per client contact. A five-year program reaching 4,000 establishments per year would then cost some 7.3 million dollars, reaching over four-fifths of regional manufacturing firms in the process. Obviously if real energy savings result from client contacts a much more expensive program can be mounted. To attain an energy savings measured, for electricity, in thousands of gwh, a state cost investment at the multi-million dollar level combined with an equivalent or even greater private investment resulting from the state programs would be consistent with the conservation strategy scenario cost criterion.

Unlike the buildings and appliance savings forecasted for the residential and commercial sectors, E.E.S.-induced conservation practices and investments would result from voluntary action,

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*Intensity is electricity consumed per unit of output. See Report I, Sec. 5.4.

based on their being cost-effective from the industry point of view. The DOE's E.E.S. evaluation suggests that an E.E.S. would produce significant additional conservation investment. The E.E.S. client group in the survey invested 55 percent more in conservation efforts than did the comparison sample. (While this was not broken down by client type, the small business clientele had the highest "take action" differential, with 18 percent more clients taking action than non-clients.) The scope and variety of attractive potential conservation in industry are great. Industries have cut electricity use 10, 20, and 30 percent and major conservation technologies -- more efficient electric motors, to name one -- are actively being developed and marketed.

The assumed ten percent potential electric energy savings appears at this time a reasonable goal around which to develop an industrial conservation program as described above. Basic policy criteria -- social cost and benefits, energy conservation, and so on -- seem adequately satisfied. The currently missing ingredient -- sufficient resources and institutional commitment to mount such a campaign -- is precisely the premise of the Conservation Strategy Case.

5.2 Cogeneration Policy

Industrial cogeneration, defined here as the simultaneous in-plant production of electricity and process thermal energy, is widely recognized as a promising energy conservation technique (Refs. 36-41). The essence of the cogeneration concept is the integration of two otherwise separate steam systems: utility produced high temperature steam to drive electric generating equipment, and industrial lower temperature steam for manufacturing process. In the absence of cogeneration, the utility's unutilized "waste" steam (amounting to roughly two-thirds of the primary energy input) is discharged to the environment, while additional fuel is consumed separately in industrial steam producing boilers (or for direct-heat).

Cogeneration systems combine these complementary systems. In an industrial setting, electricity is generated on-site with the resulting low temperature steam captured for process requirements. Energy conservation results from the efficiency of utilizing the steam output of the electric production system as an input to manufacturing process. Illustrative comparative energetics are shown below in Table 5.1 for a generic case (Ref. 41, p. 3).

TABLE 5.1

Cogeneration Versus Separate Generation Of Electricity and Steam For A Large Industrial Plant

Separate Generation Mode

	Energy Resources			Useful Energy	Energy Efficiency (%)
	50 Btu	Central Station	electricity	19 Btu	37
	100 Btu	Plant Boilers	steam	84 Btu	84
Total	150 Btu			103 Btu	69

Cogeneration Mode

	Energy Resources			Useful Energy	Energy Efficiency (%)
	125 Btu	Cogenerating Industrial Power Plant	electricity	19 Btu	82
			steam	84 Btu	
Total	125 Btu			103 Btu	82

In America, industry currently generates some 10 percent of its own electricity requirements. By comparison, West Germany currently produces 13 percent of its total electrical energy requirements through cogeneration, and more through direct generation (Ref. 48). The potential for cost-effective cogeneration appears to be very great. One recent study (limited to only very large industrial steam users) found the national potential at two to six times current levels depending on whether or not electricity not consumed at the plant was exported to the utility distribution grid (Ref. 36). Another study, which considered greater size variation but only three industrial sectors (chemicals, petroleum refining, and paper and pulp), found even greater economic potential: up to 68 percent of 1974 total electricity consumption depending on the technology used (Ref. 37). Potential in New Jersey has been estimated at comparable levels (Ref. 39).

The technical potential is vast; these studies suggest the economic potential is also great.* The central issue for conservation policy is the state government's role in overcoming the barriers to the social cost-effective development of this major indigenous energy resource.

The institutional impediments to the full take-off of cogeneration in the state are multiple. ESRG, in a report to the State Energy Office of New York State (Ref. 41), set out to identify the institutional and regulatory barriers to cogeneration investment by state industry. A number of large manufacturers were interviewed on their perceptions and intentions with regard to cogeneration as were all relevant state agencies. It was found that while some firms are actively reviewing their positions on cogeneration in the light of increasing electricity costs, there remain substantial barriers. The main institutional barriers include:

- Requirements for much higher return on cogeneration than other investments.
- Fear of regulatory scrutiny.
- Unfavorable rate structures for backup electricity (which discourage sporadic use of electricity).
- Concern about environmental regulation.

A state's role, should it adopt conservation policy orientation, lies in the development of an integrated framework for removing regulatory confusion, reviewing and establishing adequate

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*A sample economic estimate may be instructive. The incremental costs above steam equipment alone of installing a coal-fired boiler/cogeneration system to produce, say, 200,000 lbs/hr of steam is about $600 kw (Ref. 37). Assuming operation and maintenance at 3 mills/kwh, an 80 percent capacity factor (fraction of time on-line) and a 20 percent annual fixed charge rate, the non-fuel costs are about 1.5¢/kwh. Only the incremental fuel (above the fuel that would have been consumed to produce the process steam alone) is properly charged to the electricity production. The incremental heat rate is about 5000 Btu/kwh, so that the fuel charges at $\$2.00/10^6$ Btu are approximately 1¢/kwh. The total production costs, 2.5¢/kwh, could be quite competitive for many N.E. area firms.

utility/industry interface policy (particularly concerning backup charges), and creating adequate institutional mechanisms for initiating projects, raising capital, and implementing projects.

State government has a great deal of leverage here. It can aggressively work to develop a coherent regulatory framework for cogeneration addressing electric rates, fuels policy, and the application of environmental standards. It can develop a technical services capability to promote cogeneration by providing information and advice to would-be cogenerators.

Yet a more direct initiative could come from using the state regulated public utility system to own, construct, and maintain in-plant cogeneration systems. This approach has been discussed widely in the literature and is universally felt to dramatically increase the likely level of cogeneration potential in the future (Refs. 18, 37-39, 43). Private utility ownership is currently prohibited under the terms of the Public Utility Regulatory Policies Act of 1978. However, many investor-owned utilities are ambivalent at best on cogeneration development, apparently fearing an erosion of their economic base. Thus, a utility ownership program addresses many of the current obstacles to cogeneration. Specifically:

- The required rate of return is lowered (perhaps 12 percent vs. 20 to 40 percent for industrial ownership).
- Utility expertise and skills are already in-house.
- Regulation is already part of the utility business.
- Optimal plant sizes could be built because industrial electric supply and demand balancing would be less important.

Appropriate regulatory mechanisms for assuring that utilities exhaust cogeneration potential in their service area should be the subject of careful deliberation by state agencies. In a report on cogeneration in New England, for example, it has been suggested that utility rate increase requests be coupled to a review of utility performance in exploring the development of cogeneration (Ref. 40).

There are thus major areas for state policy action in removing impediments to optimal levels of cogeneration development in the region. The Conservation Case levels for increased cogeneration have been targeted at a doubling of cogenerated electricity from Base Case levels. Much of this could be satisfied through the use of the utilities to develop this resource. The economic potential for inplant generation increases substantially in the utility ownership mode. This increase has been estimated, for 1985, as 75 percent in Ref. 37 (p. I-9) and over 100 percent in Ref. 38 (p. 3.1 ff). Furthermore, if policy-makers address such issues as reasonable stand-by rates, environmental regulation impacts, and utility/industry interface problems while at the same time promoting cogeneration through technical services, a larger fraction of the economic potential will be realized. The precise quantitative potential depends on more detailed analysis of the specific industry characteristics in New England and on the degree of institutional commitment to enhancing the cogeneration resource. The Conservation Case begins to implement incremental self-generation over Base Case levels attributable to state policy initiatives in 1983 and gradually increases incremental cogeneration until, in 2000, it is double the Base Case level.* All indications are that such a target is attainable.

Additional cogeneration may, in certain instances, entail increased oil use. This is a function of the fuel used in the boilers of the particular industry. It may be coal, gas, oil, or industrial byproducts. The assessment of particular cogeneration projects will need to take anticipated tradeoffs into account.

In Report III we incorporate the utility oil savings from reduced demand from industrial cogeneration (as well as other conservation). In practice there may be some partially offsetting increase in oil use by industry (though it is likely to be but a fraction of the savings) depending upon how encouraging of cogeneration public policy is. The Federal Energy Regulatory Commission's regulations pursuant to the Public Utility Regulatory Policies Act (PURPA) will, in the short term at least, constitute the major framework for such evaluations. PURPA's intention "to encourage cogeneration" is predicated upon total benefits, not just deferred fuel.

Report III does not attempt to quantify changes in oil use by industry, so neither the oil savings that can be expected from promotion of conservation nor the possible incremental increases in oil use from more cogeneration are considered in our summary of findings.

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*In Maine, it is increased to 135 percent of Base Case levels rather than 200 percent thereof. In this state the paper industry, the dominant industry and the dominant industrial electricity producer, already provided about 63 percent of its total electricity requirements in the base year. The urgency of new institutional initiatives to promote increased self-generation in that particular industry is thus less likely to be felt as greatly as in other industries and states.

REFERENCES

1. Federal Energy Administration, "Energy Conservation Program for Appliances."
   The program is described in a series of Federal Register notices, including:
   FR 42 (155), August 11, 19-7, pp. 40701 ff.
   FR 42 (178), September 14, 1977, pp. 46141 ff.
   FR 42 (227), November 25, 1977, pp. 60150 ff.
   FR 43 (70), April 11, 1978, pp. 15138 ff.
   FR 43 (198), October 12, 1978, pp. 47118 ff.

2. National Energy Conservation Policy Act, Public Law 95-619.

3. California Energy Commission, Conservation Division Regulations for Appliance Efficiency Programs. Sacramento, California. July 19, 1978.

4. Communication from George E. Courville, Division of Buildings and Community Systems, Department of Energy, Washington. May, 1979.

5. Technology and Consumer Products Branch, Division of Buildings and Community Systems, Program Plan: September 1978. Washington: Department of Energy, Report DOE/CS-0047.

6. Arthur D. Little, Inc., Development of a High Efficiency, Automatic Defrosting Refrigerator/Freezer: Phase I, Design and Development, prepared by W. David Lee. Oak Ridge, Tennessee: Oak Ridge National Laboratory, Report ORNL/Sub-7255/1 and 7522/2, February 1980.

7. Robert A. Hoskins and Eric Hirst, Energy and Cost Analysis of Residential Refrigerators. Oak Ridge, Tennessee: Oak Ridge National Laboratory, Report ORNL/CON-6, January 1977.

8. George A. Amorali, et.al., Conservation Voltage Regulation Calendar Year 1978 Progress Report. San Francisco, California: Energy Conservation Branch, California Public Utilities Commission, April 20, 1979.

9. Robert F. Wolff, "Voltage Reduction Really Does Save Energy" Electrical World, January 15, 1980.

10. California Energy Commission, Directory of Refrigerator Freezers Sorted by Type and Volume. Sacramento, December 1977.

11. *Summary of Appliance Efficiency Programs Performed for the Federal Energy Administration*. La Jolla, California: Science Applications, Inc., Report SAI-77-894-LJ, October 1977.

12. Robert A. Hoskins and Eric Hirst, *Energy and Cost Analysis of Residential Water Heaters*. Oak Ridge, Tennessee: Oak Ridge National Laboratory, Report ORNL/CON-10, June 1977.

13. "Light Dawns--And A Better Bulb Emerges," *Science Digest*, March 1978.

14. Communication from Paul Wasdyke, Sales Engineering Manager, Duro-Test Corporation, North Bergen, N.J., July 5, 1979.

15. General Electric Co., promotional material on "Halarc" and "Circlite," 1979.

16. California Appliance Efficiency Program, *Revised Staff Report Relating to Space Heaters, Storage Type Water Heaters, and Plumbing Fixtures*. Sacramento: California Energy Commission, Report 100-6, November 1977.

17. City of Portland, Ordinance No. 148251 (Passed in Council August 15, 1979.)

18. Report to the Congress by the Comptroller General of the United States, *Electric Energy Options Hold Great Promise for the TVA*, General Accounting Office, November 1978.

19. R. Bright and H. Davitian, *The Marginal Cost of Electricity Used as Backup for Solar Hot Water Systems: A Case Study*, Brookhaven National Laboratory, Upton, New York, 1973.

20. P. Craig *et.al.*, *Energy Extension Impact for California: Context and Potential Impact*. Berkeley: Lawrence Berkeley Laboratory, Report UCID-3911, April 1977.

21. *Regulations Establishing Energy Conservation Standards for New Residential Buildings and New Nonresidential Buildings*, Sacramento, California: California Energy Commission, Report CON-45A:01, March 8, 1978.

22. *Directory of Room Air Conditioners*, Association of Home Appliance Manufacturers, April 1976.

23. J.E. Christian, *Unitary and Room Air Conditioners*, ANL/CES/TE 77-5, Argonne National Laboratory, September 1977.

24. J.E. Christian, *Unitary Air-to-Air Heat Pumps*, ANL/CES/TE 77-10, Argonne National Laboratory, July 1977.

25. Heat Pump Technology, Gordian Associates, Inc. (for the DOE), National Technical Information Service #HCP/M2121-01, June 1978.

26. California Energy Resources Conservation and Development Commission, Conservation Division, Regulations Establishing Energy Conservation Standards for New Residential Buildings and New Nonresidential Buildings, CON-45A:01, Sacramento, California, March 8, 1980.

27. Material prepared for Market Oriented Program Planning Study of DOE, Arthur D. Little, 1977.

28. S. Carhart, et.al, The Brookhaven Building Energy Conservation Optimization Model, Brookhaven National Laboratory, Formal Report, January, 1978.

29. A Study of Existing Energy Usage on Long Island and the Impact on Energy Conservation, Solar Energy, Total Energy, and Wind Systems on Future Requirements, Dubin-Mindell-Bloome Associates (for Suffolk County Dept. of Environmental Control), October 1975.

30. Choosing an Electrical Energy Future for the Pacific Northwest, Natural Resources Defense Council, Inc. (for U.S. ERDA), January 1977.

31. Energy Conservation Opportunities in Commercial Appliances, Thermo-Electron Corporation (for US/DOE), December 1978.

32. Energy Efficiency Program for Room Air Conditioners, Central Air Conditioners, Dehumidifiers, and Heat Pumps. La Jolla, California: Science Applications, Inc., Report SAI-77-858-LJ, March 1978.

33. Evaluation of the Energy Extension Service Pilot Program, Report to Congress, DOE CS-4074. Washington, D.C.: U.S. Department of Energy, March 1979.

34. David Nichols et.al., Profile of Targets for the Energy Advisory Service to Industry, Report to the State Energy Office. Albany, N.Y., Energy Systems Research Group, November 1977.

35. B. Minkin et.al, Market Analysis Major Industrial and Commercial Customers, Stanford Research Institute (for Consumer Power Company), December 1977.

36. Dow Chemical Company, Energy Industrial Center Study, prepared for Office of Energy Research and Development Policy, National Science Foundation. Washington, D.C.: June 1975.

37. Thermo-Electron Corporation, A Study of Inplant Electric Power Generation in the Chemical, Petroleum Refining, and Pulp and Paper Industries, Final Report. Prepared for Federal Energy Administration. Washington, D.C.: 1977.

38. Resource Planning Associates, The Potential for Cogeneration in Six Major Industries by 1985, Draft Final Report. Prepared for Federal Energy Administration. Washington, D.C.: 1977.

39. R. H. Williams, The Potential for Electricity Generation as a Byproduct of Industrial Steam Production in New Jersey. Princeton: Center of Massachusetts, October, 1978.

40. Cogeneration: Its Benefits to New England, Final Report of the Governor's Commission on Cogeneration, The Commonwealth of Massachusetts, October, 1978.

41. Industrial Cogeneration in New York State, Identifying and Overcoming Barriers, Energy Systems Research Group, Inc. (for the NYS Energy Office), August 1978.

42. Stanford Research Institute, "Comparison of Energy Consumption Between West Germany and the United States," Conservation Paper 33A (for the US FEA), June, 1976.

43. Final Report of the New England Energy Congress, New England Congressional Caucus, Somerville, Mass., May 1979.

44. Residential Energy Conservation. Washington, D.C.: Office of Technology Assessment, U.S. Congress, March, 1979.

45. Eugene G. Gorzelnik, "Voltage Reduction Cuts Appliance Loads," Electrical World, January 15, 1980.

46. Steven Buchsbaum and James W. Benson, Jobs and Energy: The Employment and Economic Impacts of Nuclear Power, Conservation, and Other Energy Options. New York: Council on Economic Priorities, 1979.

47. Electricity Requirements in New York State, Volume II. Boston, Massachusetts: Energy Systems Research Group, Inc., Study No. 79-12/2, July 1979.

48. Robert Stobaugh and Daniel Yergin, editors, Energy Future: Report of the Energy Project at the Harvard Business School. New York: Random House, 1979.

49. Division of Public Utility Control "Amendment of Regulations Concerning Allowable Limits for Voltage Variations," Docket No. 780721. Hartford, Conn.: State of Connecticut, issued April 6, 1979.

50. Communication with John Cox, Staff Engineer, Connecticut Division of Public Utility Control, April 1980.

51. New England Regional Commission The New England Fuelwood Survey. Boston, Massachusetts, March, 1980.

APPENDIX A

ESRG
CONSERVATION
CASE - NEW ENGLAND
DISAGGREGATED
FORECASTS

CONSERVATION SCENARIO
CONN

	1978	1983	1988	1993	1998
1: REFRIGERATORS	1840.	1919.	1848.	1680.	1456.
2: FREEZERS	443.	489.	509.	503.	483.
3: RANGES	502.	554.	603.	634.	650.
4: LIGHTING	748.	805.	438.	460.	472.
5: TELEVISIONS	202.	203.	211.	225.	244.
6: CLOTHES DRYERS	583.	713.	832.	914.	966.
7: CLOTHES WASHERS	87.	94.	103.	109.	112.
8: DISH WASHERS	128.	152.	175.	198.	219.
9: WATER HEATERS	1074.	1050.	941.	891.	836.
10: ROOM A/C	343.	363.	339.	317.	299.
11: CENTRAL A/C	128.	186.	250.	300.	324.
12: SPACE HEATERS	1113.	1268.	1291.	1309.	1320.
13: HEATINGAUXILIARY	389.	387.	369.	347.	322.
14: MISCELLANEOUS	573.	661.	763.	851.	926.

CONSERVATION SCENARIO
CONN

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	26.	35.	33.	32.	33.
2: COOLING	107.	118.	102.	102.	107.
3: LT & POWER	253.	267.	214.	214.	231.
4: AUXILIARIES	191.	201.	170.	171.	181.
2: RETAIL					
1: HEATING	35.	49.	44.	43.	44.
2: COOLING	326.	358.	347.	354.	367.
3: LT & POWER	1806.	1946.	1868.	1903.	1979.
4: AUXILIARIES	620.	647.	554.	555.	588.
3: HOSPITALS					
1: HEATING	15.	19.	17.	17.	17.
2: COOLING	79.	83.	67.	65.	66.
3: LT & POWER	387.	401.	362.	358.	366.
4: AUXILIARIES	206.	212.	172.	165.	170.
4: SCHOOLS					
1: HEATING	34.	36.	27.	26.	26.
2: COOLING	84.	73.	42.	38.	42.
3: LT & POWER	523.	447.	305.	299.	324.
4: AUXILIARIES	296.	243.	148.	137.	146.
5: OTHER					
1: HEATING	28.	40.	36.	35.	35.
2: COOLING	247.	281.	254.	255.	266.
3: LT & POWER	753.	845.	771.	779.	817.
4: AUXILIARIES	478.	532.	455.	451.	474.

CONSERVATION SCENARIO
CONN

	1978	1983	1988	1993	1998
20: FOOD	155.	176.	179.	200.	222.
22: TEXTILES	161.	154.	130.	123.	115.
23: APPAREL	42.	46.	46.	50.	55.
24: LUMBER	12.	13.	13.	14.	15.
25: FURNITURE	18.	19.	18.	19.	20.
26: PAPER PRODUCTS	317.	321.	186.	107.	1.
27: PRINTING & PUBL.	161.	198.	211.	245.	281.
28: CHEMICALS	418.	478.	426.	408.	359.
29: PETROLEUM & COAL	18.	23.	27.	34.	42.
33: PRIMARY METALS	872.	906.	797.	793.	771.
34: FABRICAT. METALS	753.	824.	791.	847.	888.
35: MACHINERY	586.	650.	656.	735.	814.
36: ELECTRIC EQUIP.	466.	568.	602.	693.	786.
37: TRANSPORTATION	1016.	1158.	1217.	1429.	1656.
30: RUBBER & PLASTIC	275.	323.	344.	407.	465.
31: LEATHER	6.	8.	8.	10.	12.
32: STONE,CLAY,GLASS	245.	282.	295.	344.	395.
38: INSTRUMENTS	227.	268.	273.	301.	328.
39: MISC. MANUFACT.	227.	291.	317.	374.	426.

CONSERVATION SCENARIO
MAINE

	1978	1983	1988	1993	1998
1: REFRIGERATORS	628.	665.	648.	597.	526.
2: FREEZERS	197.	219.	229.	228.	220.
3: RANGES	152.	169.	187.	200.	210.
4: LIGHTING	257.	283.	157.	167.	175.
5: TELEVISIONS	56.	59.	64.	72.	82.
6: CLOTHES DRYERS	171.	209.	246.	273.	293.
7: CLOTHES WASHERS	25.	28.	31.	33.	34.
8: DISH WASHERS	32.	45.	58.	72.	84.
9: WATER HEATERS	495.	497.	449.	430.	438.
10: ROOM A/C	8.	14.	18.	20.	21.
11: CENTRAL A/C	2.	3.	3.	3.	4.
12: SPACE HEATERS	242.	310.	311.	313.	315.
13: HEATINGAUXILIARY	152.	153.	147.	140.	131.
14: MISCELLANEOUS	595.	700.	823.	933.	1031.

CONSERVATION SCENARIO
MAINE

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	10.	15.	14.	13.	13.
2: COOLING	12.	13.	12.	12.	12.
3: LT & POWER	87.	92.	74.	74.	81.
4: AUXILIARIES	66.	69.	59.	59.	63.
2: RETAIL					
1: HEATING	11.	16.	14.	13.	13.
2: COOLING	35.	36.	35.	35.	37.
3: LT & POWER	573.	582.	543.	551.	573.
4: AUXILIARIES	197.	194.	158.	157.	167.
3: HOSPITALS					
1: HEATING	7.	10.	9.	9.	9.
2: COOLING	12.	12.	10.	10.	10.
3: LT & POWER	168.	176.	162.	165.	173.
4: AUXILIARIES	89.	93.	77.	77.	81.
4: SCHOOLS					
1: HEATING	13.	16.	12.	11.	11.
2: COOLING	10.	10.	6.	5.	6.
3: LT & POWER	210.	190.	134.	133.	145.
4: AUXILIARIES	119.	103.	65.	60.	65.
5: OTHER					
1: HEATING	8.	12.	11.	10.	10.
2: COOLING	24.	27.	23.	24.	25.
3: LT & POWER	221.	237.	211.	214.	225.
4: AUXILIARIES	141.	150.	124.	124.	131.

CONSERVATION SCENARIO
MAINE

	1978	1983	1988	1993	1998
20: FOOD	244.	300.	316.	370.	426.
22: TEXTILES	130.	133.	111.	107.	101.
23: APPAREL	25.	35.	43.	56.	71.
24: LUMBER	135.	152.	151.	166.	180.
25: FURNITURE	10.	11.	11.	11.	12.
26: PAPER PRODUCTS	1137.	1305.	799.	592.	321.
27: PRINTING & PUBL.	5.	6.	6.	7.	8.
28: CHEMICALS	290.	396.	473.	614.	753.
29: PETROLEUM & COAL	7.	11.	13.	17.	21.
33: PRIMARY METALS	22.	30.	35.	45.	55.
34: FABRICAT. METALS	69.	82.	86.	99.	111.
35: MACHINERY	12.	17.	19.	25.	30.
36: ELECTRIC EQUIP.	71.	109.	142.	192.	243.
37: TRANSPORTATION	57.	73.	83.	105.	128.
30: RUBBER & PLASTIC	44.	55.	60.	72.	84.
31: LEATHER	98.	121.	130.	152.	175.
32: STONE,CLAY,GLASS	74.	83.	87.	103.	119.
38: INSTRUMENTS	0.	0.	0.	0.	0.
39: MISC. MANUFACT.	30.	33.	33.	36.	38.

CONSERVATION SCENARIO
MASS

	1978	1983	1988	1993	1998
1: REFRIGERATORS	3131.	3276.	3156.	2868.	2485.
2: FREEZERS	410.	458.	478.	474.	455.
3: RANGES	568.	613.	661.	694.	718.
4: LIGHTING	1305.	1404.	762.	802.	828.
5: TELEVISIONS	390.	389.	400.	420.	450.
6: CLOTHES DRYERS	537.	599.	667.	723.	769.
7: CLOTHES WASHERS	142.	154.	168.	178.	184.
8: DISH WASHERS	156.	178.	199.	222.	245.
9: WATER HEATERS	1118.	1098.	964.	901.	897.
10: ROOM A/C	204.	209.	200.	197.	195.
11: CENTRAL A/C	60.	69.	84.	102.	117.
12: SPACE HEATERS	1790.	2050.	2091.	2125.	2149.
13: HEATINGAUXILIARY	646.	642.	613.	577.	539.
14: MISCELLANEOUS	1299.	1493.	1719.	1915.	2086.

CONSERVATION SCENARIO
MASS

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	30.	44.	41.	41.	42.
2: COOLING	201.	212.	176.	173.	180.
3: LT & POWER	463.	465.	349.	339.	362.
4: AUXILIARIES	351.	355.	286.	280.	293.
2: RETAIL					
1: HEATING	38.	59.	54.	53.	54.
2: COOLING	567.	597.	568.	576.	596.
3: LT & POWER	3071.	3146.	2942.	2982.	3096.
4: AUXILIARIES	1056.	1046.	858.	853.	902.
3: HOSPITALS					
1: HEATING	20.	29.	27.	26.	27.
2: COOLING	166.	171.	139.	134.	137.
3: LT & POWER	797.	820.	744.	745.	771.
4: AUXILIARIES	424.	435.	353.	345.	359.
4: SCHOOLS					
1: HEATING	32.	38.	29.	29.	30.
2: COOLING	140.	122.	71.	66.	72.
3: LT & POWER	853.	730.	510.	517.	576.
4: AUXILIARIES	483.	397.	246.	235.	258.
5: OTHER					
1: HEATING	31.	49.	44.	44.	44.
2: COOLING	421.	467.	414.	413.	430.
3: LT & POWER	1257.	1365.	1214.	1215.	1269.
4: AUXILIARIES	800.	862.	716.	703.	735.

CONSERVATION SCENARIO
MASS

	1978	1983	1988	1993	1998
20: FOOD	643.	769.	752.	817.	878.
22: TEXTILES	381.	347.	275.	240.	206.
23: APPAREL	68.	78.	78.	85.	93.
24: LUMBER	25.	25.	22.	23.	23.
25: FURNITURE	34.	36.	33.	33.	32.
26: PAPER PRODUCTS	889.	780.	440.	278.	103.
27: PRINTING & PUBL.	237.	297.	328.	396.	471.
28: CHEMICALS	703.	808.	804.	890.	953.
29: PETROLEUM & COAL	51.	54.	52.	54.	56.
33: PRIMARY METALS	432.	456.	415.	407.	397.
34: FABRICAT. METALS	533.	613.	580.	600.	614.
35: MACHINERY	601.	743.	739.	806.	848.
36: ELECTRIC EQUIP.	1430.	1705.	1735.	1911.	2078.
37: TRANSPORTATION	381.	460.	485.	559.	637.
30: RUBBER & PLASTIC	829.	912.	894.	965.	1029.
31: LEATHER	102.	108.	89.	79.	67.
32: STONE,CLAY,GLASS	195.	205.	175.	166.	155.
38: INSTRUMENTS	618.	643.	538.	499.	451.
39: MISC. MANUFACT.	313.	364.	359.	381.	404.

CONSERVATION SCENARIO
NH

	1978	1983	1988	1993	1998
1: REFRIGERATORS	537.	586.	579.	535.	471.
2: FREEZERS	162.	186.	196.	195.	188.
3: RANGES	146.	168.	188.	203.	214.
4: LIGHTING	211.	240.	135.	146.	154.
5: TELEVISIONS	50.	53.	57.	62.	69.
6: CLOTHES DRYERS	146.	185.	222.	252.	275.
7: CLOTHES WASHERS	22.	26.	29.	31.	33.
8: DISH WASHERS	31.	47.	64.	79.	92.
9: WATER HEATERS	356.	387.	359.	351.	361.
10: ROOM A/C	21.	31.	38.	43.	45.
11: CENTRAL A/C	6.	10.	12.	13.	13.
12: SPACE HEATERS	519.	650.	659.	668.	677.
13: HEATINGAUXILIARY	109.	111.	109.	105.	100.
14: MISCELLANEOUS	140.	171.	206.	236.	263.

CONSERVATION SCENARIO
NH

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	16.	24.	21.	21.	21.
2: COOLING	16.	19-	17.	18.	19.
3: LT & POWER	90.	100.	86.	92.	105.
4: AUXILIARIES	68.	74.	67.	71.	79.
2: RETAIL					
1: HEATING	16.	24.	21.	20.	20.
2: COOLING	39.	43.	43.	46.	49.
3: LT & POWER	505.	548.	545.	584.	635.
4: AUXILIARIES	173.	182.	163.	174.	194.
3: HOSPITALS					
1: HEATING	9.	12.	11.	11.	11.
2: COOLING	11.	12.	10.	10.	10.
3: LT & POWER	126.	136.	129.	134.	142.
4: AUXILIARIES	67.	72.	62.	63.	67.
4: SCHOOLS					
1: HEATING	18.	21.	16.	15.	15.
2: COOLING	10.	10.	6.	6.	7.
3: LT & POWER	163.	152.	114.	120.	138.
4: AUXILIARIES	92.	83.	54.	54.	61.
5: OTHER					
1: HEATING	13.	19.	17.	17.	16.
2: COOLING	26.	31.	30.	33.	36.
3: LT & POWER	190.	225.	224.	248.	280.
4: AUXILIARIES	121.	141.	132.	144.	163.

CONSERVATION SCENARIO
NH

	1978	1983	1988	1993	1998
20: FOOD	103.	144.	172.	220.	273.
22: TEXTILES	94.	93.	76.	68.	57.
23: APPAREL	2.	2.	2.	2.	3.
24: LUMBER	57.	66.	67.	74.	81.
25: FURNITURE	27.	35.	39.	48.	57.
26: PAPER PRODUCTS	384.	429.	214.	53.	-162.
27: PRINTING & PUBL.	46.	62.	74.	96.	119.
28: CHEMICALS	131.	169.	180.	205.	216.
29: PETROLEUM & COAL	0.	0.	0.	0.	0.
33: PRIMARY METALS	53.	76.	90.	114.	141.
34: FABRICAT. METALS	40.	51.	54.	64.	72.
35: MACHINERY	107.	136.	150.	178.	205.
36: ELECTRIC EQUIP.	225.	301.	339.	408.	476.
37: TRANSPORTATION	46.	78.	109.	159.	217.
30: RUBBER & PLASTIC	68.	88.	98.	118.	138.
31: LEATHER	65.	70.	66.	66.	64.
32: STONE,CLAY,GLASS	49.	54.	54.	60.	66.
38: INSTRUMENTS	17.	19.	19.	20.	21.
39: MISC. MANUFACT.	9.	12.	14.	18.	22.

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CONSERVATION SCENARIO
RI
                         1978   1983   1988   1993   1998
 1: REFRIGERATORS        526.   548.   526.   477.   413.
 2: FREEZERS              70.    78.    81.    80.    77.
 3: RANGES               101.   108.   116.   121.   124.
 4: LIGHTING             218.   233.   126.   131.   135.
 5: TELEVISIONS           64.    62.    61.    60.    60.
 6: CLOTHES DRYERS        93.   102.   113.   121.   127.
 7: CLOTHES WASHERS       22.    24.    26.    27.    28.
 8: DISH WASHERS          24.    29.    34.    40.    46.
 9: WATER HEATERS        208.   203.   178.   166.   166.
10: ROOM A/C              24.    25.    24.    24.    24.
11: CENTRAL A/C            7.     8.    10.    12.    14.
12: SPACE HEATERS        194.   225.   229.   232.   234.
13: HEATINGAUXILIARY     112.   111.   106.   100.    93.
14: MISCELLANEOUS        158.   181.   208.   231.   252.
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CONSERVATION SCENARIO
RI
                         1978   1983   1988   1993   1998
 1: OFFICES
 1:   HEATING              4.     6.     5.     5.     5.
 2:   COOLING             25.    26.    21.    21.    21.
 3:   LT & POWER          65.    64.    48.    46.    49.
 4:   AUXILIARIES         49.    49.    39.    38.    40.
 2: RETAIL
 1:   HEATING              5.     8.     7.     7.     7.
 2:   COOLING             71.    75.    71.    72.    74.
 3:   LT & POWER         437.   449.   420.   425.   440.
 4:   AUXILIARIES        150.   149.   123.   121.   128.
 3: HOSPITALS
 1:   HEATING              3.     5.     4.     4.     4.
 2:   COOLING             25.    26.    21.    20.    20.
 3:   LT & POWER         135.   139.   125.   124.   127.
 4:   AUXILIARIES         72.    74.    59.    57.    59.
 4: SCHOOLS
 1:   HEATING              5.     6.     5.     5.     5.
 2:   COOLING             20.    18.    11.     9.    10.
 3:   LT & POWER         140.   124.    85.    82.    87.
 4:   AUXILIARIES         80.    68.    41.    37.    40.
 5: OTHER
 1:   HEATING              4.     6.     6.     6.     6.
 2:   COOLING             47.    53.    47.    47.    49.
 3:   LT & POWER         162.   177.   158.   159.   167.
 4:   AUXILIARIES        103.   112.    93.    92.    97.
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CONSERVATION SCENARIO
RI
                         1978   1983   1988   1993   1998
20: FOOD                  44.    49.    48.    53.    58.
22: TEXTILES             211.   199.   147.   101.    48.
23: APPAREL               43.    49.    51.    57.    63.
24: LUMBER                 1.     2.     2.     2.     3.
25: FURNITURE              1.     2.     2.     2.     2.
26: PAPER PRODUCTS        41.    37.    17.     2.   -18.
27: PRINTING & PUBL.      32.    35.    35.    39.    42.
28: CHEMICALS             57.    78.    91.   113.   130.
29: PETROLEUM & COAL       4.     6.     7.     8.    10.
33: PRIMARY METALS       252.   302.   304.   332.   357.
34: FABRICAT. METALS      81.   102.   111.   132.   153.
35: MACHINERY             52.    62.    64.    72.    80.
36: ELECTRIC EQUIP.      103.   126.   133.   152.   168.
37: TRANSPORTATION        59.    87.   112.   152.   198.
30: RUBBER & PLASTIC     161.   214.   250.   313.   376.
31: LEATHER                3.     3.     4.     4.     5.
32: STONE,CLAY,GLASS      79.    91.    93.   104.   116.
38: INSTRUMENTS           26.    37.    46.    60.    76.
39: MISC. MANUFACT.      127.   168.   185.   218.   250.
```

CONSERVATION SCENARIO
VERMONT

	1978	1983	1988	1993	1998
1: REFRIGERATORS	277.	295.	288.	266.	234.
2: FREEZERS	104.	116.	122.	122.	118.
3: RANGES	83.	95.	106.	115.	120.
4: LIGHTING	114.	126.	70.	76.	79.
5: TELEVISIONS	26.	26.	28.	30.	34.
6: CLOTHES DRYERS	83.	102.	123.	140.	154.
7: CLOTHES WASHERS	13.	15.	17.	18.	19.
8: DISH WASHERS	17.	23.	30.	36.	42.
9: WATER HEATERS	304.	308.	285.	280.	288.
10: ROOM A/C	7.	12.	14.	15.	16.
11: CENTRAL A/C	2.	3.	4.	5.	5.
12: SPACE HEATERS	254.	309.	316.	324.	330.
13: HEATINGAUXILIARY	62.	62.	60.	57.	53.
14: MISCELLANEOUS	250.	295.	350.	399.	442.

CONSERVATION SCENARIO
VERMONT

	1978	1983	1988	1993	1998
1: OFFICES					
1: HEATING	5.	7.	6.	6.	6.
2: COOLING	6.	7.	6.	6.	6.
3: LT & POWER	32.	35.	28.	27.	29.
4: AUXILIARIES	24.	26.	22.	22.	23.
2: RETAIL					
1: HEATING	8.	12.	10.	10.	10.
2: COOLING	23.	25.	25.	25.	26.
3: LT & POWER	284.	308.	296.	300.	312.
4: AUXILIARIES	97.	102.	88.	88.	93.
3: HOSPITALS					
1: HEATING	4.	5.	5.	5.	5.
2: COOLING	6.	7.	6.	5.	6.
3: LT & POWER	69.	73.	68.	69.	73.
4: AUXILIARIES	37.	38.	32.	32.	34.
4: SCHOOLS					
1: HEATING	8.	9.	7.	6.	6.
2: COOLING	6.	5.	3.	3.	3.
3: LT & POWER	87.	79.	56.	56.	61.
4: AUXILIARIES	50.	43.	27.	25.	28.
5: OTHER					
1: HEATING	8.	12.	10.	10.	10.
2: COOLING	20.	24.	22.	23.	24.
3: LT & POWER	139.	161.	152.	159.	170.
4: AUXILIARIES	88.	101.	90.	92.	99.

CONSERVATION SCENARIO
VERMONT

	1978	1983	1988	1993	1998
20: FOOD	40.	42.	41.	43.	46.
22: TEXTILES	6.	8.	9.	11.	13.
23: APPAREL	1.	1.	1.	1.	1.
24: LUMBER	44.	52.	54.	61.	68.
25: FURNITURE	14.	17.	18.	21.	25.
26: PAPER PRODUCTS	106.	124.	107.	104.	93.
27: PRINTING & PUBL.	33.	41.	46.	57.	67.
28: CHEMICALS	8.	10.	11.	12.	13.
29: PETROLEUM & COAL	1.	1.	1.	1.	1.
33: PRIMARY METALS	7.	8.	9.	11.	13.
34: FABRICAT. METALS	16.	21.	24.	30.	36.
35: MACHINERY	71.	85.	89.	102.	114.
36: ELECTRIC EQUIP.	236.	343.	431.	572.	717.
37: TRANSPORTATION	37..	57.	74.	101.	131.
30: RUBBER & PLASTIC	49.	66.	78.	100.	122.
31: LEATHER	5.	6.	6.	7.	7.
32: STONE,CLAY,GLASS	27.	27.	12.	3.	-8.
38: INSTRUMENTS	7.	8.	8.	9.	9.
39: MISC. MANUFACT.	53.	66.	72.	83.	95.

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Final Draft

REDUCING NEW ENGLAND'S OIL DEPENDENCE THROUGH CONSERVATION AND ALTERNATIVE ENERGY

TECHNICAL REPORT III

REGIONAL OIL SAVINGS THROUGH CONSERVATION: BUILDINGS AND UTILITY SECTORS

A Report to the
General Accounting Office
of the
United States Congress

David Nichols
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June, 1980
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1. INTRODUCTION AND SELECTED RESULTS

1.1 Scope of the Report

This is the third in a series of submissions to the General Accounting Office reporting on the New England potential for conserving oil through (a) implementation of a conservation strategy to reduce demand and (b) implementation of an alternative energy strategy to increase non-conventional supply.

In the second report a conservation scenario was developed. That scenario was a selection of conservation measures and levels that could be implemented for homes and buildings in order to reduce oil consumption for electricity generation and for heating homes and buildings. In order to compute oil savings from reduced usage of electricity, using the ESRG electric load forecasting model, estimates of industrial energy conservation potential were included in the scenario. The scenario analysis is not, however, intended to include conservation of oil consumed in industrial processes or conservation of gasoline.

All of the conservation measures and levels selected in the scenario were feasible and cost-effective. A "feasible" measure is one which is on the market now or whose technical viability has been demonstrated in U.S. Department of Energy tests or one which developers plan to market. A "cost-effective" measure is one whose life-cycle costs are less than the marginal costs of the energy it displaces.

The conservation measures and levels included in the scenario went beyond those presently being implemented through market forces and public policy. The scenario was entitled the "Conservation Strategy Scenario" precisely in order to emphasize its dependence upon additional or new policy measures. Hypothetical new policies were linked to the conservation measures selected therein. In some cases a specific policy was posited -- <u>e.g.</u>, a specific appliance efficiency regulation -- and in others a range of conceivable policies is set forth. The purpose of the technical analysis engaged in was not to develop a precise set of policy proposals. It was, rather, to provide policymaking guidance by quantifying the conservation potential from feasible and socially cost-effective measures not likely to be implemented without additional institutional action.

The conservation strategy scenario of Technical Report II was designed to permit quantification of energy savings relative to that conservation which is occurring under present economic and political trends. Thus a "business-as-usual" scenario and a resulting "Base Case" forecast of energy consumption, including such ongoing conservation, was required. The business-as-usual scenario was presented in the context of the Report I long-range forecast of electric energy and demand for New England.

The high degree of detail in the Base Case and Conservation forecasts in Reports I and II was necessary in order to compute electricity savings from additional conservation, for electricity serves a wide variety of end-uses. The oil-reduction implications of reduced generation can then be calculated in a relatively straightforward fashion.

The direct consumption of oil in the buildings sector (residential and commercial/institutional uses) involves a much smaller set of end-uses. In fact, the vast bulk of such consumption is for space heating and hot water heating. The detailed projections of the forecasting model used in Reports I and II could thus be adapted for the simpler task of estimating the direct buildings oil savings from conservation measure implementations. These adaptations and computations are described in this Report.

Before summarizing the results let us restate the limitations of the context within which the findings should be understood. While the Conservation Strategy Scenario illustrates the substantial conservation potential that could be realized through a deliberate policy commitment to increasing the productivity of energy use, it by no means necessarily exhausts the potential for oil conservation. Certain sectors, like transportation and industrial oil burning, are beyond the scope of the scenario. Even within the focus on oil for electricity and heating, the analysts have not been able to be precise in every detail. Policy options and conservation measures worthy of consideration have been excluded because more information is needed about them or because their effects are uncertain at this point. Finally, conservation technologies that are not near "off-the-shelf" status, yet may attain technical viability or economical attractiveness during the scenario period, have been excluded from consideration.

1.2 Summary of Results: Utility Sector

Implementation of the Conservation Strategy Scenario has profound implications for the oil requirements of the utility sector in New England. The cost of oil makes oil-fired plants the most expensive to operate. Because it is the marginal fuel, reductions in electricity consumption initially reduce oil-based generation. This is reflected in the economic dispatch practices of the regional utility systems and is the assumption used in computing oil savings from conservation. By the year 2000, oil generation is reduced to 9 percent of total generation by fuel type. The impact of the Conservation Case on oil used by the utility sector is shown in Table 1.

TABLE 1

OIL CONSUMPTION BY THE UTILITY SECTOR IN NEW ENGLAND IN 1978, 1990, AND 2000, BASE CASE AND CONSERVATION CASE (10^{12} BTU)

Case	1978	1990	2000
Base	472	309	363
Conservation	-	127	101

The conservation scenario's impact is very substantial. Almost sixty percent of 1990 oil use and over seventy percent of 2000 oil use is eliminated.

A number of assumptions in addition to the oil-displacement premise described above were used in making the estimates listed above. First, we extrapolated implementation of the current New England Power Pool (NEPOOL) construction program. This includes completion of planned nuclear units and conversion of only two plants to coal. The plants included in this "NEPOOL construction program," are listed in Report IV. Second, we have used the ESRG Base Case forecast rather than NEPOOL or utility forecasts as our benchmark for comparison with conservation. Finally, we have used an estimated average heat rate of 10,400 Btu/kwh to compute the oil consumption implications of the reduction in generation from oil-fired plants.

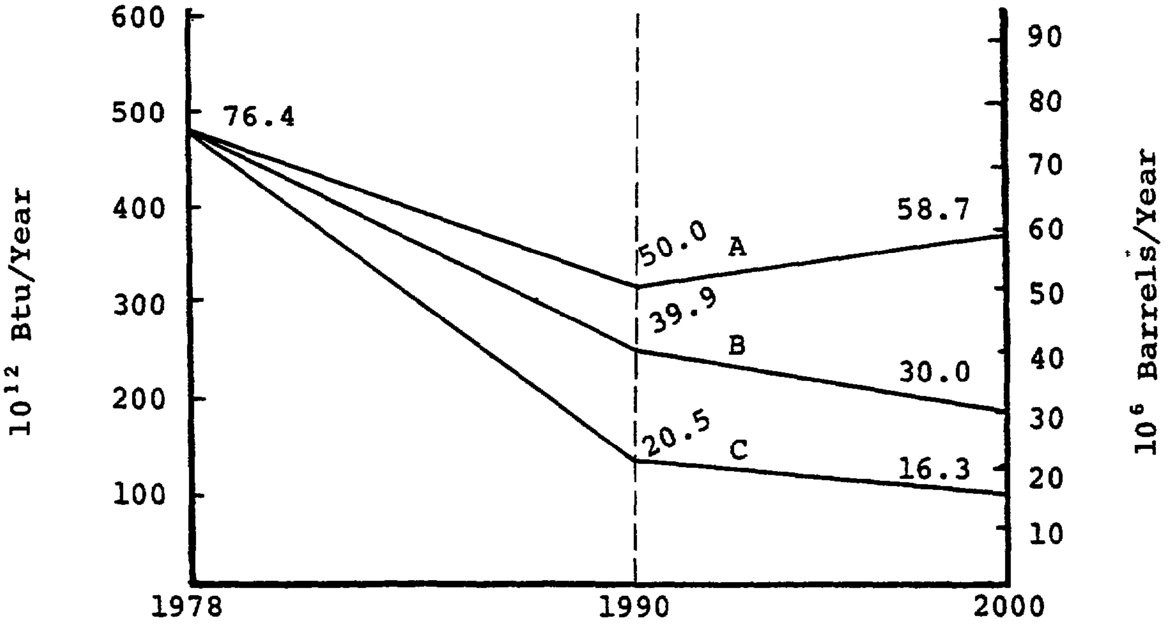
The ESRG Base Case forecast is lower than NEPOOL's forecast for New England. For the period 1980-1990, the annual rate of growth of system peak is 2.17 percent in the ESRG forecast and 2.51 percent in the NEPOOL forecast (Ref. 4). The real divergence comes after 1990, when the growth rate increases to 3.2 percent per year in the NEPOOL forecast. For 1990, the NEPOOL-forecasted peak is 20,650 ms. The ESRG-forecasted peak is 6 percent less. By 1995, the NEPOOL forecast is for a peak of 24,170 mw. The ESRG-forecasted 1995 peak is 14 percent less. The NEPOOL forecast implies a higher "Base Case" level of oil consumption than projected in this study.

The NEPOOL and ESRG forecasting models are similar in incorporating a considerable degree of end-use detail. While the ESRG model employs a range of demographic assumptions from available economic and demographic forecasts, the NEPOOL model uses its own demographic/economic module to derive demographic assumptions concerning customer and employment growth. In terms of the forecasting models *per se*, there are certain significant differences between the ESRG and the NEPOOL approach. In general, the NEPOOL model relies more on price elasticities and historic trend relationships to derive energy intensity assumptions than does the ESRG model. The ESRG model explicitly models the penetration of commercial sector conservation measures while the NEPOOL model uses long-term price elasticities to capture the effects of conservation here. The models are sufficiently detailed, and sufficiently different, that there are numerous possible sources of forecast divergence between the two.

With respect to our assumption concerning the "NEPOOL construction program," it should be pointed out that there is some uncertainty as to whether the new nuclear or coal capacity assumed therein will be completed. If it is not, oil use will be greater in both Base and Conservation Cases. On the other hand, as Report IV shows, there is a substantial alternative supply potential in New England. Pursuit of this potential in conjunction with the conservation potential could meet a significant portion of required generation. For convenience, two figures showing the comparative impacts of either (a) conservation potential implementation or (b) alternative supply potential realization is included below. Each potential is indicated separately in relation to the Base Case demand level and supply mix. A strategy of pursuit of both potentials could, if it realized a significant portion of each, cope with a portion of lost generation from coal or nuclear sources. For a fuller discussion of the methodology for computing utility oil savings, see Report IV.

FIGURE 1

NEW ENGLAND OIL CONSUMPTION FOR ELECTRICAL GENERATION, 1978, 1990, AND 2000, UNDER BUSINESS AS USUAL, CONSERVATION, AND ALTERNATIVE SUPPLY SCENARIOS*



A Base Case Forecast

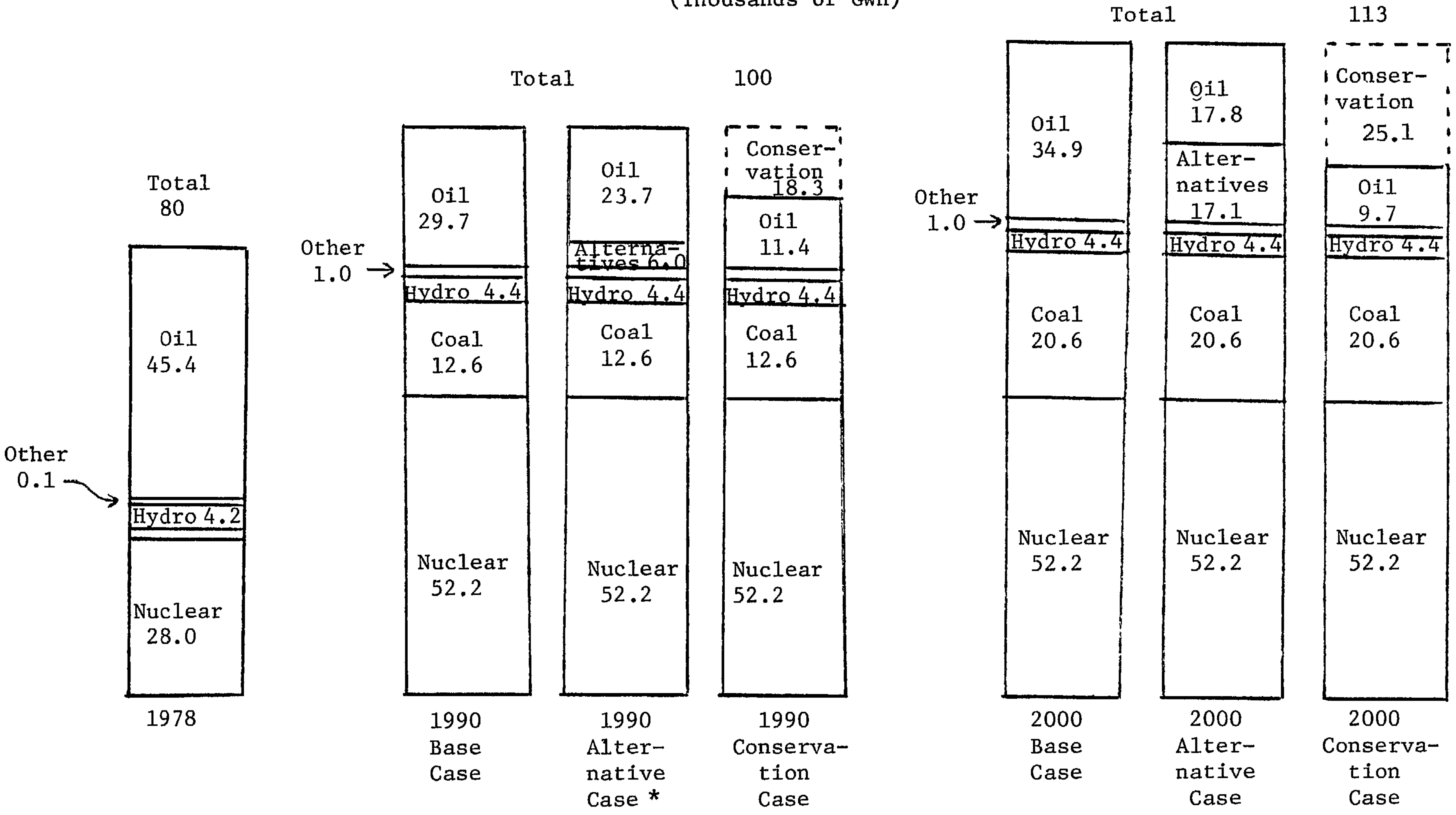
B Base Case Forecast and Implementation of Alternative Supply Potential

C Conservation Case Forecast

of two generating stations from oil to coal.

FIGURE 2

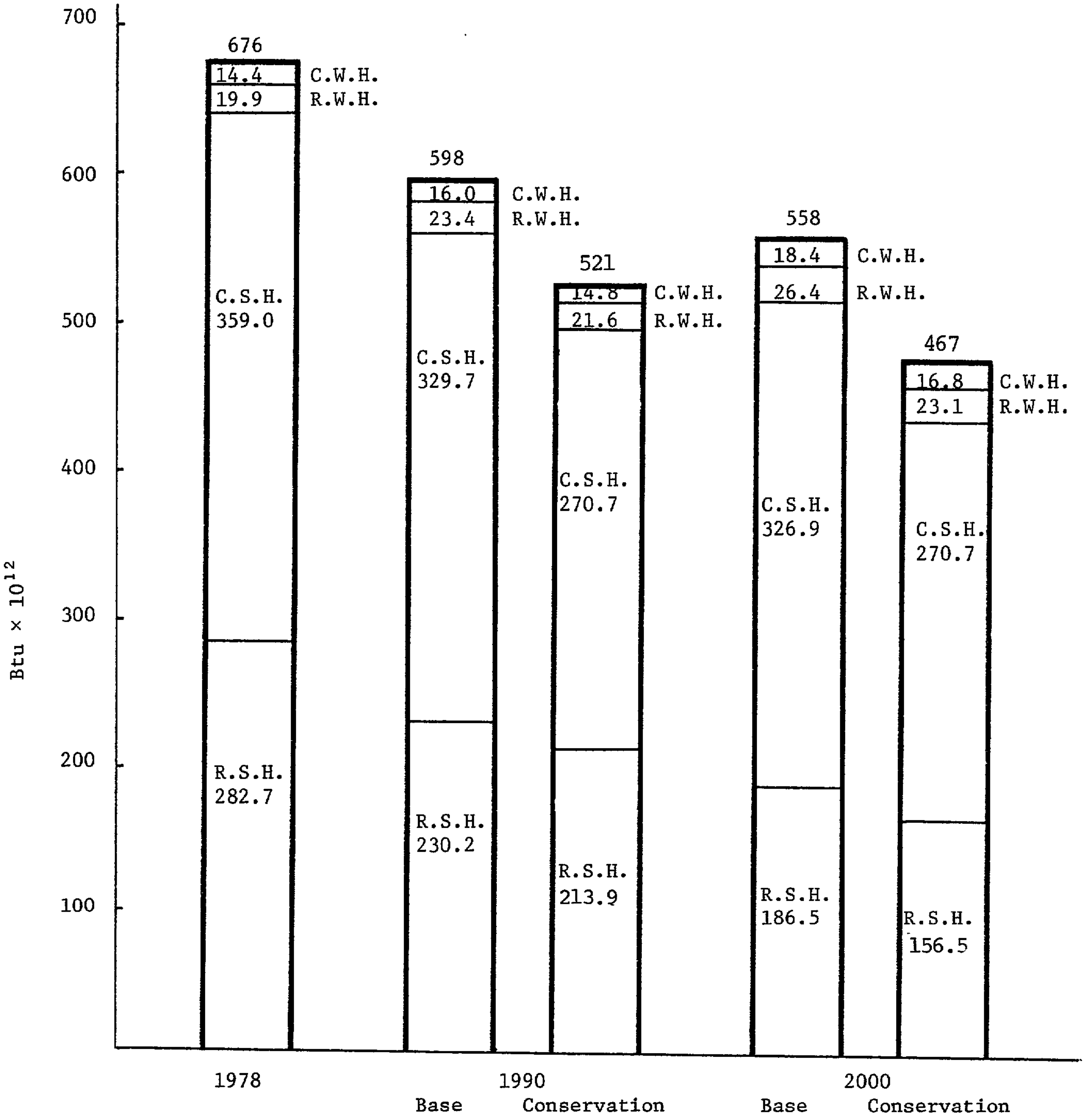
ELECTRICAL GENERATION BY FUEL TYPE
(Thousands of GWH)



*"Alternative" sources include electricity from solid waste, hydropower, tidal power, windpower, and wood. (A small amount of generation from such sources is included within "Other" fuel types for 1978 and Base Case 1990 and 2000 forecasts.)

FIGURE 3

NEW ENGLAND OIL CONSUMPTION FOR HEATING, 1978, 1990, AND 2000, BASE CASE AND CONSERVATION CASE



R.S.H.	Residential space heating
C.S.H.	Commercial-institutional space heating
R.W.H.	Residential water heating
C.W.H.	Commercial-institutional water heating

1.3 Summary of Buildings Sector Savings

In addition to its dramatic impact on oil use for electrical generation, the conservation scenario has a relatively smaller but still significant impact on oil use as heating fuel for buildings. The buildings sector consists of residential units and "commercial" buildings (hospitals, stores, offices, schools, warehouses, etc.) The two oil uses affected by conservation are space and water heating. Conservation Case consumption for these end-uses is shown in Table 2.

TABLE 2

NEW ENGLAND OIL CONSUMPTION FOR SPACE AND WATER HEATING IN RESIDENTIAL AND COMMERCIAL BUILDINGS, 1978 HISTORIC AND 1990 AND 2000 CONSERVATION SCENARIO TOTALS (10^{12}Btu)

End-Use	1978	1990	2000
Residential space heating	282.7	213.9*	156.5
Residential water heating	19.9	21.6*	23.1
Commercial space heating	359.0	270.7	270.7
Commercial water heating	14.4	14.8	16.8
Total	676.0	521.3	467.1

*1990 values estimated by linear interpolation for illustrative purposes.

One of the measures in the conservation scenario is the restriction of new unassisted electric resistance heating. This measure causes the number of oil-heated buildings to increase in the Conservation Case forecast. Additional oil is burned as heating fuel, and less is burned as utility fuel, with overall savings due to the restriction. Other measures in the conservation scenario -- increases in building thermal integrity and commercial heating system efficiencies -- produce a direct fuel savings. Overall, the conservation scenario produces savings of sixteen percent (relative to the Base Case forecast) by the year 2000. Figure 3 below presents a visual comparison of the Conservation and Base Case forecasts.

2. METHODOLOGY FOR BUILDINGS SECTOR SAVINGS COMPUTATIONS

2.1 Residential Sector Methodology

The oil savings estimates presented above were developed by utilizing and adapting the analytic detail incorporated in the long-range forecasting model described in Reports I and II. Two end-uses in the residential sector consume oil directly. These are space heating and, to a much lesser extent, water heating. Let us consider each in turn.

To compute year 2000 oil heat consumption under Base Case and Conservation Case conditions, the forecast of fossil-fuel heating homes embedded in the forecasting model's customer growth and electric space heat assumptions was made explicit through a series of calculations. These calculations culled out the net fossil fuel residential units being added during the forecast period. The fraction of all fossil fuel heated homes that were supplied by oil fuel was held constant. This was an analytical assumption based on the not unrealistic premise that the current price advantage of gas will erode during the 1980s.

One impact of the electric space heat ban incorporated in the Conservation Strategy Scenario is to increase the number of homes using oil heat. The additional 130,000 oil-heated units represent an addition of less than four percent to the number of oil-heated units projected for New England in 2000 in the Base Case. Given the very strong oil savings implications of heating with a fossil fuel rather than resistance heating discussed in Report II, the overall effects of the conservation scenario's space heating regulation are quite positive.

To compute the average heating demand of oil-heated homes in the year 2000, 1978 unit demands were adjusted to 2000 levels. Statewide average unit demands, weighted across housing types, were developed from Ref. 1. They were then adjusted by the ratio of average 1978 heating system efficiency (.55) to projected 2000 average heating system efficiency (.80). This adjustment was the same for both the Base Case scenario and the Conservation scenario, for although work on high-efficiency oil burners is being underwritten by the U.S. D.O.E., the economic and technical viability of high-efficiency oil space heaters is less certain than in the case of gas heaters. Thus a furnace efficiency measure significantly above the minimum standards expected to be promulgated during 1980 by the D.O.E. was not included in the Conservation Scenario. This may have been a somewhat cautious choice.

On the other hand, weatherization levels did differ from one another in the Conservation and Base Case scenarios. These changes were captured by multiplying 1978 unit demands (after the computation and adjustment described in the above paragraph) by the ratio of heating auxiliary unit usage in 2000 to heating auxiliary unit usage in 1978. The difference between Base and Conservation Case year 2000 heating auxiliary unit usages is attributable to the higher level of thermal integrity incorporated in the conservation scenario, which reduces the heating load in fossil fuel homes. Since the change in heating auxiliary usage is definitionally identical to the change in heating demand itself,* the ratio of the two 2000 usage levels captures the effects of improved weatherization. The only assumption involved that is not already specified in Reports I and II is that conservation scenario weatherization improvements impact oil heated homes as much as they do other fossil heated (*i.e.*, gas) homes. Table 3 presents the summary findings for home heating oil.

TABLE 3

COMPARISON OF OIL USE FOR RESIDENTIAL SPACE HEAT IN NEW ENGLAND IN 2000, BASE CASE AND CONSERVATION CASE

	Base Case			Conservation Case		
State	Oil Heated Homes (To nearest 500)	Average Unit Demand (10^6 Btu/Year)	Total Annual Consumption (10^{12} Btu)	Oil Heated Homes	Average Unit Demand (10^6 Btu/Year)	Total Annual Consumption (10^{12} Btu)
Connecticut	930,600	46.6	43.4	957,300	37.9	36.23
Maine	437,200	64.2	28.1	458,100	50.1	23.3
Massachusetts	1,451,100	50.3	72.9	1,486,500	41.2	61.3
N.H.	311,500	59.1	18.4	339,100	46.3	15.7
R.I.	251,300	51.0	12.8	255,600	41.9	10.7
Vermont	174,700	62.6	10.9	189,000	49.4	9.3
Total N.E.	3,556,400	52.5	186.5	3,685,600	42.4	156.5

As Table 3 indicates, implementation of the conservation scenario relative to the business-as-usual baseline produces a direct heating oil use saving of 8.8 million Btu/year for the average New England home, a reduction of some 19 percent. The total regional residential heating use reduction is 24.9 trillion Btu, or some 16 percent relative to the Base Case.

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*See Report II, Sec. 3.3.10

To these savings must be added the relatively minor water heating savings from implementation of the conservation scenario. The forecasting model projects a range of saturations for electric water heaters (e.w.h.). The saturation for non-electric water heaters is then simply: 1 - e.w.h. The task was then to decide what fraction of non-e.w.h. homes had oil-heated hot water. To make this computation, the ratio of oil-fired hot water to oil-heated homes was developed for each state from 1970 Census data. The resulting ratios were then multiplied against the saturations of oil-heated homes in 2000, which had been developed for the oil heating analysis described above, to provide fractions of non-e.w.h. units which could be held to represent state-specific oil water heating saturations. The state-specific saturations were then multiplied against the total year 2000 households in the state (from the customer forecast in section 8 of Report I) to yield year 2000 households with oil-heated hot water (o.w.h.).

The estimate of unit usage for these households heated with hot water was then developed in two steps for each forecast case. First, e.w.h. unit usages in 1978 (derived from Base Case data inputs) at essentially 100 percent conversion efficiency, were adjusted to reflect fuel usage for oil-fired tanks at a nominal 50-55 percent efficiency. On the assumption that e.w.h. and oil hot water appliance efficiencies change in essentially the same ways in both forecast cases, the resulting o.w.h. unit usages were decreased by the ratio of year 2000 e.w.h. unit usage to year 1978 e.w.h. unit usage. The effects of differing housing mixes (between single-family and multifamily) and different efficiency changes (between e.w.h. and o.w.h. appliances) were judged too small to require specific computational treatment. (However, a minor adjustment was made to approximate the somewhat slower expected rate of improvement of o.w.h. units.) The estimates for each state and the region are presented in the below table.

TABLE 4

COMPARISON OF OIL USE FOR RESIDENTIAL WATER HEAT IN NEW ENGLAND IN 2000, BASE CASE AND CONSERVATION CASE

State	Total Annual Consumption (10^{12} Btu)	
	Base Case	Conservation Case
Connecticut	6.5	5.8
Maine	2.4	2.1
Massachusetts	11.7	10.0
N.H.	2.5	2.3
R.I.	2.4	2.0
Vermont	0.9	0.8
Total	26.4	23.1

2.2 Commercial Sector Methodology

The method for estimating commercial sector conservation savings of oil for direct heat and hot water was developed to take advantage of the Arthur D. Little, Inc., data base employed in Sec. 4 of Report I and Sec. 4 of Report II for purposes of commercial end-use forecasting. Essentially, the forecasting inputs for the commercial sector were revised and the model run for both forecast cases. The results were as follows.

TABLE 5

COMMERCIAL SECTOR OIL USE CONSUMPTION FOR SPACE AND WATER HEATING, 1978, 1990, AND 2000, BASE AND CONSERVATION CASES

Consumption in 10^{12} Btu

State	1978	1990		2000	
		Base	Conservation	Base	Conservation
Connecticut	48.8	46.0	38.0	46.0	38.4
Maine	13.3	12.3	10.2	12.3	10.4
Massachusetts	278.0	255.9	209.0	255.2	210.1
N.H.	9.4	9.5	9.6	10.2	9.9
R.I.	22.5	20.6	16.9	20.3	16.8
Vermont	1.4	1.4	1.2	1.4	1.2
Total	373.3	345.7	285.5	345.3	287.6

The results illustrate the order of magnitude of the direct oil conservation potential that exists in the commercial-institutional sector. Total regional direct oil consumption is 288×10^{12} Btu in the Conservation Case as opposed to 345×10^{12} Btu in the Base Case, a reduction of 17 percent. The o.w.h./space heating breakdown was presented visually in Figure 3.

Specifically, the model was adapted in the following manner. Of the four end-uses in the commercial model, three were eliminated, leaving space heating; and a thermal (hot water) end-use was added. Intensities of oil use for these two end-uses (in Btu/ft^2/year) were obtained, as in the case of the electricity forecast, from the A.D.L. buildings data base utilized in the Building Energy Conservation Optimization Model (Ref. 2), and were entered as data items. Fractions of loads saved at each of the three conservation levels, analagous to those in Table 4.5 of Report I, were then entered from Ref. 2 for the two oil end-uses. Conservation level penetration fractions for the heating and hot water end-uses were entered, as in Table 8.21 of Report I. One hundred percent of level 3 was chosen for the Conservation Case, as in the Report II forecast.

Saturations for oil heat and hot water were needed for 1975 and 2000 in order to complete input data requirements. Fossil heat saturations were taken as: 1 - e.s.h. These overall fossil saturations were then multiplied by the oil fraction of statewide fossil fuel consumption computed from the National Emissions Data System (NEDS). NEDS contains total consumption by type of fuel for the commercial-institutional sector for each New England state, nominally for 1976 (Ref. 3). The resulting oil heat saturations were then entered. Model entries affecting only electric heating energy use -- such as voltage regulation or heat pump penetrations -- were disabled and the commercial model was run for oil use in both the Base and the Conservation Case.

Because the model was adapted from its original function as a load forecast machine, a special adjustment was needed for the Conservation Case. The Conservation Case for commercial oil use was first run without considering the impact of the conservation scenario's electric resistance heating regulation on oil saturations, a course necessitated by the structure of the commercial model. Then, the electric energy decrement for heating determined by comparing the original conservation run including the e.s.h. ban (Report II, Sec. 4) with a sensitivity run without the ban, was allocated to oil heat using the oil fraction of all non-electric heating fuel discussed above and an adjustment for the assumed average efficiency of commercial oil heating systems in 2000 (80 percent) as opposed to electric resistance efficiency (100 percent).

In both the commercial and residential subsectors, adaptation of the end-use forecasting model and its output to compute changes in oil consumption entailed the use of some simplifying assumptions, such as the assumption that the oil fraction of fossil-fueled space and water heating does not change during the forecast period. On the other hand, the adaptation of the long-run electric forecast model to the analysis of oil consumption in residential and commercial buildings enabled the incorporation of significant detail on the complex factors driving demand.

2.3 Base Year Oil Usage

Precise 1978 base year figures on heating oil consumption in New England are not available, for the use of oil is not centrally metered as is electricity. Instead, there are a number of estimates developed by different researchers. The lack of a precise base year figure on historic usage is not of crucuial importance in this study. Here, our quest for precision is focussed more on the relative reduction in oil consumption that can be achieved through implementation of the conservation scenario than upon the precise historical data with which the conservation case forecast begins. Nevertheless, it is important to have a resonable working estimate of historic consumption. The estimate should err on the low side so that absolute oil savings projections are not overstated.

Our residential oil use estimate was independently developed in the following way. We began with our 1978 housing data (developed from the sources cited in Report I, Sec. 8.1.1). We then determined the number of all housing units that were oil heated on the bases of the data in the New England Energy Congress report (Ref. 5). For the resulting numbers of oil heated units, we estimated oil consumption by using oil heating demand figures developed by Brookhaven National Laboratory (Ref. 6). B.N.L.'s were regional figures for the Northeast, but we derived figures for each state by adjusting for state-specific heating degree days. The resulting figures were entered in the first row of Table 5 under the 1978 column. The oil water heating figures are estimates based on E.S.R.G. knowledge of average water heating loads. Our 1978 oil total of 303 X 10^{12} Btu for residential heating is probably a low estimate. Two different Energy Information Administration (E.I.A.) data sources have higher estimates. One gives a 1975 figure of 377 X 10^{12} Btu, but it also shows a decline for the years preceding 1975, a decline that may well have continued through 1978 due to price effects (Ref. 7). The other source gives a 1978 figure of 425 X 10^{12} Btu (Ref. 8).

Our commercial/institutional oil use estimate was derived from Environmental Protection Agency data on oil consumption for 1976 (Ref. 3). We used this result -- 374 X 10^{12} Btu -- for our base year 1978 estimate. For comparison, the first E.I.A. source gives 377 X 10^{12} Btu for 1975, with a declining trend before that year (Ref. 7); the second gives a figure of 425 X 10^{12} Btu (identical to the residential figure) for 1978 (Ref. 8). Our commercial figure for 1978 is thus likely to be on the low side, but somewhat less on the low side than our residential figure.

REFERENCES

Massachusetts Audubon Society, data files developed for the New England Energy Congress study (Report II, Ref. 43). Unpublished.

Steven C. Carhart, The Least-Cost Energy Strategy: Technical Appendix. Arlington, Virginia: Mellon Institute, 1979.

U.S. Environmental Protection Agency, National Emissions Data Systems Fuel Use Report, EPA-450/4-79-020, 1979.

New England Load and Capacity Report 1980-1995. West Springfield, Massachusetts: New England Power Planning, April 1, 1980.

New England Energy Congress, A Blueprint for Energy Action, Final Report (Somerville, Mass., 1979), and work papers therefor.

S. Carhart et. al., The Brookhaven Buildings Energy Conservation Optimization Model, Formal Report, Upton, N.Y.: Brookhaven National Laboratories, 1978.

Energy Information Administration, Federal Energy Data System (FEDS), Statistical Summary. Washington, D.C.: U.S. Department of Energy, February 1978.

Energy Information Administration, State Energy Data Report, Washington, D.C., Department of Energy, Report DOE/EIA - 0214(78), April 1980.

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Final Draft

REDUCING NEW ENGLAND'S OIL DEPENDENCE THROUGH CONSERVATION AND ALTERNATIVE ENERGY

TECHNICAL REPORT IV

THE ALTERNATIVE SUPPLY STRATEGY SCENARIO

A Report to the
General Accounting Office
of the
United States Congress

Stephen Bernow
Adam Jaffe
Richard Rosen
David Nichols

April, 1980
Final Revision February, 1981

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1. INTRODUCTION AND SUMMARY

1.1 Purpose of the Alternative Supply Scenario

In Technical Report II, a conservation strategy scenario designed to reduce New England's dependence on oil consumption for electricity generation, was developed. There the approach focused on the demand side of the supply/demand relationship. A set of conservation policies and measures were established subject to the constraint that no change in the final services or end-use demands themselves occur. Rather, this set of policies and measures would achieve oil conservation through improvement in the efficiency with which these various final demands, ordinarily met by electricity purchased from a utility, are satisfied.

It is also possible to reduce the consumption of oil for electricity generation, without affecting the final demand serviced, by focusing on the supply side itself, the locus of the oil consumption. In Technical Report IV, therefore, attention shifts to the identification of a set of alternative electricity supply options.[†] While it is both possible and desirable to achieve oil conservation in this domain by improving the efficiency with which oil is consumed in the generation of electricity[*], the focus here is on supply options using renewable sources of primary energy. These options constitute a major approach to reducing the use of oil for electricity generation in New England.

In Technical Report II, the conservation strategy scenario was constructed out of measures affecting electricity demand over and above those assumed to occur in the Base Case. For Technical Report IV it is similarly necessary to specify the supply measures that are assumed to exist in the Base Case. The current NEPOOL capacity expansion plan is used for this purpose. The potential for oil reduction from alternative supply measures is measured relative to what would occur assuming extrapolation of the current NEPOOL construction plan and limited coal conversions.

[†] On-site cogeneration, although technically on the electricity generation or supply side, has already been discussed as a demand side conservation measure. While the demarcation could be construed to be on the basis of reducing purchased electricity, utility ownership of on-site facilities is not precluded.

[*] E.g., combined cycle turbines. Fuel cells are a borderline or hybrid case since they can use both petroleum derived and other, renewable, resources.

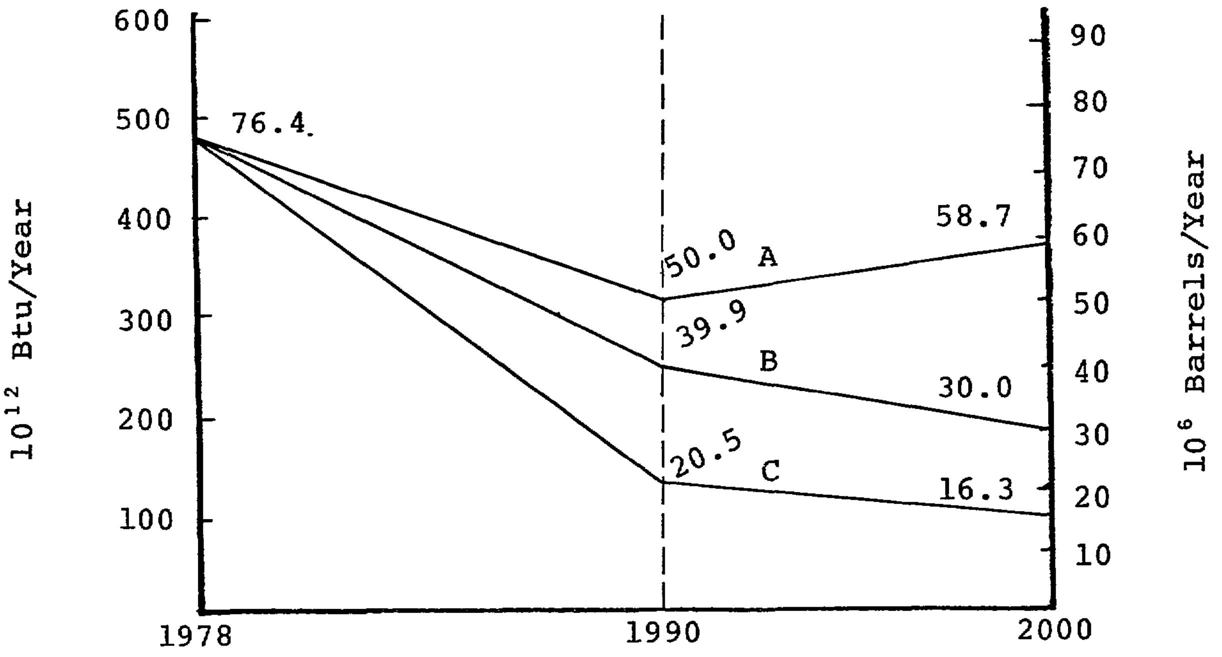
As with the elements of the conservation strategy, alternative supply options are selected that are both technically feasible and cost-effective. It is recognized that implementation of alternative supply options will take time. These measures are not expected to make a significant contribution before about 1990. The tests of feasibility and cost-effectiveness will be applied, therefore, to the technological and economic conditions expected to prevail by 1990. Since such predictions are inherently highly uncertain, care is taken to ensure that the inclusion of alternative supply measures in the estimated alternative generation potential embodies reasonably conservative assumptions.

1.2 Summary of Results

Figure 1 compares the estimated annual oil use for electrical generation in New England between now and the year 2000 under three scenarios. In the Base Case (including the "NEPOOL construction program"), oil use will fall from the 1978 level of some 76 million barrels per year to about 59 million barrels in 2000. Two approaches to reducing year 2000 consumption are presented. Vigorous development of alternative energy supply sources (without additional conservation) could reduce year 2000 oil use for generation to 30 million barrels per year. A vigorous conservation program (without alternative supply sources) could reduce oil consumption to about 16 million barrels per year, assuming the "NEPOOL construction program" is implemented. A combination of conservation and alternative sources could reduce oil-based generation to the minimum use necessary for the utility system to follow daily and seasonal load variations, which is probably less than 5 million barrels annually. In fact, if the alternative potential identified here were fully implemented in addition to conservation scenario implementation, some 25 to 50 percent of the generation from alternative sources would be substituting for other fuels, most likely coal. Since an oil-fired cost estimate was the criterion for assessing the attractiveness of measures and options on both the demand and the supply side, the analysis here cannot be held to positively confirm the direct economic attractiveness of full implementation of both the conservation and the alternative supply potential.

Figure 1

NEW ENGLAND OIL CONSUMPTION
FOR ELECTRICAL GENERATION



A: Base Case Forecast, NEPOOL Construction Program

B: Base Case Forecast, NEPOOL Construction Program plus alternative supply options.

C: Conservation Forecast, NEPOOL Construction Program

All Cases assume conversion of the Brayton Point and Mt. Tom Generating Stations from oil to coal. To the extent that there is additional coal-burning oil use will be less in each of Cases A, B, and C.

2. ASSESSING THE POTENTIAL FOR ALTERNATIVE SUPPLY

2.1 Criteria for Assessment of Electricity Supply Options

In order to realistically assess the potential for oil savings from electricity generation from alternative sources, it is necessary to identify technologies that appear likely to be both technically feasible and reasonably cost-effective in New England during the 1978-2000 period. Such "alternative sources" could include a large variety of technologies, other than conventional fossil fuel combustion and nuclear fission, that are capable of providing electrical energy to the grid. The present assessment focuses on electricity generation technologies that utilize renewable resources, rather than technologies that utilize fossil fuels.

For purposes of analytical caution, it was decided to focus on technologies likely to be technically feasible by 1990. This limits the study scope to alternative sources for which the underlying technology is proven and commercial-scale demonstration projects have been undertaken. For the purpose of judging cost-effectiveness, the cost per kwh of each alternative supply option was compared to the cost of fuel for oil-fired generation. This was estimated to be about 6-8¢/kwh (1980 $) in 1990*. The sum of fixed and variable costs of alternative supply options were compared with only the variable fuel cost of conventional generation because the need for additional capacity in New England is uncertain at this time. Furthermore, in the present analysis the alternative supply options are seen as displacing oil-fired generation rather than displacing elements of any capacity construction program. Of course, to the extent that alternative sources do provide additional capacity, they will be even more attractive if, within a context of new capacity needs, they compare favorably with other capacity expansion options. Technologies were considered likely to be cost-effective if the best current estimates of their 1990 levelized busbar costs per kwh were in or near the range given above.

For the purpose of this study, technologies are considered "demand-reduction" measures, rather than supply options, if they operate primarily to reduce a customer's demand for purchased electricity. Thus, dispersed windmills and cogeneration are not considered "supply" measures even though they could feed power to the grid part of the time.

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*The average price paid by New England utilites for oil was $4.13/MMBtu in January 1980 (Ref. 1). Assuming an average heat rate of 10,400 Btu/kwh (Refs. 18, 19), this translates to 4.3¢/kwh. Assuming that the price of oil will increase between 4% and 6% annually in real terms (Refs. 20, 21), this yields a 1990 cost of about 6-8¢/kwh in real 1980 dollars for the fuel component of oil-fired electricity generation.

The alternative technologies identified as the most promising for New England, on the basis of the technical and cost criteria given above, are wind power, conventional and small scale hydroelectric power, tidal power and municipal solid waste facilities for thermal and/or electrical energy production. In the following section, these technologies are described along with estimates of their costs and their potential for the New England region.

Over the long term, other technologies, such as solar electric production, may become viable. The identification of alternative potentials that are relatively near-term priority options is not intended to imply that policies to promote research, development and application of more long-term options should be pursued.

The potentials discussed below represent reasoned judgments based largely on the criteria of 1990 technical feasibility and cost-effectiveness. No systematic consideration has been given to institutional or environmental constraints that might limit the degree of realization of the potentials. However, we have attempted, in a preliminary and qualitative way, to take some account of which technologies are most likely to be substantially limited by such constraints in quantifying alternative potentials below.

2.2 Description of Technologies

Priority Options

Windpower. The extraction of energy from wind has a long history. Windmills were first used to generate electricity before 1900, and a 1.25 megawatt (mw) wind turbine was operated on Grandpa's Knob in Vermont in the 1940's. The widespread availability of cheap oil and gas, however, prevented substantial interest in wind generation until the mid-1970's.

The U.S. Department of Energy (D.O.E.) in conjunction with the National Aeronautics and Space Administration (N.A.S.A.), has a wind energy program which has the goal of commercial operation of wind energy conversion systems (WECS) in the megawatt size range by the mid-1980's. Several smaller units are already in use by electric utilities under D.O.E. sponsorship (Ref. 2). The MOD-2 2.5 mw turbine is being built by Boeing with delivery to D.O.E. of the first unit planned for June 1980 and the second and third by April 1981. It is expected that initial commercial introduction could begin as early as 1982 or 1983, with large-scale production under way by 1984 (Ref. 3). Wind generation is, therefore, considered technically feasible for the purpose of this study. The "wind farm" concept, a group of about fifty 2 mw units occupying about fifty acres is currently being discussed as a promising approach for ultimate commercialization (Ref. 4). Such concentration would be aimed at efficient management of operations and maintenance requirements of the machines, which could result in significant scale economies in these costs. The Bonneville Power Administration will begin testing the wind farm concept with three MOD-2 WECS in 1980 and 1981.

The cost-effectiveness of WEC systems is somewhat uncertain. The cost of commercial machines can only be estimated from experience with the construction of prototypes. These costs must be projected from the costs of current prototypes using an assumed "learning curve*" as well as factor input escalation assumptions. Moreover, the cost per kwh generated by a WECS depends on both the cost of the machine and the wind speed at the particular site. The latter will, of course, be site-specific, and furthermore it will affect the choice of machine design.

Lower costs per kwh will, in general, be achieved at WECS sites having higher average wind speeds. This requires that the WECS be designed appropriately for the specific wind conditions. The rated wind speed of the machine indicates the conditions for which it is designed and therefore used most efficiently. Since most of the wind energy occurring at a site will be carried by winds higher than the site average, optimally designed machines will generally have wind speed ratings considerably higher than the average wind speed at the site. Since the cost of the WECS (per kw) depends on the rated wind speed, comparisons of different machines can be misleading if their rated wind speeds differ. For example, a more costly machine with a high rated wind speed can produce cheaper power at a given windy site than a cheaper machine rated for lower speeds. Also, a machine that will produce low-cost power at the site for which it was designed would not do so at a site with a substantially different wind pattern. On the other hand, it appears that the sensitivity of optimum design to site characteristics is not so great that a design specific to each site will be necessary. It should be possible to select from a set of mass produced models (e.g., high, moderate, and low wind) for most sites (Ref. 5).

Due to these uncertainties, it is inappropriate to develop a single generic figure for the cost of WECS power. Estimates made by the Bonnerville Power Administration indicate that its prototype wind farm would produce power for 10¢/kwh. The California Energy Commission (C.E.C.) has made capital cost estimates which (converted to 1980 dollars) fall in the range $800-$1300/kw for the 100th commercial unit (Ref. 4). For a machine with design wind speed rating of 27.5 mph, the C.E.C. calculates a levelized busbar cost of power of 7.9¢/kwh, based on $1307/kw (1980 $) capital cost (Ref. 6). MITRE Corporation estimates that a machine operating in 1990 will produce electricity at a levelized busbar cost of 5.7¢/kwh (Ref. 7). Boeing is constructing a 2.5 mw unit rated at 27.5 mph, designed for optimum operation at a site with 14 mph average wind speed. The

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[*] Standard practice is to assume a 5% reduction in cost for every doubling of cumulative output (95% learning curve). Under this assumption, the 100th unit produced would cost about 70% as much as the prototype, ignoring inflation.

100th production unit of this prototype is expected to produce at a busbar cost of 2.5¢ to 5¢/kwh (Ref. 3).* Despite the breadth of this range of estimates it appears reasonable to conclude that electricity generation utilizing wind energy will be cost-effective by 1990 according to the criterion of this report.

It is difficult to estimate the magnitude of wind potential in the New England region. The economics of wind power depends strongly on the site conditions. Therefore, the regional potential in turn depends strongly on the presence and identification of suitable sites. Twelve mph is thought to be the minimum viable average wind speed (Ref. 8). The MOD-2 machine being built by Boeing is designed for a 14 mph average wind speed. Even average wind speeds are not, however, adequate to characterize potential sites. The distribution of wind speeds is crucial, because WECS produce most efficiently at their rated wind speeds (Ref. 9). The fraction of wind energy that is captured declines at speeds above or below this optimum, and the machine cuts out completely above a certain maximum and below a certain minimum speed.

There are estimates of the regionwide potential which indicate that wind potential may be significant. MITRE has estimated that 35 100-mw wind farms could be developed in New England by the year 2000 (Ref. 7). The New England Energy Congress, scaling national estimates by the President's Council on Environmental Quality to this region, estimated a regional potential of 5,400 to 10,800 mw by the year 2000 (Ref. 10). If this maximum estimate were realized, and the capacity factor is .3 (i.e., operation at rated capacity for an average of 30 percent of the time), windmills could generate about 28 million megawatt-hours (mwh) of electricity annually, saving the equivalent of 50 million barrels of oil. Similarly, a recent generation planning study performed by General Electric for the Electric Power Research Institute (EPRI), the utilities' main research agency, concluded that for oil-dependent utilities wind power might economically exceed 10 percent of a utility system's total installed capacity. This would be about 2200 mw based on current regional capacity, and about 2950 mw based on NEPOOL's planned year 2000 capacity. The California Energy Commission has also set a year 2000 goal of wind-powered generation serving 10 percent of that state's electricity needs (Ref. 22).

The economic attractiveness of wind power machines is significantly enhanced if the recent rapidly increasing cost of oil for utility electricity generation continues. Moreover, study by General Electric (Ref. 12) has concluded that, despite the intermittance of wind power electricity, storage devices are not required to increase the economic attractiveness of wind power systems. The GE report has shown that the cost-effectiveness of storage depends on the overall characteristics of the utility system and its load. At the levels of WECS penetration considered in this report, the attractiveness of storage is relatively insensitive to this penetration. The economics of the WECS themselves are, in turn, rather

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* Again this is converted from 1977 dollars (in Ref. 3), to 1980 dollars, assuming 30 percent total inflation.

insensitive to the level of storage. On the other hand, if one is interested in the capacity advantages of wind, it is important to note that study has indicated that from the standpoint of overall system reliability, the equivalent capacity addition would generally be in a range below 50% of rated capacity at the 10 percent penetration level considered here. In the final analysis this equivalence factor is utility system specific.

The above substantial estimates of the wind power potential in New England contrast with the figures mentioned by NEPOOL in a recent planning document for New England (Ref. 11). NEPOOL states that "under existing technological, economic and political conditions" the "maximum potential" for wind power by 2000 is 71.2 mw. This assertion is based on a survey of its member companies. However, even NEPOOL's capital cost figures for wind machines of $856/kw to $1177/kw indicate that wind energy at a site with an average wind speed of 15 mph or greater would fall below 9.3¢/kwh, and thus would probably come close to or meet our cost criterion. It is therefore not clear what basis NEPOOL has used which limits the "maximum potential" penetration of this technology so severely.

It is unclear at this time to what extent wind power will be significantly constrained by environmental objections. The megawatt-size machines discussed here are very large, and it is likely that the ideal wind locations would be in areas (along the coast, on top of mountain ridges) where aesthetic objections to their presence might be severe. Some of the prototype machines have also created problems with television interference and low frequence vibrations. The possibility that environmental objections may loom large could make our wind estimate the least cautious of the quantitative "priority options" listed in this section.

Conventional Hydropower. Technically feasible sites for new conventional hydro-electric generation capacity also exist in New England. The U.S. Corps of Engineers has identified 17 major sites with a total potential for 975 mw and 2020 gwh/year. These totals do not include the controversial Dickey-Lincoln School project in Maine, that could add 760 mw and 1540 gwh/year (Ref. 10). According to Ref. 10, the Corps has established favorable benefit/cost (B/C) ratios for less than half this capacity, with the remainder having B/C ratios in the range of .8 to 1.0. It is quite likely, however, that the 1979/1980 oil price increases have pushed all this capacity over the economic justification threshold. Nonetheless, it is reasonable to expect that projects planned for these sites would encounter substantial environmental, land and water use conflicts.

Small Scale Hydropower. Much attention has been focused on the potential for hydro-electric power at small dam sites in New England. In January, the New England River Basin Commission published a final Report based on its three-year investigation of this potential (Ref. 15). Carried out in conjunction with the U.S. Army Corps of Engineers, the study involved detailed engineering and economic analysis of the approximately 1,750 New England dams that do not now produce power but possibly could. This report showed that, while the maximum economic potential is well below the technically feasible limit, there exists significant potential that is already economical.

The economic potential is shown in Table 1. Depending on the required rate of return on the investment, approximately 500 mw of capacity in New England is cost-effective by our criterion, at a rate of return expected by a private enterprise. Public ownership, by lowering the required rate of return, could increase this to about 700 mw.

TABLE 1

HYDROELECTRIC POTENTIAL AT EXISTING DAMS IN NEW ENGLAND

(Based on August 1978 Construction Costs)

Required Rate of Return (Percent)	Output Cost (mills/kwh)	Number of Sites	MW	GWH/YR (.4 Capacity Factor)
6.9	90	448	740	2600
	67	317	640	2200
	45	209	470	1600
10.5	90	290	600	2000
	67	195	450	1500
	45	120	270	930
14.0	90	211	460	1700
	67	148	330	1200
	45	82	160	580

Source: Ref. 15

The 40% capacity factor is used by the NERBC/COE study because they consider it typical of existing hydroelectric power plants in the region (Ref. 15, Vol. I, p. 73). NEPOOL assumes a 50% capacity factor for small hydro (Ref. 11). In reality, capacity factors will vary widely for different sites. It is important to note, however, that the energy (GWH/YR) available at a particular site is fixed by the annual flow past the site and the hydraulic head of the dam. The capacity of the turbine to be installed (MW) and hence the capacity factor that will result are chosen on the basis of economics. If the turbine is sized to utilize the peak flow past the site, the maximum energy will be produced, but the plant will operate at a low capacity factor because the average flow will be much less than the peak flow for which the turbine is sized. At the other extreme, the turbine could be sized for the minimum flow, in which case it would operate at a 100% capacity factor but would lose much of the energy available at the site. The optimal turbine size (and hence capacity factor) is somewhere between these extremes. If the average optimum for New England turns out to be greater than 40% (i.e., turbines should be smaller relative to peak flows than was assumed by the NERBC/COE), then the capacity and energy totals in Table 1 are too large. If the optimum capacity factor is lower than 40%, then the true potentials are actually greater than those presented in Table 1.

Municipal Solid Waste. New England has already begun to utilize its municipal solid waste (MSW) as a resource. This is probably a result of high oil prices and waste disposal costs. Municipal waste can be used in facilities to generate thermal energy in the form of steam or hot water, electrical energy using steam, or both if operated in a cogeneration mode. Whether a market exists for these products from a given facility may depend on a number of considerations, including the levels, time variation, and dependability of these energy outputs, their proximity to the load center or customer, and their price. The RESCO plant, in Saugus, Massachusetts, was one of the first successful large resource recovery plants in the nation. This plant burns 1200 tons per day (tpd) of solid waste, and generates steam that is sold to a nearby General Electric plant. An 1800 tpd facility in Bridgeport, Connecticut, that processes MSW to produce recycled materials and a powdered fuel called "Ecofuel II" began operation in 1979. Ecofuel II is being burned with oil by United Illuminating Company at their Bridgeport Harbor station. Other facilities are under consideration for Hartford, New Haven, and elsewhere.

MSW can provide fuel for electric generation in one of three ways. A refuse-derived fuel (RDF) such as that produced in Bridgeport can be burned by the utility, usually along with existing fuels;* a utility can contract to purchase steam for use in an existing station from a facility that burns raw or processed MSW; or, a facility specifically designed to generate electricity from waste combustion can be constructed. These options will be among the considerations in siting a facility. In any case, the maximum potential of the resource can be estimated on the basis of the available waste stream.

The economics of a MSW facility can be characterized by an output price (in ¢/kwh or $/MMBtu of steam) and a "tipping fee" (in $/ton refuse paid by the waste supplier or agency responsible for waste disposal). For a given technical configuration, the output price can be lowered by raising the tipping fee, and vice-versa. To be cost effective, a facility must produce energy at a cost competitive with oil, while charging a tipping fee that is competitive with competing disposal costs. Within these constraints flexibility may be important for establishing or extending markets. As noted above, only counting the fuel cost, electricity from oil is expected to cost 6 to 8¢/kwh (1980 $) in 1990.

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*In Bridgeport, each pound of garbage produces about one-half pound of Ecofuel. Since the MSW has a heat content of about 4500 Btu/lb and the Ecofuel is about 8000 Btu/lb, about 85-90% of the energy in the MSW remains in the fuel.

Since this estimate is based on an oil cost of $5 to $6.75/MMBtu, refuse derived fuels would have to be priced in that range to be competitive. An equivalent price for steam, assuming 85 percent combustion efficiency, is $7 to $9 per MMBtu. The tipping fee that would be low enough to attract a steady MSW stream will be highly dependent on local disposal practices and costs.

Recent experience in the operation and planning/design of MSW facilities suggests that these facilities could be cost-effective under conditions that can be expected to prevail in New England during the next 20 years. In Saugus, Massachusetts, the RESCO plant sells steam to a nearby General Electric Company plant for a very attractive $2.50/MMBtu. At the same time it charges $13/ton (1977) as a tipping fee (Ref. 10). NEPOOL has estimated the capital cost of an MSW-fueled power plant at $2200-2750 per kw (Ref. 11).* If both operating costs and tipping fee benefits are ignored, this results in electricity costs of 7.3 to 9.2¢/kwh.** A planned 35 mw facility in San Francisco is expected to produce electricity at 3.3¢/kwh with a tipping fee of $15/ton (1980 $) (Ref. 6). While the overall attractiveness of an MSW facility producing electricity, RDF, or thermal energy will be site specific, it appears that, based on the estimates and experience, recovery of energy from MSW would be cost-effective according to the criterion used here, even with relatively low tipping fees.

While interest in the U.S. is presently in large (>1000 tons/day) plants, such plants are only feasible in metropolitan areas, since they require waste from about 500,000 people and transportation of MSW any great distance is not economical. In Europe, smaller plants (100-450 tons/day) are common. These could presumably be built here if they were economically justified. Here again, siting is important from both the input MSW side and the product market side. Last fall, construction began on a 150 tpd plant in Auburn, Maine. This plant is designed to produce steam for local industry to be sold at a price indexed to the price of oil. The plant is expected to cost $3.2 million, with an initial tipping fee of $8.50/ton (Ref. 13). It is unclear, however, whether the output from such a small plant (enough for about 5 mw of electric demand) would be sufficient to be of interest to an electric utility. The potential and problems associated with a large number of such facilities may be similar to those of other small dispersed sources such as on-site cogeneration and small scale hydro power.

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*Converted from 1979 dollars to 1980 dollars assuming 10 percent inflation.

**Assuming a fixed charge rate (i.e. annual capital charges) of 17.5% of total capital cost and an annual capacity factor of 60% (i.e. operation 60% of the hours in the year).

Brookhaven National Laboratory has made estimates (Ref. 14) of the energy available in MSW in 1970 for some New England towns. These are given in Table 2, along with the electrical output this could produce and the capacity this represents. It is likely of course, that some of the energy potential from MSW will be used directly by industry rather than for electrical generation. MSW could be burned with about 85% efficiency to produce steam, so about 85% of the heat content totals in column one of the table could be available as steam. It is also possible that MSW or RDF combustion could be used to cogenerate electricity and steam, or hot water, in which case the electrical output in Table 2 plus some process or space heat could be obtained. It should be noted that the totals in Table 2 include the waste already being used in the Saugus and Bridgeport facilities.

These values can be expected to increase gradually over time, as both the MSW output per capita and its average heat content rise due to increased affluence and greater use of plastics and paper. (Ref. 14). The values in Table 2 are, therefore, minimum estimates of future potential. The increased heat content also increases the economic attractiveness of using MSW as a fuel. Since disposal costs are also likely to rise in the future, the cost-effectiveness of recovering energy from MSW should continue to improve. So too should the economical distances for MSW facilities and thereby the fraction of available waste derived energy that can be economically produced. Because of the relatively high population density in most parts of New England, a large fraction of the theoretical municipal solid waste potential could be used economically, particularly if smaller (100-450 tpd) units become widely available.

Tidal Power. The technology for the generation of electricity from tidal action is similar to that used for hydroelectric generation, except that the direction of flow reverses with the tidal cycle, and the equipment must be designed to withstand the corrosive effects of saline water. Tidal variations on the order of 15 ft. are generally considered necessary for tidal power generation. Such a tidal range does occur along portions of the upper Maine coast.

Cost estimates for power produced from tidal projects in Maine range from about 7 to 8.5¢/kwh in 1980 $ (Ref. 10, converted from 1976 dollars assuming 35% total inflation.) If realized, these costs would be cost-effective by our criteria, though they are too high to allow economic justification of the projects according to federal (B/C ratio) standards.

The maximum potential for tidal power in New England has been estimated at 1200 mw or 3000 gwh (Ref. 10). This potential consists of the Cobscook Bay area and other sites along Maine's upper coast. Development of these projects would require resolution of potential environmental conflicts.

TABLE 2

1970 SURVEY OF ENERGY POTENTIAL FROM SOLID WASTE IN NEW ENGLAND

CITY	TRILLION BTU/YR	GWH/YR*	MW†
Connecticut			
Hartford	3.65	291	55.3
New Haven	1.93	154	29.2
Bridgeport	1.69	135	25.6
New London-Groton	1.13	90	17.1
Waterbury	1.13	90	17.2
Stamford	1.12	89	17.0
New Britain	.98	78	14.9
Middletown	.93	75	14.2
Norwalk	.70	56	10.6
Danbury	.43	34	6.5
Meriden	.30	24	4.6
Total Larger Towns	13.94	1112	212.
Entire State**	20	1580	300
Massachusetts			
Boston	14.92	1189	226.2
Springfield-Holyoke	2.87	229	43.5
Worcester	1.87	149	28.3
Lawrence-Haverhill	1.26	100	19.1
Lowell	1.15	92	17.5
Brockton	1.03	82	15.6
New Bedford	.83	66	12.5
Pittsfield	.43	34	6.5
Fall River	.42	34	6.4
Total Larger Towns	24.78	1974	376
Entire State**	38	3050	580
New Hampshire			
Manchester	.63	50	9.5
Concord	.45	36	6.8
Nashua	.36	29	5.5
Total Larger Towns	1.45	115	21.8
Entire State**	4.8	380	73

TABLE 2
(Continued)

	CITY	TRILLION BTU/YR	GWH/YR*	MW*
Maine				
	Bangor	1.04	83	15.7
	Portland	.77	61	11.6
	Lewiston-Auburn	.39	32	6.0
	Total Larger Towns	2.20	176	33.3
	Entire State**	6.5	520	99
Rhode Island				
	Providence	5.07	404	76.8
	Newport	.42	33	6.3
	Total Larger Towns	5.49	437	83.1
	Entire State**	6.2	490	94
Vermont				
	Burlington	.43	34	6.5
	Entire State**	2.9	230	44
New England				
	Total Larger Towns	48.33	3850	732
	Entire Region**	78	6250	1190

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[*] Assumes a heat rate of about 12,500 Btu/kwh and a capacity factor of .6. These figures are based on hypothetical co-combustion of refuse and coal. Other schemes, such as production of RDF, would have slightly different efficiencies, but the potential would be approximately the same.

[**] Estimated based on 1970 Census population, assumed generation rate of 4 lb/capita/day, and assumed average heat content of 4500 Btu/lb.

Wood. The wood resources in New England could provide the basis for the development of the wood-electricity option in the region. Existing technology derives steam suitable for electrical generation from the combustion of green wood chips in a spreader-stoker boiler. A 17 mw wood-fired power plant is currently operated by the Burlington (Vermont) Electric Department, and planning is underway for a 50 mw facility expected to come into service November 1983 (Ref. 11). NEPOOL has estimated that the planned facility will produce electricity at 9 to 11¢/kwh.* A facility of this size, however, requires a very large and steady supply of wood -- about 60 to 70 truckloads per day for the 50 mw plant. Since there are several competing uses for the region's forest and wood resources, it is not certain at this time that the development of a number of such facilities would entail an efficient use of these resources. Thus, the cost-benefit criterion for the development of this resource would ultimately require a more extended set of comparisons and analyses than a direct comparison with oil costs.

Other Supply Options

There are other technologies and primary energy sources that could be used to provide electricity in the New England region as part of an oil conserving strategy. Their exclusion from the foregoing discussion should not imply that they will not be viable energy supply options in the coming decades. Rather, it represents a judgement that the technologies discussed earlier have a sufficiently higher chance to achieve commercial status to merit priority attention. The second group of supply options are discussed briefly below.

Solar Generation. Electricity can be generated in two ways using solar radiation as the primary energy source. The direct heat of the sun can be used, with appropriate collecting and concentrating equipment, to produce steam to drive a conventional turbine generator. This is generally referred to as a solar thermal electric system. Solar radiation can also produce electricity by striking arrays of photovoltaic cells fabricated from certain semiconductor materials. Both of these technologies are being studied by the U.S. Department of Energy (D.O.E.). The D.O.E. has recently budgeted nine photovoltaic demonstration projects ranging from 17.5 to 150 kw, and a pilot solar thermal plant with 10 mw capacity is scheduled to begin operation in California next year (Ref. 6). Solar thermal electric systems have not yet been demonstrated commercially. Consequently, it cannot be considered likely that they will be feasible until after 1990. The technical feasibility of photovoltaic electric generation has been established; however, the cost remains prohibatively high. The California Energy Commission has estimated a busbar cost of 18¢/kwh (1980 $) based on D.O.E. cost reduction targets for photovoltaic power production (Ref. 6). Thus, without substantial cost reducing developments this technology cannot be expected to meet the cost-effectiveness criterion used in this report.

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*The NEPOOL figure has been converted from 1979 to 1980 dollars assuming 10 percent inflation.

Ocean Power (other than tidal). The possibility of generating electricity from wave action and ocean thermal gradients has been discussed over the past few years. Ocean thermal and wave energy are still at the early stage of development. It is unlikely that the waters near New England would have sufficient temperature gradient* or adequate wave energy characteristics for these sources to be suitable even if they do become technically feasible.

District Heating. District heating is a form of central-station cogeneration that reduces oil use per kwh of electricity generated due to the correlated production of thermal energy for heating (or cooling) building complexes or neighborhoods. It does not fall within our criterion of an alternative technology, since it does not ordinarily utilize renewable resources. Nevertheless it is a promising method of increasing the efficiency of energy production. Moreover, a central-station cogeneration district heating system could derive both technical and economic advantages from local MSW thermal plants providing supplementary heat. On the other hand, an established district heating network could provide economic advantages to contemplated MSW facilities. In March, 1980, the United Illuminating Company completed a study to determine the district heating potential for New Haven and Bridgeport. The economics of district heating appear favorable due to the high cost of space heating in Connecticut, a condition that exists throughout New England. Any city in New England, including Boston, that has conventional power plants situated in or around the city could probably be economically served by a district heating system at least for part of its heating requirement (Refs. 16, 17). However, when existing power plants are connected to a district heating system, the electrical capability of the plants has to be derated somewhat. Electric supply technologies based on renewable resources could help make up for this loss.

ESRG has studied district heating extensively and is convinced that it is a promising mid-term option. In fact, to the extent that government aid is available to make it more currently cost-effective, as on the Bridgeport project that U.I. plans to move ahead with, it is a near term option. Its exclusion from this study, with its focus on renewable resource options, was only part of an attempt to delineate a concrete research design.

2.3 Summary of Alternative Electric Generation Potential

Table 3 presents estimates of the feasible and cost-effective alternative electrical generation potential in New England. These totals are in addition to use of these resources already planned by NEPOOL and hence included in the Base Case. For comparison, NEPOOL (Ref. 11) estimates of the potential, similarly adjusted for plants already included in the Base Case, are presented in Table 4.

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*Rapidity of temperature drop between the surface and depths below.

TABLE 3

ALTERNATIVE ELECTRIC GENERATION POTENTIAL IN NEW ENGLAND

(BEYOND BASE CASE[1] QUANTITIES)

	1990			2000		
	CAPACITY (MW)	CAPACITY FACTOR[2]	ANNUAL ELECTRIC GENERATION (GWH)	CAPACITY (MW)	CAPACITY FACTOR[2]	ANNUAL ELECTRIC GENERATION (GWH)
Wind	500	.3	1300	2900	.3	7600
MSW	480	.55	2310	850	.55	4100
Small Hydro	510	.4	1790	510	.4	1790
Conventional Hydro	195	.25	420	580	.26	1300
Tidal	12.5	.37	40	710	.29	1800
Wood	30	.7	180	80	.7	490
Total	1730	.40	6040	5630	.35	17,080

1. The Base Case includes existing capacity: 1290 mw of large-scale hydro, 60 mw of refuse energy (in the form of fuel pellets made at Bridgeport), 17 mw of wood capacity in Vermont, and negligible amounts of other alternative capacity. It also includes the already planned refuse plants of Massachusetts Municipal Wholesale Electric Cooperative (MMWEC 1 and 2, totalling 150 mw), 91 mw of planned small hydro, and the planned J. C. MacNeil wood station in Vermont (50 mw). Thus all of this capacity is deducted from the capacity shown here.

2. Capacity factors are from Ref. 10 except in the case of small hydro (Ref. 15) and wood (Ref. 11). Capacity factors for individual conventional hydro projects range from .24 to .46, and for individual small hydro projects from .27 to .35.

TABLE 4

NEPOOL ESTIMATES[1] OF ALTERNATIVE SUPPLY POTENTIAL[2] FOR NEW ENGLAND

	1990			2000		
	CAPACITY (MW)	CAPACITY FACTOR	ANNUAL ELECTRIC GENERATION (GWH)	CAPACITY (MW)	CAPACITY FACTOR	ANNUAL ELECTRIC GENERATION (GWH)
Wood	32-243	.70	196-1490	82-502	.7	503-3078
MSW	0-175	.60	0- 920	25-410	.7	153-2514
Small Hydro	60-334	.5	262-1462	101-482	.5	442-2111
Wind	9- 38	.3	24- 99	13- 71	.3	35- 187
Total	101-790	~.55	482-3971	221-1465	~.6	1133-7890

1. Estimates are from Ref. 11 dated December 1979. NEPOOL numbers are rounded to the nearest whole integer.

2. NEPOOL planned facilities listed in note 1 to Table 3 are deducted from the NEPOOL estimates in Ref. 11 on the assumption that they had been included therein due to their status as planned capacity additions. Table 4 lists only estimates of potential exclusive of that existing or planned, for comparison with Table 3.

advanced state of development of WECS and their relatively competitive economics. Of course, the NEPOOL estimates assume existing economic conditions, but these can hardly be expected to prevail in 2000, and the cost of oil and other utility fuels will likely rise substantially in real dollars by then. The estimated potential of 2900 mw assumes that environmental objections will not significantly hinder the development of favorable WECS sites. To the extent that such objections are, in fact, likely to occur, this estimate should be considered very uncertain.

The capacity factor for WECS depends on the site. An average capacity factor of 30% has been assumed, giving a regionwide annual energy production estimate of 7600 gwh for the year 2000. For 1990, it is assumed, somewhat arbitrarily, that 500 mw of the ultimate total (year 2000) capacity, corresponding to five large wind farms regionwide, could be achieved.

For municipal solid waste, it is assumed that the full potential from the larger towns in Table 2 could be recovered by 1990. When the existing capacity is subtracted, this is about 480 mw corresponding to 2310 gwh per year. For the year 2000, recovery of an amount of energy equivalent to the total heat content of MSW in New England in 1970, 850 mw or 4100 gwh, is assumed. In fact, there are some parts of New England where MSW energy will probably never be recovered, because of low disposal costs and very low population density. Such areas, however, generate a very small fraction of the region's waste. It is likely that the increase in waste generation and heat content over 1970 levels will more than compensate for the small amount of waste that may not be recovered.

The year 2000 estimate for MSW potential in New England given above is about 65% greater than NEPOOL's "maximum" estimate of 510 mw. This is probably due at least in part to NEPOOL's assumption of existing economic conditions (Ref. 11). It is also true that some of the MSW potential will be used by industry, in which case it would be unavailable to the utilities. Oil savings, however, would be similar whether the resource is used by industry or NEPOOL.

For small hydro, all the sites identified by the New England River Basin Commission Corps of Engineers as cost-effective by the criterion of this report* have been included. After subtracting the small hydro capacity included in the NEPOOL plan, this is 510 mw. All this potential is assumed to be developed by 1990. This estimate is somewhat higher than NEPOOL's maximum of 480 mw. The NERBC study is, however, the most careful and thorough one available.

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*At private rates of return of 10.5 percent.

For new conventional hydroelectric power and tidal power illustrative fractions of the technically feasible potential discussed earlier have been included. Since the primary constraints to development of this potential are environmental, institutional, and social rather than economic, any estimate must be fairly arbitrary. The amounts included in Table 3 are those given by the New England Energy Congress in their supply mix scenarios.* The Energy Congress report was a consensus document reflecting the views of representatives of many interest groups. Thus, there is some reason to hope that these goals can be realized.

For tidal power, these estimates are based on a small demonstration project by 1990, plus development of Cobscook Bay (500 mw) and other upper Maine coast (200 mw) sites by the year 2000. For new hydro, the estimates assume four sites identified by the Corps of Engineers will be developed by 1990 (195 mw), plus seven additional sites (385 mw) by 2000.

Finally, for wood, NEPOOL's minimum estimate of the potential has been adopted, since it appears that the most economical use for wood and wood waste is for home heating and cogeneration in wood-based industry, not for utility electrical generation.

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* The Energy Congress target dates were 1985 and 2000. Here we made the conservative assumption that their 1985 targets would be achieved by 1990.

3. EFFECTS OF CONSERVATION AND ALTERNATIVE SUPPLY OPTIONS ON THE NEW ENGLAND GENERATING MIX

Figure 2 illustrates the current electricity generation fuel mix in New England, and the future mixes that might be expected, assuming implementation of a projected NEPOOL construction program (See Sec. 2.2 of Summary Brief for list of plants). In 1978, about 58% of the region's electrical energy was generated with oil. Under the ESRG Base Case demand forecast, this would decline to about 30% in 1990, primarily because of increased nuclear capacity and conversion of the Brayton Point plant from oil to coal. (Mt. Tom and Brayton Point are the only conversions assumed here.) This percentage would stay roughly constant between 1990 and 2000, though the absolute quantity of oil burned would increase, until by 2000 the region would be burning almost 80% as much oil for generation as it did in 1978, despite the addition of almost 7000 MW of additional non-oil capacity.

The analysis below assumes that oil is the marginal fuel for the generation system at all times. That is, all non-oil facilities are assumed to operate to the maximum of their capacity, with oil plants operated only as much as needed to meet the remaining demand. Nevertheless, some oil is burned every hour of the year. This assumption is consistent with the focus of this report -- minimizing oil consumption -- and is also consistent with the economic dispatch practices of the utilities, since the cost of oil makes oil-fired plants the most expensive to operate. There is, however, some minimum amount of oil that would be needed to operate peaking and cycling plants necessary to follow daily and seasonal load variations in the absence of storage facilities. This minimum amount could be up to about 5% of total delivered energy. Neither conservation nor alternative sources can be used to reduce oil consumption below some such minimum.

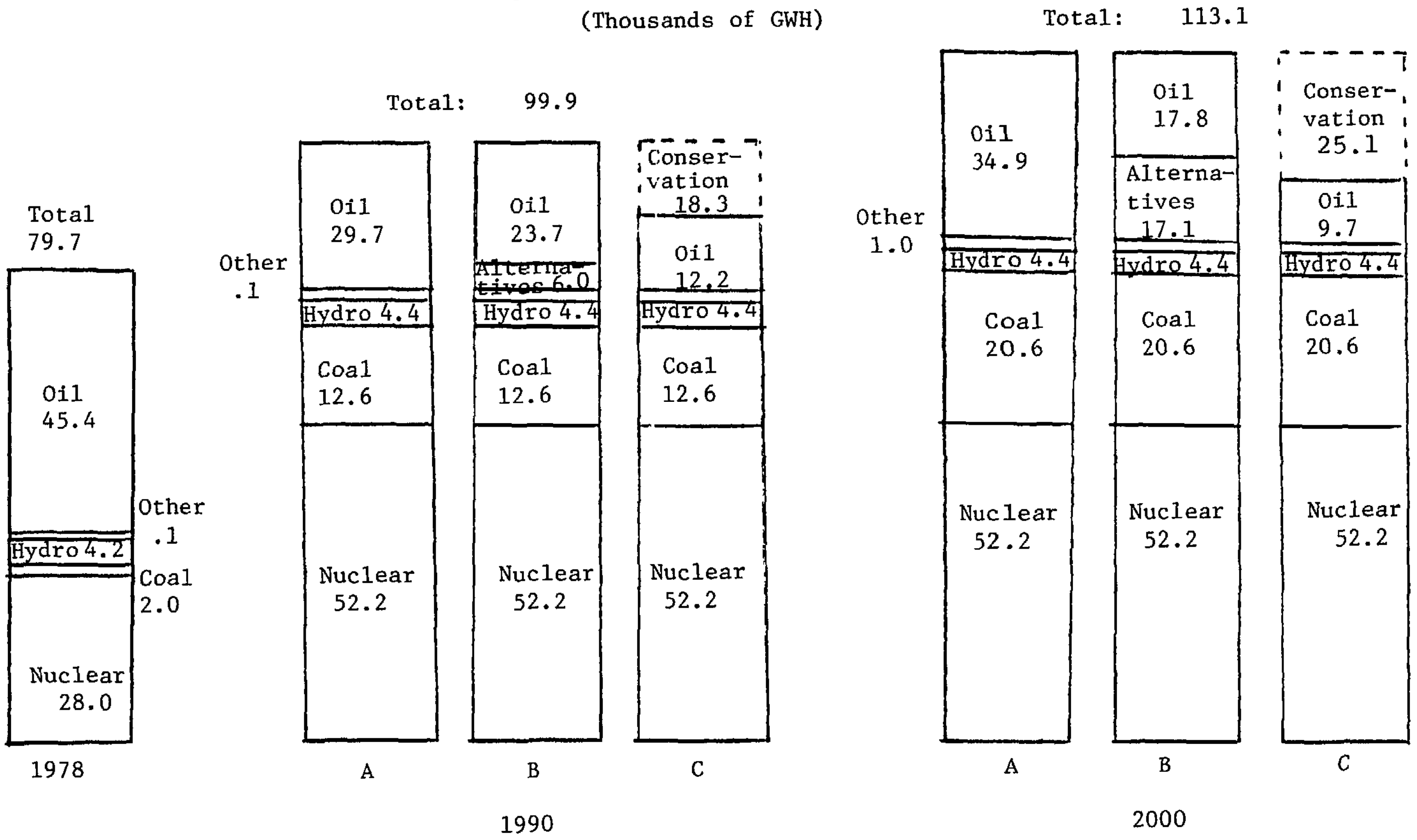
Because of the position of oil as the marginal fuel, the effect of electricity conservation is to reduce oil-based generation by the full amount of the energy saved. Each GWH of electricity saved reduces the region's oil consumption by about 1700 barrels of oil. Under the conservation strategy case, oil would be needed for only 15% of electrical generation in 1990 without any alternative supply options. This would be further reduced to about 11% in 2000, at which time the region would be burning about 25% as much oil as it did in 1978, if the "NEPOOL construction program" is carried out.

Figure 2 also illustrates the potential for reduction of oil consumption by use of alternative supply sources. As long as oil is the marginal generating fuel, alternative sources also displace oil; each GWH hour generated saves the same 1700 barrels. Under the 1990 oil-based generation to 23.7 thousand GWH, or about 24% of all generation. By the year 2000, alternative sources could reduce oil-based generation to 17.8 thousand GWH, or about 16% of all generation.

FIGURE 2

ELECTRICAL GENERATION BY FUEL TYPE [1]

(Thousands of GWH)



A: Base Case Forecast, NEPOOL Construction Program

B: Base Case Forecast, NEPOOL Construction Program plus alternative supply options.

C. Conservation Forecast, NEPOOL Construction Program

[1] All Cases assume conversion of only the Brayton Point and Mt. Tom Generating Stations from oil to coal. "Hydro" refers to existing conventional hydro. A small amount of other "alternatives" is included in "other." The "Alternatives" blocks contain the array of generation quantified in Table 3.

We have not constructed a scenario combining the potentials for conservation and alternative generation technologies to exhibit the degree of oil savings possible. This is because oil use in the Conservation Case is already low enough that oil can probably not be considered the marginal fuel at all times. Once the Conservation Case is assumed implemented, it cannot be assumed that alternative sources could substitute on a one-for-one basis for oil-fired generation. During off-peak hours demand would probably be satisfied entirely by non-oil generation. Most alternative-source generation cannot be dispatched at will and must be used when it is available. For example, some of the listed wind potential would be realized at night. Under the Conservation Case, night-time demand would probably be low enough to be satisfied entirely by non-oil generation. Thus, wind generation at such times would not reduce oil consumption. Most of the 17,100 GWH of such generation identified for the year 2000 would displace non-oil generation (probably coal) during off-peak hours.

An alternative-source generation would reduce oil consumption by some amount even in the Conservation Case, for some of its output would in fact be available at times when oil is still being burned. It would be necessary to employ a detailed generation dispatch model in order to ascertain precisely what fraction of alternative-source generation would displace oil in the Conservation Case. If enough alternative-source generation were available on a timely basis, 5300 GWH of oil-fired generation could be displaced. This is based on 5 percent of year 2000 generation (4400 GWH) remaining oil-fired for peaking and cycling functions. In the limiting case, in which no oil-fired generation is required, the full 9700 GWH of remaining year 2000 oil-fired generation might be displaced by alternative sources. Thus, between 25 and some 50 percent of alternative-source generation might substitute for oil even in the Conservation Case.

In addition to those oil savings it will produce, implementing the alternative supply scenario in addition to conservation has other benefits. Reduction of coal use has environmental benefits and probably has economic benefits too.

From a long-run point of view of the energy system as a whole, we may have to consider a transition away from coal, just as we have from oil. It, too, is a finite resource, and its use may be severely limited in the next century by the buildup of atmospheric CO_2. Development of alternatives now could make the transition from coal less traumatic than might otherwise be the case.

In addition, it is possible that some of the nuclear or coal plants in the NEPOOL plan may not be built. In that case, oil use could still be kept to a minimum by aggressive development of the alternative supply technologies. For example, the 17,000 gwh of alternative supply potential that we identified is equivalent to 94% of the combined output of the Seabrook 1, Seabrook 2, and Pilgrim 2 plants (assuming 60% capacity factor for the nuclear plants).

These results also are useful for considering the issue of coal conversion in New England. We have assumed conversion of only the Mt. Tom and Brayton Point facilities, since these were the only conversions indicated as likely at the time of this analysis. In fact, the above discussion of alternative sources under the Conservation Case applies as well to coal conversion: if conservation is implemented, there will be very little required oil-based generation left to convert, assuming that the NEPOOL construction program is carried out. Except during peak hours, the converted plants would lie idle as demand was met entirely from planned non-oil generation capacity. Of course, coal conversion could reduce oil consumption considerably during the 1980's, in the period before NEPOOL's major capacity additions are on-line. But coal conversion would be needed to achieve minimum oil use after 1990 only if the NEPOOL construction program, the conservation scenario and the alternative generation potential are all seriously limited in their implementation.

REFERENCES

1. U.S. Department of Energy, *Cost and Quality of Fuels for Electric Utility Plants - January 1980*, FPC Form 423, DOE/EIA-0075 (80/01).

2. Glasgow, J.C. and W.H. Robbins, "Utility Operational Experience on the NASA/DOE MOD-OA 200 KW Wind Turbine," *Proceedings of the Sixth Energy Technology Conference*, February 1979.

3. Low, J.E. and W.W. Engle, "The MOD-2 Wind Turbine -- Status and Outlook," in Ref. 2.

4. California Energy Commission, *Technical Assessment Manual*, Volume 1, Electrical Generation. September, 1977.

5. JBF Scientific Corp., Summary of Current Cost Estimates of Large Wind Energy Systems. April, 1977.

6. California Energy Commission, *Commercial Status*, *Electrical Generation and Non-Generation Technologies*. September, 1979.

7. Miller, C.G. and D.L. deJong, *Toward a National Plan for Accelerated Commercialization of Solar Energy: Utility Applications Workbook*, MTR-80W00022. January, 1980. MITRE Corporation.

8. Davitian, H., *Wind Power and Electric Utilities: A Review of Problems and Prospects*, Brookhaven National Laboratory, April, 1978.

9. March, D.W., *Requirements Assessment of Wind Power Plants in Electric Utility Systems*, EPRI Report ER-798-SY. January, 1979.

10. *Final Report of the New England Energy Congress*. May, 1979.

11. Alternate Generation Subgroup of the NEPOOL Generation, *Task Force Assessment of Alternate Generation Potential in New England, 1985-2000*. December, 1979.

12. "Requirements Assessment of Wind Power Plants in Electric Utility Systems," prepared by General Electric Company, Schenectady, New York, EPRI ER-978-SY, Volume 1, Summary Report, January 1979.

13. "Auburn Builds Resource Recovery Facility," *Energy Forum in New England*, Fall 1979.

14. Meier, P.M. and McCoy, T.H., *Solid Waste as an Energy Source for the Northeast*, BNL 50559. June, 1976.

15. New England River Basin Commission, *Potential for Hydropower Development at Existing Dams in New England*. January, 1980.

16. Santini, D.J., Davis, A.A., and Marder, S.M., Economic and Technical Analysis of Retrofit to Cogenerating District Energy Systems; North Central Cities, Argonne National Laboratory, ANL/CNSV-TM-11, June 1979.

17. Davis, A.A., Santini, D.J., Marder, S.M., and Bernow, S.S., Analysis of Costs and Scarce Fuel Savings Associated with Nine Eastern and North Central Center City Conversions to a District Energy System, Argonne National Laboratory, ANL/CNSV-TM-12, February 1979.

18. Department of Energy, Monthly Cost and Quality of Fuels, December 1978. (Oil consumption for electrical generation, Btu.)

19. Edison Electric Institute, Statistical Yearbook 1978. (Oil based generation, gwh.)

20. Direct Testimony and Exhibits of Neil H. Talbot, Theodore P. Heuchling, and Donald H. Korn of Arthur D. Little, Inc., Maine Public Utilities Commission, Dockets U3238 and U3239, filed April 18, 1979. (1979-1990 real oil fuel price increase of over 6 percent.)

21. Energy Information Administration, Service Report, Preliminary Energy Forecasts for Annual Report to Congress 1979. (1979-1990 oil price increase of 4 percent.)

22. "Environmental and Safety Standards Begin Emerging for Wind-Powered Generators," Electrical Week, September 1, 1980.

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Draft Report

REDUCING NEW ENGLAND'S OIL DEPENDENCE THROUGH CONSERVATION AND ALTERNATIVE ENERGY

TECHNICAL REPORT V

THE IMPACT OF ENERGY CONSERVATION ON EMPLOYMENT

A Report to the
General Accounting Office
of the
United States Congress

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1. INTRODUCTION AND SELECTED RESULTS

1.1 Scope of the Report

This is the fifth in a series of reports to the United States General Accounting Office dealing with the potential for oil displacement through conservation and renewable resources in New England. Technical Report I presented a long-run forecast of future electric demand and energy requirements in each state in New England. This forecast, developed on an integrated end-use forecasting model of electric demand in each state, is designed to represent estimates of future electricity needs should the present identifiable trends in energy prices, supply availability, energy conservation, and government policies continue for the next twenty years. In Technical Report II, an alternative to this "Base Case" forecast is developed by reforecasting assuming the phase-in of an energy conservation strategy for New England. The potential electricity savings which could be achieved during the forecast period (1980-2000) by implementing feasible, cost-effective energy conservation opportunities beyond those included in the Base Case are quantified in the "Conservation Strategy Scenario."

Technical Report III quantified the additional regional savings in direct on-site oil use for building space and hot water heating which would result from the conservation strategy. Additionally, New England oil savings resulting from reduced electricity consumption in the Conservation Strategy Scenario are combined with the direct savings to compute estimates of the net oil savings which would result should the region manage demand growth through conservation policy innovations. Technical Report IV outlines the feasibility and potential of cost-competitive alternative electric energy supply options in New England, including wood, solar, wind, hydropower, and solid waste. The oil savings potential resulting from vigorous pursuit of these options over the next twenty years was quantified.

In this report the indirect economic ramifications of the conservation measures embodied in the conservation scenario of Reports II and III are assessed. Specifically, an input-output analysis of the New England regional economy is used to quantify the impacts of full implementation in New England. The results of the analysis indicate that large employment increases would result if the conservation scenario were implemented. Changes due to residential sector conservation alone would produce approximately 16,700 additional jobs per year between 1980 and 2000. These positions represent a net increase, allowing for some decreased employment in energy supply-related fields. The bulk of the employment gains are not directly caused by conservation activities. Instead, they arise from the indirect effects of conservation investments and consequent energy savings upon the economy.

The task is to identify the relative employment impacts in the earlier reports and estimate the changes in employment in shifting from the "business-as-usual" policy framework (the basis of the Base Case forecasts) to an aggressive conservation policy approach (specifically those which formed the basis of the Conservation Strategy forecasts). Such employment impact estimates provide an additional dimension for assessing the merits of alternative long-term energy policy strategies beyond such questions as relative social costs, environmental tradeoffs, and scarce fuel conservation.

In analyzing employment impacts, the end-use methods adopted in the earlier reports for forecasting electric energy and demand have been continued. The Conservation Strategy forecast differs from the Base Case forecast due to the implementation of technologies and activities designed to improve the efficiency of energy use in New England. In this Technical Report, the employment impacts associated with such a shift in the residential sector are developed by collecting the effects of each of these conservation measures. The analysis links the differences between the two forecasts to the implementation of specific measures, which in turn leads to difference in aggregate employment and in the mix of employment by job type.

1.2 Background on Energy and Employment

The relationship between energy policy and regional employment/ economic activity is of particular importance in New England where a number of economic difficulties are currently confronted. Many of these difficulties, such as aging physical plant, are related to the area's status as a mature economic region (Ref. 1). Employment repercussions are important considerations in evaluating alternative New England regional planning or policy choices. In particular, with energy issues now on the agenda in policy deliberations, an important factor has emerged for addressing, at least in part, some of the area's economic development requirements.

As this report has quantified, there are two important ways in which the region's dependence upon foreign oil can be eased: curtailment of demand or substitution of other sources of energy. The first involves the promotion of conservation together with the use of alternative sources of energy at the point of consumption. The second involves displacing the oil used for electric generation by the construction of typically nuclear or coal fired electric generating plants, together with the conversion of existing oil fired facilities to coal where feasible and environmentally appropriate.

Advocates of the second approach often stress the favorable impacts such projects might have upon the local economy. In addition to decreasing dependence upon foreign oil, such projects are seen as a source of employment, both directly through the employment of otherwise idle construction workers and indirectly through the manufacture and sale of materials to the construction project, spending by the newly employed construction workers, and all the other activity stimulated by those expenditures. Power plants are large projects having effects on the local economy which are extremely visible.

Conservation, as defined and discussed in Technical Report II of this series, results from a large number of small decisions. The inherently diffuse nature of the conservation strategy option makes its economic consequences more difficult to gauge than large-scale central station projects.

However, for New England to make informed choices concerning its energy and economic future, all the major consequences of both alternatives must be consistent. At this time, a major missing element of information is the probable effect of conservation on the regional economy. The goal of the present Technical Report is to help fill this gap. However, before presenting the approach and results used for estimating employment impacts in New England of the Conservation Strategy, a brief sketch of the results obtained elsewhere will be presented to provide a background against which to view and evaluate the findings.

Studies concerned with the energy/economy interface originally focused on economy activity at a general level. The impetus for such studies was a desire to anticipate the impacts of changes in energy price and availability on economic activity in order to facilitate interventions to mitigate the repercussions of rapid price increases or fuel shortages. This type of analysis has led, for example, to proposals at the national and local level for the substitution of coal for petroleum products where possible.

Recently, it has been recognized that analysis of the energy/economy interaction could shed light on the specific economic problem of unemployment. Most analyses of the connection between energy and unemployment have followed the pattern developed by Bruce Hannon and his colleagues at the Center for Advanced Computation at the University of Illinois in their studies of the employment consequences of changes in capital expenditure patterns (such as the diversion of highway trust funds to mass transit facilities).* In such studies, a set of expenditures resulting from a given policy option are identified, their cost is determined, and their total economic and employment impact is assessed. In general, this body of work shows that a shift in expenditures away from capital intensive investments leads to an increase in employment.

Over the last few years, there have been a large number of studies focused on the connection between energy and employment, particularly employment in solar energy conservation development. The United States Department of Energy has recently performed a survey of the data bases, models, and studies in this area, concluding that while information is increasing, existing studies do not yet provide a sufficiently complete picture of the energy/economy interaction (Refs. 3 and 4). It further suggests the importance of considering not only indirect effects in addition to direct job creation but also the timing, duration, mix, and geographic distribution of jobs created. The DOE survey suggests that policies which promote conservation and the development of solar energy can at the same time stimulate the economy and create a net increase in employment.

Studies involving the regional employment impact of energy policy decision require the development and use of regional economic models. These models are tools which permit the analyst to draw together the various impacts of a policy as well as tracing its effects throughout the economy. There are numerous approaches to the development of such models. These are reviewed briefly in Appendix A of this Technical Report. In order to perform its analysis, the ESRG Staff has developed an extensive computerized model which makes use of the Regional Industrial Multipliers, developed by the Bureau of Economic Analysis of the Department of Commerce, to provide a complete and detailed analysis of the effects of specific conservation measures on the economy of a state or region. This model, developed under contract with Brookhaven National Laboratory, has been extended and applied in four regional studies, two of which have been in the New England area. The approach is discussed in Section 2 of this Technical Report; the mathematical structure of the model is specified in Appendix B. Here, a brief overview of the methods of analysis is presented as an aid to understanding the summary findings given in Section 1.3 below.

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* See Ref. 2 for a summary.

To review, in earlier volumes of this report, base and conservation case forecasts were developed for each of the New England states. Because the forecasts are end-use based, the conservation producing measures which impact residential consumption can be quantified in an appropriately detailed manner. For example, one might, as a part of a conservation plan, wish to increase the installation rate of storm windows. In the forecast model, this would appear as one of the factors involved in reducing the energy demand for space heating. Comparing the base and conservation forecasts allows the identification of the exact number of added storm windows each year. This provides the implementation data for our economic analysis. Analagous procedures for the full array of conservation measures given a running stream of disaggregated conservation implementation which is used to drive the employment impact model.

To analyze the economic consequences of an individual conservation measure, such as the addition of a storm window, it is necessary to specify the labor and material requirements involved. In the course of previous studies ESRG has developed a data base containing such information. This data base, expanded and adjusted for New England conditions, provides a key input to the computations. Separate data exist on measures for new and existing, and single and multifamily dwellings. The employment model maps the input data on the labor and materials required for each measure, as well as the number of applications of each measure, into estimates of the various effects upon the local economy.

These include the effects of:

- On-site employment required to install the measures.
- Demand for materials on local sales activity.
- Spending of wages of on-site workers on local sales.
- Decreased energy consumption on local energy sales.
- Increased household disposable income on local sales.
- Indirect effects of all of the above throughout the regional economy.

Based upon such output, one may both derive the general impact of conservation on the regional economy and specify the particular impact of conservation by state and by source of the employment effect.

SECTION 1.3 SUMMARY OF EMPLOYMENT RESULTS

In the preceding sections of this report, the general approaches to the analysis of energy employment interactions as well as the general characteristics of the ESRG Employment Model have been discussed. In this section the quantitative results of the analysis of the employment impacts in the New England region associated with the the transition from the Base Case to the Conservation Case forecast are reported.

The results presented in this section were developed through numerous runs of the ESRG Employment Model. Details concerning this model, and the structure of its output are contained in Section 2 of this report. Here, central results have been organized into summary Tables to facilitate exposition. The discussion will be organized around six major findings. Each finding will be discussed in detail and documented through the use of appropriate data obtained from the Employment Model. In addition to discussing the findings themselves, comparisons with the results of other major studies of energy and employment will be presented.

Findings

First, a change from Base Case to Conservation Case assumptions produces a large increase in regional employment over the course of the next twenty years. In Table 1 below, summary results are presented of the employment impacts of a transition from the Base Case to Conservation scenario assumptions. Increase in employment attributable to the extra conservation actions are shown for each state. Annual effects shown at five year intervals allow one to see the pattern of increased employment taking place as conservation activity grows and more of the benefits of this activity, in the form of energy conservation and shifts of disposable income are plowed back into the regional economy. The Column labelled "total" in Table 1 gives the cumulative total employment induced by all incremental conservation over the twenty-two year period of the study. Average employment per year can be obtained by dividing these totals by the twenty-two year length of the study period.

Table 1 presents net changes in regional employment. That is, all losses of employment due to such factors as reduced activity in the energy sector resulting from reduced demand have been accounted for. Thus, the figures in Table 1 can be thought of as additional positions within the region which would be created as a consequence of the shift from "business-as-usal" conditions to those included in our Conservation Case forecast.

In order to gain some perspective on the import of these results for the region, it is useful to compare them with current levels of unemployment. According to the most recent issue of the Statistical Abstract of the United States, unemployment for 1978, the last year reported, was 340,000 in the New England region. The average yearly employment created in the transition from Base to Conservation Case conditions (approximately 15,240), totals about six percent of the

1978 unemployment level in the New England region. Of course, employment impacts shown in Table 1 cannot simply be subtracted from future unemployment levels. The changes from Base to Conservation Case conditions assume in themselves the somewhat extensive reorganization of the energy sector of the New England economy, implying accompanying changes in other sectors and possible implications for migration patterns. However, the results clearly suggest that the transition would significantly reduce unemployment in the New England region.

TABLE 1.

TOTAL ANNUAL EMPLOYMENT IMPACT
BY STATE AND YEAR IN THE NEW ENGLAND REGION

	1983	1988	1993	1998	TOTAL*
Maine	485	1,562	1,962	2,858	34,249
New Hampshire	630	1,567	1,922	2,914	34,276
Vermont	245	713	887	1,262	15,176
Massachusetts	2,330	7,414	9,076	12,704	156,111
Rhode Island	311	1,031	1,234	1,664	21,085
Connecticut	1,250	3,528	4,321	5,850	74,336
New England	5,251	15,815	19,402	27,252	335,233

* Total for all years, not just those shown.

Given the magnitude of the impact, it is worth stressing that the current study may underestimate the employment increases which would take place. There are two reasons for this possible underestimation. The first is the time frame of the study itself. Many of the employment impacts will occur after the end of the study time frame in 2000. Table 1, for example, shows only employment impacts through the year 2000. Even if no conservation activity were continued after the end of the study, measures would continue to pay for themselves and yield additional savings, which, in turn, would further stimulate the economy. These effects will produce net employment increases after the end of the study, which have not been included. Second, cautious assumptions have been made concerning manufacturing activity in the New England region. In particular, we have not assumed that the industrial mix will be altered to meet the demands of large conservation-oriented local activity. Were this to take place, many additional jobs would be created in the manufacturing sector. On the other hand, it should be pointed out that there is also a possible depressing effect on the estimates. As has been suggested in response to previous studies of this type, utilities finding themselves with excess capacity caused, in part, by increased conservation activity, may tend to pass costs on in the form of higher rates.

The three factors described above have been examined through sensitivity runs of the model. Apparently, the net effect is to produce a slight underestimate of the total employment associated with the transition.

The second finding is that much of the employment associated with the change to the Conservation Case conditions is not directly visible as conservation-related activity. The direct on-site conservation activity is only "the tip of the iceberg" of the economic consequences of these actions.

In making the analysis, one can distinguish three levels of economic activity associated with the implementation of a particular conservation-related activity. First, there is the activity at the conservation site itself. This involves labor, sometimes that of a homeowner, sometimes that of someone employed by the homeowner, to install a particular device. Occasionally, as in the purchase of more efficient appliances, no on-site labor is involved. Second, there is a change in the demand for goods and services obtained locally which can be linked directly to on-site activity. Materials are purchased locally, labor is recruited from the local labor force to install conservation-related devices, energy demands on local energy dealers decrease as a consequence of additional conservation, etc.

All of these effects can be viewed as inputs to local industry from the on-site activity. These local industries, be they retail concerns or manufacturing concerns, respond through increased economic activity, and, therefore, increased employment. This set of activity has been termed "input industry" in this study. Additionally, these input industries themselves put further demand upon the regional economy as a whole. This set of activity is termed "total indirect demand."

Employment impacts broken down by on-site and off-site components with the off-site component further subdivided by breaking out "input industry" (as defined above is presented in Table 2. Examination of Table 2 shows that the indirect effects are a very substantial portion of the total employment impacts. Interestingly, the on-site activities are the smallest of the major component.

TABLE 2.

BREAKDOWN OF TOTAL EMPLOYMENT IMPACT BY STATE AND BY LEVEL OF MULTIPLIER EFFECT

	ME	NH	VT	MA	RI	CT	N.E.
On-Site	7,492	6,910	3,382	26,521	4,332	15,903	64,540
Input Industry	14,851	1,998	7,059	56,942	9,160	33,292	123,302
Off-Site Total	26,757	27,366	11,794	129,590	16,753	58,433	270,693
Grand Total*	34,249	34,276	15,176	156,111	21,085	74,336	335,233

* Grand Total equals the sum of On-Site plus Off-Site Total Employment.

The <u>third finding</u> is that savings due to additional conservation beyond that in the Base Case are far larger than the investment requirements needed to make the change. Table 3 displays the total investment and the total dollar value of energy savings for each New England state. Also shown is the total shift in disposable income representing the energy savings debited after repayment of the conservation investment.

Specifically, total investment is the additional outlay required to apy for the additional conservation above Base Case levels. Total Savings refers to the value of the incremental fuel savings due to increased conservation. After the additional conservation has been paid for out of the saving due to increased conservation, household income originally used to pay fuel bills is "shifted" to other uses. This income is shown in the "Shifted Disposable Income" row.

TABLE 3.

TOTAL CONSERVATION INVESTMENT, ENERGY SAVINGS AND SHIFTED DISPOSABLE INCOME (10^6 1980 $)

	ME	NH	VT	MA	RI	CT	TOTAL
Total Conservation Investment	680	659	335	2,559	413	1,630	6,276
Energy Savings	2,058	1,991	960	7,222	1,187	4,257	17,675
Shifted Disposable Income	1,618	1,557	743	5,695	943	3,251	13,807

As these figures indicate, energy savings are almost three times larger than the total capital requirements necessary to obtain those savings. The result of this high savings-to-cost ratio is that income previously allocated to paying for fuel costs may now be shifted to the purchased of other goods and services. This shift has profound consequences for the regional economy, as we will explain in subsequent findings.

The same information is presented in Table 4 on a yearly basis for New England as a whole. The data shows that while there is some up-front capital cost, savings accumulate sufficiently rapidly so that after a few years they are actually larger on a yearly basis than are the capital requirements for continued investment. This pattern is important when evaluating the impact of start-up costs for the Conservation Scenario upon other activities within the region. When conservation programs are analyzed, total investment costs are sometimes compared with total savings and the question is asked, Where will the investment funds come from? In the conservation package suggested in this study (where most of the measures are small) funds are likely to come from savings, from reallocations of disposable income, or from some form of credit.

TABLE 4.

YEARLY CONSERVATION INVESTMENT,

ENERGY SAVINGS AND SHIFTED DISPOSABLE INCOME IN NEW ENGLAND

(10^6 1980$)

	1978	1983	1988	1993	1998	TOTAL
Total Investment	0	161	379	366	368	6,276
Energy Savings	0	91	617	1,129	1,641	17,675
Shifted Disposable Income	0	48	410	869	1,411	13,807

The data in Table 4 additionally suggest that the payback period viewed as a regional aggregate for the changes we have suggested is quite short and that the savings redistributed via disposable income will in fact overtake the capital requirements quite rapidly. The measures pay back so quickly that the net positive effects of their installation soon overtake any other depressing effects associated with the need to pay for their installation.

It should be remembered that the analysis takes account of both the initial capital requirements and their repayment. The disposable income calculation assumes that savings associated with the installation of a measure are diverted out of disposable income entirely until the measure is paid for. In effect, all measures are paid for out of individual savings. However, this computational procedure is also roughly consistent with the assumption that savings are paid for out of current disposable income, which is then recovered through the first few years' fuel savings. Whichever interpretation one places on the model output, it must be stressed that the shifted disposable income is net of the cost of the measures as well as their maintenance. Therefore, it does represent a real addition to discretionary spending on the part of those who have installed the conservation measures. As will be seen, in this has profound employment effects.

The <u>fourth finding</u> is that of the four principal ways in which conservation creates jobs, disposable income shifts associated with lower energy costs is the most significant. Earlier, in discussing the second finding, employment-creation effects were discussed in terms of the economic activity level at different stages removed from on-site employment. Here the issue is addressed in a slightly different fashion.

Reviewing, it is useful to distinguish three different ways in which the effects of on-site conservation-related activity are linked to the local economy. The three are: (1) through the demand for materials purchased locally, and through the spending of wages to on-site workers, (2) through decreased consumption of local energy services, and (3) through shifts in household income made possible by the re-allocation of energy savings. Table 4 presents the total employment impact by state disaggregated according to these different effects. Also presented for the perspective are the total direct employment on-site as well as the over-all total employment.

An examination of Table 5 reveals that indirect employment, that is, employment off-site, gives the bulk of the impact in each of the states. Further, it is clear that this employment is a composite of competing effects. Purchase of materials, the spending of wages, and the effect of shifts in disposable income tend to increase local employment, while decreased spending for energy tends to decrease employment. It is particularly interesting to compare the decrease in employment due to fuel savings with the increase due to the shift in funds associated with these savings. Remembering that the spending of energy savings only commences <u>after</u> the original capital investment in conservation is paid for, the results show that the net effect of this shift is to strongly increase regional employment.

TABLE 5.

TOTAL EMPLOYMENT IMPACT DISAGGREGATED
BY ECONOMIC EFFECT OF CONSERVATION

	ME	NH	VT	MA	RI	CT	N.E.
On-Site	7,492	6,910	3,382	26,521	4,332	15,903	64,540
Indirect Employment Due To:							
Labor and Materials Purchases	14,490	15,171	6,248	69,356	9,266	33,718	148,249
Reduced Energy Expenditures	-39,468	-39,418	-16,613	-174,828	-24,500	-80,875	-375,702
Consumer Spending of Energy Savings	51,736	51,614	22,159	235,062	31,988	105,589	498,148
Sub-Total Indirect Employment	26,757	27,366	11,794	129,590	16,753	58,433	270,693
Total Employment	34,249	34,276	15,176	156,111	21,085	74,336	335,233

This phenomenon has been noted in other studies. In particular, the California Energy Commission staff study (Ref. 5), observes that investment in energy is far less employment-intensive than general investments in the economy. Thus, the shift from spending on energy to general discretionary income spending has a large stimulative effect. Viewing this stimulation as, in part, cancellation of the effects associated with the decrease in energy consumption, highlights the fact that an analysis which focuses only upon on-site employment, together with labor spending and materials purchases associated with such employment will vastly understate the employment impacts associated with the conservation program. Unfortunately, such a focus has been the scope of most studies to date. Finally, we should note that the results concerning the effect of shifting from energy expenditures to general economic expenditures show that a shift to least-cost energy strategies (Ref. 6) would lead to a dramatic increase in employment. This derives not only through the labor and materials demands for such devices, either directly or indriectly, but, in addition, through the effects of shifts in disposable income. The "least-cost" energy strategy is likely to increase economic and employment activity.

The yearly impacts of each of the basic employment factors for New England as a whole is given in Table 6. Here again, labor and materials impacts together with on-site employment are dominant in the early years. However, by the mid-point in the study period, they are overtaken by the effects of re-spending.

TABLE 6.

TOTAL ANNUAL EMPLOYMENT IN NEW ENGLAND DISAGGREGATED BY ECONOMIC EFFECTS OF CONSERVATION

	1983	1988	1993	1998	TOTAL
On-Site	1,534	4,440	3,703	3,245	64,540
Indirect Employment Due To:					
Labor and Material Purchases	4,002	9,207	8,383	8,591	148,249
Reduced Energy Expenditures	-2,005	-12,667	-24,039	-35,471	-375,702
Consumer Spending of Energy Savings	1,721	14,836	31,353	50,888	498,148
Sub-Total Indirect Employment	3,718	11,376	15,697	24,008	270,693
Total Employment	5,251	15,815	19,402	27,252	335,233

The details of this pattern are related to the particular assumptions employed in the distribution of savings due to conservation. Savings are credited toward the cost of a conservation measure until that measure is paid off. Only then does additional disposable income become available. Other financing possibilities exist, such as "split savings" financing, where only part of the yearly savings would go toward the cost of the measure, with part retained by the measure-owner to be allocated to increased discretionary income.

Use of such split savings techniques has been advocated as a method for increasing the penetration of such high cost technologies as active solar systems. The analysis presented in Table 6 shows that the use of such a technique would spread the job benefits associated with the shifts of disposable income more evenly across the study period. Since steady employment is preferable to lumped employment, such financing schemes might benefit for the region economically.

The fifth finding is that from the standpoint of local employment-creation investment in conservation is very efficient. In Table 7, yearly employment per million dollars of total investment and per million dollars of local economic activity is given. The second category is a measure of the fraction of the expenditures on conservation which remain in the local economy. So, for example, if the measure under consideration were insulation, the local economy would be credited with the local transportation, wholesale, and if appropriate, retail costs, associated with the insulation, together with any on-site labor involved in its installation. However, if the insulation were manufactured outside New England, no manufacturing costs would affect the local economy. The data in Table 7 shows that approximately two-thirds of the total investment in conservation leads to local economic activity and that about two-thirds of the employment obtained nationally, is, in fact, found in the local region.

TABLE 7.

EMPLOYMENT PER MILLION DOLLARS
OF CONSERVATION INVESTMENT BY STATE

	ME	NH	VT	MA	RI	CT	TOTAL N.E.
Total Employment	34,249	34,276	15,176	156,111	21,085	74,336	335,233
Total Investment	680	659	335	2,558	413	1,630	6,275
Employment Per 10^6 \$ Invested	50.4	52.0	45.3	61.0	51.1	45.6	53.4
Local Spending	404	414	180	1480	236	929	3643
Employment Per 10^6 \$ Spent Locally	84.8	82.8	84.3	105.5	89.3	80.0	92.0

In the California Commission study cited earlier, a similar analysis was performed for power plant construction. Depending upon the preceise nature of the power plant, the California Commission found that fourteen to forty-nine percent of the employment associated with power plant construction was local. A similar finding was made in the Long Island employment impact study (Ref. 6) where it was determined that investment in conservation produced comparative employment benefits that were even greater at the local level than they were at the national level.

In general, these findings suggest that investment in conservation is more efficient than power plan construction as a source of stimulation of local employment. Given such results it is natural to raise the possibility designing energy policy so as simultaneously to obtain an efficient use of natural resources and at optimal stimulation of employment.

Our sixth finding is that saving a kilowatt-hour of electricity creates more employment than producing a kilowatt-hour of electricity. In order to obtain the information necessary for the analysis leading to this finding, it was necessary to slightly modify the procedures used in the rest of this study. Many of the measures considered in the overall analysis involved more than one fuel. In order to develop some comparative analysis, special runs were performed on the set of measures that affect only electrical consumption: more efficient refrigerators, freezers, electric ranges, and lighting. Table 8 summarizes the results on the number of jobs per billion kilowatt-hours saved. These figures represent only a subset of measures, but have the virtue that they can be compared to similar figures developed by the California Energy Commission for energy produced by power plants fueled by oil, coal, and nuclear energy. The latter figures are shown in Table 9 below. As is suggested comparing Tables 8 and 9, saving a kilowatt-hour of electricity is much more productive of employment than creating the kilowatt-hour through the construction of power plants.

TABLE 8.

TOTAL EMPLOYMENT PER BILLION

KILOWATT-HOURS SAVED*

	ME	NH	VT	MA	RI	CT	TOTAL N.E.
Total Employment	8,120	7,741	3,504	50,517	6,789	19,607	96,278
10^9 KWH Saved	4.45	4.05	2.06	20.42	3.35	12.09	46.42
Employment Per 10^9 KWH Saved	1,825	1,911	1,701	2,474	2,027	1,622	2,074

* This table reflects only the three appliance measures and improved lighting, as discussed above.

TABLE 9.

EMPLOYMENT PER BILLION KILOWATT-HOURS PRODUCED OR SAVED

	California	Total U.S.
Power Plants		
Oil	184-620	1209-1289
Coal	357-385	943-1781
Nuclear	278	790- 859

Reproduced from J. Lerner and F. Posey, The Comparative Effects of Energy Technologies on Employment, California Energy Commission, November 1979.

Together the findings present a coherent picture of the employment impacts resulting from the transition from Base to Conservation Case assumptions in the residential sector. Total regional employment would be greatly enhanced by such a change. Such enhancement, however, would not in the main be directly identifiable with the particular conservation measures. Indeed, it is only by a rather detailed and technical analysis involving a set of indirect effects that the total impacts have been quantified. It appears that the conservation strategy offers both a cost-lowering and employment-increasing energy policy future.

2. METHODOLOGY

2.1 Link Between Forecast Results and Employment Impacts

The goal of the present study is to establish the incremental direct and indirect employment impacts involved in a transition from the Base Case growth scenario (Technical Report I) to the Conservation Case scenario (Technical Reports II and III). The impact estimates throughout this study are restricted to the subset of conservation measures affecting energy usage in the residential sector.

For each of the conservation measures it is necessary to specify certain characteristics of each implementation such as direct labor and materials requirements and the total number or such implementations year-by-year. The data needed to specify measure characteristics is discussed in Sec. 2.4. Here the procedures by which the implementation rates for each measure are derived from the forecasts is described.

It is useful to begin by reviewing requirements developed in earlier volumes for the residential sector. As a sample, the forecast results of the Base and Conservation Case forecasts of Connecticut are reproduced below as Table 10. As the results indicate, the forecast is developed for a series of end-uses (further disaggregation by housing type is not explicitly displayed in Table 1). That is, each of the major uses of electricity in the residential sector -- refrigeration, air conditioning, heating, cooking, water heating, etc. -- is analyzed separately. Examination of the results presented in Table 1 for refrigeration, for example, shows that in the Conservation Case, consumption associated with refrigeration drops below that experienced in the Base Case. In Table 11, we show the difference between the Base and the Conservation Cases for refrigeration on a year-by-year basis. Column 1 contains the consumption under Base Case conditions; Column 2, under Conservation Case conditions; and Column 3 the yearly difference. The numbers in Column 3 represent the cumulative savings associated with improvements in refrigeration through each year. Thus, the difference shown in Column 3 for 1985 reflects improvements in refrigerator efficiency between the Base and Conservation Cases which have taken place between the starting year and 1985. As indicated in the description of the forecasting model, this effect reflects the phase-in of improved units through replacements and retirements of existing units and net additions to the appliance stock. In Column 4, the differences between the savings shown in Column 2 for successive years are presented. Thus, for 1985, the difference between the cumulative savings through 1985 and the cumulative savings through 1984 are shown. This difference represents the additional savings due to the conservation related improvements in 1985 alone.

In analyzing the employment impact of these savings, the first step is to identify the additional savings due to conservation investment in a particular year with the purchase of specific items of

TABLE 10.

SAMPLE RESIDENTIAL FORECAST OUTPUT

BASE CASE - CONNECTICUT

```
CONN            BASE CASE - RESIDENTIAL SECTOR - ENERGY IN GWH
                               1978    1983    1988    1993    1998
  1:  REFRIGERATORS           1840.   1958.   1993.   1952.   1852.
  2:  FREEZERS                 443.    493.    561.    550.    554.
  3:  RANGES                   502.    557.    612.    649.    669.
  4:  LIGHTING                 748.    805.    865.    895.    900.
  5:  TELEVISIONS              460.    471.    486.    500.    511.
  6:  CLOTHES DRYERS           583.    713.    832.    914.    966.
  7:  CLOTHES WASHERS           87.     94.    103.    109.    112.
  8:  DISH WASHERS             128.    152.    175.    198.    219.
  9:  WATER HEATERS           1074.   1114.   1123.   1137.   1149.
 10:  ROOM A/C                 343.    379.    387.    387.    383.
 11:  CENTRAL A/C              128.    196.    251.    285.    301.
 12:  SPACE HEATERS           1113.   1366.   1626.   1781.   1869.
 13:  HEATINGAUXILIARY         389.    387.    388.    382.    373.
 14:  MISCELLANEOUS            315.    357.    405.    446.    479.
```

CONSERVATION CASE - CONNECTICUT

```
CONSERVATION SCENARIO
CONN
                               1978    1983    1988    1993    1998
  1:  REFRIGERATORS           1840.   1919.   1848.   1680.   1456.
  2:  FREEZERS                 443.    489.    509.    503.    483.
  3:  RANGES                   502.    554.    603.    634.    650.
  4:  LIGHTING                 748.    805.    438.    460.    472.
  5:  TELEVISIONS              460.    471.    486.    500.    511.
  6:  CLOTHES DRYERS           583.    713.    832.    914.    966.
  7:  CLOTHES WASHERS           87.     94.    103.    109.    112.
  8:  DISH WASHERS             128.    152.    175.    198.    219.
  9:  WATER HEATERS           1074.   1050.    941.    891.    886.
 10:  ROOM A/C                 343.    363.    339.    317.    299.
 11:  CENTRAL A/C              128.    186.    224.    246.    254.
 12:  SPACE HEATERS           1113.   1267.   1285.   1298.   1306.
 13:  HEATINGAUXILIARY         389.    387.    356.    315.    277.
 14:  MISCELLANEOUS            315.    357.    405.    446.    479.
```

TABLE 11.

CALCULATION OF IMPLEMENTATIONS FOR REFRIGERATOR MEASURE (CONNECTICUT CONSUMPTION DATA)

YEAR	BASE CASE CONSUMPTION	CONSERVATION CONSUMPTION	CUMULATIVE SAVINGS	YEARLY SAVINGS	NUMBER OF IMPLEMENTATIONS
1978	1840	1,840	0	0	0
1979	1874	1,872	2	2	6,369
1980	1902	1,895	9	7	22,293
1981	1927	1,913	23	14	44,586
1982	1944	1,921	46	23	73,248
1983	1958	1,919	85	39	124,204
1984	1969	1,913	141	56	178,344
1985	1975	1,902	214	73	232,484
1986	1982	1,889	297	83	264,331
1987	1988	1,871	414	117	372,611
1988	1993	1,848	559	145	461,783
1989	1997	1,824	732	173	550,955
1990	1999	1,798	933	201	640,127

more efficient equipement in that year. Before explaining the details of this identification procedure, some of the differences between the forecasting model and the model used in the employment impact analysis should be classified.

The forecasting model allows for the continual improvement in various end-uses. Thus, over time, the efficiency of refrigerators may increase in a continuous fashion in both the Base and Conservation Cases. It is the difference between those increases that are captured in taking the difference between the forecast output for the two cases. The operations involved in the employment analysis, on the other hand, are essentially discrete in nature (e.g., each unit has a fixed efficiency improvement). For the implementation of equipment improvement, a detailed engineering description is required. In our example, in order to analyze an improved refrigerator, a list of materials and labor, including their cost, as well as fuel savings and other pertinent economic data is necessary.

In order to combine the forecasting and employment portions of the model, a bridge must be made between the continuous improvements in the forecasting model and the discrete improvements permitted in the employment analysis. This bridge is accomplished through "the method of equivalent implementations." This method begins with the development of an engineering-based analysis of a particular conservation implementation -- in our example, an improved refrigerator. This improvement is defined as above and beyond the engineering characteristics of a Base Case refrigerator, which itself changes over time according to efficiency improvements assumed operative in the Base Case itself. The specific incremental Conservation Case improvements are described in the earlier Technical Reports. One of the items developed there is an estimate of the yearly decrease in consumption associated with the replacement of a Base Case refrigerator by the improved refrigerator. It is this quantity of energy in kilowatt hours that is associated with the use of one improved unit. The method of equivalent implementations reduced the yearly improvement shown in Column 4 of Table 10 to yearly implementations -- that is, yearly number of changes from Base Case to improved refrigerators -- by dividing the yearly savings by the improvement associated with one such replacement. So, for example, the savings shown for 1985 divided by the average saving when changing from a Base Case to a Conservation Case refrigerator, yields the unit implementations shown in Column 5 of Table 1. These implementations on a yearly basis provide one of the basic items of data input to the jobs model.

The method of equivalent implementations is an approximation to the continous changes which occur in the forecasting model. However, from the standpoint of input-output analysis, it is a quite appropriate approximation. In some cases, the method may overstate the per unit savings in a given year due to the phase-in of the improvements in both the Base and Conservation Cases. Though this may result in a smaller than actual number of implementations, the cost of changing from the Base to the Conservation Case assumptions is commensurately overstated. Engineering analysis shows that the cost and savings are roughly linearly related. Thus, the overstatement in cost, together with an understatement in the actual number of implementations made, balance so that not only are the total energy savings accurately approximated but the total bill for materials and labor required to make the total savings possible is also correct. These totals, not the unit data, are the key factors in driving the employment model.

In Table 12, the measures used in our employment analysis are listed. They are grouped in categories which are intended to show general relationships among the measures. Thus, the appliance measures are grouped together, the thermal integrity measures are grouped together, and the fuel switching measure is segregated because of its unique character. The refrigeration measure, which has served up to now as an example of the procedures, is among the simplest of the measures in terms of the determination of implementations. Other measures, particularly those involved with air conditioner or efficiency improvements and building thermal integrity measures, present additional difficulties. They exhibit what might be termed "the problem of dual effects." In the forecasting model there are two distinct reasons for decline in air conditioner unit usage. One is the improvement in the units themselves, in particular in the design and operation of the compressor of the dwellings in which the air conditioners are used. In making of the dwellings in which the air conditioners are used. In making assignments of energy savings together with costs, only the savings due to improved compressor operation should be credited to the investment in more efficient air conditioners. The additional savings associated with thermal integrity are appropriately credited to investments in insulation, weather stripping, and other improvements in the thermal integrity of the dwelling. This requires a procedure somewhat more complicated than that for the refrigerator example. In order to deal with this problem, a special interface program was developed for this investigation. It takes the output of the forecasting program and allocates the energy savings on a yearly basis among the appropriate measures.

The procedures employed, while essentially similar to those shown in Table 11, are sufficiently complicated so that computerization is necessary. Similar difficulties are encountered when both electrical and fossil fuel effects are entailed in a given measure. For example, consider the case of fossil fuel heated homes. Such heating systems normally employ electrical auxiliaries -- pumps, fans, etc. Improvements in dwelling thermal integrity decrease not only the fossil fuel consumed but also the electricity used in these auxiliaries. The usage of these auxiliaires is shown under the heating auxiliary category in the forecast output, as indicated in Table 10. In developing the implementations for thermal integrity measures for fossil heated dwellings, the effects on heating auxiliaries must be simultaneously accounted for. Also, the electrical savings associated with those auxiliaries must be shown in the engineering data associated with the measure. This, too, is accomplished through the interface program.

The entire project described in the five Technical Reports of this study can be summarized figuratively as a three-stage procedure, as shown in Figure 1. First, an analysis of electrical savings and other fuel savings is performed. The electrical savings, being more

TABLE 12.

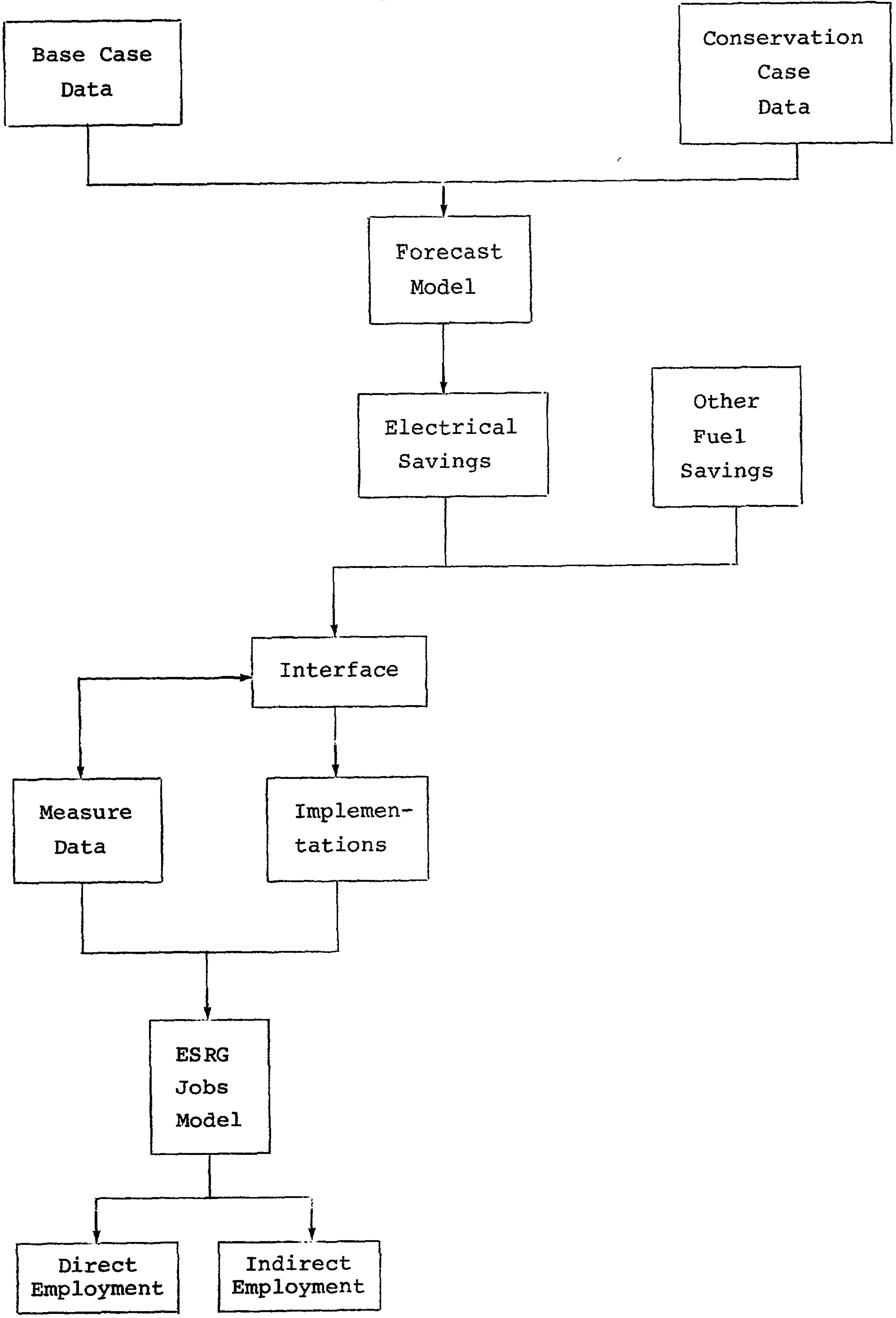
MEASURES USED IN THE CONSERVATION/EMPLOYMENT ANALYSIS

	MEASURE	SEPARATELY SPECIFIED FOR HOUSING TYPE		
	Title	Fossil/Electric Heated Units	New/Existing Units	Single Family Multifamily
I.	More Efficient Electrical Equipment	No	No	No
1.	Refrigerator	No	No	No
2.	Freezer	No	No	No
3.	Electric Range	No	No	No
4.	Lighting	No	No	No
5.	Room Air Conditioner (1)	No	No	No
6.	Central Air Conditioner (1)	No	No	Yes
II.	Thermal Integrity/ Heating Fuel Mix Related Measures			
1.	Thermal Integrity Improvement	Yes	No	Yes
2.	Improved Heat Pump	Electric Only	New Only	Yes
3.	More Efficient Plumbing Fixtures	Yes	No	No
4.	More Efficient Water Heater	Yes	No	No
III.	Switch From Electric Resistance Heating To Alternative Mode			
1.	Heat Pump (Base Case Efficiency) (2)	Electric Only	New Only	Yes
2.	Gas Heat	Electric Only	New Only	Yes
3.	Oil Heat	Electric Only	New Only	Yes
4.	Active Solar Assisted Resistance Heat	Electric Only	New Only	Yes

(1) Part of forecast savings for air conditioning consumption is to thermal integrity improvement.

(2) "Switched" heat pumps are improved by application of Measure II-3.

FIGURE 1.


Base Case Data
Conservation Case Data
Forecast Model
Electrical Savings
Other Fuel Savings
Interface
Measure Data
Implementations
ESRG Jobs Model
Direct Employment
Indirect Employment

complex in nature and development, are determined via runs of the ESRG forecasting model using Base Case and Conservation Case data. In addition to the determination of electrical and other fuel savings, engineering estimates of particular changes in residential end-uses which could account for such savings are developed. These changes go under the general term of "measure data." Given the measure data and the fuel savings, an interface program computer the number of implementations of the given measures which are necessary to account for the forecast fuel savings. Finally, with the measure data and the number of implementations developed, the ESRG jobs model is employed to develop estimates of direct -- that is, on-site -- and indirect employment which would occur if there were a change from Base to Conservation Case conditions.

2.2 Steps in the Creation of Employment

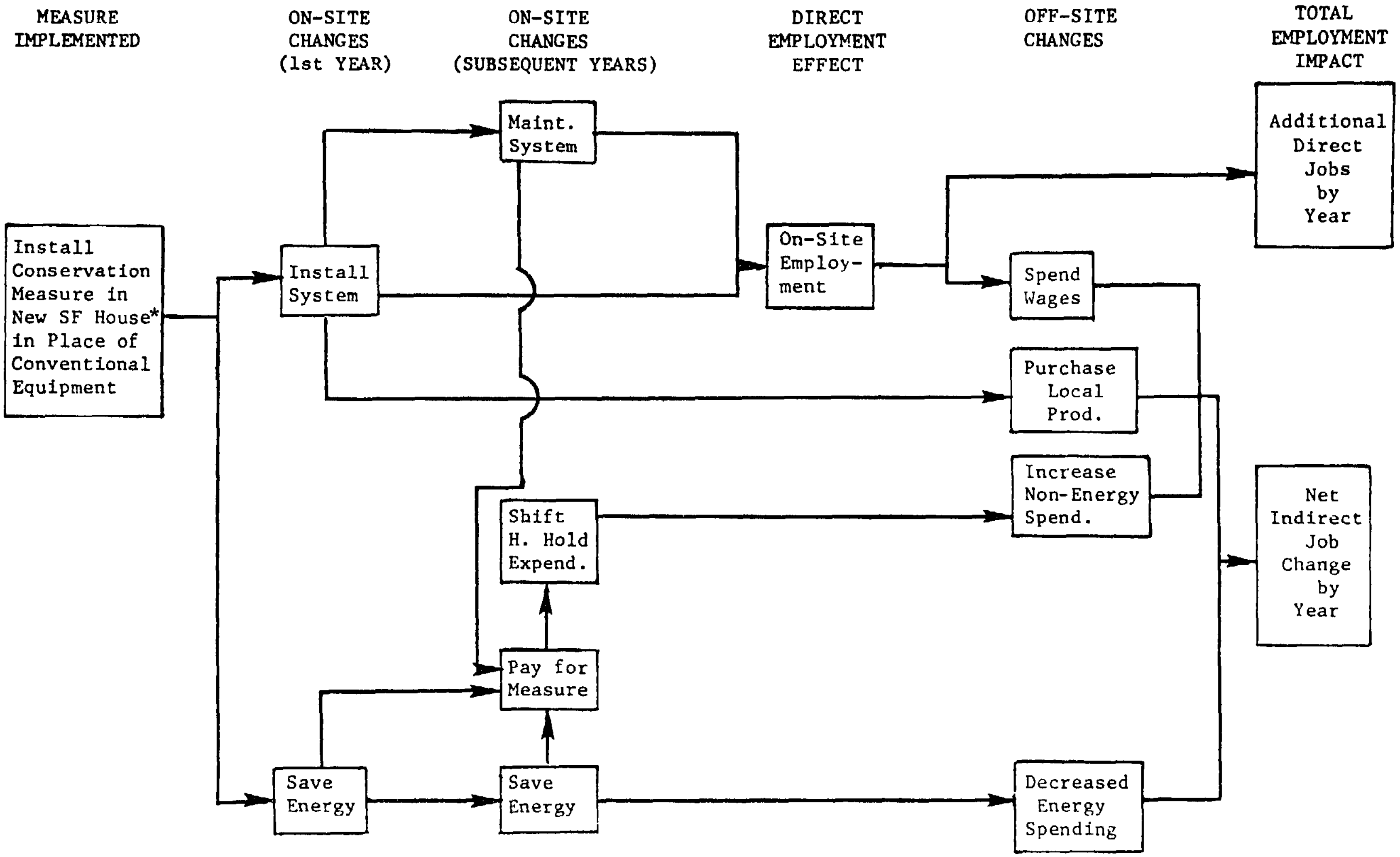
The analysis of the employment impacts of energy conservation provided by the ESRG Employment Model is rather complicated. This complexity mirrors the complexity of employment creation within the economy itself. In Figure 2 we show in schematic form the steps which are involved.

Beginning on the left, the installation of a measure triggers a series of economic responses. In addition to the labor involved in installation, there is, maintenance for certain measures. Installation and maintenance activity together constitute the direct employment effect -- that is, the on-site employment due to the installation of the measure. The on-site employment leads to the first off-site effect: the spending of wages which are paid to workers engaged in the installation and maintenance of the measure. This is shown in the off-site changes column of the diagram. Directly below this is shown two other off-site effects. The first is the purchase of locally produced materials. Here are also included any regional wholesale, retail, or transportation activity associated with goods produced outside the region.

Next is shown the increases due to non-energy spending. This is perhaps the least obvious but empirically the most important effect of conservation. Many conservation measures pay for themselves quite rapidly and so have a useful life far beyond the period needed to repay the cost of the installation. During this period, disposable income increases, leading to increased purchases and employment, as shown in the summary of results in Section 1.3. The effect is traced beginning with the savings of energy in the first year and then in subsequent years. Energy savings eventually pay for the measure, as indicated in the diagram. Of course, deducted from savings are any maintenance or upkeep expenses on the system. Beyond that, once the measure is paid for, the continued savings are shifted to general household expenditures, through which they increase non-energy spending within the economy.

FIGURE 2.

THE EMPLOYMENT EFFECTS OF
ONE CONSERVATION MEASURE APPLICATION



* Or any other appropriate unit as shown in Table 12.

In addition to the three sources of increased employment, there is one source of decreased employment. The decreased demand for energy caused by the conservation measures leads to decreased economic activity in the energy producing sectors and related decreased employment. These energy industries include the electric and gas utilities, the petroleum industry, and the various aspects of retail, wholsale, and transportation which are dependent upon such activities. Here, in addition, it should be noted that particular measures may cause decreased activity. For example, the ban on electric space heating accounts for decreased employment among electricians. This is shown in the direct jobs by year, as discussed in Section 1.3.

2.3 Structure of the ESRG Employment Model

In Section 2.1 the linkage between the ESRG forecasting model and the ESRG employment model was described. In this section, the internal structure of the employment model itself will be schematized. This is intended to orient the reader for the more detailed discussion in the following two sections. The ESRG model and its data structures are complicated. A model logic outline and interconnection is shown in Figure 3 below. In digesting this diagram, it is useful first to separate the portion of the model dealing with the input data from the portion of the model performing essential computations. This division is shown by the double line in the figure.

The upper left hand portion of the diagram represents the portion of the model centered around the "Measure Sheet." This is the structure which contains the measure data -- that is, the engineering information concerning the cost, materials and labor, and the energy savings associated with a particular measure. This portion of the model allows one to use, update, and print the data on individual measures. A sample output from this portion of the program is contained in Table 14, below. The implementation data, the other major data input to the employment model, is developed by the interface portion of the system (see Figure 1 and discussion).

In addition to the measure sheet portion of the system, there are four major programs used in the ESRG model. These are labeled "Scenario," "Energy," "Cost," and "RIMS," the last standing for Regional Industrial Multiplier System. These components are located in the central portion of the chart. In general, once data on the measures and their implementation has been determined, the information flows through the model, as indicated by the arrows in Figure 3. Each program performs specific computations, printing its results as indicated or passing its results on for further processing. COST prints fuel savings, as well as additional disposable income due to such savings. RIMS accepts the data from COST and ENERGY and, depending upon the options chosen by the user, computes the indirect effects due to different components of the on-site activities and fuel savings.

FIGURE 3.

THE ESRG EMPLOYMENT MODEL FLOWCHART

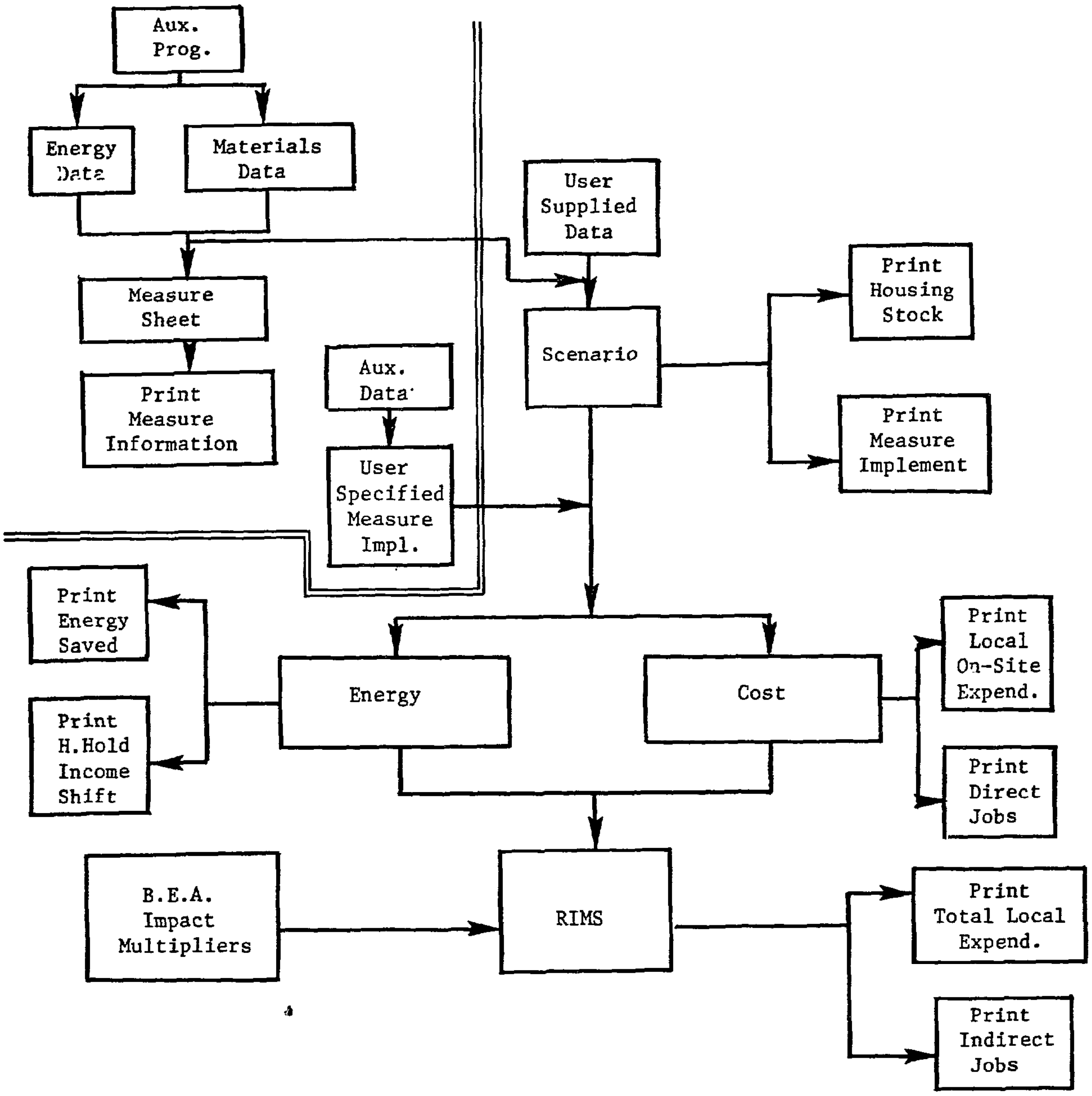


TABLE 14.

SAMPLE MEASURE SHEET

```
     200: More Efficient Refrigerators                                   SF+MF ALL
                         (1)
     NO LABOR USED

     MATERIALS COSTS         (1)
     MATERIALS I/O CODE           $ MATERIALS COST         % LOCALLY AVAILABLE (2)
     3632                              36.58                     0
                              (3)
     100.0% DO-IT-YOURSELF
     CONTRACTOR CODE 6902  (1)         0.0% MARK-UP ON LABOR

     IMPLEMENTATION
     100.0% AVAILABLE  0.0% OF AVAILABLE IMPLEMENTED
      1 IS YEAR IMPLEMENTATION BEGINS

  (4)'TECH' 0.000      TAX CODE 2      END USE CODE  2
                                                                   (5)
                         FUEL MIX (5)             A/C SATURATION
                      GAS   OIL   ELECTRIC
     START YEAR 0.000 0.000 1.000                    0.000
     FINAL YEAR 0.000 0.000 1.000                    0.000
  (6)
     ENERGY SAVINGS
       0.000 MCF GAS        0.0 GAL OIL        312 NON A/C KWH      0 A/C KWH

     MAINTENANCE  0.0% OF MATERIALS              0.0% OF LABOR

     MEASURE LIFE IS 20 YEARS
```

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1) Labor and Materials codes classify the on-site activities. The labor classifications are shown in the output of COST, below. The materials classification is based upon the B.E.A. classification system.

2) Local availability data allows the model to distinguish the material and labor components which come from the local area. The materials data is based upon manufacturing employment data. Labor data is estimated by ESRG staff.

3) % do-it-yourself gives the percentage of measure applications performed by residents themselves.

4) This line gives technical parameters indicating technology assumptions, federal tax credit status, and end-use affected by the measure.

5) Mix of fuels affected by the measure. Separate air conditioning data is required to account for the secondary effects of certain measures.

6) Total energy savings per measure are computed for each fuel separately.

2.4 Measure Data and Other Model Data Requirements

Analysis of the series of employment repercussions of the conservation measures requires an adequate description of the measures themselves. This data is organized in the form of a computer generated "measure sheet." A sample sheet is given in Table 14. These sheets provide the basic data required for the analysis. Materials and labor costs are broken out by category. In addition to the absolute amount involved in each category, a "locally available fraction" is noted. This allows one to reduce expenditures to reflect only those which are associated with local economic activity. The measure sheet also contains a variety of technical information necessary to completely describe the economic activity involved. This includes such items as contractor costs and the tax treatment of the expenditures involved.

Finally, there is information concerning the energy savings in terms of both the absolute amount of savings possible using the measure and the mix of fuels from which the savings will be obtained. The information provided on the measure sheet is sufficient to characterize the economic activity associated with the installation of a given measure.

All cost data shown on the measure sheets are at wholesale prices for 1980, adjusted for specific New England state conditions. For those measures involving household activity, the cost must be adjusted to reflect the retail mark-up. The "do-it-yourself" fraction shown on the measure sheet indicates the portion of materials which are expected to be purchased at retail prices. That fraction, together wtih appropriate material-specific mark-ups, is used to compute the retail portion of the material's cost. Similarly, the same fraction of labor cost is removed, since retail purchase are assumed to correspond to householder activity without additional labor. Since the costs are given in 1980 dollars, one must deal with the real changes in wages, materials, and fuel costs. Here our general assumptions are the same as those employed and discussed in the earlier Technical Report of this study.

There is an issue of maintenance and replacement of measures once they are installed. Maintenance assumptions are shown explicitly on the measure sheet, as is the life of the measure. The model itself takes account of maintenance and replacement as necessary. In general, measures are replaced once they wear out.

2.5 The Four Component Programs of the ESRG Employment Model

The major elements involved in job creation, the data requirements, and the overall structure of the employment model have now been summarized. Here the computing components of the ESRG jobs model are discussed. These are programs which actually produce the output results concerning employment effects which are shown in Section 1.3 (and Appendix C). Each of the four component programs will be briefly reviewed in turn.

SCENARIO This program is not an important analystic component in the current study. Its main function in the ESRG system is to perform market penetration analyses when the implementation of measures is not determined from independent forecasts. Here its only function is to provide information concerning the payback period for each of the measures under consideration. This information is passed to the program ENERGY. Its function will be described below.

COST This program performs a number of computations. First, the effects of the various measures are aggregated so that all of the materials used in the total scenario are grouped by produced industry. In order to accomplish this, the materials cost, given at wholesale prices, must be reduced by wholesale and transportation mark-ups to obtain prices at the factory level. Second, wages for on-site labor are allocated to the appropriate wage category. Finally, adjustments, such as contractor mark-up and its allocation, are made. Once all of these computations are complete, data on all on-site expenses are available. This data is passed to the RIMS program, where the multiplier effects of these expenditures resulting from indirect stimulation of the entire regional manufacturing network are estimated.

The COST program prints the on-site employment associated with conservation activity. A sample output for Connecticut is shown in the Table 15 below. In reviewing this table, the reader should keep in mind that the total at the far right refers to the cumulative jobs for all years in the period, not just those shown. Note also that the loss in electricians' jobs is due to the elctric space heating ban element of the conservation scenario.

TABLE 15.

SAMPLE ON-SITE OUTPUT

```
JOBTYPE:                1978     1983     1988     1993     1998
ELECTRICIAN               0.     -26.     -22.      -8.     -34.     -394.
INSULATION INSTALLER      0.     343.    1090.     899.     750.    15515.
SHEETMETAL                0.      26.      22.       9.      34.      398.
HVAC/SOLAR INSTALLER      0.      25.      22.       8.      33.      384.

TOTAL                     0.     368.    1112.     908.     783.    15903.
```

The second output of COST is an estimate of the expenditures on-site. These are reported in two ways -- localized to reflect total economic activity within the region and unlocalized to reflect the total cost of the program. An example is given in Table 16 Here it should be noted that the total cost shown in the Table does not represent the price as viewed by the purchaser, since they do not reflect tax benefits, which the purchaser may apply against the price of a given measure. These costs represent the changes in local and national demand associated with the implementation of the conservation case.

TABLE 16.

SAMPLE COST OUTPUT

```
COST

LOCAL SPENDING, THOUSANDS OF 1979 DOLLARS

1978          0.
1983      25815.
1988      58426.
1993      52372.
1998      52337.
TOTAL    928977.

TOTAL SPENDING, THOUSANDS OF 1979 DOLLARS

1978          0.
1983      44209.
1988      97515.
1993      96236.
1998      93292.
TOTAL   1630335.

F.T.E. JOBS CREATED
```

ENERGY This portion of the program treats the fuel savings associated with the measures. It implements the measures yearly, as indicated on the implementation schedule, passed to it by the interface program. After measures are implemented, it keeps track of their pay-back periods, using the information on pay-back developed in the program SCENARIO. When a measure has paid for itself, ENERGY automatically credits the fuel savings, net of maintenance, if any, to disposable income, thereby setting in motion the "re-spending effect" discussed earlier.

The energy portion of the program prints the output on fuel savings by fuel type, as well as the additional disposable income yearly generated by the re-spending effect. This is shown in Table 17 below.

TABLE 17.

SAMPLE ENERGY PROGRAM OUTPUT

```
ENERGY

ENFRGY SAVINGS IN MILLIONS, FUEL

                    1978      1983      1988      1993      1998
GAS  MCF              0.        0.        2.        3.        4.       50.
OIL  GAL              0.        6.       41.       79.      107.     1178.
FLEC KWH              0.      250.     1722.     1656.     1942.    25765.
ENERGY SAVINGS IN MILLIONS, $

                    1978      1983      1988      1993      1998
GAS                   0.        3.       13.       27.       42.      430.
OIL                   0.        7.       51.      114.      178.     1770.
ELEC                  0.       16.       88.      131.      170.     2057.
ADDITIONAL DISPOSABLE INCOME IN MILLIONS OF 1979 DOLLARS

1978        0.
1983       12.
1988       97.
1993      207.
1998      326.
TOTAL    3251.
```

RIMS This portion of the program performs the multiplier analysis needed to convert the demand created by conservation activity into a total level of economic activity. Before discussing the operation of this program, it is perhaps appropriate to say a few words about the multiplier concept (a more detailed discussion is provided in Appendix A).

In general, if a purchase of a dollar's worth of some material is made -- let us say, of steel -- this creates more than a dollar's worth of total economic activity. In order to produce the steel, coal must be mined, transportation provided, and so on. The relationship between final demand -- in our example, a dollar's worth of steel -- and total economic activity is one of proportionality. The constants of proportionality are the multipliers involved.

In making our computation, we use a system of multipliers developed by the Bureau of Economic Analysis of the United States Department of Commerce. These multipliers are called the regional industrial multiplier system. The multipliers are disaggregated by input industry and express the ratio between final demand and total demand for a given industry in a given state. A different set of multipliers is used for each state under consideration in the study. Once the total level of economic activity is developed, a second set of multipliers is employed to convert from gross economic activity to employment.

The RIMS portion of the model has as its output the total off-site employment and the associated level of economic activity. Sample output is shown below as Table 18. A distinctive feature of the output is the separation of the jobs produced from the initial expenditure from the total employment. These jobs are shown under "input industry job" corresponding to local materials purchased and the spending of wages for on-site work. Comparison of these figures with the total impacts illustrates the substantial portion of the off-site impacts which are hidden in the local economic activity.

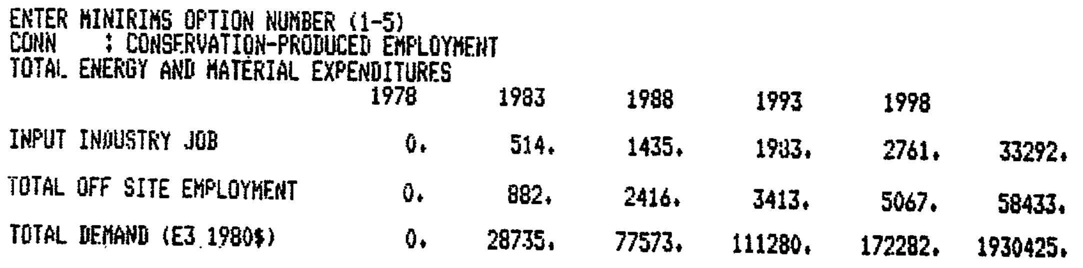
In addition to the employment impacts of the model, RIMS provides a current dollar estimate of the total indirect impact of additional conservation on the local economy. This is shown at the bottom of the RIMS output.

In addition, this portion of the model has the option of allowing one to distinguish the various off-site employment effects discussed earlier. For example, one may retrieve separately the employment associated with the spending of on-site wages, the purchase of materials, and the shift of disposable income from fuel purchases to general household expenditures. In addition, one can obtain the loss in employment due to decreased energy consumption. Output for these taken separately corresponds to that of Table 20 for total effects. This flexibility in the method of implementation of the multiplier analysis permits the disaggregated output of off-site employment presented in Section 1.3.

In addition to the employment impacts of the model, RIMS provides a current dollar estimate of the total indirect impact of additional conservation on the local economy. This is shown at the bottom of RIMS output.

TABLE 18.

SAMPLE RIMS OUTPUT



```
ENTER MINIRIMS OPTION NUMBER (1-5)
CONN    : CONSERVATION-PRODUCED EMPLOYMENT
TOTAL ENERGY AND MATERIAL EXPENDITURES
                          1978      1983      1988      1993      1998

INPUT INDUSTRY JOB          0.      514.     1435.     1983.     2761.     33292.

TOTAL OFF SITE EMPLOYMENT   0.      882.     2416.     3413.     5067.     58433.

TOTAL DEMAND (E3 1980$)     0.    28735.    77573.   111280.   172282.   1930425.
```

REFERENCES

1. Richard Syrin, "Regional Experience During Business Cycles -- Are We Becoming More or Less Alike," New England Economic Review, Nov./Dec., 1978.

2. Roger Bezdek, Long Range Forecasting of Manpower Requirements, Institute of Electrical and Electronics Engineers, 1974.

3. M. Schacter, Creating Jobs Through Energy, D.O.E./P.E.-0013, U. S. Government Printing Office, 1979.

4. ___________, The Job Creation Potential of Conservation and Solar, May 1979 (Unpublished).

5. Lionel Lerner and Frederick Posey, The Comparative Effects of Energy Technologies on Employment, California Energy Commission, November 1979.

6. Roger Sant, The Least Cost Energy Strategy, Mellon Institute Energy Productivity Center, 1979.

7. Steve Buchsbaum and James Benson, Jobs and Energy, Council on Economic Priorities, 1979.

APPENDIX A: BRIEF SURVEY OF REGIONAL ECONOMIC MODELLING

In the body of this report, employment impacts in the New England states of the conservation scenario have been discussed. Such an investigation falls within the general area of regional economic analysis. In particular, it involves that portion of regional economic analysis which attempts to quantify the effect of a particular activity or program, in this case the conservation policy measures on a given state's economy. A shift in regional final demand will produce a series of changes throughout the region resulting in a complex adjustment in the level of regional economic activity. To quantify this, the "multiplier" concept is introduced. For example, if the purchase of $1 worth of insulation resulted in an additional demand for regional goods and services worth $3.00, a crude multiplier would be 4. To refine the multiplier cooncept, suppose only $0.50 of the value of the $1 worth of insulation was added in the state and $0.50 of materials imported into the state. Then a better multiplier would be 2.5. In the original example, $1 of demand resulted in $3 worth of additional related activity. Likewise, $0.50, under the same general conditions, yields $1.50. The multiplier in this case is 2.5 @ $1.50 + $1.00 divided by the original expenditure. As suggested by this example, multipliers form the link between direct cost of the conservation measures and the resulting regional economic activity.

There are three basic approaches to the development of multipliers of the type required for this anlaysis: Economic Base Analysis, Regional Econometric Modelling, and Regional Input/Output Analysis. In this section each approach will be discussed briefly and the basis for the use of a regional input-output (I/O) approach in this study will be explained. (For a general introduction to regional analysis see Ref. 1.)

Economic Base Analysis (Ref. 2)

In this approach, one attempts to isolate those portions of the regional economy which "drive" the total economy. The driving portion is called the base. As an example, consider the classic company town, geographically isolated and containing a single large manufacturing plant serving a national market. In the long run all economic activity depends upon the plant, or transfer payments such as government aid (e.g., Social Security). In the short run, some sectors, such as residential construction, have a limited autonomy (e.g., construction may continue unabated despite a brief plant closing). Thus, depending on the time frame, the plant, plus perhaps certain other activities such as government and construction, form the local economic base. These activities do not depend essentially on the level of other current local economic activity, rather their demand for local goods and services stimulates the remaining local economic acitivity. Theoretically, one could define a multiplier using base and total economic activity, but it is more usual to move directly to employment levels relating base to total employment.

In order to use an Economic Base approach to compute total impact of conservation policies upon a state, one would have to divide the direct employment produced by the policies into base and non-base components. The total employment would then be the direct, non-base employment plus the direct base employment times a multiplier, representing the ratio of total to base employment in the entire regional economy. If appropriate data is available one can improve this procedure, dividing each industry into base and non-base components, and incorporate historic data into the determination of the ratio of total to base employment (Ref. 35).

Econometric Modelling (Refs. 3, 4, 36)

Here one attempts to formulate a complete model of the regional economy based upon the general relationships postulated by moder macroeconomics (Refs. 5, 6). The precise equations relating the various dependent variables (e.g., income) to "explanatory" variables (e.g., investment) of the local economy are determined statistically using the general relations suggested by economic theory and historic data on the regional economy (Ref. 3).

Once such a model has been constructed, one can change one of the independent variables in the equations developed, then, by solving the equations, obtain the remaining changes in the regional economy.

However, depending upon the specific form of the model equations, multipliers can be determined from the coefficients of the model equations directly. The following simple example will give some idea of the procedure. Let Y denote total regional income, which is divided into savings S, and consumption, C. A very simple model might assume that C is a linear function of Y. This means that C can be obtained from Y by an equation of the form $C = a + bY$ when a and b are numerical constants. Given this structural assumption, one could proceed using the techniques of econometrics together with historic data on C and Y to estimate the values of a and b which be express the historic relationship. Let us assume that it is found that $a = 100$ and $b = 8$ are the "best fit" values. Then the equation $C = 100 + 8Y$ would become part of the model. In a simple model, such an equation would allow the determination of the effect of an additional investment of I, on the regional economy. Economic theory shows that $\Delta C = \Delta I/(1-b)$ (where "Δ" signifies "change in"), so that in this particular case, an investment of I dollars would create $Y = 5I$ in additional income (Ref. 5, p. 26).

As this example suggests, the econometric approach to estimating total employment associated with conservation policies requires the use of multipliers culled from the model equations. In general, one would begin with the direct employment andtotal direct investment due to the policies. From investment, increased income would be computed as in the example. This would then be converted to indirect employment via a second multiplier. The total employment impact would then be the sum of the direct and indirect effects (Refs. 4, 36).

Regional Input/Output Analysis (I/O) (Refs. 8, 9)

Input/Output analysis is a general methodology for keeping track of the flow of goods and services in an economy. The analysis is based upon a standard type of tabular array, called an input/output flow table. Such a table is reproduced in Figure A.1 below. In order to understand I/O, it is necessary to understand how this table is constructed.

The I/O flow table presents a summary of all the transactions in the economy for a given period, usually one year. Beginning on the right, in the section marked final markets, we have four columns denoting the utltimate consumers of goods and services in the economy. Each row gives a different category. For example, the first entry under Persons contains the value of the agricultural products consumed by the household sector. Final consumption is net of consumption during the manaufacturing process. Each row of the darkened portion gives the part of an industry's gross output consumed in the production of goods and services. For example, the first entry in the construction column gives the value of agricultural products (such as wood) used in construction. Reading down the construction column through the darkened portion we find all of the inputs to construction from other productive sectors. The remainder of the value of construction is in the value added portion at the lower left. Here we find wages, depreciation, profits and taxes. These give the portion of the value of an industry's output added in the manufacturing process, and so represent the difference between an industry's input and output. In sum, reading up the column for an industry one finds all of the inputs to its gross product. Reading across the row for that same industry one finds the disposition of its output.

Let us suppose one wishes to analyze the effects on the economy related to a given final demand for personal consumption, say, for example, $100 worth of agriculture products. From the agriculture column, it is clear that to end up with this, extra agricultural production is required, and in addition inputs from the other industries, labor, capital, and the government are required. Further, if one looked at the input from the construction industry needed to produce the agricultural output, it could be traced back to an additional set of outputs from industry, labor, etc. Thus, in principle, one has an infinite sequence of interindustry transactions.

Each of the approaches described above has certain strengths and weaknesses. In selecting a particular methodology, both the general strengths and weaknesses of the approach, and the needs of the objectives of the analysis, must be considered. In the current study, the regional I/O approach was adopted for the following reasons:

1) Disaggregation. The Conservation measures are specified on a detailed end-use basis. Their implementation leads

FIGURE A.1
INPUT-OUTPUT FLOW TABLE

		INPUT TO PRODUCERS								FINAL MARKETS				TOTAL OUTPUT
		Agriculture	Mining	Construction	Manufacturing	Trade	Transportation	Services	Other	Persons	Investors	Foreigners	Government	
OUTPUT OF PRODUCERS	Agriculture	▨	▨	▨	▨	▨	▨	▨	▨	Personal consumption expenditures	Gross private domestic investment	Net exports of goods and services	Government purchases of goods and services	ROW TOTALS
	Mining	▨	▨	▨	▨	▨	▨	▨	▨					
	Construction	▨	▨	▨	▨	▨	▨	▨	▨					
	Manufacturing	▨	▨	▨	▨	▨	▨	▨	▨					
	Trade	▨	▨	▨	▨	▨	▨	▨	▨					
	Transportation	▨	▨	▨	▨	▨	▨	▨	▨					
	Services	▨	▨	▨	▨	▨	▨	▨	▨					
	Other	▨	▨	▨	▨	▨	▨	▨	▨					
VALUE ADDED	Employees	Employee compensation												
	Owners of Business and Capital	Profit type income and capital consumption allowances												
	Government	Indirect business taxes												
TOTAL OUTPUT		COLUMN TOTALS												

to direct employment in specific job areas. Only I/O analysis would allow this level of disaggregation. Economic base and econometric approaches provide much more aggregate results.

2) Cost. Initially regional I/O studies were extremely costly to perform. However, with the development of the Regional Industrial Multiplier System (RIMS) by the Regional Economic Analysis Division of the Bureau of Economic Analysis, United States Department of Commerce (Ref. 11), it became possible to obtain the multipliers associated with a fully regionalized I/O table at low cost. No similar faculty exists for economic base or econometric studies. Thus, for a comparable level of complexity, they are considerably more expensive.

3) Accessibility. The basic theory underlying I/O analysis is simple and well understood (Ref. 7). The construction of the national I/O table on which the RIMS system is based is well documented (Refs. 12, 13). The procedure used to construct the RIMS systems from the national data has been published (Ref. 10) as have preliminary assessments of its accuracy (Ref. 14). In contrast the other two approaches are much less open to scrutiny. In the Economic Base approach, problems of judgment and availability of data are extremely serious (see, e.g., 15, 16). In the econometric approach the complexity of even moderate scale models create serious problems (Ref. 17). In addition many regional econometric models are linked to national level models such as the well known Data Resources Incorporated, Wharton, and Chase models which are privately owned and whose equations and data base are proprietary.

In addition to such positive features of the I/O approach, it was found that what are usually seen as negative features associated with an I/O approach had minimal effect upon the objectives of this study. One source of difficulty may arise from the fact that the table of flows on which an I/O model is based reflects conditions in a particular year, and so also at a specific production level using a fixed technology. Attempts have been made to project the whole national table, accounting for future changes (Ref. 18). However, such procedures are extremely complex and may introduce the effects of historic trends which themselves could change in the future. Such procedures are not currently a part of the RIMS approach used in this study. In evaluating the importance of the difficulty of using a fixed year's data, it must be remembered that uncertainty exists on economic forecasting in general, as documented in recent surveys of the record (Refs. 19, 20). The questions is not one of absolute error, but rather of comparisons with other available alternatives. Here the record is clear. Detailed studies of a large number of forecasts have shown that those based upon an I/O approach perform at least as well and generally better than those made using alternative methods (Refs. 21, 22).

TABLE A.1

DESCRIPTION OF THE MATHEMATICAL BASIS FOR INPUT/OUTPUT ANALYSIS

Definitions

$Y = (y_1, \ldots, y_1)$ is the n-entry vector of final demands. The y_i terms are the entries in the Total Output column of Figure 2.1 expanded from 8 to n sectors.

$X = (x_1, \ldots, x_n)$ is an n-entry vector of total demand. x_i is the total production of industry i required to produce the final output y_i.

$$B = \begin{bmatrix} b_{1,1}, & \ldots, & b_{1,n} \\ b_{n,1}, & \ldots, & b_{n,n} \end{bmatrix}$$

B is an n by n matrix corresponding to the darkened portion of Figure 2.1. Its entry $b_{i,j}$ in the i^{th} row and j^{th} column is the amount of input from Industry i required for the output of industry j.

$C = (c_1, \ldots, c_n)$ is an n-entry vector whose j^{th} entry c_j is the sum of the inputs to the j^{th} industry as shown at the bottom of the left side of Figure 2.1.

A is an n by n matrix whose entries are given by the formula:

$$a_{i,j} = b_{i,j}/c_j$$

$a_{i,j}$ is the value of the input of industry i which is required to produce $1 of output from industry

E is an n-entry vector. Its i^{th} component is the number of equivalent full time employees per $10,000 of total output in industry i.

F is an n-entry vector. Its i^{th} component is the number of full time equivalent employees in industry i required to produce the total output x_i.

Equations

The total required output from industry i, x_i, is the final demand y_i plus the sum of the fractions of x_i used in the production of the total products $x_1, \ldots, x_n$. The required equality is given by

$$y_i + a_{i,1} \quad x_1 + \cdots + a_{i,n}x_n = x_i$$

This equality holds for each industry i. The resulting equation can be viewed as a system of equations for the x_i's in terms of the y_i's. It is known that this system of equations has the theoretical properties to allow its solution for the values of the x_i's given the y_i's (Ref. 7). Once x_i is known the associated employment can be found by multiplication:

$$f_i = e_i \times x_i/10{,}000$$

The procedure can be formulated easily in terms of matrices. Beginning with the original system of equations we have

$$Y^t + AX^t = X^t$$

$$Y^t = (I-A)X^t$$

$$X^t = (I-A)^{-1}Y^t$$

then

$$F = EX^t/10{,}000$$

where "t" denotes the transport matrix and "-1" denotes matrix inversion.

The second difficulty is that an I/O approach does not take into account limitations on the supply of labor or capital. Limitation in the appropriate labor supply might be of some consequence if the computed employment requirements were greatly different from what would otherwise be expected or if the labor market were tight. Under such conditions the labor required by the conservation measures, directly or indirectly, might come at the expense of other activities, or might exceed the supply of available labor altogether. However, given the specific labor requirements associated with the conservation scenario, no such difficulties are likely to be encountered.

Appendix A: References

1. W. Isard et.al., Methods of Regional Analysis, John Wiley and Sons, Inc., 1960.

2. C. Tiebout, The Community Economic Base Study, Committee for Economic Development Suplementary Paper No. 16, 1962.

3. K. Wallis, Introductory Econometrics, Aldine Publishing Co., 1972.

4. R. Dusansky, The Economic Impact of the University Hospital, The Economic Research Bureau of the State University of New York at Stony Brook, 1978.

5. R. Allen, Macro Economic Theory, St. Martins Press, 1968.

6. B. Hansen, A Survey of General Equilibrium Systems, McGraw-Hill Book Co., 1970.

7. R. Dorfman et.al., Linear Programming and Economic Analysis, McGraw-Hill Book Co., 1958.

8. P. Vanderwerf, Regional Employment and Income Effects of a 50 MW Wood-Fired Power Plant, Publication No. DSD #90, Thayer School of Engineering, Dartmouth College, 1978.

9. W. Isard and R. Kuenne, "The Impact of Sleet upon the the Greater New York-Philadelphia Industrial Region," The Review of Economics and Statistics, 1949.

10. P. VanderWerf, Appendices to DSD #90, Publication No. DSD #122, Thayer School of Engineering, Dartmouth College, 1978.

11. U.S. Water Resources Council, Guideline 5 Regional Multipliers, 1977.

12. The Interindustry Economics Division, B.E.A.," The Input/Output Structure of the U.S. Economy: 1967," Survey of Current Business, February, 1974.

13. The Interindustry Economics Division, B.E.A., The Input/Output Structure of the U.S. Economy, Vol. 1-3, 1974.

14. R. Drake, "A Short Cut to Estimates of Regional Input/Output Multipliers," International Regional Science Review, 1976.

15. NEPOOL Load Forecasting Task Force and Battelle-Columbus Laboratories, Report on Model for Long Range Forecasting of Electric Energy and Demand, 1977.

16. P. Raskin et.al., Assessment of the NYPOOL-Battelle Long-Range Electric Demand Forecasting Model, ESRG, 1979.

17. L. Mayer, "The Value of an Econometric to Forecasting an Energy Future," Proceedings of the International Conference on Energy Use Management, Pergamon Press, 1978.

18. R. Earley and M. Mohladi, EIA Input/Output Model Simulation Procedures, Document No. DOE/EIA-010313 UC-13, Department of Energy, 1978.

19. W. Ascher, Forecasting, An Appraisal for Policy Makers and Planners, Johns Hopkins Press, 1979.

20. R. Bezdek, Empirical Tests of Input/Output Forecasts, B.E.A., 1974.

21. A. Shapiro, Input/Output Analysis as a Predictive Tool, U.S. Department of Commerce, 1972.

22. N. Saunders, "The U.S. Economy to 1990: Two Projections of Growth," Monthly Labor Review, U.S. Department of Labor, December 1978.

23. C. Killingworth, "Structural Unemployment without Quotation Marks," Monthly Labor Review, U.S. Department of Labor, June 1979.

24. M. Schader, The Job Creation Potential of Solar and Conservation: A Critical Evalution, Advanced Energy Systems Policy Division, U.S. Department of Energy, 1978.

25. V. Personich, "Industry Output and Employment: BLS Projections to 1990," Monthly Labor Review, U.S. Department of Labor, April 1979.

26. C. Bullard et.al., Net Energy Analysis: Handbook for Combining Process and Input/Output Analysis, Center for Advanced Computation Document No. 214, University of Illinois at Urbana, 1976.

27. J. Stutz and A. Israel, A Methodology for Estimating Total Economic and Employment Impacts of Energy Related Construction, ESRG, 1978.

28. J. Benson et.al., The Long Island Jobs Study, Council on Economic Priorities (to appear).

29. J. Stutz, The Employment Impact of Solar Energy and Conservation on Springfield, Mass., ESRG (to appear).

30. J. Carlwright, the RIMS Multiplier System, B.E.A. (unpublished).

31. Statement of W. Winpersinger before the Joint Economic Committee of Congress, March 16, 1978.

32. A Pleszkun, *Calculating Energy and Labor Impacts of Capital Readjustments Due to Changes in Personal Consumption*, Center for Advanced Computation Document No. ERG 266, University of Illinois at Urbana, 1979.

33. "Inflation Leads Many Reluctantly to Switch from Saving to Buying," *Wall Street Journal*, July 25, 1979.

34. "Homeowner Rush to Shift to Gas as Price of Oil Spirals," *Wall Street Journal*, July 11, 1979.

35. *Socioeconomic Impacts of Western Energy Resource Development*, Vol. II, Denver Research Institute, 1979.

36. N. Glicksman, *Econometric Analysis of Regional Systems*, Academic Press, 1977.

37. *Jobs and Energy*, Environmentalists for Full Employment, 1977.

38. H. Lee et.al., *The New England Energy Policy Alternatives Study*, Mass. Energy Office, 1978.

APPENDIX B: MATHEMATICAL STRUCTURE OF THE ESRG EMPLOYMENT MODEL

In this Appendix, we describe the mathematical structure of three of the four programs which form the bulk of the ESRG Employment Model. The programs COST, ENERGY, and RIMS are described in detail. SCENARIO, the fourth program in the system, is concerned largely with market penetration analysis for conservation and solar measures. Since, in this study we have determined penetration exogenously to the employment model, we have not included a detailed description of the scenario program*. In the descriptions of the structure of the programs, it is assumed that the reader is familiar with the general purpose of the programs as described in Section 2.5 of the main body of the text.

COST

In this portion of the model, on-site employment and total material, service, and labor demands resulting from a previously specified schedule of yearly implementations for the set of measures under consideration are computed. This schedule is specified directly by making use of the "user specified measure implementation feature" discussed earlier. The computations in COST are shown in Table B.1. The COST portion of the analysis is largely an accounting exercie; each input for a measure implementation is broken down and assigned to a specific category or categories. The details of this process are determined by the input/output (I/O) analysis which follows in the RIMS portion of the model. The I/O data is the Regional Economic Analysis Division of the Bureau of Economic Analysis (BEA) of the United States Department of Commerce. All input data must be classified according to standard BEA codes. Hence, each item in the analysis must be assigned such a code. The BEA codes are approximately the same as the four-digit Standard Industrial Classification (SIC) system. The on-site employment is classified according to job type using the categories shown in COST output in Section 2.5, above.

Note that when dealing with a single measure, we refer to materials and labor types by the indices for that measure, G1 and G2. When dealing with all the measures, however, we refer to materials and labor types by their BEA code or labor type, I and J, respectively. For each measure, the transition from the measure-specific indices to the BEA code is given by an equation, I - C1 (G1). Similarly, for the job type code, J = J$ (G2). With this in mind, the manipulations are relatively straightforward.

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* The reader interested in a description is referred to a previous ESRG study, Analyzing the Economic Impacts of State Policies to Promote Energy Conservation, performed for the Renewable Resource Division/Massachusetts Office of Energy Resources.

TABLE B.1

COST EQUATIONS

Variable Code

BY	Base Year (Currently 1978)
T	Year (T=1 in base year)
I	A dummy variable standing for a BEA Code
J	A dummy variable for an ESRG labor code
RMI	Fractional yearly real increase in materials costs
RWI	Fractional yearly real increase in labor costs
W$(J,T)	The total hours of labor of type J in year T. (Aggregated over all measure implementations in year T)
Y	An index indicating if do-it-yourself is being considered
AC(I,T)	The total value, in BY dollars, of on-site expenditures in BEA category I in year T
FWW	Fraction of wages withdrawn (Soc. Sec., taxes, etc.)
FWS	Fraction of wages saved
MARG(I,N)	The four margin codes (N = 1 for rail, 2 for trucking, 3 for wholesale, and 4 for retail

NOTE: The following variables are all measure specific. We continue our convention of suppressing the index K, denoting the measure, to simplify notation.

D(T,1)	The number of initial implementations of measure K in year T
D(T,2)	The number of replacement implementations of measure K in year T
D(T,3)	The total number of initial implementations of measure K cumulative to year T
DOSELF	The fraction of the implementation activity which is "do-it-yourself"
FLABOR	Contractor mark-up in labor
MAINTL	Fraction of initial wages cost spent on yearly maintenance
MAINTM	Fraction of initial materials cost spent on yearly maintenance
JNUM	The number of labor categories used in measure K
G2	An index for the labor categories used in a single measure (G2 = 1 to JNUM)
J$(G2)	The ESRG index of the G2nd labor type in measure K (See text for further discussion)
W1(G2)	The hours of labor of type J$(G2) in measure K
W2(G2)	The wages paid for labor of type J$(G2) for measure K
P(G2)	The percentage of labor type J$(G2) which is available locally
CCODE	The BEA category for the contractor who installs the measure K
INUM	The number of materials used in measure K
G1	An index for the materials used in a measure (G1 = 1 to INUM)
C1(G1)	The BEA code for category for material G1 in measure K
C2(G1)	The wholesale cost of material G used in an implementation of measure K
C3(G1)	The percentage of material G1 which is produced locally
LOC1(K,J)	A variable used to determine the fraction of labor type J used in measure K which is supplied by local residents (See Equation 9.7)
LOC2(K,I)	A variable used to obtain the fraction of material I used in measure K which is produced locally (See Equation 9.13)

NOTE: The following variables are all measure specific. However, they are used in equations which aggregate results over all measures. Thus, to avoid confusion, we show the measure dependence explicitly via the index K for the measure number.

F1(K,J,T)	The total number of hours of labor time of type J used in implementation or maintinance of measure K in year T
F2(K,J,T)	The total wages paid for the F1(K,J,T) hours of labor.
X$(K,I,T)	The wholesale price of material I used in the implementation or maintenance of measure K in year T

Equations (All for $T \geq 2$)

Determine yearly hours and wages by measure and job type

If J = J$(G2) for some G2 = 1 to JNUM

$$F1(K,J,T) = W1(G2) \times P(G2) \times (1 - Y \times DOSELF) \times \left[D(T,1) + D(T,2) + MAINTL \times D(T-1,3) \right] \quad (1)$$

$$F2(K,T,T) = F1(K,J,T) \times \frac{W2(G2)}{W1(G2)} \times (1 + RWI)^{T-2} \quad (2)$$

(cont.)

TABLE B.1 (cont.)

If $J \neq J\$(G2)$ for any $G = 1$ to JNUM

$$F2(K,J,T) = F1(K,J,T) = 0 \tag{3}$$

Determine total yearly labor by job type

$$W\$(J,T) = \sum_{K} F1(K,J,T) \tag{4}$$

Compute contractor mark-up and assign 20% to contractor costs.

$$AC(CCODE,T) = \sum_{K,J} .2 \times FLABOR \times F2(K,J,T) \tag{5}$$

Define a factor to give the fraction of labor type J obtained locally

$$LOC1(K,J) = \begin{cases} P(G1) & \text{if for measure } K, J = J\$(GI) \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

Credit savings from wages and contractor income to banking (BEA Code 7001)

$$AC(7001,T) = \sum_{K,J} \left[F2(K,J,T) \times (1-FWW) \times FWS \times (LOC(K,J) + .8 \times FLABOR)\right] \tag{7}$$

Allocate remaining contractor income and wages to the household category (BEA code 8888)

$$AC(8888,T) = \sum_{K,J} \left[(.8 \times FLABOR + LOC1(K,J)\right] \times \left[(1-FWW) \times (1-FWS) \times F2(K,J,T)\right] \tag{8}$$

Compute the wholesale cost of material I used in year T in measure K

If $I = C1(G1)$ for some $G1 = 1$ to INUM then

$$X\$(K,I,T) = C2(G1) \times \left[(1+RMI)(1-TECH)\right]^{T-2} \times \left[D(T,1) + D(T,2) + MAINTM \times D(T-1,3)\right] \tag{9}$$

If $I \neq C1(G1)$ for any $G1 = 1$ to INUM then

$$X\$(K,I,T) = 0 \tag{10}$$

Allocate the markup on materials used in do-it-yourself activity to the retail category (BEA Code 6902)

$$AC(6902,T) = \sum_{K,I} X\$(K,I,T) \times Y \times DOSELF \times MARG(I,4) \tag{11}$$

Allocate the remaining margins

$$AC(I\$(N),T) = \sum_{K,I} X\$(K,I,T) \times MARG(I,N)$$

where $I\$(N)$ is the BEA code for the category for margin N,

$$N = 1, 2, 3 \tag{12}$$

Define a factor to give the fraction of material I produced locally

$$LOC2(K,I) = \begin{cases} C3(G1) & \text{if for measure } K, \; I = C1(G1) \\ 0 & \text{otherwise} \end{cases} \tag{13}$$

Reduce wholesale costs to costs at the point of production and allocate the local production to BEA categories

$$AC(I,T) = \sum_{K} X\$(K,I,T) \times \left[1 - \sum_{N=1}^{3} MARG(I,N)\right] \times LOC2(K,I) \tag{14}$$

where I runs over the BEA categories for materials

Referring to Table B.1, the calculations begin with the total labor time and wages in each job category for implementations of each measure in each year (Eqs. 1, 2, and 3). Note that this is specified for all job types for each measure. If a certain job type does not occur, the hours and wages are set to zero (Eq. 3). Next on-site labor is determined by aggregating over the set of measures (Eq. 4). Next wages and contractor income are allocated to the appropriate BEA categories. Under the assumptions that measure implementations are performed by small local contractors, 20 percent of the mark-up is assigned to the BEA category appropriate to the contractor's business type (Eq. 5). Wages are reduced for transfers and an appropriate fraction assigned to savings (Eq. 7). The transfer and savings fractions can be specified by the user, as can the hourly wage rate. Finally, the remaining contractor income and wages assigned to the household category (Eq. 8).

Next, materials are considered. The first step is to get the wholesale cost of materials I used in implementation and maintenance for measure K in year T. As in the case of wages, this is zero for materials which do not appear in measure K (Eqs. 9 and 10). Next, retail margins on do-it-yourself activity and the other three margins on all activities are allocated to the appropriate BEA categories (Eqs. 11 and 12). Finally, prices of materials used in the measures are reduced from wholesale to producers' prices and the fraction produced locally allocated to the appropriate BEA materials category (Eqs. 13 and 14). All items of on-site expense which are produced or purchased locally have been allocated to an appropriate BEA category. The data in the array AC (I, T) are passed to the RIMS portion of the model, where it is combined with similarly organized data on fuel savings and income shifts from the ENERGY portion to compute all of the indexed effects on the local economy.

ENERGY

The computations in the ENERGY portion of the model are summarized in Table B.2. It begins with a computation of cumulative energy savings and energy savings per year due to initial implementations. In order to make this calculation, implementations for all fuels, as opposed to singel fuel, must be divided among the fuel types. The function, defined in Eqs. 1 and 2 of Table B.2 allows for this and the treatment of all implementation options in a uniform manner. With the aid of this function, fuel savings are computed in Eqs. 3 and 4. The division of electricity into two parts, to accomodate the dual role palyed by air conditioning, leads to the two-step process in these equations; savings are computed for our four "fuels" separately and then the last two are combined to give the total figures for electricity (Eqs. 5 and 6). Once the yearly savings have been determined, they must be reduced to producers' prices by the removal of retail, wholesale, and transportation margins, and then the aggregate margin amounts and fuel savings allocated to appropriate BEA categories. (Unlike the materials, the fuel prices are retail, since they represent household purchases.) The margin allocation is made in Eq. 7, and the fuel allocation in Eq. 8.

The second step in this part of the analysis is the allocation of net fuel savings beyond the purchase price of the measure to the household category. We begin by computing the yearly energy savings (Eq. 9). When dealing with all fuels, the savings are weighted by the saturations of the fuels. Next, for each possible implementation year, the cumulative savings over the life of the measure are computed (Eq. 10). This is used to construct an index which, for each pair of years (S, T), indicates if the savings through year T from an implementation in year S have paid for the measure (Eq. 11). If SAV1 (S, T) = 1, then in year T an implementation in year S, initial or replacement, will produce savings in excess of the cost of the measure. The index SAV1 (S, T) is defined for each measure K. In Eq. 12, for each year T, all fuel savings are summed, net of maintenance, which come from measure implementations which have "paid for themselves" via the amortization process, and allocate these savings to the household category.

RIMS (Regional Industrial Multiplier System)

In this portion of the model, the on-site impacts are converted into total impacts on the region, making use of the "multipliers" provided by the Bureau of Economic Analysis. The structure of this portion of the model, shown in Table B.3, is deceptively simple. This simplicity is due to the fact that most of the analysis has been performed by the BEA. In Table B.4 below, data provided by the BEA for a typical category of on-site demand is shown.

Data on materials, expenses, energy savings, etc., flow into RIMS from COST and ENERGY. The first step in the multiplier computation of Table B.3 is to combine these data into a single set of local expenditures, deflated to 1967 dollars. This is done in Eq. 1. Deflation is necessary because the BEA tables are designed for 1967 dollars. In the analysis, we wish to capture the multiplier effects of wage spending as well as shifts in household expenditures due to fuel savings. To do this directly would require multipliers for the household sector. The version of RIMS used in the study did not contain these multipliers. This problem was dealt with by the use of a bridge vector which allocates the household purchases among the various industrial, trade, and service categories. This is done in Eq. 2. In Eq. 3, total impacts are determined and then reflated to get the total impact in BY dollars. Next, using additional data supplied by the BEA, the local employment is developed. This is done in two steps. First, using the "household" multiplier component, M (I, 1), wages in the industries impacted directly by final demand are computed. These are converted to "input industry jobs," as shown in the RIMS output multiplication by an employment to earnings ratio (Eq. 4). Next, the remaining multiplier components, M (L, 2), for direct and M (L, 3) for indirect/induced, are summed and multiplied first by the output to earnings ratio and then by the employment to earnings ratio. This gives the remaining off-site employment. These are added to the results of the first computation of total off-site employment (Eq. 4).

TABLE B.2

ENERGY EQUATIONS

Variable Code

BY	Base Year
T	Year (T=1 in base year)
S	A second dummy variable for year
Z25	A code indicating which fuel the implementations are for (Z25 = 0 for all, 1 for gas only, 2 for oil only, 3 for electric only)
F	An index for fuels (F = 1 for gas, 2 for oil, 3 for electricity (non a/c), and 4 for electricity (a/c only))
Z0	The number of years for which the analysis runs
K	The measure number
I	A dummy variable for the BEA categories
MARG(I,N)	The four margin codes (N = 1 for rail, 2 for trucking, 3 for wholesale, and 4 for retail
F$(1,F,T)	Total savings of fuel F through year T, physical units
F$(2,F,T)	Total saving of fuel F through year T, in BY year dollars
F$(3,F,T)	Savings of fuel F in BY year dollars due to initial implementations in year T
A	A dummy variable for the code Z25
F$1(N1,F,T)	An intermediate variable in the computation of F$, N1 = 1, 2, 3
LIST(N2)	A list of the BEA codes for gas utilities, petroleum, electric utilities, rail, trucking, wholesale and retail, N2 = 1 to 7.
AF(I,T)	The total value, in BY dollars, of on-site expenditures in BEA category I in year T. (Note: Fuel savings are negative expenditures.)

NOTE: The following variables are measure specific. We have suppressed the index K to simplify notation.

LIFE	The measure's useful life
U(T)	The cost of maintanance in year T for an implementation of measure K (From SCENARIO, Equation 6.4)
E$1(F,T)	The percentage of the measure related demand met by fuel F in year T (From SCENARIO, Equation 6.12)
SAVING(F)	Savings of fuel F due to an application of measure K
UC(T,F)	Unit cost of fuel F in year T (From SCENARIO, Equation 6.13)
D(T,1)	Initial implementations of measure K in year T
D(T,2)	Replacement implementations of measure K in year T
D(T,3)	Cumulative initial implementations of measure K to year T
FNB(A,F,T)	An internally defined function used to allocate the implementations of measure K by fuel
ESAV(T)	The energy savings for measure K in year T in BY dollars
SAV(S,T)	Savings through year T from an implementation of measure K in year S
SAV1(S,T)	An index showing when fuel saving exceeds measure cost
Z2$(T)	The cost of an implementation of measure K in year T after all tax or other credits (From SCENARIO, Equation 6.11)

Equations

Define the function to allocate measure implementations by fuel:for each K

$$\mathrm{FNB}(0,F,T) = \mathrm{E\$1}(F,T) \times \mathrm{SAVING}(F) \quad \text{For } F = 1 \text{ to } 4,\ T \geq 1 \tag{1}$$

$$\mathrm{FNB}(A,F,T) = \begin{cases} \mathrm{SAVING}(F) & \text{if } A = F \quad \text{For } A \neq 0,\ T \geq 1 \\ 0 & \text{if } A \neq F \end{cases} \tag{2}$$

Compute fuel savings:

$$\mathrm{F\$1}(1,F,T) = \sum_{K} \mathrm{FNB}(\mathrm{Z25},F,T) \times D(T,3) \tag{3}$$

$$\mathrm{F\$1}(2,F,T) = \sum_{K} \mathrm{FNB}(\mathrm{Z25},F,T) \times \mathrm{UC}(F,T) \times D(T,3) \tag{4}$$

For N1 = 1,2

$$\mathrm{F\$}(N1,F,T) = \mathrm{F\$1}(N1,F,T) \quad \text{for } F = 1,2 \tag{5}$$

$$\mathrm{F\$}(N1,3,T) = \mathrm{F\$1}(N1,3,T) + \mathrm{F\$}(N1,4,T) \tag{6}$$

(cont.)

TABLE B.2 (cont.)

Allocate the margins on the fuel savings to BEA categories

$$\mathrm{AF(LIST(N2),T)} = \sum_{\mathrm{N=1}}^{3} \mathrm{MARG(LIST(N),N2-3)} \times \mathrm{F\$(3,N,T)} \quad \text{For N2 = 4 to 7} \tag{7}$$

Remove margins and allocate fuel savings to BEA categories

$$\mathrm{AF(LIST(N),T)} = \mathrm{F\$(\ ,N,T)} \times \left(1 - \sum_{\mathrm{N2=4}}^{7} \mathrm{MARG(LIST(N),N2-3)}\right) \quad \text{For N=1,2,3} \tag{8}$$

For each measure K

Define the energy savings for one implementation in year T

$$\mathrm{ESAV(T)} = \sum_{\mathrm{F}} \mathrm{FNB(Z25,F,T)} \times \mathrm{UC(F,T)} \tag{9}$$

Compute saving through year T of an implementation of measure K in year S

$$\mathrm{SAV(S,T)} = \begin{cases} \sum_{\mathrm{R=S}}^{\mathrm{T}} (\mathrm{ESAV(R)} - \mathrm{U(R)}) & \text{if } 0 \leq \mathrm{T} - \mathrm{S} \leq \mathrm{LIFE} \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

Define index showing when fuel saving exceeds measure cost

$$\mathrm{SAV1(S,T)} = \begin{cases} 1 & \text{if } \mathrm{SAV(S,T)} > \mathrm{Z2\$(S)} \\ 0 & \text{otherwise} \end{cases} \tag{11}$$

Then, when this is complete for all measures,
Credit net fuel savings to the household category

$$\mathrm{AF(8888,T)} = \sum_{\mathrm{K}} \sum_{\mathrm{S=1}}^{\mathrm{T}} \mathrm{SAV1(S,T)} \times (\mathrm{ESAV(T)} - \mathrm{U(T)}) \times (\mathrm{D(S,1)} + \mathrm{D(S,2)}) \tag{12}$$

TABLE B.3

THE RIMS (I/O) EQUATIONS

Variable Code

BY	Base Year
T	The year (T = 1 in the base year BY)
I	The BEA code for an on-site expenditure.
DEF (I)	An index used to deflate expenditures in category I from BY + 1 to 1967 dollars
M (I, L)	The components of the RIMS multiplier for industry; L = 2 for direct, and L = 3 for indirect induced.
EMPL	The employment to earnings ratio
EARN	The earnings to output ratio
REF	An index used to relate expenditures from 1967 to BY + 1 dollars
AC (I, T)	Expenditures on category I, year T, from COST
AF (I, T)	Expenditures on category I, year T, from ENERGY
A (I, T)	Total expenditures on category I, year T
BRIDGE (I)	The fraction of household income allocated to industry (adjusted for margin removal)
B (1, T)	The total demand in year T, BY + 1 year dollars
B (2, T)	Total employment due to initotal off-site purchases in year T
B (3, T)	The total induced employment in industry L, year T

Equations

Determine total net on-site effects, deflated to 1967 dollars:

$$A(I, T) = (AC(I, T) + AF(I, T))/DEF(I) \text{ for all } I, T \qquad (1)$$

(cont.)

TABLE B.3 (cont.)

Allocate "household" expenses to other categories:

$$A(I, T) = A(I, T) + A(8888, T) * \text{BRIDGE}(I) \text{ for all } I \neq 8888 \text{ and all } T \qquad (2)$$

Compute total economic impact in BY + 1 dollars: (3)

$$B(1, T) = \sum_{I} \text{REF} \times A(I, T) \times \left(\sum_{L=1}^{3} M(I, L)\right)$$

Compute initial off-site employment impact: (4)

$$B(2, T) = \text{EMPL} \times \sum_{I} A(I, T) \times M(I, 1) \text{ for all } I, T$$

Compute total off-site employment impact: (5)

$$B(3, T) = B(1, T) + \text{EMPL} \times \text{EARN} \times \left(\sum_{I} A(I, T) \times (M(I, 2) + M(I, 3)\right) \text{ for all } I, T$$

TABLE B.4

CONNECTICUT

COMPONENTS AND MULTIPLIERS

INDUSTRY NAME	SUM OF DIRECT COEFFS	HOUSEHOLD COEFFICIENT	DIRECT COMPONENT	INDIRECT INDUCED COMPONENT	TOTAL MULTIPLIER
PAVING MIXTURES AND BLOCKS	.3464	.2345	.581	1.077	2.657
ASPHALT FELTS AND COATINGS	.4323	.2455	.678	1.277	2.954
RUBBER	.5073	.3126	.820	1.575	3.394
HYDRAULIC CEMENT	.3419	.2500	.592	1.099	2.691
CLAY	.3388	.4700	.809	1.551	3.360
CONCRETE, LIME, AND GYPSUM	.4726	.2916	.764	1.457	3.220
OTHER STONE AND CLAY PRODUCTS	.4137	.3487	.762	1.452	3.214
ALUMINUM ROLLING AND DRAWING	.2126	.1759	.389	.692	2.080
PRIMARY IRON AND STEEL MANUFACTURING	.3932	.3347	.728	1.381	3.109
OTHER PRIMARY METAL MANUFACTURING	.5699	.1717	.742	1.410	3.152
FABRICATED STRUCTURAL STEEL	.5569	.2798	.837	1.611	3.447
OTHER FABRICATED METALS AND ORDNANCE	.4765	.3031	.780	1.490	3.270
ENGINES AND TURBINES	.5439	.2999	.844	1.626	3.469
CONST., MINING, AND MATERIALS HANDLING MACH. AND EQUIP.	.5321	.3142	.846	1.630	3.475
METALWORKING MACHINERY AND EQUIPMENT	.4259	.3915	.817	1.568	3.365
SPECIAL INDUSTRY MACHINERY	.5156	.3272	.843	1.624	3.466
GENERAL INDUSTRIAL MACHINERY AND EQUIPMENT	.4656	.3404	.806	1.545	3.351
OFFICE, COMPUTING, AND ACCOUNTING MACHINERY	.4143	.3353	.750	1.427	3.177
MISCELLANEOUS MACHINERY, EXCL. ELECTRICAL	.5218	.2251	.747	1.421	3.167
CARBON AND GRAPHITE PRODUCTS	.3953	.3065	.702	1.327	3.028
ELECTRIC TRANS. AND DIST. EQUIP. AND INDUSTRIAL APPARATUS	.4806	.3338	.814	1.562	3.376
HOUSEHOLD APPLIANCES	.5868	.2644	.851	1.641	3.491
ELECTRIC LIGHTING AND WIRING EQUIPMENT	.4866	.3079	.794	1.520	3.313
RADIO AND TELEVISION RECEIVING SETS	.4327	.4293	.862	1.664	3.525
ELECTRONIC COMPONENTS AND ACCESORIES	.5328	.3632	.896	1.737	3.632
MISCELLANEOUS ELECTRICAL MACHINERY, EQUIPMENT, AND SUPPLIES	.4718	.2851	.757	1.442	3.198
MOTOR VECHICLES AND EQUIPMENT	.3870	.3034	.690	1.302	2.991
AIRCRAFT AND PARTS	.5027	.4017	.904	1.754	3.657
TRANSPORTATION EQUIPMENT, NEC	.4418	.3820	.824	1.583	3.407
GLASS PRODUCTS	.3385	.3745	.713	1.350	3.062
SCIENTIFIC INSTRUMENTS, WATCHES, AND CLOCKS	.5005	.3005	.801	1.535	3.335
PHOTOGRAPHIC AND OPTICAL GOODS	.4001	.4260	.826	1.587	3.413
MANUFACTURING, NEC	.3988	.2964	.695	1.312	3.007
TRUCKING AND WAREHOUSING	.2842	.4523	.736	1.398	3.133
AIR TRANSPORTATION	.2455	.3543	.600	1.116	2.715
LOCAL AND INTERURBAN HIGHWAY PASSENGER TRANSPORTATION	.1367	.4057	.542	.997	2.539
WATER TRANSPORTATION	.2745	.2798	.554	1.022	2.575
TRANSPORTATION SERVICES, EXCL. RAILROAD SERVICES	.1360	.6881	.824	1.583	3.407
PIPELINE TRANSPORTATION	.2762	.1500	.426	.765	2.190
TELEPHONE AND TELEGRAPH COMMUNICATIONS	.1405	.3362	.477	.866	2.343
RADIO BROADCASTING AND TELEVISION	.2644	.3330	.597	1.110	2.706
ELECTRIC UTILITIES	.1652	.1532	.338	.592	1.930
GAS UTILITIES	.3907	.1366	.527	.967	2.494
WATER AND SANITARY SERVICES	.1183	.2494	.366	.651	2.018
WHOLESALE AND RETAIL TRADE	.2036	.5265	.730	1.385	3.115
FINANCE AND INSURANCE	.3608	.4497	.811	1.556	3.366
REAL ESTATE	.2772	.0166	.294	.508	1.802
HOTELS AND LODGING PLACES	.4165	.5021	.917	1.786	3.704
AUTOMOBILE PARKING AND REPAIR SERVICES	.3050	.2565	.562	1.038	2.600
PERSONAL AND REPAIR SERVICES	.3064	.4379	.744	1.415	3.158
BUSINESS SERVICES	.2752	.4360	.711	1.346	3.056
AMUSEMENT AND RECREATION SERVICES	.3210	.2834	[illegible]	1.124	2.726
PROFESSIONAL SERVICES	.2626	.6149	.877	1.696	3.572

REGIONAL INDUSTRIAL MULTIPLIER SYSTEM
REGIONAL ECONOMIC ANALYSIS DIVISION
BUREAU OF ECONOMIC ANALYSIS

APPENDIX C: DETAILS ON INVESTMENT, SAVINGS AND EMPLOYMENT IMPACT BY STATE

This appendix contains data on investment costs, value of fuel savings, employment impacts associated with the change from Base Case to Conservation Case conditions. The information is presented by state for selected years following the pattern used in Tables 4 and 6 in Section 1.3 above. The reader should refer to the discussion the main text for an explanation of these tables.

TABLE C.1

YEARLY CONSERVATION INVESTMENT, ENERGY SAVINGS AND SHIFTED DISPOSABLE INCOME IN CONNECTICUT

(10^6 1980$)

	1978	1983	1988	1993	1998	TOTAL
Total Investment	0	44	98	96	93	1,630
Energy Savings	0	26	152	272	390	4,257
Shifted Disposable Income	0	12	97	207	326	3,251

TABLE C.2

YEARLY CONSERVATION INVESTMENT, ENERGY SAVINGS AND SHIFTED DISPOSABLE INCOME IN MAINE

(10^6 1980$)

	1978	1983	1988	1993	1998	TOTAL
Total Investment	0	16	41	40	41	680
Energy Savings	0	11	69	132	195	2,058
Shifted Disposable Income	0	5	45	100	170	1,618

TABLE C.3

YEARLY CONSERVATION INVESTMENT, ENERGY SAVINGS AND SHIFTED DISPOSABLE INCOME IN MASSACHUSETTS

(10^6 1980$)

	1978	1983	1988	1993	1998	TOTAL
Total Investment	0	63	154	151	149	2,559
Energy Savings	0	41	254	461	668	7,222
Shifted Disposable Income	0	20	175	358	578	5,695

TABLE C.4

YEARLY CONSERVATION INVESTMENT, ENERGY SAVINGS AND SHIFTED DISPOSABLE INCOME IN NEW HAMPSHIRE

(10^6 1980$)

	1978	1983	1988	1993	1998	TOTAL
Total Investment	0	19	40	36	40	659
Energy Savings	0	1	68	127	189	1,991
Shifted Disposable Income	0	5	43	98	164	1,557

TABLE C.5

YEARLY CONSERVATION INVESTMENT, ENERGY SAVINGS AND SHIFTED DISPOSABLE INCOME IN RHODE ISLAND

(10^6 1980$)

	1978	1983	1988	1993	1998	TOTAL
Total Investment	0	10	25	25	24	413
Energy Savings	0	7	42	75	109	1,187
Shifted Disposable Income	0	4	29	59	95	943

TABLE C.6

YEARLY CONSERVATION INVESTMENT, ENERGY SAVINGS AND SHIFTED DISPOSABLE INCOME IN VERMONT

(10^6 1980$)

	1978	1983	1988	1993	1998	TOTAL
Total Investment	0	9	21	18	21	335
Energy Savings	0	5	32	62	90	960
Shifted Disposable Income	0	2	21	47	78	743

TABLE C.7

TOTAL ANNUAL EMPLOYMENT IN CONNECTICUT DISAGGREGATED BY ECONOMIC EFFECTS OF CONSERVATION

	1983	1988	1993	1998	TOTAL
On-Site	368	1,112	908	783	15,903
Indirect Employment Due To:					
Labor and Material Purchases	973	2,107	1,877	1,927	33,718
Reduced Energy Expenditures	-479	-2,848	-5,175	-7,462	-80,875
Consumer Spending of Energy Savings	388	3,158	6,710	10,603	105,589
Sub-Total Indirect Employment	319	1,054	1,524	2,469	26,757
Total Employment	1,250	3,528	4,321	5,850	74,336

TABLE C.8

TOTAL ANNUAL EMPLOYMENT IN MAINE DISAGGREGATED BY ECONOMIC EFFECTS OF CONSERVATION

	1983	1988	1993	1998	TOTAL
On-Site	166	508	438	389	7,492
Indirect Employment Due To:					
Labor and Material Purchases	340	896	848	853	14,490
Reduced Energy Expenditures	-188	-1,267	-2,526	-3,816	-39,468
Consumer Spending of Energy Savings	167	1,425	3,201	5,432	51,736
Sub-Total Indirect Employment	319	1,054	1,524	2,469	26,757
Total Employment	485	1,562	1,962	2,858	34,249

TABLE C.9

TOTAL ANNUAL EMPLOYMENT IN MASSACHUSETTS DISAGGREGATED BY ECONOMIC EFFECTS OF CONSERVATION

	1983	1988	1993	1998	TOTAL
On-Site	613	1,820	1,531	1,334	26,521
Indirect Employment Due To:					
Labor and Material Purchases	1,816	4,294	3,968	4,003	69,356
Reduced Energy Expenditures	-922	-5,905	-11,184	-16,497	-174,828
Consumer Spending of Energy Savings	823	7,206	14,761	23,864	235,062
Sub-Total Indirect Employment	1,717	5,594	7,545	11,370	129,590
Total Employment	2,330	7,414	9,076	12,704	156,111

TABLE C.10

TOTAL ANNUAL EMPLOYMENT IN NEW HAMPSHIRE DISAGGREGATED BY ECONOMIC EFFECTS OF CONSERVATION

	1983	1988	1993	1998	TOTAL
On-Site	205	469	386	348	6,910
Indirect Employment Due To:					
Labor and Material Purchases	473	940	797	922	15,171
Reduced Energy Expenditures	-197	-1,267	-2,521	-3,807	-39,418
Consumer Spending of Energy Savings	150	1,425	3,260	5,450	51,614
Sub-Total Indirect Employment	425	1,098	1,536	2,566	27,366
Total Employment	630	1,567	1,922	2,914	34,276

TABLE C.11

TOTAL ANNUAL EMPLOYMENT IN RHODE ISLAND DISAGGREGATED BY ECONOMIC EFFECTS OF CONSERVATION

	1983	1988	1993	1998	TOTAL
On-Site	92	296	253	218	4,332
Indirect Employment Due To:					
Labor and Material Purchases	228	571	540	530	9,266
Reduced Energy Expenditures	-135	-834	-1,568	-2,300	-24,500
Consumer Spending of Energy Savings	126	997	2,009	3,217	31,988
Sub-Total Indirect Employment	219	735	981	1,446	16,753
Total Employment	311	1,031	1,234	1,664	21,085

TABLE C.12

TOTAL ANNUAL EMPLOYMENT IN VERMONT DISAGGREGATED BY ECONOMIC EFFECTS OF CONSERVATION

	1983	1988	1993	1998	TOTAL
On-Site	90	235	187	173	3,382
Indirect Employment Due To:					
Labor and Material Purchases	172	399	353	356	6,248
Reduced Energy Expenditures	-84	-546	-1,065	-1,589	-16,613
Consumer Spending of Energy Savings	67	625	1,412	2,322	22,159
Sub-Total Indirect Employment	155	478	700	1,089	11,794
Total Employment	245	713	887	1,262	15,176

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