Q. Above, you showed the approximate effect on the PECO forecast of a correction for the use of aggregate data on square footage per employee. Can you propose a similar correction for the use of aggregate intensity data?

A. No, I cannot. In my view the degree of over aggregation in the Company analysis of electric intensity and other related considerations is so great that, short of providing an entirely different procedure as I have done in Exhibit ___ (JS-4), I can provide no correction on this point. I should point out that I do regard the 34 KWH per square foot itself as extremely suspect. The data on which I have relied, shown in Table 8.12 of Exhibit ___ (JS-4), shows a maximum of 31.2 KWH per square foot with an average value far lower. These data are based upon the A. D. Little data, on which PECO has also relied. Their use beginning in 1975 produces good agreement with the average commercial consumption of 18 KWH per square foot reported by PECO in the base year 1977. Based upon an examination of the original data underlying the results in office building consumption reported by PECO in Exhibit ___(WCH-1), p. 210, I find that the 34 KWH per square foot figure is out of line with historic consumption levels. Since it is reflective of the 1974/77 period, I would expect that increased awareness of energy conservation as a goal in commercial building use would lead to a fall in the basic intensity of consumption toward the historic levels. This view is in accord with the energy intensity assumptions I have utilized in my forecast.

Q. In your comments thus far you have addressed the portion of the Company forecast dealing with new construction. Would the same comments hold for the Company analysis of usage in existing buildings?

A. Yes, they would. The same types of methodological difficulties involving over aggregation are present in both parts of the Company forecast.

Q. In its discussion of the base commercial forecast in Exhibit ___ (WCH-2), p. 221, the Company mentions certain "noncommercial" loads which are included in its commercial forecast. How have you dealt with these loads in your forecast?

A. These loads are included in my "other" building category as part of the light and power end-use. After completing my initial forecast for the commercial sector, I added to this building type/end-use combination an additional load to account for such "noncommercial" loads. This load is phased in linearly from 0 in 1978 to 740 million KWH in 1998.

Q. Might not this procedure involve double counting of growth in this category?

A. Yes, it might. For that reason the procedure is conservative and so consistent with my general forecasting approach.

Q. Thus far you have discussed only the approach used in the Company base case commercial forecast. Do you have any comments concerning the alternate procedures which they have developed?

A. Yes, I have a number of comments. First, from a methodological point of view, I note that all of the other approaches, as described in Exhibit ___ (WCH-1) p. 214-220, are at least as aggregate in approach as that developed by the Company for the base case. Thus none of these additional approaches addresses any of the methodological problems of over aggregation which I have raised. Second, concerning the results of the forecasts, I note that the approach used in the Company base case produced the lowest forecast of any of their methods. Given the substantial reduction which my correction for the use of aggregate square footage data produced in their base case, I am extremely skeptical concerning the usefulness of the other models. Finally I would like to make three comments concerning the regression models developed by PECO:

- Aggregate econometric models have a built-in assumption that the past will be similar to the future in its structural relationships. With respect to commercial energy consumption, I find this a dubious assumption.
- Good "model statistics" do not mean that a model will be a good predictor, they merely mean that you have put in enough variables to approximate the past.
- Even if we believe that a given model will reflect future relationships, there remains the question of the "explanatory variable." In the case of PECO's Model 2, this is real disposable income as forecast by Wharton Associates. This is a separate forecast, the construction of which one is largely ignorant. To understand it

completely, one would have to make a study of the Wharton model and its input assumptions. Referring to Figure 4 on p. 219 of Exhibit ___ (WCH-1), we see that the forecast produced by Model 2 increases much more sharply than was the case in the 1973/77 period, and in fact essentially parallels pre-1973 experience. Computations with the equation used in the model show that the type of growth exhibited in Figure 4 can only be the product of substantial increases in forecast disposable income. Given the current economic conditions, I find such growth suspect.

Q. Please begin your discussion of the Company forecast of industrial energy rates.

A. Sales to the large manufacturing class of customers (defined as SIC's 20-39 on PECO Rates PD and HT) account for most of PECO's sales to industry. In 1977, such sales accounted for 97%. The Company's basic forecast for the large manufacturing class is a time trending procedure: as explained in Exhibit ___ (WCH-1), p. 192, a time trend in sales per man hour of employment is developed using historic data for each 2-digit SIC. (The "SIC"'s, Standard Industrial Classifications, are standard groupings of industrial firms established by the federal government and used routinely for data gathering and analysis.) The yearly trended value of energy sales per man hour is multiplied by a forecast of man hours worked to obtain yearly forecast sales of 2-digit SIC. SIC's 29 and 33 are dominated by large petroleum and steel plants. For these categories the Company forecast is modified to take account of information concerning the future plans of these large firms.

Q. Is this an appropriate forecasting approach?

A. There is a conceptual difficulty. In the analysis of industrial production, one usually distinguishes three factors of production: energy, labor, and capital. In a given industry, one does expect a stable relationship between these factors of production, and so the use of an historic trend involving the relationship between factors, such as energy and labor, or between total production and energy as is done in the ESRG industrial forecast, is indeed appropriate. What is inappropriate is the use of sales as opposed to total consumption. A trend involving the relationship between electrical consumption and man hours of employment expresses the historical relationship between energy and labor as utilized by industries in the Philadelphia area. The question of the relationship between sales and consumption is a separate question which, I believe, should be treated separately from any forecast of consumption. As is shown in Section 5 of Exhibit ___ (JS-4), the ESRG model does operate in the manner I have suggested. First, total industrial electrical consumption is forecast on the basis of a forecast of industrial production, and then a sales forecast is derived.

Q. Can you explain why the Company forecast combines the two steps you have proposed, the forecast of consumption and then the derivation of sales, into one step?

A. Yes, I believe I can. The difference between consumption and sales is due to industrial self-generation of electricity. This is the production of electricity by industries themselves. The term "cogeneration" is commonly applied to this process since the production of electricity is usually combined with the production of steam or hot water to meet industrial process requirements. In Exhibit ___ (WCH-1), p. 186, it is stated that "... no change in the ratio of self-generated to purchased power has been factored into this or previous forecasts." This means that the Company assumes that the ratio of total electricity to sales is constant. This being the case, it is not surprising that it has collapsed the two steps in forecasting of sales of electricity to industry into a single operation.

Q. Your forecast of industrial sales differs from that prepared by the Company. Does your treatment of self-generation account for the difference between the two forecasts?

A. Yes, it does. Using the year 1987 for purposes of illustration, I note that the Company forecasts industrial sales (Manufacturing sales plus 10% of sales to small C & I) of 10,515 million KWH. ESRG forecasts sales of 9860 million KWH in its Base Case. I have rerun the ESRG forecasting model to forecast industrial sales under the assumption that the fraction of electrical consumption satisfied by self-generation remains at 1976 levels. The result was a sales forecast of 10,535 million KWH in 1987, in virtual agreement with the Company.

Q. Do you accept the Company assumption that there will be no change in the fraction of energy supplied by cogeneration?

A. No, I do not. The Company itself has recently participated in a study by the Pennsylvania Electrical Association which documents the potential for increased cogeneration in its service territory. Other well-known national studies (see Exhibit ___ (JS-5), Sec. 5.2, for citations and discussion), also serve to establish this potential. The Company has assumed that, despite this acknowledged potential, there will be no change. In response to our interrogatory LF. 18d., the Company states with respect to growth in cogeneration, "...without government incentives not now known or effective, it is not highly probable that this growth will occur." "This growth" refers to the growth needed to keep up with total consumption as assumed in the Company forecast. What the Company is saying is that, absent additional government incentives, cogeneration may actually decline in importance. This directly contradicts, for example, the findings of the Thermo Electron Corporation, one of the reports cited above. They show growth in cogeneration without government incentives. Overall, I find the assumptions in the Company forecast of industrial energy sales unduly pessimistic concerning the future role of cogeneration.

Q. How is cogeneration treated in the ESRG forecast?

A. The ESRG forecast reflects the current uncertainty in this area. I find that some increase in cogeneration will take place but that it will be modest. As a high case assumption, I accept the Company assumption of no change. In the low case, I assume some increase as shown in Table 8.19 of Exhibit ___ (JS-4). My Base Case is the average of the forecasts resulting from my high and low case assumptions. I note that even in the low case, I have used less optimistic assumptions than, for example, are given in the Thermo Electron study. Thus, my Base Case assumptions concerning increases in cogeneration are extremely modest and in my view are extremely likely to be met or exceeded.

Q. In addition to its forecast of manufacturing sales based upon man hours, the Company has presented a number of econometric models as a basis for forecasting such sales. Do you have any comments concerning these models?

A. Yes, I do. First I note that these models are extremely aggregate in nature. I would direct the same general criticism to them as I directed to the Company's aggregate models for the commercial sector. In addition, I note that these models have much poorer statistical properties than those proposed in the commercial sector and that, as shown in Exhibit ___ (WCH-1), pp. 196-197, that the actual sales do not lie entirely within the 95% confidence interval about the output of these models. While accurate reproduction of historic data is no guarantee of a model's predictive power, the failure of a model constructed by regression for historic data to fit the historic sales, is a reason for serious concern. In sum, I find that these models are not likely to prove useful in forecasting future industrial sales.

Q. Do you have any comments concerning the Company forecast of peak demand?

A. Both the Company and ESRG forecast peak growth as a function of energy growth. The methodologies and results both are quite similar. Both find a slight improvement in load factor over the forecast period. In general, the differences in the two forecasts of peak growth are due to differences in the underlying forecasts of growth in energy consumption.

Q. Please discuss briefly the Conservation Policy scenario described in your Exhibit ___ (JS-5).

A. Conservation Policy scenario assumptions and results differ from thosein the Base Case. These differences account for the differences between the Base Case and Conservation Policy Case forecasts. They assume that a fundamental change has taken place in the regulatory environment. The Base Case assumed the smooth continuation of current state-level conservation policy activity. The Conservation Policy Case, on the other hand, assumes a transition to the aggressive implementation of an integrated set of socially cost beneficial conservation policy measures as a result of action by the state. The measures are phased in by 1985. By posing such a conservation scenario, one can assess the implication (and desirability) of a conservation policy direction for the state. The broad policy areas addressed in the Conservation Policy scenario are listed in Table 2.1 of Exhibit ___ (JS-5). This is followed by a detailed specification and quantification of each policy measure. The constraints imposed on measure selection were technological feasibility and decreasing social costs. The latter is construed to mean that the costs of achieving the improved energy efficiency implied by a given measure should not exceed the incremental costs of delivering the extra electrical (and other) energy that would be required in the absence of the measure. Indeed, the cost of saving a kilowatt-hour of electricity through these policies is generally considerably less than the cost of producing the energy equivalent. The Conservation Policy scenario results forecasts are presented alongside the Base Case results in the summary Tables 1.1 of Exhibit ___ (JS-4) and in more detail in Sec. 1.2 of Exhibit ___ (JS-5).

The Conservation Policy scenario shows that there is a great deal the state can do through implementing energy efficiency programs to manage long range electricity demand growth. The conservation results show energy consumption as essentially flat and peak demand falling, though no lessening in economic activity, decrease in end-use ownership levels, or decline in quality of life is assumed. Indeed, the Conservation scenario is designed to lower the overall costs of energy services in the state and, as we have shown earlier in a similar study for the State of New York, is likely to have the important additional benefit of creating a substantial number of jobs.

Q. Does this complete this portion of your testimony?

A. Yes, it does. As I indicated earlier, I will file supplementary testimony concerning the "essential human needs" rate.

ESRG 79-25/1
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Exhibit ___ (JS-4)

PHILADELPHIA ELECTRIC COMPANY SYSTEM FORECAST

VOLUME I:

THE STATE BASE CASE FORECAST

Paul D. Raskin
John K. Stutz
David R. McAnulty

November, 1979

ENERGY SYSTEMS RESEARCH GROUP, INC.
Boston, Massachusetts 02109

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1. INTRODUCTION

1.1 Background

This volume summarizes the methodology, assumptions, and results of the ESRG Base Case long range forecast of electric energy and demand in the Philadelphia Electric Company (PECO) system. Along with the companion volume, Vol. II: The State Conservation Policy Case, it is presented as a contribution to the utility planning assessments being undertaken by the Pennsylvania Office of the Consumer Advocate.

The analysis offered in these documents focuses on electric demand growth issues for the PECO service area. The implications for such supply questions are addressed in complementary forthcoming ESRG studies and testimony. Specifically, corresponding to the sequence of the volumes, the following issues are treated:

- Base Case Forecast: long-range forecast of electricity demand by end-use and by utility service area under "business-as-usual" state policy and regulatory assumptions.

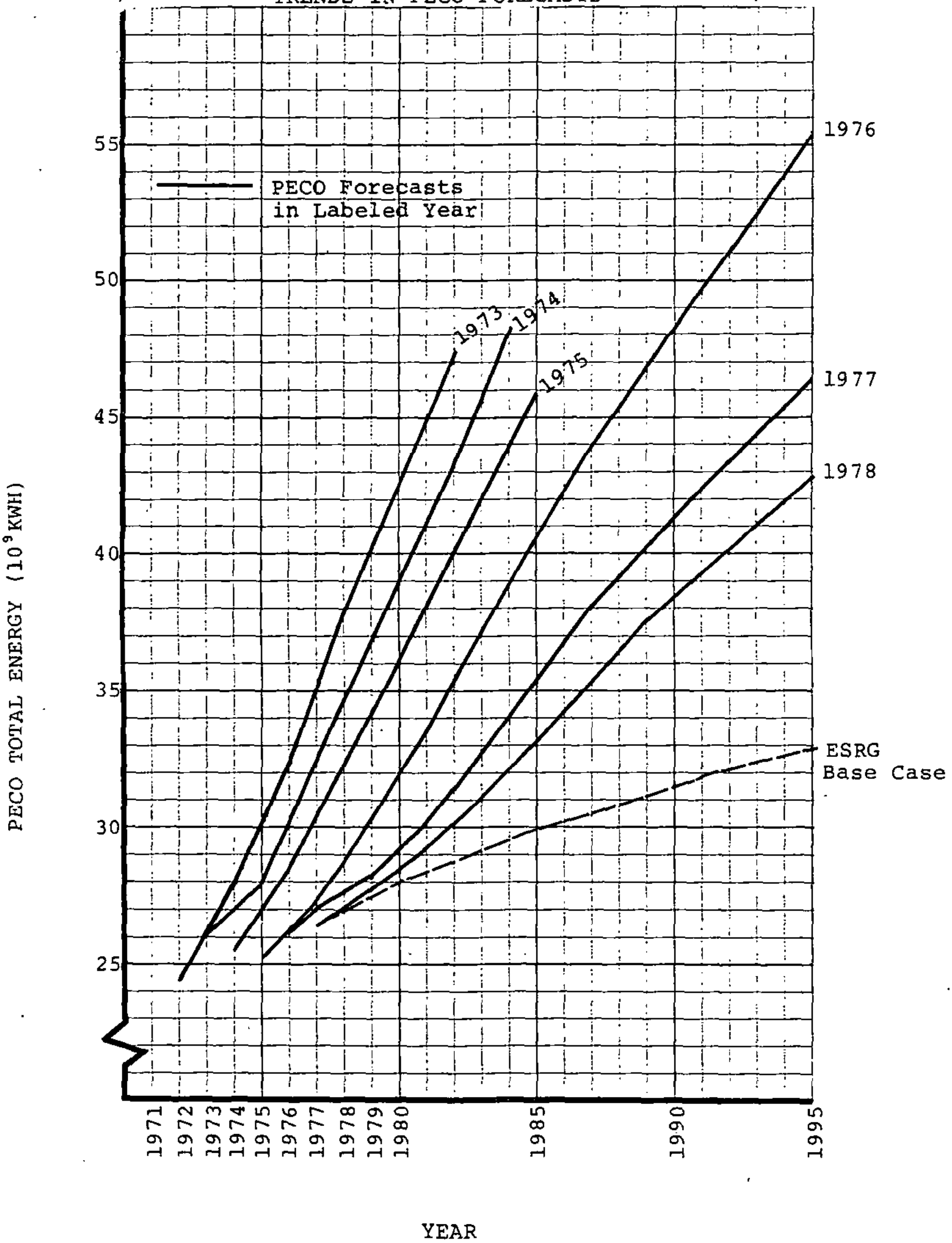
- Conservation Policy Case Forecast: interruption of base case growth with an array of concrete State conservation policy interventions designed to minimize electric energy growth consistent with the dual criteria of technological feasibility and favorable social costs.

After presenting a brief summary of the Base Case forecast results below, the remainder of the report describes in detail the conceptual basis and mathematical structure of the forecasting model, as well as the data and assumptions relied upon.

1.2 Forecast of Energy and Peak Load

The Company produced long range forecasts have declined dramatically over the past half dozen years. This is shown graphically in Figure 1.1. The steady decline of PECO forecasts reflects the Company's methodological and assumptive adjustments to some fundamental shifts in the five major dimensions affecting electrical energy consumption in the long run: (1) economic dimensions measuring the level of income, employment, prices, etc., (2) demographic dimension measuring population, households, age distribution, etc., (3) technological dimension identifying changes in conventional equipment (home appliances, building shell materials, etc.) and properties of emerging equipment, (4) policy dimension referring to the procedures and regulations promulgated by governmental

FIGURE 1.1
TRENDS IN PECO FORECASTS



bodies, such as appliance efficiency standards, fuels policies, rate structures, etc., and (5) the institutional dimension referring to the influence on patterns of energy usage related to value and customs (consumerism, conservation ethic, etc.). The post-1973 period has been characterized by major changes in each of these interrelated dimensions. Population growth has tapered, economic conditions have deteriorated, technologies have evolved, energy policy at both the State and Federal level is unprecedented, and attitudes are in flux. The annual decay of the PECO forecasts depicted in Figure 1.1 reflects a gradual adjustment to these new realities. The ESRG Base Case forecast suggests that the process of adjustment is not yet complete.

The adequacy of a long-range electricity forecasting model is related to its ability to capture each of these dimensions in the mathematical structure used to simulate demand. The fundamental weakness of forecasting models has been excessive rigidity in the face of fundamental changes in the social, economic, and political determinants of energy consumption. This rigidity has taken several forms: the tendency to forecast aggregate rather than end-use energy variables, the tendency to attempt to collapse all five dimensions into the economic one alone, and the tendency to temporally extend unadjusted historic trends and relationships.

Though the complexity of the long-range forecast renders some such rigidity inevitable, the goal animating the present effort is, given current limits on data availability and theoretical development, to incorporate flexibility through end-use disaggregation. multi-dimensionality, and avoidance of extrapolation. The bulk of this report is devoted to explicating the resulting model.

The Base Case reflects the "business-as-usual" scenario, incorporating the current constellation of energy policy, demography, technology, conservation, etc. Base Case forecasts are bracketed by "High" and "Low" forecasts. These, as will be specified in Section 8, reflect a range of uncertainty in the input data used to define "business-as-usual" conditions. The Base Case is designed as the best "business-as-usual" estimate with the high/low band representing a measure of the overall forecast uncertainty. It is important to emphasize that this triad--Base, High, Low--all refer to the non-conservation policy scenario. The Low forecast represents, not a conservation forecast, but a lower bound on the "business-as-usual" scenario. The Conservation Scenario is the subject of the next volume of this report.

In Tables 1.1, 1.2, and 1.3, we present the forecast results of peak loads, total electric energy requirements, and breakdowns of the latter by major customer sector for three cases: "high, "low", and "base", respectively.

TABLE 1.1
ENERGY AND PEAK FORECAST: HIGH CASE

HIGH CASE

PECO	ENERGY IN GWH RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	PEAK POWER LOAD IN MW SUMMER	WINTER
1977	8438.	8863.	8085.	2775.	28163.	5580.	4518.
1978	8790.	9010.	8400.	2840.	29010.	5720.	4710.
1979	9050.	9150.	8720.	2910.	29840.	5880.	4880.
1980	9350.	9290.	9030.	2970.	30640.	6000.	5060.
1981	9630.	9420.	9340.	3040.	31430.	6140.	5230.
1982	9900.	9550.	9630.	3100.	32200.	6270.	5380.
1983	10140.	9680.	9970.	3180.	32950.	6390.	5550.
1984	10370.	9800.	10280.	3220.	33670.	6510.	5710.
1985	10570.	9920.	10590.	3290.	34360.	6630.	5850.
1986	10780.	10000.	10780.	3330.	34890.	6720.	5980.
1987	10980.	10070.	10970.	3380.	35400.	6810.	6100.
1988	11190.	10150.	11150.	3510.	36000.	6910.	6230.
1989	11380.	10220.	11350.	3640.	36580.	7010.	6360.
1990	11590.	10290.	11540.	3770.	37180.	7110.	6480.
1991	11620.	10370.	11730.	3890.	37610.	7180.	6580.
1992	11650.	10440.	11920.	4010.	38030.	7230.	6640.
1993	11680.	10510.	12110.	4130.	38440.	7330.	6710.
1994	11710.	10590.	12300.	4250.	38850.	7410.	6790.
1995	11740.	10660.	12480.	4360.	39260.	7480.	6860.
1996	11750.	10730.	12670.	4500.	39660.	7550.	6930.
1997	11780.	10800.	12850.	4620.	40050.	7620.	7000.
1998	11810.	10870.	13040.	4740.	40470.	7690.	7080.
1999	11840.	10950.	13230.	4860.	40870.	7760.	7150.
2000	11870.	11020.	13410.	4990.	41280.	7830.	7220.

TABLE 1.2
ENERGY AND PEAK FORECAST: LOW CASE

LOW CASE

PECO	ENERGY IN GWH RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	PEAK POWER LOAD IN MW SUMMER	WINTER
1977	8438.	8863.	8085.	2775.	28163.	5580.	4518.
1978	8560.	8610.	8190.	2910.	28270.	5610.	4580.
1979	8650.	8750.	8290.	2840.	28540.	5500.	4630.
1980	8720.	8710.	8370.	2850.	28670.	5530.	4680.
1981	8750.	8660.	8450.	2880.	28750.	5530.	4710.
1982	8790.	8610.	8510.	2910.	28820.	5530.	4740.
1983	8820.	8560.	8570.	2930.	28880.	5530.	4790.
1984	8850.	8510.	8610.	2950.	28920.	5520.	4800.
1985	8890.	8450.	8650.	2970.	28950.	5510.	4820.
1986	8900.	8470.	8700.	3000.	29070.	5510.	4850.
1987	8920.	8490.	8750.	3020.	29180.	5510.	4880.
1988	8930.	8510.	8790.	3130.	29370.	5630.	4920.
1989	8940.	8540.	8840.	3240.	29560.	5650.	4960.
1990	8950.	8560.	8880.	3350.	29740.	5660.	5000.
1991	8920.	8580.	8920.	3450.	29870.	5670.	5030.
1992	8890.	8600.	8850.	3550.	29890.	5680.	5050.
1993	8830.	8620.	8990.	3660.	30110.	5680.	5070.
1994	8780.	8640.	9030.	3770.	30230.	5690.	5090.
1995	8750.	8690.	9060.	3870.	30340.	5680.	5110.
1996	8700.	8680.	9090.	3980.	30450.	5700.	5130.
1997	8650.	8710.	9120.	4080.	30560.	5700.	5150.
1998	8610.	8730.	9150.	4180.	30670.	5710.	5170.
1999	8580.	8750.	9170.	4290.	30790.	5710.	5200.
2000	8560.	8770.	9200.	4390.	30920.	5720.	5220.

TABLE 1.3
ENERGY AND PEAK FORECAST: PROBABLE CASE

BASE CASE	ENERGY IN GWH					PEAK POWER LOAD IN MW	
	RESIDENT.	COMMER.	INDUSTR.	OTHER	TOTAL	SUMMER	WINTER
1977	8433.	8882.	8085.	2773.	28180.	5580.	4518.
1978	8680.	8810.	8300.	2830.	[illegible]	5570.	4650.
1979	8830.	8860.	8500.	2870.	[illegible]	5740.	4780.
1980	9030.	9000.	8700.	2920.	[illegible]	5820.	4870.
1981	9130.	9040.	8900.	2950.	[illegible]	5880.	4970.
1982	9340.	9080.	9060.	3000.	[illegible]	[illegible]	[illegible]
1983	9480.	9120.	9270.	3050.	[illegible]	[illegible]	[illegible]
1984	9610.	9150.	9450.	3080.	[illegible]	6070.	[illegible]
1985	9730.	9180.	9620.	3130.	[illegible]	[illegible]	[illegible]
1986	9840.	9240.	9740.	3180.	[illegible]	[illegible]	5430.
1987	9950.	9290.	9880.	3220.	[illegible]	[illegible]	[illegible]
1988	10080.	9330.	9990.	3330.	[illegible]	6280.	[illegible]
1989	10150.	9380.	10090.	3440.	33080.	[illegible]	[illegible]
1990	10270.	9420.	10210.	3580.	[illegible]	[illegible]	5770.
1991	10270.	9470.	10330.	3670.	33740.	[illegible]	[illegible]
1992	10280.	9520.	10440.	3750.	[illegible]	6460.	[illegible]
1993	10260.	9570.	10550.	3900.	[illegible]	[illegible]	[illegible]
1994	10250.	9610.	10660.	4010.	[illegible]	6550.	[illegible]
1995	10240.	9660.	10770.	4120.	[illegible]	[illegible]	[illegible]
1996	10230.	9710.	10880.	4240.	[illegible]	6630.	6050.
1997	10220.	9750.	10980.	4350.	[illegible]	[illegible]	6080.
1998	10210.	9800.	11100.	4460.	[illegible]	[illegible]	6130.
1999	10210.	9850.	11200.	4570.	[illegible]	6710.	6170.
2000	10210.	9900.	11310.	4580.	[illegible]	6750.	6210.

Table 1.4 recasts the forecast results in terms of average annual rates of growth for ten and twenty year periods. Note that growth rates are forecast to decrease somewhat in the second decade of the forecast period as equipment saturations are approached and the full effects of recently initiated conservation practices fully penetrate into the equipment stock. The rates of growth reported here lie below the most recent available forecasts reported by PECO (Ref. 19) of 2.3% average annual growth over the next ten years in system peak.

TABLE 1.4
AVERAGE ANNUAL GROWTH RATES (%/year)

	Peak Load			Energy		
	High	Base	Low	High	Base	Low
1977-1987	2.0	1.1	.1	2.3	1.4	.4
1977-1997	1.6	.9	.1	1.8	1.1	.4

1.3 Forecast by End-Use

The model, as we shall see, builds up system forecasts from a composite of end-use submodel forecasts. Such disaggregated forecasts are an intermediate output allowing for a more detailed understanding of the components of demand growth, the impacts of specific assumptions, and the assessment of policy impacts. For completeness, these disaggregated energy forecasts are displayed in Tables 1.5, 1.6, and 1.. for the residential, commercial, and industrial sectors, respectively.

1.4 Approach and Alternatives

Electricity consumption at the system level is a composite of the myriad end-use demands serviced by the given utility. The model employed here is based on the conviction that system requirements can best be understood and the impacts of the various factors driving growth best be computed if the model, itself, consistent with data constraints, is a composite of submodels for the major end-uses.

The approach--sometimes called engineering/end-use--identifies the actual physical energy-demanding stock and its energy requirement characteristics. In this way,the effects of definite changes in, say, equipment efficiencies, fuel mix, manufacturing processes, etc., are tracked at the point where they actually occur. Further, the disaggregated approach enables the user to flexibly and eclectically draw from the best subsidiary data sources available, be they optimization studies, market penetration analyses, or national and state economic and demographic projections. For example, the impact of a specific policy option, such as improved appliance efficiencies, can be accounted for directly where they impact (appliance submodels incorporating retirement schedules, vintages, and technology changes).

TABLE 1.5
DISAGGREGATED ENERGY FORECASTS: RESIDENTIAL SECTOR

.III HIGH CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

		1977	1982	1987	1992	1997
1:	REFRIGERATORS	2555.	2713.	2728.	2554.	2491.
2:	FREEZERS	446.	584.	581.	581.	583.
3:	RANGES	342.	401.	449.	475.	480.
4:	LIGHTING	648.	687.	729.	757.	762.
5:	TELEVISIONS	592.	617.	650.	682.	733.
6:	CLOTHES DRYERS	449.	555.	654.	733.	750.
7:	CLOTHES WASHERS	106.	115.	125.	131.	133.
8:	DISH WASHERS	134.	201.	230.	258.	273.
9:	WATER HEATERS	888.	1088.	1238.	1335.	1346.
10:	ROOM A/C	348.	358.	354.	352.	347.
11:	CENTRAL A/C	430.	628.	784.	823.	865.
12:	SPACE HEATERS	520.	864.	1208.	1382.	1426.
13:	HEATINGAUXILIARY	544.	551.	558.	561.	558.
14:	MISCELLANEOUS	423.	512.	614.	680.	758.

PEIC LOW CASE - RESIDENTIAL SECTOR - ENERGY IN GWH

		1977	1982	1987	1992	1997
1:	REFRIGERATORS	2555.	2584.	2546.	2448.	2238.
2:	FREEZERS	443.	447.	440.	412.	414.
3:	RANGES	342.	350.	357.	358.	358.
4:	LIGHTING	648.	650.	637.	608.	583.
5:	TELEVISIONS	414.	416.	405.	402.	401.
6:	CLOTHES DRYERS	449.	514.	553.	527.	500.
7:	CLOTHES WASHERS	106.	110.	113.	115.	115.
8:	DISH WASHERS	134.	187.	204.	215.	228.
9:	WATER HEATERS	888.	855.	832.	804.	770.
10:	ROOM A/C	348.	334.	316.	311.	303.
11:	CENTRAL A/C	430.	531.	581.	603.	604.
12:	SPACE HEATERS	520.	648.	745.	798.	814.
13:	HEATINGAUXILIARY	544.	540.	538.	530.	521.
14:	MISCELLANEOUS	587.	606.	624.	637.	642.

TABLE 1.6
DISAGGREGATED ENERGY FORECASTS: COMMERCIAL SECTOR

PECO — HIGH CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	PECO	1977	1982	1987	1992	1997
1:	OFFICES					
1:	HEATING	49.	108.	143.	171.	189.
2:	COOLING	275.	311.	341.	365.	382.
3:	LT & POWER	357.	399.	428.	446.	464.
4:	AUXILIARIES	296.	294.	316.	330.	345.
2:	RETAIL					
1:	HEATING	38.	81.	108.	123.	139.
2:	COOLING	629.	658.	680.	695.	709.
3:	LT & POWER	1886.	1922.	1951.	1947.	1941.
4:	AUXILIARIES	352.	349.	347.	343.	344.
3:	HOSPITALS					
1:	HEATING	23.	51.	70.	88.	101.
2:	COOLING	272.	279.	281.	276.	271.
3:	LT & POWER	593.	589.	583.	580.	571.
4:	AUXILIARIES	364.	356.	352.	349.	338.
4:	SCHOOLS					
1:	HEATING	29.	46.	64.	85.	104.
2:	COOLING	272.	244.	230.	237.	244.
3:	LT & POWER	460.	401.	371.	362.	383.
4:	AUXILIARIES	262.	219.	198.	201.	205.
5:	OTHER					
1:	HEATING	47.	102.	137.	160.	182.
2:	COOLING	517.	664.	700.	718.	737.
3:	LT & POWER	1034.	1323.	1563.	1739.	1915.
4:	AUXILIARIES	955.	743.	791.	803.	814.

PECO — LOW CASE - COMMERCIAL SECTOR - ENERGY IN GWH

	PECO	1977	1982	1987	1992	1997
1:	OFFICES					
1:	HEATING	27.	48.	64.	80.	94.
2:	COOLING	269.	259.	246.	234.	224.
3:	LT & POWER	345.	320.	295.	286.	276.
4:	AUXILIARIES	291.	250.	240.	233.	227.
2:	RETAIL					
1:	HEATING	25.	44.	58.	67.	73.
2:	COOLING	622.	563.	528.	527.	525.
3:	LT & POWER	1851.	1663.	1562.	1584.	1604.
4:	AUXILIARIES	641.	537.	481.	492.	501.
3:	HOSPITALS					
1:	HEATING	22.	39.	52.	62.	70.
2:	COOLING	280.	275.	262.	239.	215.
3:	LT & POWER	715.	720.	712.	686.	666.
4:	AUXILIARIES	381.	362.	371.	343.	316.
4:	SCHOOLS					
1:	HEATING	25.	36.	47.	60.	72.
2:	COOLING	273.	227.	180.	159.	141.
3:	LT & POWER	479.	402.	352.	331.	313.
4:	AUXILIARIES	297.	207.	170.	159.	147.
5:	OTHER					
1:	HEATING	29.	55.	75.	94.	113.
2:	COOLING	627.	627.	623.	614.	607.
3:	LT & POWER	1047.	1252.	1442.	1618.	1795.
4:	AUXILIARIES	675.	704.	718.	721.	725.

TABLE 1.7
DISAGGREGATED ENERGY FORECASTS: INDUSTRIAL SECTOR

PECO	HIGH CASE - INDUSTRIAL SECTOR - ENERGY IN GWH 1977	1982	1987	1992	1997
20: FOOD	658.	881.	782.	1012.	1253.
22: TEXTILES	120.	135.	150.	165.	179.
23: APPAREL	60.	75.	90.	105.	120.
24: LUMBER	15.	22.	30.	37.	45.
25: FURNITURE	11.	13.	16.	18.	21.
26: PAPER PRODUCTS	555.	667.	754.	806.	858.
27: PRINTING & PUBL.	193.	255.	317.	380.	448.
28: CHEMICALS	1024.	1127.	1158.	1119.	1031.
29: PETROLEUM & COAL	1158.	1288.	1331.	1303.	1275.
33: PRIMARY METALS	1728.	2279.	2790.	3150.	3543.
34: FABRICAT. METALS	324.	402.	479.	547.	621.
35: MACHINERY	361.	431.	491.	534.	578.
36: ELECTRIC EQUIP.	429.	537.	626.	687.	748.
37: TRANSPORTATION	326.	409.	483.	541.	603.
30: RUBBER & PLASTIC	435.	559.	623.	652.	664.
31: LEATHER	4.	5.	6.	7.	8.
32: STONE,CLAY,GLASS	176.	181.	201.	207.	212.
38: INSTRUMENTS	102.	170.	244.	314.	382.
39: MISC. MANUFACT.	358.	411.	402.	337.	255.

PECO	LOW CASE - INDUSTRIAL SECTOR - ENERGY IN GWH 1977	1982	1987	1992	1997
20: FOOD	658.	607.	616.	706.	789.
22: TEXTILES	120.	115.	110.	106.	102.
23: APPAREL	60.	62.	63.	63.	63.
24: LUMBER	15.	16.	16.	16.	16.
25: FURNITURE	11.	12.	13.	13.	13.
26: PAPER PRODUCTS	555.	519.	475.	437.	395.
27: PRINTING & PUBL.	195.	220.	236.	250.	260.
28: CHEMICALS	1024.	1053.	1043.	1032.	994.
29: PETROLEUM & COAL	1188.	985.	785.	606.	424.
33: PRIMARY METALS	1728.	1931.	2071.	2200.	2328.
34: FABRICAT. METALS	324.	359.	362.	382.	401.
35: MACHINERY	361.	414.	451.	470.	486.
36: ELECTRIC EQUIP.	429.	473.	481.	490.	461.
37: TRANSPORTATION	326.	409.	483.	541.	603.
30: RUBBER & PLASTIC	435.	552.	641.	709.	796.
31: LEATHER	4.	4.	3.	3.	3.
32: STONE,CLAY,GLASS	175.	180.	183.	186.	193.
38: INSTRUMENTS	102.	128.	146.	153.	159.
39: MISC. MANUFACT.	358.	466.	534.	552.	563.

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:

Energy Consumption in End-Use Category = End-Use Measure × 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.

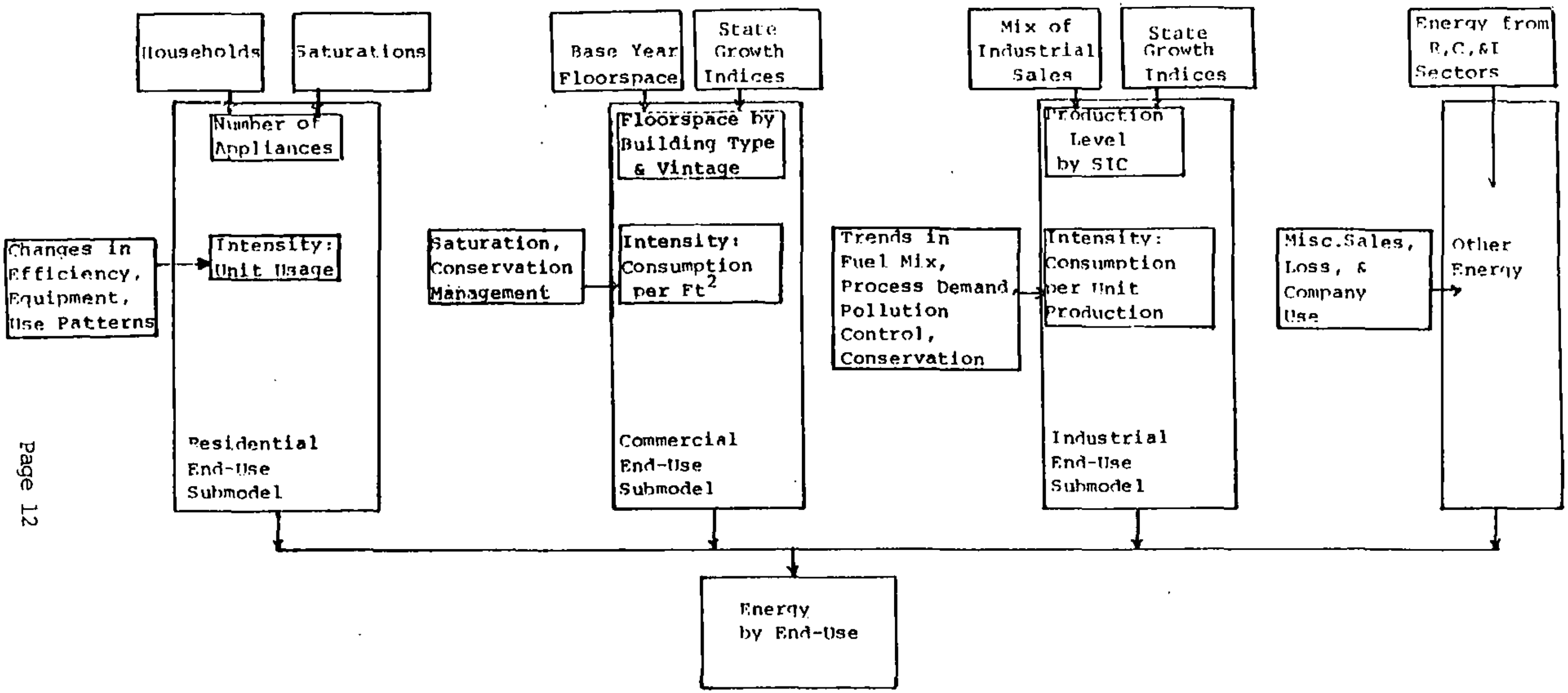
The forecasting technique consists of three fundamental steps: (1) analysis of base year energy-consuming stock in terms of average measure levels and intensities, (2) specification of growth in the end-use measures and (3) simulation of the factors affecting the intensity of unit energy use. The actual 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 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 each 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. The energy forecast model is schematized in Figure 2.2.

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



The model, from one perspective, 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), allowing for testing 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.

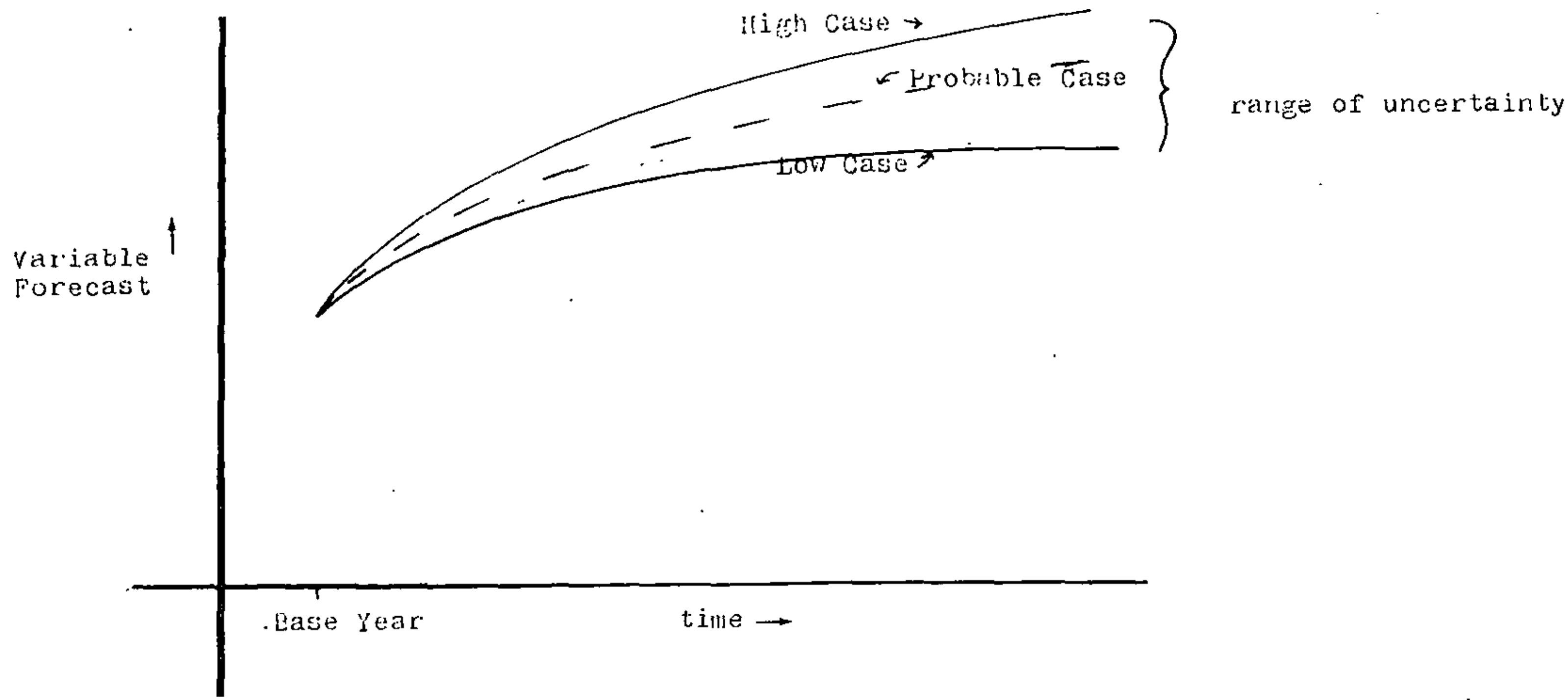


Figure 2.3. Forecast Scenarios.

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:

$$E_{t,i}=N_{t,i}\times C_{t,i} \qquad (3.1)$$

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:

$$SAT_t = \frac{STERM}{1+\left(\frac{STERM-SBY}{SBY}\right)\times e^{-A\cdot(t-1)}} \quad (3.5)$$

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.

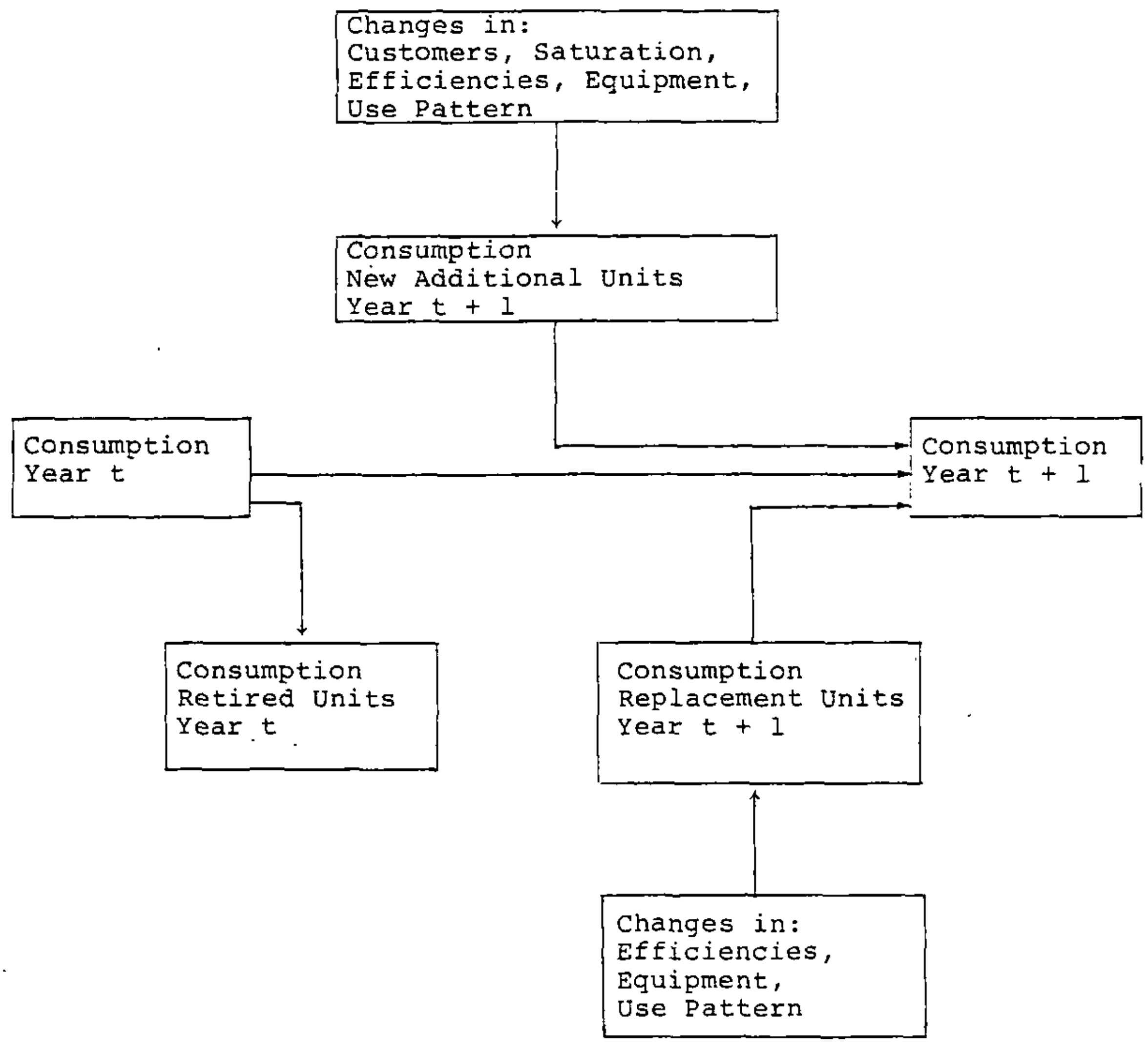
The submodels will be discussed in the sequence given in Table 3.1. In each case, we give a brief qualitative description in the text and the system of equations in an accompanying table. Although the end-uses have particular characteristics which require unique model elements, the overall strategy displayed 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.

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 $t \le ALT$
NEWENI	Energy use of new units
RETENI	Energy use of retired units
ENREU	Annual appliance energy demand

Equations

Stock stream:

$$TOTNUM_{t,k,i} = SAT_{t,k,i} \times HSTOCK_{t,k,i} \tag{3.6}$$

Initialize:

$$ENREU_{1,k,i} = TOTNUM_{1,k,i} \times UNAVBS_{k,i} \tag{3.7}$$

Iterate for t>1:

$$ENREU_{t,k,i} = ENREU_{t-1,k,i} - RETENI_{t,k,i} + NEWENI_{t,k,i} \tag{3.8}$$

where

$$RETENI_{t,k,i} = UNREP_{t,k,i} \times TOTNUM_{t-1,k,i}/ALT_i \tag{3.9}$$

$$NEWENI_{t,k,i} = (TOTNUM_{t,k,i} - TOTNUM_{t-1,k,i} + TOTNUM_{t-1,k,i}/ALT_i) \times UNNEW_{t,i} \tag{3.10}$$

and

$$UNREP_{t,i} = \begin{cases} UNOLD_{t,i} & \text{for } t \le ALT_i \\ UNNEW_{t-ALT_i} & \text{for } t > ALT_i \end{cases} \tag{3.11}$$

$$UNNEW_{t,i} = (1 - EFFIMP_t) \times UNNEW_{1,i} \tag{3.12}$$

$$EFFIMP_{t,i} = \begin{cases} \left[(t-1)/(TEND-1)\right] \times EFFIMT_i & \text{for } 1 < t \le TEND \\ EFFIMT_i & \text{for } t > TEND \end{cases} \tag{3.13}$$

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:

$$TOTNUM_t = SAT_t \times HSTOCK_t \quad (3.14)$$

Initialize:

$$ENREU1_1 = TOTNUM_1 \times HSTOCK_1 \quad (3.15)$$

Iterate for t>1:

$$ENREU1_t = ENREU1_{t-1} - RETENI_t + NEWENI_t \quad (3.16)$$

where

$$RETENI_t = ENREU1_{t-1}/ALT \quad (3.17)$$

$$NEWENI_t = (TOTNUM_t - TOTNUM_{t-1}) \times UNNEW_t + \left(TOTNUM_{t-1}/ALT\right) \times UNNEW_t \quad (3.18)$$

and

$$UNNEW_t = (1-EFFIMP_t) \times UNAVBS \quad (3.19)$$

with

$$EFFIMP_t = \begin{cases} EFFIMT \times (t-1) / (TEND-1) \\ EFFIMT \end{cases} \text{for} \begin{cases} t<TEND \\ t \geq TEND \end{cases} \quad (3.20)$$

Microwave oven adjustment:

$$ENREU_t = ENREU1_t \times (1-MSAT_t) + MSAT_t \times EDF \times ENREU1_t \quad (3.21)$$

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

$$ENREU_t = UNAV_t \times HSTOCK_t \qquad (3.22)$$

with

$$UNAV_t = UF_t \times UNAVBS \qquad (3.23)$$

with efficient bulb capturing market fraction:

$$UNAV_t = (1-MF_t) \times UNAVBS + MF_t \times (1-RELEFF_t) \times UNAVBS$$

or

$$UF_t = 1-MF_t \times RELEFF_t \qquad (3.24)$$

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:

$$TOTNUM_{t,k} = SAT_{t,k} \times HSTOCK_{t,k} \quad (3.25)$$

Initialize:

$$ENREU_{1,k} = TOTNUM_{1,k} \times UNAVBS \quad (3.26)$$

Iterate for t>1:

$$ENREU_{t,k} = ENREU_{t-1,k} - RETENI_{t,k} + NEWENI_{t,k} \quad (3.27)$$

where

$$RETENI_{t,k} = ENREU_{t-1,k} / ALT \quad (3.28)$$

$$NEWENI_{t,k} = (TOTNUM_{t,k} - TOTNUM_{t-1,k} + TOTNUM_{t-1,k} /ALT) \times ((1-FRBW_t) \times NEWCOL_t + FRBW_t \times NEWBW_t) \quad (3.29)$$

and

$$NEWCOL_t = (1-EFIMCO_t) \times NEWCOL_1 \quad (3.30)$$

$$NEWBW_t = (1-EFIMBW_t) \times NEWBW_1$$

with

$$EFIMCO_t = \begin{cases} (t-1 / (TEND-1) \times EIMCOT & \text{for } t<TEND \\ EIMCOT & t>TEND \end{cases} \quad (3.31)$$

(similarly for $EFIMBW_t$)

Decrease usage for multiple ownership (for $SAT_{t,k}>1$):

$$ENREU \longrightarrow ENREU_{t,k} \times (1+DUF \times (SAT_{t,k} -1) / SAT_{t,k}) \quad (3.32)$$

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:

$$TOTNUM_t = SAT_t \times HSTOCK_t \qquad (3.33)$$

Initialize:

$$ENREU_1 = TOTNUM_1 \times UNAVBS \qquad (3.34)$$

Iterate for $t>1$:

$$ENREU_t = ENREU_{t-1} + NEWENI_t - RETENI_t \qquad (3.35)$$

where

$$RETENI_t = ENREU_{t-1} / ALT \qquad (3.36)$$

$$NEWENI_t = (TOTNUM_t - TOTNUM_{t-1} + TOTNUM_{t-1} / ALT) \times UNNEW_t$$

and (3.37)

$$UNNEW_t = (1-EFFIMP_t) \times UNAVBS$$

with

$$EFFIMP_t = \begin{cases} (t-1)/(TEND-1) \times EFFIMT & \text{for } t<TEND \\ EFFIMT & t \geq TEND \end{cases} \qquad (3.38)$$

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:

$$TOTNUM_{t,i} = SAT_{t,1} \times HSTOCK_{t,i} \quad (3.39)$$

Initialize:

$$ENREU_{1,i} = TOTNUM_{1,i} \times UNAVBS_{i} \quad (3.40)$$

Iterate for t>1:

$$ENREU_{t,i} = ENREU_{t-1,i} + NEWENI_{t,i} - RETENI_{t,i} \quad (3.41)$$

where

$$RETENI_{t,i} = ENREU_{t-1,i}/ALT_{i} \quad (3.42)$$

$$NEWENI_{t,i} = (TOTNUM_{t,i} - TOTNUM_{t-1,i} + TOTNUM_{t-1,i}/ALT_{i}) \times UNNEW_{t,i} \quad (3.43)$$

and

$$UNNEW_{t,i} = (1 - EFFIMP_{t,i}) \times UNAVBS_{i} \quad (3.44)$$

with

$$EFFIMP_{t,i} = \begin{cases} (t-1/_{(TEND-1)}) \times EFFIMT & \text{for } t<TEND \\ EFFIMT & \text{for } t \geq TEND \end{cases} \quad (3.45)$$

(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

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

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 affected 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:

$$TOTNUM_{1,k} = SBY_k \times HSTOCK_{1,k} \quad (3.48a)$$

$$TOTNUM_{t,k} = TOTNUM_{t-1,k} \quad (3.48b)$$

$$+ (HSTOCK_{t,k} - HSTOCK_{t,1,k}) \times PEN_{t,k}$$

$$+ [(HSTOCK_{t,k} - HSTOCK_{t-1,k}) \times (1-PEN_{t,k})] \times [(SBY-ESHSAT_{1,k})/(1-ESHSAT_{1,k})]$$

"Other" water demand:

$$OTHW_t = (UNAVBS \times AVEFF_1 - DWHW_1 - CWHW_1) \times (1-HWREOT_t)$$

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

By definition

$$NUNEFF_t = AVEFF_1/(1-EFFIMP_t)$$

where

$$EFFIMP_t = \begin{cases} (t-1)/(TEND-1) \times EFFIMT & \text{for } t<TEND \\ EFFIMT & \text{for } t \geq TEND \end{cases} \quad (3.50)$$

Average efficiency from:

$$TOTNUM_t \times AVEFF_t = (TOTNUM_t - TOTNUM_{t-1} + TOTNUM_{t-1}/ALT) \times NUNEFF_t$$

$$+ (TOTNUM_{t-1} - TOTNUM_{t-1}/ALT) \times AVEFF_{t-1} \quad (3.51)$$

then,

$$UNAV_t = (DWHW_t + CWHW_t + OTHW_t)/AVEFF_t \text{ (w/o solar)} \quad (3.52)$$

$$\times (1-FS_t + FS_t \times (1-PCSOLW)) \text{ (w solar)}$$

Finally,

$$ENREU_t = TOTNUM_t \times UNAV_t \quad (3.53)$$

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.

TABLE 3.9
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:

$$TOTNUM_{t,k,i} = SAT_{t,k,i} \times HSTOCK_{t,k} \qquad (3.54)$$

Initialize:

$$ENEUI1_{1,k,i} = TOTNUM_{1,k,i} \times UNAVBS_{k,i} \qquad (3.55)$$

Iterate for t>1:

$$ENEUI1_{t,k,i} = ENEUI1_{t-1,k,i} + NEWENI_{t,k,i} - RETENI_{t,k,i} \qquad (3.56)$$

where

$$RETENI_{t,k,i} = ENEUI1_{t-1,k,i}/ALT_{i} \qquad (3.57)$$

$$NEWENI_{t,k,i} = (TOTNUM_{t,k,i} - TOTNUM_{t-1,k,i} + TOTNUM_{t-1,k,i}/ALT_{i}) \times UNNEW_{t,k,i} \qquad (3.58)$$

and

$$UNNEW_{t,k,i} = (1 - EFFIMP_{t,i}) \times UNAVBS_{k,i} \qquad (3.59)$$

with

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

Correct for changes in thermal integrity:

$$ENREU_{t,k,i} = (1-TIIMP_{t,k,i}) \times ENEUI1_{t,k,i} \qquad (3.61)$$

where

$$TIIMP_{t,k,i} = \Big[TIIMP_{t-1,k,i} \times HSTOCK_{t-1,k} + TIE_{t,k,i} \times BYHSTK_{t,k} - TIE_{t-1,k,i} \times BYHSTK_{t-1,k} + TIN_{t,k,i} \times (HSTOCK_{t,k} - HSTOCK_{t-1,k} + BYHSTK_{t,k} - BYHSTK_{t-1,k})\Big] / HSTOCK_{t,k} \quad \text{for } t>1 \qquad (3.62)$$

and

$$BYHSTK_{t,k} = HSTOCK_{1,k} \times (1-HRET_{k})\ t-1 \qquad (3.63)$$

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 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
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:

$$TOTNUM_{t,k} = TOTNUM_{t-1,k} + PEN_{t,k} \times (HSTOCK_{t,k} - HSTOCK_{t-1,k}) \quad (3.63)$$

Initialize:

$$ENREU_{1,k} = TOTNUM_{1,k} \times UNAVBS_{k} \quad (3.64)$$

Iterate:

$$ENREU_{t,k} = ENREU_{t-1,k} + NEWENI_{t,k} \quad (3.65)$$

where

$$NEWENI_{t,k} = NESHDI_{t,k} + NESHHP_{t,k} + NESHSA_{t,k} \quad (3.66)$$

The subcomponents of new demand are given by:

$$NESHDI_{t,k} = (1-FHP_{t,k} - FSA_{t,k}) \times (TOTNUM_{t,k} - TOTNUM_{t-1,k}) \times (TIF_{k} \times UNAVBS_{k}) \quad (3.67)$$

$$NESHHP_{t,k} = (FHP_{t,k} \times (TOTNUM_{t,k} - TOTNUM_{t-1,k})) \times (TIF_{k} \times UNAVBS_{k}/COP_{k,t}) \quad (3.68)$$

(continued)

E S R G

TABLE 3.10 (Continued)

where

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

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

Phase in fractional breakdowns:

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

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

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 3.76) 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,

$$ENEUI_{t,k} = ENEUI1_{t,k} + ENEUI2_{t,k} \quad (3.76)$$

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 3.75). The average unit usage deviates from base year values by a factor which is phased in linearly over the forecast period (Equations 3.76 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:

$$ENREU_t = UNAV_t \times HSTOCK_t \quad (3.75)$$

where

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

with

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

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 (see 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 (Reference 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

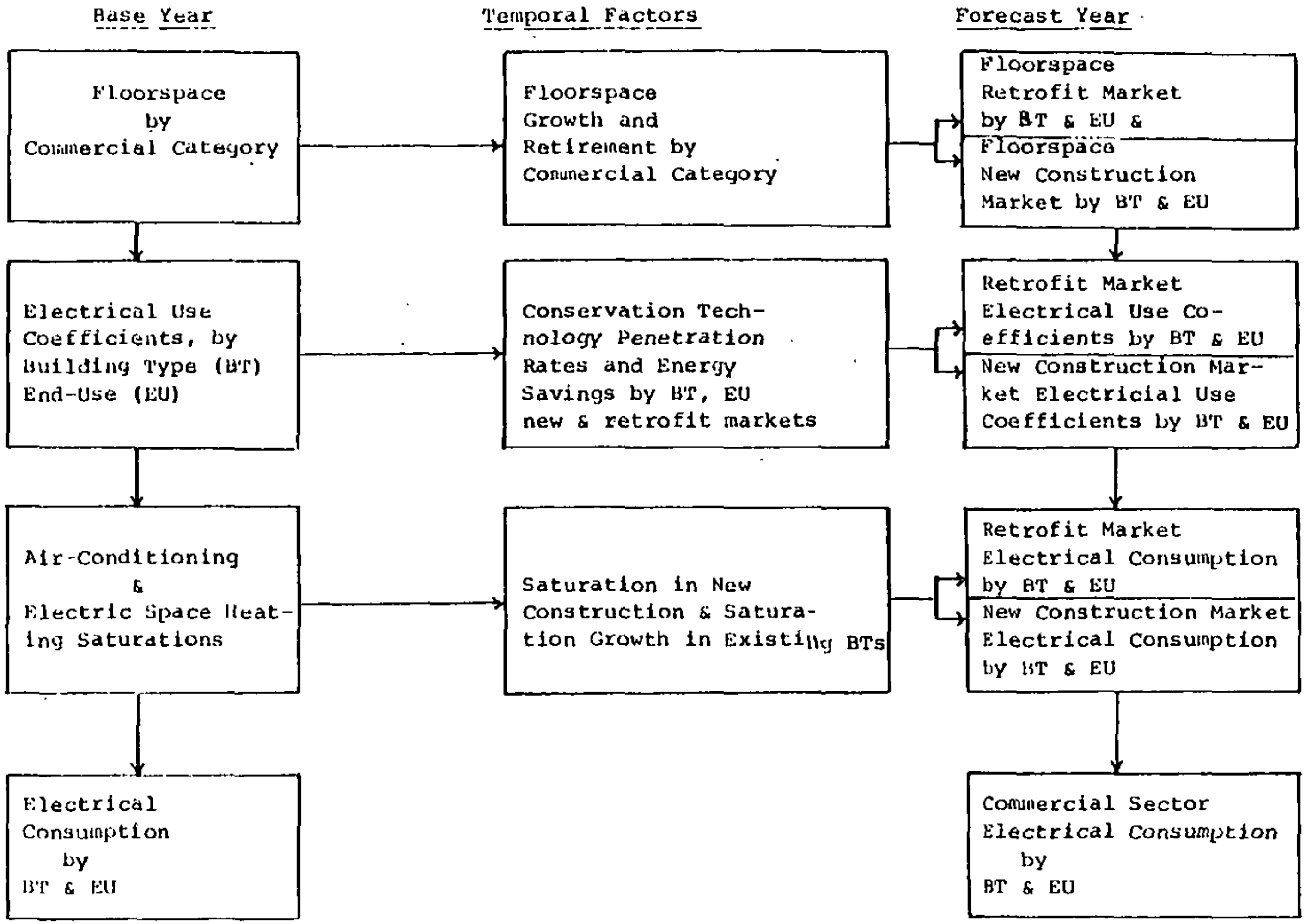


FIGURE 4.1
COMMERCIAL SECTOR MODEL SCHEMATIC

TABLE 4.2
COMMERCIAL MODEL - FLOORSPACE

Indices

t = 1,2,...	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:

$$PARAM_{t,j} = EMP_{t,j} \times UPOP_t / SPOP_t \qquad (4.1)$$

for j = 1 to 12 and

$$PARAM_{t,13} = UPOP_t \qquad (4.2)$$

$$PARAM_{t,14} = SAPOP_t \qquad (4.3)$$

Growth indices:

$$COMIND_{t,j} = PARAM_{t,j} / PARAM_{t-1,j} \quad \text{for } t>1 \qquad (4.4)$$

Iterate:

$$SQFTCC_{t,j} = COMIND_{t,j} \times SQFTCC_{t-1,j} \text{ for } t>1 \qquad (4.5)$$

with $SQFTCC_{1,j}$ inputted.

Aggregate to building type:

$$SQFTBT_{t,k} = \sum_j AGG_{j,k} \times SQFTCC_{t,j} \qquad (4.6)$$

Breakdown to existing and new:

$$SQFTBT_{t,k} = OSQFT_{t,k} + \sum_{t'=2}^{t} NSQFT_{t',k} \qquad (4.7)$$

(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:

$$COMIND_{t,j} = (1 + GRSQFTCC_{t,j}) \qquad (4.10)$$

where

$GRSQFTCC_{t,j}$ = 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
County Business Patterns Admin. & Auxiliary Services		200

* Source: References 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: 1) improvements which provide quick payback and require minimal engineering expertise (e.g., insulation, reduced lighting requirements, and other "housekeeping"), (2) level 1 improvements plus off-the-shelf technologies that require building and equipment modification (e.g., night setback, HVA/C system controls), and 3) levels 1 & 2, plus capital intensive modifications requiring considerable engineering support (e.g., building automated systems, waste heat reclamation). These three groupings are labelled by "m" in Table 4.4.

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

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	Percent (÷100) energy savings (i,k,n) at given conservation
PENSUM	Fractional energy decrease
HPFRAC	Fraction new electrically heated buildings
COP	Heat pump coefficient of performance

Equations

From definitions:

$$EUC_{t,i,k,n} = (1 - PENSUM_{t,i,k,n}) \times EUC_{1,i,k,n} \quad (4.11)$$

where

$$PENSUM_{t,i,k,n} = \sum_m PIMP_{t,k,n,m} \times PEN_{t,i,k,n,m} \quad (4.12)$$

and

$$INTEN_{t,i,k,n} = SAT_{t,i,k,n} \times EUC_{t,i,k,n} \quad (4.13)$$

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

$$INTEN_{t,1,k,2} = (HPFRAC_t/COP + (1-HPFRAC_t)) \times SAT_{t,1,k,2} \times EUC_{t,1,k,2} \quad (4.14)$$

where HPFRAC is given the following linear parameterization:

$$HPFRAC_t = \begin{cases} \left(\frac{t-1}{10}\right) \times HPFRAC_{11} & \text{for } t \leq 11 \\ HPFRAC_{11} & t > 11 \end{cases} \quad (4.15)$$

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

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:

$$\text{Commercial Energy Sales, year } t = \sum_{i,k,n} ENCEU_{t,i,k,n} \qquad (4.16)$$

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:

$$ENCEU_{t,i,k,1} = INTEN_{t,i,k,1} \times OSQFT_{t,k} \qquad (4.17)$$

New Construction:

$$ENCEU_{t,i,k,2} = \sum_{t'=2}^{t} INTEN_{t',i,k,2} \times NSQFT_{t',k} \qquad (4.18)$$

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. Growth 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

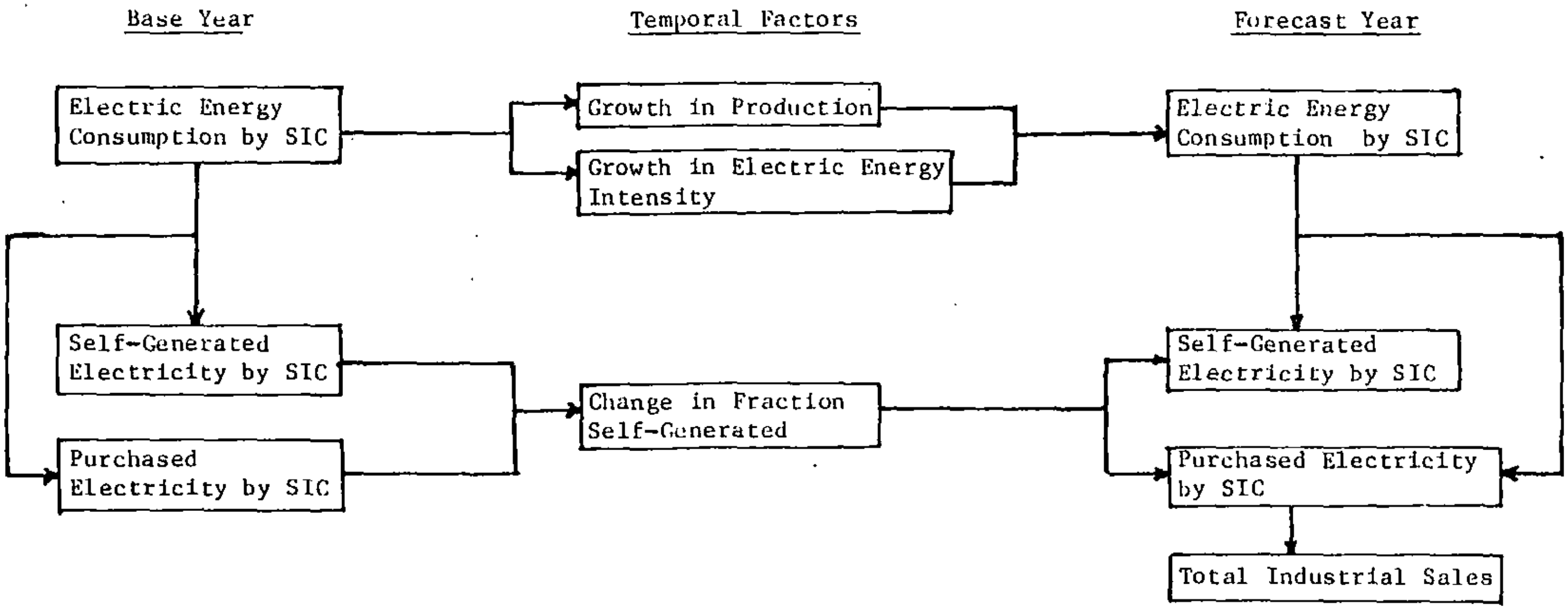


FIGURE 5.1
INDUSTRIAL SECTOR MODEL SCHEMATIC

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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. Economic measures often used in forecasting - value added, employees, value of shipment - do not track production directly. 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 U.S. production occurring in the state. The best available forecasts on the ratio of state-to-national production activity are provided by the BEA (Reference 7) on the basis of earnings.

Combining these factors, we arrive at the expression for state production index (SPI) given in Table 5.2. As we shall see in Section 5.6, the ratio of $SPI_{t,j}$ 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. 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

Equation

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

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):

$$PENSIC_{1,j} = MIX_j \times ISALES \quad (5.2)$$

$$TESIC_{1,j} = PENSIC_{1,j}/(1 - SGEN_{1,j}) \quad (5.3)$$

For t>1, define growth index:

$$IND_{t,j} = (SEI_{t,j} \times SPI_{t,j}) / (SEI_{t-1,j} \times SPI_{t-1,j}) \quad (5.4)$$

Then,

$$TESIC_{t,j} = IND_{t,j} \times TESIC_{t-1,j} \quad (5.5)$$

$$PENSIC_{t,j} = TESIC_{t,j} \times (1-SGEN_{t,j}) \quad (5.6)$$

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

$$OTHEN_t = OSALES_t + FRLS_t \times (SUM_t + OSALES_t) \tag{6.1}$$

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 while the weather sensitive fractions WSFR are given in Table 7.2. Additionally, 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.

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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 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,k,j,n	End-use indices as defined in Sections 3-5

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
TREHP	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:

$$RESSA_t = \sum_{i=1}^{14} ENREU_{t,i} \quad (7.1)$$

$$COMMSA_t = \sum_{k=1}^{5} \sum_{i=1}^{4} \sum_{n=1}^{2} ENCEU_{t,k,n,i} \quad (7.2)$$

$$INDSA_t = \sum_{j=1}^{19} PENSIC_{t,j} \quad (7.3)$$

Total energy:

$$TOTEN_t = RESSA_t + COMMSA_t + INDSA_t + OTHEN_t \quad (7.4)$$

Define intermediate sums:

$$RWSSUM_{t,p} = \sum_{i=10}^{13} WSFR_{i,p} \times ENREU_{t,i} \quad (7.5)$$

$$AFBEU_{t,p} = \sum_{i=1}^{9} WSFR_{i,p} \times ENREU_{t,i} \quad (7.6)$$

$$CWSSUM_{t,p} = \sum_{k,n} ENCEU_{t,k,n,3-p} \text{ (3-p is end-use label)} \quad (7.7)$$

then

$$BE_t = TOTEN_t - \sum_{p=1}^{2} (RWSSUM_{t,p} + CWSUM_{t,p}) - OPBER_t \quad (7.8)$$

where

$$OPBER_t = \begin{cases} CNWH_t \times ENREU_{t,8} \\ FOPRB_t \left[\sum_{i=6,7,9} ENREU_{t,i} + (1-CNWH_t) \times ENREU_{t,8} \right] + CNWH_t \times ENREU_{t,8} \end{cases} \quad \text{for } \begin{cases} t \leq RTOUY \\ t > RTOUY \end{cases}$$

and

$$FOPRB_t = (t-RTOUY)/(2001-BY-RTOUY) \times FOPRBT \quad (7.9)$$

TABLE 7.1 (Continued)

Weather sensitive energy:

$$WSE_{t,1} = RWSSUM_{t,1} + CWSSUM_{t,1} \quad (7.10)$$

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

where

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

Define:

$$CLFB = BD / BE_1 \quad (7.13)$$

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

then

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

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 52.

8. DISCUSSION OF INPUT DATA AND ASSUMPTIONS

The model, as described in Sections 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 requirement forecasts, peak levels, etc.). This section describes the data utilized and assumptions made in generating the high case and low case forecasts. It is worth reemphasizing that the uncertainty bands in input parameters are intended to represent the plausible range of business-as-usual futures. Other cases, such as a conservation scenario forecast based on, say, the impacts of a State commitment to demand-reducing policies and alternative technology implementation, are considered in Volume II of this report.

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 Section 1. The base year, which serves as the departure point for forecasting, is 1977 throughout the study since this was the most recent year of experienced sales breakdowns available from PECO.

8.1 Residential Sector

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

8.1.1 Demographics

Base year and projected Statewide population data was available from four sources: Refs. 7, 18, 21, and 22. Both high and low cases use the Pennsylvania Office of State Planning and Development (OSPD) state population data, a middle-range forecast relative to others available (see Table 8.1). Note that the independent population projection produced by the federal government sources show smaller growth rates than does that of the OSPD for the state as a whole. It is thus deemed a reasonably optimistic basis for both statewide population forecasts and for the five county region served, in the main, by PECO. State and service area growth rates, it will be recalled, are used for substate commercial floorspace growth allocation and to drive the hospital and health sector floorspace growth (Sec. 4.2.2 and Table 4.2). Additionally, as we shall see below, the population forecasts are utilized in developing residential customer growth estimates.

Base year residential customer estimates are from Company sources (Refs. 19, 20). We have consistently included residential customers on master metered rates in the residential category though the Company reports such sales as commercial. In generating customer growth rates, the OSPD five county growth rates need to be combined with trends in the population per household which has been decreasing gradually since 1950. For example, the U.S. average has decreased from 3.14 persons per household in 1970 to 2.86 in 1977. The corresponding values for Philadelphia are 3.21 and 2.91, respectively. Future trends are, of course, somewhat uncertain. For example, PECO has assumed values of persons per household phased to 2.71 by 1990 (Ref. 19, p. 44). For that year, we have assumed values of 2.55 in the high case based on Census projections (quoted in Ref. 19) and the 2.75 for the low case based on Ref. 23. Had we used the PECO assumption, our base residential forecast would be decreased somewhat.

TABLE 8.1
COMPARISON OF FOUR FORECAST SOURCES ON POPULATION

Area	Source	Ref.	Ratio 1985/1975	Ratio 2000/1975	Gr.Rate to 85	Gr.Rate to 2000	Publ. Date
Penn.	Census Series II-A	22	1.019	1.051	.19%	.20%	March, 1979
	Census Series II-B		1.014	1.039	.14%	.15%	
5 Counties	O.S.P.D. State Gov. Office	18	1.020	1.043	.20%	.17%	June, 1978
Penn.			1.031	1.067	.31%	+.26%	
Penn.	BEA	7	1.014	1.04	.14%	+.156%	1977
5 Counties	PECO	19	-	1.086	-	+.33%	Dec., 1978

The other required demographic input is the breakdown of total households into single family and multifamily units which, it may be remembered, is used to track differential use patterns in a number of the end-use submodels. It is commonly assumed that the relative demand for multifamily units should increase over time due to assumed decreases in family size and the increasing fraction of total population that is elderly and/or single. In the 1970-1977 period, approximately 50% of the new construction were multifamily units. We have assumed a continuation of that breakdown in the high case and an increase to 55% in the low case. The base year breakdown reflects the inclusion of the single point metered apartments (131,400 for 1977 from Ref. 19, p. 175-6). Table 8.2 summarizes the high and low case residential customer projections.

TABLE 8.2
RESIDENTIAL CUSTOMER PROJECTIONS (10^6 CUSTOMERS)

	Base	1980		1985		1990		1995	
	Year	Low	High	Low	High	Low	High	Low	High
Single Family	.961	.975	.985	.998	1.027	1.020	1.069	1.025	1.075
Multifamily	.331	.342	.355	.361	.397	.379	.440	.384	.445

8.1.2 Appliance Saturations

Appliance saturation assumptions are summarized in Table 8.3. The symbols in parentheses give the nomenclature used in Equation 3.5 for the saturation logistics curve. The end-uses not included in the table have predetermined saturation values: lighting and miscellaneous are each fixed at one, while heating auxiliary saturation is defined as one minus the electric space heat saturation.

Appliance saturation data, both in the base year and in earlier years, was given in the PECO Forecast document (Ref. 19). Estimations of terminal saturations also were referenced against PECO saturation estimates. For the appliances, the growth indices ("A") are computed by fitting the logistic curve (Sec. 3.2) to historical saturation data. Guidance in estimating the terminal saturation levels was derived from econometric relationships between appliance saturation and price/income variables. Specifically, saturation growths to the year 2000 were calculated using the econometric relationships given in Refs. 32 and 33, driven by the following annual growth rates:

	Income	Electricity Price	Oil Price	Natural Gas Price
High Case	1.5%	1%	4%	4%
Low Case	.5%	2.5%	2%	2.5%

In all cases, the terminal saturations employed exceed these estimates.

TABLE 8.3
APPLIANCE SATURATION ASSUMPTIONS

Appliance	Base Year Sat("SBY")	High Case		Low Case	
		Terminal Sat("STERM")	Growth Parameter ("A")	Sat("STERM")	Growth Parameter ("A")
Refrig(SF)	1.20	1.20	0	1.20	0
(MF)	1.04	1.04	0	1.04	0
Freezer(SF)	.28	.50	.169	.28	0
(MF)	.09	.15	.157	.09	0
Range	.38	.50	.107	.38	0
TV(SF)	2.00	2.20	.118	2.00	0
TV(MF)	1.20	1.20	0	1.20	0
Cl. Dryer	.35	.60	.086	.45	..134
Cl. Washer	.80	.85	.124	.80	0
Dishwasher	.35	.80	.069	.60	.090
Water Heat	.13	-	-	-	-
AC/room	.918	1.20	.014	1.00	.036
AC/cen.(SF)	.152	.40	.140	.25	.184
(MF)	.152	.40	.140	.25	.184
ESH(SF)	.023	-	-	-	-
(MF)	.098	-	-	-	-

Increases in the number of electric space heat and water heating customers were formulated in terms of penetration rates in Secs. 3.3.7 and 3.3.9, respectively. The penetration rates are modeled to increase linearly from initial year to 1990 values using the data below.

	High Case		Low Case	
	1978	1990	1978	1990
Single family	.50	.65	.30	.30
Multifamily	.70	.65	.60	.30

Historic penetration rates have been dependent on a complex mix of factors: construction practices, gas curtailment policy, economic promotion, etc. From 1970 to 1973, penetration rates in the PECO service area fluctuated, ranging from .13 to .34, then increased rapidly to over .50 in the gas curtailment years of 1974 and 1975. Given the recent rebound of the gas market, bans on new master metered units, and the continuing economic inferiority of electric heating, our assumption of continued high electric space heat penetration may be a source of forecast overestimation.

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 drive the electricity usage per unit submodels (the "C" in Equation 3.1). Average unit usage for the base year is given in Table 8.4 along with the efficiency improvements assumed in the forecast runs. The latter require some clarifying comments:

- The efficiency improvements are at FEA target levels (Reference 34). These targets may well 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 which achieve the maximum improvement in energy efficiency which the Secretary determines is technologically feasible and economically justified" (Reference 35). On this criterion, improvements of 52% versus the FEA-targeted 28% are possible for refrigerators (Reference 36), 33% versus 15% for electric water heaters (Reference 37), and so on.

- The achievement date in the FEA program is 1980. The forecasts assume 1981 and 1985 for the low and high cases, respectively.

- Improvements in the energy requirements of hot water heaters 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 affect electrical consumption, they will impact indirectly on electric hot water requirements (see Section 3.3.7).

TABLE 8.4

APPLIANCE USE DATA

Appliance	Base Year Average Annual Unit Usage†	Forecast Unit Efficiency Improvement††
	Kwh	Percent
Refrigerators*	1704	28
Freezers*	1372	22
Ranges	700	3
Televisions (B&W)	280	23
Televisions (Color)		13
Clothes Dryers	993	4
Clothes Washers	103	0
Dish Washers	363	20
Water Heaters	5160	15
Room A/C	293	22
Central A/C	2187	17
Space Heaters	11560	0
Heating Auxiliaries	419	0
Lighting	700	(see text)

* Weighted over frost-free and standard units
† Source: References 17, 19, 31, 38, 39 and Text.
†† Source: Reference 34 and text. Efficiency Improvement defined as percent energy reduction in this study.

- Energy reductions for televisions are not assumed to be as large as the government targets; the forecasts assume 29% and 13% for black-and-white and color models, 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 (Reference 38):

	Black-and-white	Color
Tube	220 kwh/unit	528
Solid state	100	320

- We have assumed the 1977 units at five-eighths of the 1972 to 1980 improvement which works out to 367 kwh/unit and 141 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.

- The base year averages in Table 8.4 are averages over all housing types. For certain end-uses, consumption levels for single family and multifamily homes should be 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 (e.g. oil and gas) 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. A/C COP, heat pump COP, etc.) and which are treated separately and additively by the model.

Prototypical savings levels for single and multifamily units (broken down by new and retrofit markets) are defined in Volume II, Sec. 3.2. The Base Scenario embodies thermal integrity improvements associated with "business-as-usual" trends. No retrofit of existing electrically heated homes is assumed. On the other hand, there is substantial potential for improvement due to retrofit of existing non-electrically heated homes to higher levels of thermal integrity. The Base Scenario assumes that a cumulative penetration of 25 percent of the retrofit market at the prototypical levels will occur over twenty years. Given the rapidly rising costs of home heating oil this is a modest assumption. The high case assumes 40 percent achieved by 1998 and the low case assumes 10 percent is achieved by 1998. The penetration of the retrofit market is assumed to grow linearly starting at zero in the base year.

The full discussion of the estimated existing thermal integrity levels and improvements appears in Volume II of this report, in which the Base Scenario and Conservation Scenario are compared. The improvements entail increased levels of insulation, weatherstripping, and storm windows and doors, the details of which are presented in Volume II along with associated reductions in heating and cooling loads for prototypical dwelling units to which the measures are applied. At this point we can summarize the Base Scenario average thermal integrity improvements which are expressed relative to the average existing energy loads.

Heating Auxiliaries

Electrically driven auxiliaries (fans, pumps, motors, blowers) associated with home heating systems are assumed to use electrical energy in rough proportion to the total heating demand. Thus improvements resulting in a 20 percent reduction in final demand met by an oil heating system would also result in a 20 percent reduction in electrical energy consumed by heating auxiliaries. The results of the Base Scenario estimates presented in Volume II are reproduced here,

HEATING AUXILIARIES
(TIMP)

	High		Low	
	Single Family	Multi Family	Single Family	Multi Family
Retrofit	.02	.02	.08	.08
New	.20	.20	.20	.20

where TIMP is the fraction reduction in final demand relative to existing usage. TIMP for new units is the improvement in all new units relative to the average existing units. TIMP for retrofit units is the average improvement in 1998 relative to the average existing units, assuming 10 percent and 40 percent cumulative penetration in the High and Low cases respectively. These are phased in linearly from zero over the twenty years. Thus, the Base Scenario entails average unit savings of 120 KWH and 60 KWH for all new single family and multifamily units relative to average existing usage. The Base Scenario assumes that no more than these levels are achieved, even in the low case, for new units. Given the rapidly rising costs of home heating this can be considered to be a conservative assumption.

Air-Conditioning

The Base Scenario assumes that savings calculated for the prototypical units described in Volume II of this report will apply on a fractional basis to all service-area specific air-conditioning loads. The levels of thermal integrity are applied with the same penetration assumptions as described for heating auxiliaries. The table below summarizes the results presented in Volume II.

HEATING AUXILIARIES
(TIMP)

	High		Low	
	Single Family	Multi Family	Single Family	Multi Family
Retrofit	0	0	.05	.05
New	.10	.15	.10	.15

Electric Space Heating

A detailed description of the average existing building shell characteristics and usage are described in Volume II of this report. Average annual requirements for electric space heating are in the neighborhood of 16000 KWH for single family units and 8300 KWH for multifamily units. The estimated 5 percent lower usage for new units would results in savings of about 800 KWH and 415 respectively for single family and multifamily units. The 5 percent figure is used in the high case while 10 percent improvements in new homes versus the base year mix of electrically heated homes is assumed in the low case.

8.1.5 Additional Data Requirements

The basic model structure utilizes base year and forecast counts of residential customers, saturations of the various end-uses and usage 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 underestimating energy demand growth.

For refrigerators, we need an estimate of unit usage for the 1962 vintage. According to Ref. 36, 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. 40, 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. 19, average size was about $14ft^3$, 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 (Reference 41):

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

Electric Range

The electric range submodel (Section 3.3.2) requires input date 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 (Reference 42) 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. For PECO service territory, the Company analysis of microwave penetration in Reference 19 was in agreement with other utilities' projections and their data was incorporated into the forecast model.

Lighting

There are a number of reasons to suspect that lighting energy demands decrease: smaller family size, trend in housing mix toward smaller units, conservation induced by increasing prices, more efficient flourescent bulbs and new lighting technology. Furthermore, the new 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.

In the high case, we have made the cautious assumption that none of these demand decrementing factors significantly impacts lighting levels. In the low case, we have included the possibility of market penetration of screw-in fluorescent bulbs. These bulbs are 70% more efficient than incandescent bulbs. Cost-benefit analysis indicates that 22% of the residential market is currently capturable by the new bulb (Reference 46). In the low case, it is thus assumed that penetration levels reach 25% by the end of the forecast period. That is, in the low case, "MF" in Table 3.4 is phased linearly from zero in the base year to .25 in 1997 while "RELEFF" is phased linearly from 0 to .30 so that the overall effect phases quadratically to a 7.5% reduction after twenty years.

Televisions

The television submodel (Section 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 (Reference 44) 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 (Reference 45):

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

Based upon PECO data, Reference 19, the model runs use .55 for the base year fraction of black-and-white sets. Regression against time on the above data leads to a value of .20 in 1997. Consequently, the forecast spans this value by assuming the fraction black-and-white goes to 40% in the low case and phases to zero by 1997 in the high case.

Water Heater

In addition to the inputs already discussed, the electric water heater submodel (section 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 3.9) could reflect, for example, the effects of slow flow shower devices, which could save, according to manufacturers' estimates, about 75% of the thermal energy in hot water. Assuming a similar potential in other faucets, reductions in "other" hot water demand would be .75 times the ultimate market fraction. The latter is taken as zero in the high case and 8% in the low case after 1981.

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:

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

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-1977	PB-1997
High	19 years	12.8
Low	10	4.5

Based on 30% penetration at payback of seven years (Reference 47) and zero penetration at twenty year payback, the above assumptions lead to:

	Penetration	
	1977	1997
high	0	.17
low	.18	.53

on average penetrations over the forecast period of about 8% 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 1997 in the low case.

Electric Space Heat

There are three elements in the submodel (Section 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 Reference 50 . These lead to penetration estimates defined here as the fraction of the additional electric space heat units that come on-line in 1997 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 1997 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. Some rough estimates of relative costs are contained in Table 8.5.

TABLE 8.5

RELATIVE ECONOMICS OF ALTERNATIVE HEATING AND COOLING SYSTEMS

	First Cost*	Capital+	Heating Fuel++	Total
Electric Resistance	$1300	$140	$550	$690
Natural Gas	2200	240	210	450
Electric Heat Pump	2950	320	275	595
Electric Resistance with A/C	3050	330	550	880
Gas with A/C	3950	430	210	640

* Northeast estimates for single family units in 1979 dollars (References 8, 24, 43)
\+ Assumed financed at 9 percent over twenty years
++ Fuel costs based on 5¢/KWH electricity, 11,000 KWH per household, gas boiler efficiency at 0.7, heat pump COP = 2, 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, if one compares heat pump carrying costs to resistance and gas with air-conditioning (since this is the equivalent commodity, remembering that heat pumps are year-round devices), it appears that heat pumps are competitive with gas heating and superior to resistance heating. Consequently, it is assumed that the rapid increase in saturation of electric heating is associated with increasing fractions of new electrically heated homes which use heat pumps. Table 8.6 below provides the assumptions of fractions of new homes with heat pumps, for the base year and for terminal saturations. These estimates tend to be based upon PECO-provided data and discussion, as well as the considerations outlined above. It is assumed that, in each case, growth in heat pump penetration will peak by 1990.

TABLE 8.6

HEAT PUMP FRACTION OF ESH PENETRATION IN PECO SERVICE TERRITORY

	Initial Fraction	Terminal Fraction	
		Low	High
Single family	.788	.788	1.00
Multifamily	.063	.50	1.00

The fraction of existing ESH customers with heat pumps is set, using Company provided information, at .55 and 0 for single and multifamily units, respectively.

- 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 (Reference 51) 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 ^{o}F
  Y is perfentage of nominal COP at temperature T.

Table 8.7 summarizes the data.

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

TABLE 8.7

HEAT PUMP PERFORMANCE DATA

	Nominal COP	Temperature Range ($^{\circ}F$)	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	-0.0147
Commercial	2.7	$-10 \leq T \leq 20$	56.75	0.875	0.0075
		$+20 \leq T \leq 70$	65.32	0.531	0.0043

For the forecast region, 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 8.8.

TABLE 8.8
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 8.5)
$STNDRD_s$	Nominal COP (see Table 8.5)
$TEMPL_{m,l}$	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

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

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

$$PCCOPM_{s,m} = A_s + B_s \cdot TEMP_m + C_s \cdot TEMP_m^2 \quad (8.3)$$

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

$$LOTEMP = (\sum_l LOTEML_l \times POP_l) \ / \ \sum_l POP_l \quad (8.4)$$

$$PCCOPL_s = A_s + B_s \cdot LOTEMP + C_s \cdot LOTEMP^2 \quad (8.5)$$

$$COPA_s = PCCOPA_s \times STNDRD_s \ / \ 100 \quad (8.6)$$

$$COPL_s = PCCOPL_s \times STNDRD_s \ / \ 100 \quad (8.7)$$

TABLE 8.10

COMMERCIAL FLOORSPACE

Commercial Category	1975 Floorspace (10^6 ft^2)
1. F.I.R.E.	20.686
2. Federal Government	11.413
3. State, Local Government	31.043
4. Professional Services	9.028
5. Wholesale & Retail	151.880
6. Trucking, Warehousing	51.982
7. Other Transportation	15.454
8. Communications	3.745
9. Lodging, Personal Services	13.082
10. Business & Repair Services	29.866
11. Amusement, Recreation	30.868
12. Railroad	2.201
13. Health Services	58.009
14. Schools, Education	95.363

The total of 524.6 million square feet is compatible with the Company estimate for 1978 of 543 million square feet (Ref. 26).

8.2.2 Floorspace Growth Indices

As indicated in Section 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 Table 8.11. The low case is based on OSPD's Pennsylvania forecasts of employees by commercial category (Reference 18). Additionally, we have

$$\text{employees} = (\text{employees}/\text{earnings}) \times \text{earnings}$$

Earnings projections for Pennsylvania were derived from BEA (Reference 7). Estimates of employees-to-earnings were developed by regressing on historic data on employees and earnings for the 1963-1976 period. It was found that for each of the commercial categories, using a 2% annual rate of increase (for consistency with residential high case economic assumptions) of employee earnings consistently gives higher forecasts than the historic trends. Consequently, it was judged that this rate of increase leads to a satisfactory upper bound on employment growth.

TABLE 8.11

EMPLOYMENT GROWTH INDICES

Commercial Category	Emp. 1985÷Emp. 1975		Emp. 2000÷Emp. 1975	
	High Case	Low Case	High Case	Low Case
1. F.I.R.E.	1.371	1.162	1.609	1.434
2. Fed. Government	1.092	1.008	1.085	.993
3. State&Local Gov.	1 518	1.154	1.986	1.350
4. Prof. Services	1.510	1.126	1.995	1.354
5. Retail	1.205	1.061	1.214	1.126
6. Truck & Ware.	1.403	1.154	1.561	1.376
7. Other Trans.	1.083	.895	.895	.725
8. Communications	1.463	1.080	1.951	1.242
9. Lodging&Pers.Ser.	.947	1.051	.736	.986
10. Bus.&Repair Ser.	1.652	1.282	2.067	1.785
11. Amuse.&Recrea.	1.063	1.097	1.022	1.227
12. Railroad	.828	.817	.572	.580

Hospital floorspace growth is equated with population growth forecasts discussed in the demographic subsection. School floorspace growth is equated with growth in school age population from Reference 18.

8.2.3 1975 Electric Intensities

Electric intensity estimates are required to initialize the commercial sector energy growth iteration as described in Section 4.3.1 and Table 4.4. PECO experienced 1975 commercial energy (Reference 19) and 1975 floorspace data were used to develop an overall energy intensity (KWH/Ft^2/YEAR). Then intensities appropriate to building type and end-use were developed by prorating Northeast electric use coefficients from Reference 8 (as quoted in Reference 6), with weather sensitive usage scaled, as appropriate, by heating and cooling degree days. Weighted values for the latter are 5018 and 1028, respectively, for PECO service territory counties from Reference 52. The resulting coefficients are shown in Table 8.12 for both the existing 1975 stock and prototypical new floorspace.

For the PECO service area, five localities were used to compute the mean monthly temperature. This temperature was used in Equation 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 Reference 52. The coefficients are from Table 8.7. 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 (Equation 8.4). The heating degree days are computed by subtracting the average monthly temperatures (when they are less than $65^{\circ}F$) from $65^{\circ}F$ and multiplying by the number of days in the month (Equation 8.2). The low temperature is construed as the average temperature on the day of the winter peak. Finally, average and low COP's are computed in Equations 8.6 and 8.7.

The results are as follows:

Heat Pump COP's

	Average	Low
Residential	2.248	1.763
Commercial	2.507	1.886

As with other appliances, efficiency improvements are anticipated for heat pumps. The forecasts assume improvements of 4% and 15% by 1987 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:

- 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 100% increase in miscellaneous use per customer during the forecast period while assuming no increase in the low case.

8.1. 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 8.9

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
Dish Washer	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: Reference 53

8.2 Commercial Sector

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

8.2.1 1975 Floorspace

Initial estimates of the 1975 PECO service territory commercial floorspace is needed as input to the floorspace submodel which is summarized in Table 4.2. The computational methodology is explained in Section 4.2.1. The results are given below:

TABLE 8.12

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

Building Type	Existing				New			
	Htg.	Cooling	Lt&Power	Aux.	Htg.	Cooling	Lt&Power	Aux.
Office	5.6	5.6	4.8	3.6	8.0	3.9	4.8	3.0
Retail	2.6	6.3	12.4	4.4	4.0	4.3	12.4	4.0
Hospital	6.1	7.2	12.0	6.4	9.9	3.3	12.0	6.0
Schools	5.1	9.2	5.2	3.0	7.3	3.3	5.2	2.4
Other	2.9	6.3	6.8	4.4	4.4	2.4	6.8	4.0

Very little source data exists on commercial saturations. Electric space heat saturations appear to be similar to residential space heat saturation levels (Refs.19,26,31) and the base year values were assumed to be comparable in the forecast. Additionally, Reference 6 provides regional estimates of commercial heating and cooling saturations which are used here as a cross check.

8.2.4 Future Intensities

The methodology for incorporating future adjustments to electric intensities is described in Section 4.3.2. Penetration of the conservation levels has been computed in Reference 6 for the northeast based on cost optimization analysis of commercial investments in equipment and building shell 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 displayed below in Table 8.13 for the years 1985 and 2000. Consult Table 4.4 for definitions. Note that separate penetration matrices are developed for the electric space heat end-use. These are fractions of floorspace at these conservation levels; the remainder, when the sum is less than one, have no conservation above base year levels.

TABLE 8.13

CONSERVATION LEVEL PENETRATION FRACTIONS

		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	--

The relationship between the levels and load saved is given in Table 4.5. The fractional penetrations contained in Table 8.13 were used directly in the low case forecast since they depend on the assumption of investment according to economic optimization. For the high case, it was assumed that such an optimization does not occur and half the fractional penetrations of Table 8.13 were employed.

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 to capture 30% of the space heat markets in the low case and 50% for the high case. These same penetrations are used for the existing stock where the size of the ESH retrofit market is based on a thirty year lifetime for existing equipment. The saturation assumptions are summarized in Table 8.14.

TABLE 8.14

COMMERCIAL SECTOR ELECTRIC SPACE HEAT SATURATIONS

Case	Building Vintage	Year Base	2000
High	Existing	4%	30%
	New	50%	50%
Low	Existing	4%	20%
	New	30%	30%

The use of heat pumps is expected to increase over the forecast period (see analogous discussion for residential sector). The Company, for example, assumes that 70% of new small commercial and industrial space heat customers will install heat pumps by 1988. The high and low forecasts incorporate such increases for the new commercial space heating customers. Specifically, heat pump usage as a fraction of new heating usage is phased linearly from zero in 1975 to 50% and 100% by 1985 for the high and low cases, respectively. Heat pump COP assumptions and analyses for the commercial sector will be found in Sec. 8.1.5.

Air Conditioning saturation of commercial floorspace for 1975 was taken at .66 based on the data for small commercial and industrial customers (Ref. 19, P. 237). This figure was cross-checked by matching calculated summer weather-sensitive commercial sector consumption to experienced seasonal sales. In the low case, it has been assumed that existing unit saturations will stay constant while saturation in new commercial structures will increase by from .66 to .80 due to HP penetrations. In the high case, both new and existing units are assumed to experience an increase, with 80% of existing units having cooling by the year 2000 and 100% of new commercial units having A/C by that year.

The use of heat pumps is expected to increase over the forecast period. The high and low cases assume, respectively, values phased linearly up to 50 percent and 100% heat pump of ESH usage by 1985 for new commercial floorspace. Heat pump COP assumptions and analyses for the commercial sector will be found in 8.1. (See, especially, Table 8.8).

8.3 Industrial Sector

The industrial sector model is described in Section 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

Total base year industrial sales was 8085.1 Gwh (10^6 KWH) with the fractional breakdown by two-digit SIC given below (Refs. 19 and 26).

TABLE 8.15

INDUSTRIAL SALES MIX

SIC	Fraction of Sales
20	.081
22	.015
23	.007
24	.002
25	.001
26	.069
27	.024
28	.127
29	.148
30	.054
31	.001
32	.022
33	.213
34	.040
35	.045
36	.053
37	.041
38	.013
Misc.	.044

8.3.2 Production Growth

The model requires growth estimates of "State Production Indices" as indicated in Table 5.3, Equation 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 Reference 14 and earnings projections from Reference 7, is used to establish production growths. These growth assumptions are summarized in Table 8.16 which gives production levels relative to the base year (base year = 1) for two selected years.

TABLE 8.16

STATE INDUSTRIAL GROWTH BY STANDARD INDUSTRIAL CLASSIFICATION

SIC	SPI 1985 / SPI 1977	SPI 2000 / SPI 1977
20	.96	1.58
22	1.01	1.02
23	1.13	1.27
24	1.14	1.25
25	1.28	1.60
26	1.32	1.60
27	1.26	1.64
28	1.39	1.99
29	1.12	1.05
30	1.59	2.36
31	1.03	.95
32	1.13	1.22
33	1.36	1.62
34	1.24	1.52
35	1.31	1.67
36	1.40	1.83
37	1.32	1.66
38	1.50	1.94
39 (+ mining)	1.57	1.95

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, Equation 5.4.)

We begin by investigating the historic trend in the electrical intensities for the State of Pennsylvania. Linear regression is used to develop time trends for the 1963-1976 period. The computation is summarized in Table 8.17. The historic production index is derived from national production index data (Reference 13) and state-to-national earnings ratios (Reference 7) as discussed in Section 5.3 (Equation 8.8). The intensities are then formed as the ratio of total electrical energy consumption (purchased and self-generated) from Reference 12, and state production indices for each historic year and SIC (Equation 8.9).

The time axis is then shifted so that the resultant intercept is automatically based on the base year = 1 (Equation 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 (Equation 8.11). Finally, after defining some intermediate summations, the slopes and intercepts are computed.

TABLE 8.17
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

$$SPIH_{r,j} = NPIH_{r,j} \times SNER_{r,j} / 100 \quad (8.8)$$

$$SEI_{r,j} = SPROSH_{r,j} / SPIH_{r,j} \quad (8.9)$$

$$YR_r = YR1_r - BY + 1 \quad (8.10)$$

$$N = END - START + 1 \quad (8.11)$$

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

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

$$SEI_j = BI_j + SLOPEI_j \times (t-1) \quad (8.14)$$

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 8.17, is given below in Table 8.18.

TABLE 8.18

STATE ENERGY INTENSITY INDEX

SIC	High Case	Low Case
20	1.2	0.9
22	1.3	0.9
23	1.4	0.9
24	1.9	0.9
25	1.2	0.9
26	1.0	0.9
27	1.3	0.9
28	0.7	0.8
29	1.0	0.9
30	0.8	0.9
31	1.6	0.9
32	1.0	1.0
33	1.2	1.0
34	1.2	0.9
35	1.0	0.9
36	1.0	0.8
37	1.1	1.1
38	1.7	0.9
39	0.6	0.9

8.3.4 Fraction Self-Generated

Recent studies have indicated that a sharp increase in industrial cogeneration is likely with or without government interaction. The primary reason is the escalating costs of electricity. To estimate the range of likely effects, we assume, in the high case, that base year levels (References 19, 26) do not change. For the low case, we assume historic state levels (Reference 12) re-achieved by 1985, or the lowest level 1985 potential for the Northeast given in Ref. 27 for SICs 26, 28, and 29 (steam turbines, no government action) achieved by the year 2000 or the potential cogeneration levels found by the Pennsylvania Electric Association and provided in Reference 26, whichever is higher. The input data assumptions for fraction self-generated (SGEN in Table 5.3) are shown in Table 8.19.

TABLE 8.19

FRACTION SELF-GENERATED BY TWO-DIGIT SIC

SIC	BASE YEAR	1985 HIGH CASE	1985 LOW CASE
20	.071	.071	.099
22	0	0	.021
23	0	0	.004
24	.343	.343	.343
25	0	0	.019
26	.201	.201	.466
28	.047	.047	.223
29	.303	.303	.54
30	0	0	.063
31	0	0	.171
32	0	0	.101
33	.131	.131	.266
34	0	0	.002
35	0	0	.005
36	0	0	.081
37	.154	.154	.154
38	0	0	.007
39	0	0	.004

8.4 Other Energy Requirements

Sales to customers other than those in the three major service sectors are discussed in Section 6. Base year energy sales to the "other" category for PECO are 1182 Gigawatthours (References 19, 26). This represents about 4% of total company sales. PECO forecasts of other energy sales (Reference 19) are accepted in the ESRG model. The other required input datum is line losses and the own-use of electric utility company. This enters the program as a fraction of total sales. (See Table 6.1 and discussion.) This is derived as 6% from output and sales data contained in Reference 28.

8.5 Peak Power

The peak power computations are summarized in Section 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.

There are three items of load data required for the state: winter peak, summer peak and "base peak". In the base year 1977, the winter peak of 4519 MW was given by PECO (Reference 26) and the corrected summer peak of 5580 MW was drawn from Reference 19.

The base peak is defined in Section 7 as the non-weather sensitive portion of the peak. PECO gives this figure as 3763 MW for 1977 (Reference 19). This figure closely cross-checked the ESRG analysis of the relationship between monthly peaks (Reference 26) and mean temperature on the peak day (Reference 30) as follows:

$$Peak_m = \text{Base Peak} + A \times (65 - T_m)$$

where

m = month (exclusive of summer months, June-September)
Peak = peak load
T_m = mean temperature
Base Peak, A = regression coefficients

The base peak, consistent with its definition, is defined by the absence of heating degree days on the monthly peak day. A fit was obtained resulting in a base peak value of 3757 megawatts.

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. Section 7 provides a discussion of the underlying load management mechanisms modelled to shift peak demand. In the residential sector, time-of-use rates are expected to influence the patterns of time-flexible appliances. In the commercial sector, thermal storage is anticipated to influence time-of-use. 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 8.20 below.

TABLE 8.20

LOAD MANAGEMENT

Case	Year Impact Begins	Impact Year 1990				
		Ind.	Res. Use Shift*	Res. Thermal Storage	Comm. Use Shift**	Comm. Thermal Storage
High	2000+	0	0%	0	0	2%
Low	1983	0	25%	0	10%	5%

* FOPRB in Table 7.1
** FOPCWS in Table 7.1

Finally, in driving peak demand and establishing base and weather-sensitive load factors, 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. 19 as .60. This is assumed to decrease to .47 by 1990 consistent with Company assumptions of no additons in the number of controlled heaters. Unit usage of controlled heaters is taken at 2/3 the unit usage from uncontrolled heaters based on Company load analysis. Should the number of controlled water heaters not remain constant, peak forecasts would, of course, be adjusted downward.

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BEFORE THE

PENNSYLVANIA PUBLIC UTILITY COMMISSION

*** *** ***

PENNSYLVANIA PUBLIC UTILITY COMMISSION

VS.

PHILADELPHIA ELECTRIC COMPANY

R.I.D. R-79060865

*** *** ***

Supplementary Testimony of John K. Stutz as to Long Range Load Forecasting

December 17, 1979

E S R G

Q. What is the purpose of your additional testimony?

A. Mr. Hoch has, in his additional testimony, provided a discussion of the differences between the forecasts and forecasting methods of the Philadelphia Electric Company ("PECO") and Energy Systems Research Group, Inc. ("ESRG"). Unfortunately, his discussion is marred by a number of errors concerning the operation of ESRG models. Additionally I will comment on differences in approach and output for the two forecasts.

Q. Before beginning your specific comments, do you have any general remarks that you wish to make?

A. Yes, I do. I should like to point out that, in my view, Mr. Hoch's additional testimony is most interesting for what it omits rather than for what it contains. In my original testimony I indicated a number of areas of difficulty in the PECO forecast. These included the base case forecast for the commercial sector and the treatment of what I have termed miscellaneous residential consumption. In the former I pointed out that disaggregating the floorspace data used in the PECO base case commercial forecast rather than using gross overall estimates for this extremely heterogeneous sector reduces the growth in commercial square footage substantially. On p. 16-17 of my testimony, I recalculated the PECO commercial forecast using PECO data assumptions, but substituting the disaggregated growth information supplied by Wharton Associates to the Company for the aggregate data relied upon by PECO. This procedure reduced the original PECO forecast for 1988 from 12,320 GWH to 10,754 GWH. This correction accounts for over 50% of the difference between the PECO and ESRG forecasts for the commercial sector. It also points up the major difference between the two forecasts at a methodological level: ESRG disaggregates its commercial forecast; PECO doesn't. Mr. Hoch has made no mention of this aspect of my testimony. The situation is similar with respect to "miscellaneous" usage. On p. 10-13 of my testimony, I presented detailed criticism of the company forecast for six separate areas of miscellaneous usage. None of these areas were addressed by Mr. Hoch in the course of his testimony. As in the discussion of the commercial sector, the issue here is separable from any discussion of the ESRG forecast. From the PECO residential forecast (Exhibit (WCH-1), p. 159) one sees that between 1978 and 1988, growth in dehumidifiers, supplementary heat, "Transportation," and "Other appliances" accounts for 25% of the total residential growth. I have argued, based in large part on information supplied by PECO, that this growth is unlikely to take place. This portion of my testimony is simply not discussed by Mr. Hoch. To be fair, I should note that he does touch in the area of cooking appliances. Here, however, it is clear from the context that he is discussing the ESRG forecast for electric ranges and not miscellaneous usage.

In the remainder of this testimony, I will deal with the major points raised by Mr. Hoch concerning the ESRG forecast. However, it should not be overlooked that, in the absence of any alternative forecast, my testimony shows that the PECO forecast is likely to greatly overstate future long-term load growth.

Based upon my review of Mr. Hoch's additional testimony I remain convinced that the ESRG base case forecast remains the most accurate guide to probable future load growth.

Q. Please begin your discussion of Mr. Hoch's comments concerning the commercial sector forecast prepared by ESRG.

A. The commercial sector represents the area of greatest difference between the PECO and ESRG forecasts. PECO staff visited the ESRG offices in Boston to examine the ESRG model and were permitted to make runs using the model. However, despite this experience and existence of detailed documentation presented in Exhibit ___(JS-4) and made available at the ESRG offices, certain confusions on the part of PECO staff seem to have occurred. These are reflected in Mr. Hoch's testimony.

Mr. Hoch states on p. 11 that "The fundamental error that ESRG made in applying their model to the PECO area is that they have not particularized the base data employed in the model to the PECO area..." Three examples of this "fundamental error" are cited by Mr. Hoch: analysis of economic activity, specifically employment; analysis of hospital floor space; and analysis of school floor space. However, only in the first case does Mr. Hoch actually deal with the issue of local vs. state-wide data use.

The use of employment in the ESRG commercial forecast is described in equation 4.1, p. 43 of Exhibit ___(JS-4). This equation defines the growth rates for 12 of the 14 "commercial categories" in the floor space section of the ESRG model. Notice that the employment growth factor described on p. 43 as statewide employees is adjusted by the ratio of utility (PECO) to state population. Equation 4.1 shows that Mr. Hoch is simply wrong concerning operation of the ESRG commercial forecasting model. The first step in the operation of the ESRG model is to adjust statewide employment estimates to reflect local conditions through the introduction of local population data.

Q. Is there other evidence of PECO's failure to correctly deal with the ESRG commercial forecasting model?

A. Yes, there is. The entire discussion of "backcasting" shows a failure to understand the ESRG approach in commercial forecasting. On p. 10 Mr. Hoch states that "ESRG has neglected to align its model to other historic data available to them, specifically 1975, 1976, 1978, and 1979 (commercial sales)." This remark suggests that it is Mr. Hoch's belief that the ESRG model is designed to reproduce the historic sales for these years as accurately as possible. This is simply wrong. The ESRG commercial forecasting model is neither a trend nor an econometric model. The structural relations in the model are designed on the basis of an engineering and economic analysis of commercial consumption. The structural relations are not developed by fitting historic data as is the case in trending or econometric models.

There is a simple reason why the ESRG model does not proceed via the trending or econometric approach. In our view electrical consumption, particularly in the commercial sector, is undergoing a historic shift. Rather than attempting to capture the recent gyrations in demand, we have designed a model which will we feel capture emerging long term trends. The ESRG model is not designed to produce output for years ealier than 1977 and, in my opinion, it is totally incorrect from a logical point of view to attempt to produce such output. Of course PECO is free to produce whatever they wish; however, as the author of the model, I cannot attach any significance to the results.

Q. Please discuss the ESRG and PECO commercial forecasts in light of the 1975-1979 historic experience.

A. As shown in Mr. Hoch's Figure C-1, commercial sales have grown at 2.2% per year between 1975 and 1979. From 1979 to 1988, PECO projects an increase in growth to 3.7% per year while ESRG shows a fall to .2% per year. I find neither of these forecasts to be "in line" with the historic record.

Again, from Figure C-1, I find that in 1978 the growth was above that forecast by ESRG but below that forecast by PECO. In 1979 it appears that growth will follow the pattern forecast by ESRG.

In my view the important question is how and to what extent future usage patterns will differ from past and current experience. Here Mr. Hoch has expressed his view quite clearly. On p. 14 he argues that high levels of commercial construction will continue and that the recent level of consumption in new buildings (34 KWH per sq. ft) will continue. I would dispute both assumptions.

Given the current economic situation, including tight money and the long-term prospect of substantial levels of inflation, I am not convinced that Mr. Hoch's views concerning new construction will be borne out. On the issue of the intensity of usage I would simply note again that the 34 KWH per sq. ft. figure is far above historic usage, not to mention what is currently feasible. Given the increasing stress on conservation I simply cannot accept the view that this unnecessarily high level of consumption will continue. One of the major strengths of the ESRG model is its detailed analysis of the intensity of consumption. Nothing in Mr. Hoch's testimony would lead me to doubt this analysis.

Finally I would like to touch upon an aspect of the ESRG model which Mr. Hoch has not mentioned. The ESRG model is, by design, a long-range model. It is formulated to pick up such things as retirements of existing commercial space, retrofit of existing space, as well as the addition of future space at improved efficiencies. All of these effects will, in the long run, move to offset any spurt in current growth. Thus in the long run, through and beyond 1988, to 2000, the final year of the ESRG forecast, the ESRG forecast will I believe provide an accurate guide to the probable pattern of commercial load growth. The importance of a long-run perspective is pointed up by Mr. Hoch's comments on the consumption of schools, shown in the last figure in his testimony. His data shows falling school age population together with sales growing rapidly to

1973, then fluctuating along a modest upward trend. Contrary to Mr. Hoch's view, I find the falling off of growth in 1973-79 consistent with my assertion that in the long run school consumption will follow the number of people in school. While we are on the subject of this figure, I would point out that there is no ESRG sales projection for 1975 or 1976. Further, since the ESRG forecast is normalized to 1977 sales, it is implausible that anything concocted by PECO from ESRG data would match 1975 sales exactly as shown in this figure. A similar comment applies to the preceding figure in Mr. Hoch's testimony showing data on health services. These represent simple misapplications of our model.

Q. Please discuss the ESRG and PECO residential forecasts, beginning with population.

A. It is clear that ESRG and PECO have very similar population forecasts. The only real question is how these minor differences could impact the two forecasts. Mr. Hoch points out correctly that both forecasts begin with the same estimates of population, broken down in the same way between houses and apartments. These are shown on p. 176 of Exhibit ___(WCH-2) and p. 67 of Exhibit ___(JS-4). In the ESRG forecasts there are different assumptions on both the growth in the number of customers and the mix of new customers between houses and apartments. The only end-use which would show significant effects of these assumptions would be electric space heating. Here the different assumption of growth and housing mix, together with different penetration and usage assumptions lead to the differences between the ESRG and PECO forecasts of residential electric space heating. Mr. Hoch is correct in observing that in my original analysis of the PECO forecast, the number of residential customers they assume for 1988 were overstated. All this indicates is that the differences between the two forecasts are a bit more subtle than first expected. Mr. Hoch's discussion of differences in the forecast of residential customers is largely irrelevant in explaining the difference in the two residential forecasts which use such similar methodological approaches.

Q. What are the differences between the ESRG and PECO forecasts for residential electric space heating?

A. As one might expect, beyond the effects of growth in the total number of customers, there are differences in assumptions concerning the degree of penetration and unit consumption. In the case of the ESRG forecast, I believe these assumptions are clearly stated in Exhibits ___(JS-4) and ___(JS-5). Mr. Hoch's fallacious statements to the contrary can only confuse the record in this case. Mr. Hoch also observes that some of the ESRG data concerning the number and performance of heat pumps in the base year do not agree with company data. As Mr. Hoch also observes, changes in these two variables would increase the ESRG base year estimates of electric space heating consumption. Mr. Hoch neglects to point out that these differences would <u>not</u> alter the ESRG forecast of growth in electric space heating. In sum, on those points related to the <u>growth</u> in electric space, the differences are primarily in the area of housing mix, penetration, and future usage. On these points I continue to support my original position.

Q. Please discuss the differences between the two residential forecasts which are due to the differences in assumptions concerning the saturation growth for refrigerators and freezers.

A. Here the difference is quite clear. ESRG assumes, for all the reasons cited in my testimony, including Exhibit ___ (JS-4), that growth in saturation will level off; PECO assumes it will continue to grow. These are assumptions concerning long-term trends. I should begin by pointing out that the company has stated that no definitive data is available on the trend in second refrigerator ownership (Exhibit ___ (WCH 1), p. 75) and that it has no survey data on multiple ownership in new apartment dwellings (Response to Question LF.58). The data presented by Mr. Hoch in his testimony is interesting but far from convincing. There are a large number of reasons why one might believe that the long-term trend in growth in multiple ownership has peaked. To declining family size and apparent shift to apartments, one might add the increasing price of electricity, increased consumer consciousness concerning energy consumption, to name just two. As a statement of long-term trend I still find the ESRG assumptions conservative.

Q. Please discuss the differences in the forecasts in the area of "miscellaneous" consumption.

A. As I observed earlier, Mr. Hoch chose not to discuss my criticism of the company forecast in this area. Instead he has chosen to raise a few technical points concerning the ESRG forecast. Here I merely want to clear up those points.

For the base year I find that there is some uncertainty in the distribution of residential consumption. This can be traced ultimately to uncertainty concerning the use of the second televisions which many PECO customers own. This uncertainty effects my estimate of miscellaneous consumption for 1977. I find nothing odd or confusing in this situation. It is clearly described in my Exhibit ___ (JS-4). There is, however, a typographical error in Exhibit ___ (JS-4). In my high case I assume 50% growth in miscellaneous usage by 1994, not 100% as stated on p. 82 of Exhibit ___ (JS-4). A review of my comments concerning the PECO forecast will, I think, show that this estimate is generous.

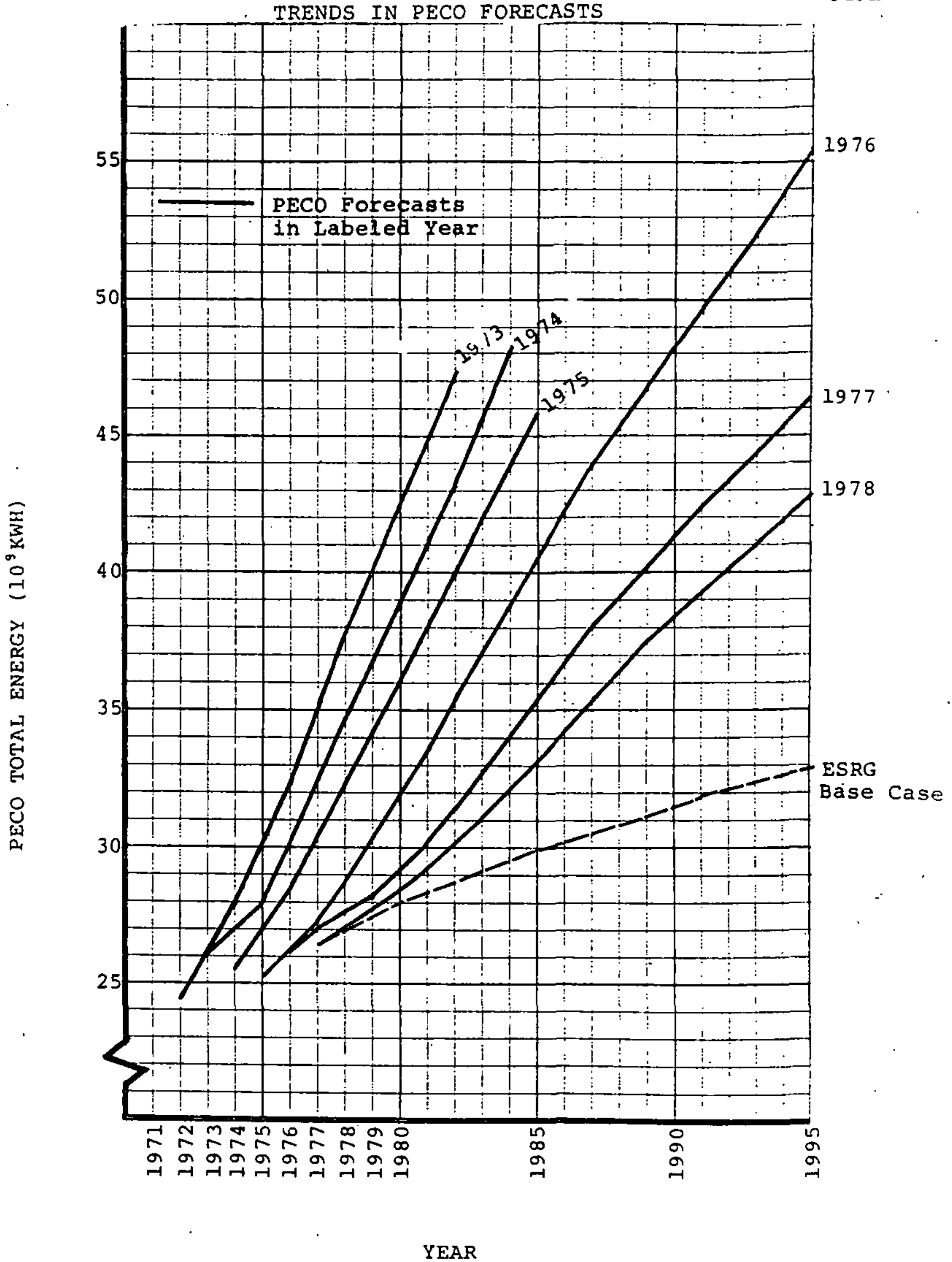
Q. Please comment on Mr. Hoch's discussion of the difference in the industrial forecasts.

A. I agree with Mr. Hoch in his statement that the difference in the forecasts is due to different treatments of cogeneration. However, his characterization of the ESRG forecast is inaccurate. We used three, not two, sources in considering future levels of cogeneration. Also the levels in the Thermo-Electron study which we used did not assume any new federal incentives, despite the suggestion by Mr. Hoch. Further, as I pointed out during my cross-examination, we at ESRG have had direct experience surveying New York State firms concerning their cogeneration plans. This confirmed other studies in the literature that there is currently a renewed interest in cogeneration, one that will be substantially enhanced should utility rates and practices with regard to in-plant cogeneration come under regulatory review, say in the context of PURPA hearings. Finally, on the issue of cogeneration and reduced oil consumption, I should point out to Mr. Hoch that in general cogeneration facilities which will tend to displace oil-fired electric generating capacity is likely to save a good deal of oil, not increase oil usage as suggested.

Q. Do you have any final comments on Mr. Hoch's testimony?

A. Yes, just one. In his opening statement on p. 1 of his testimony, Mr. Hoch states that "the ESRG base forecast growth sale approximates that projected for the PECO low-range forecast." This presumably means that the ESRG forecast is an approximate lower limit to what PECO now feels might come to pass. With this in mind I suggest that one might profitably examine Figure 1.1 in Exhibit __(JS-4). For the reader's convenience I have reproduced this figure at the end of this testimony. The figure shows the results of PECO forecasts since 1973. Given the historic record, I find the lower edge of the current PECO forecast range a relatively comfortable position.

FIGURE 1.1
TRENDS IN PECO FORECASTS



CROSS EXAMINATION

BY MR. HALL:

Q Dr. Stutz, am I correct that your graduate and undergraduate degrees including your Doctorate are in the field of mathematics?

A. That's correct.

Q And I believe you refer to various teaching positions which you have held, is that not correct?

A. That is correct.

Q And are those also principally in the field of mathematics?

A. It varies with the institution. At MIT I was an instructor in the Mathematics Department. At the State University at Albany, I joined in the Mathematics Department, but after the first year, I joined an interdisciplinary program within the University where I taught a range of courses including mathematics and economics.

At Fordham, my format was in the Math Department. Part of my teaching duties were with a joint directorship with an undergraduate program in mathematics and economics. That is as precise a description as I can give you.

Q In those joint programs, were you the Mathematics Department's representative?

A. In the Fordham program, I was. In the interdisciplinary program where I taught for four years, we didn't divide interdisciplinary lines. I taught a range of courses, some of which were strictly mathematics, others of which were straight economics and one was research methods, which was a combined course.

Q Am I correct that you have no degrees in economics or in the field of engineering?

A That is correct.

Q During the study which you prepared and which has been submitted as your testimony and accompanying exhibits in this proceeding, did you visit the Philadelphia Electric Company's Service territory for the purpose of collecting any data for a use in that study?

A No, I did not.

Q Have you conducted any surveys of PECO customers in connection with the preparation of your testimony for this proceeding?

A No, I have not.

Q Doctor, you have employed an econometric model in your forecasts, have you not?

A No, I have not.

Q You have not. Could you describe to me what you have employed?

A Yes. It varies, depending upon the area I am forecasting in - - excuse me. I have a slight cold. In the residential and commercial area, I have employed an end use analysis, sometimes called an engineering end use model. In the commercial area, it is somewhat less disaggregated than the residential area. But both would be accurately described in that way.

In the industrial area, I have employed a rather complicated trending analysis, including an adjustment for the presence of co-generation. Econometric models make their appearance in my forecast principally through the determination of input data items such as terminal saturations in the residential area.

Q Doctor, referring to page 6 of your testimony, you there indicate that for the forecast years 1988, there is, in your opinion, different households forecasted in the ESRG forecast which is your forecast and the PECO forecast. Is that not correct?

A Yes.

Q Can you quantify for me, Doctor, the extent of the difference in the two forecasts' kilowatt hour total for that year being 1988, as the result of this difference in households?

A Difference in households alone?

Q Yes.

A Without any other effects?

Q Without any other effects.

A. No, I cannot do that.

Q. What other effects must you consider in making such an analysis?

A. I would have to consider the residential energy saturations and the residential end use consumptions.

Q. Would you then be giving me merely a difference between your residential forecast and the company's residential forecast?

A. That would be what I could supply you with right now.

Q. How would you go about calculating the difference as a result of solely the household portion of the item?

A. I am not sure I could do that, exactly, for this reason. We don't forecast exactly the same mix of end uses in the same way. If I could match end use by end use exactly, the assumptions in the two forecasts, then I could get just the effect of households. But my understanding is that that wouldn't be exactly possible because of this difference in methodology.

Q. Doctor, would you refer me to the source of your statement that the company's 1988 household projection is 1.475 million households as you state on line 6 of page 6?

A. I would have to look for the exact values.

Q. Before we do that, Doctor, am I correct that as indicated in the first paragraph on page 6, it is your view that this difference in the measurements of households between your number which is 1.426 million and that of the company which is 1.475 million is a major cause of the differences in the resulting forecasts of your forecast and that of the company?

A It is, according to my analysis, of some importance, because of the effect it has on the penetration of space heating. The assumptions on penetration, as I explained, are somewhat similar but because of the difference in population growth, you get more space heating customers in absolute numbers in the company forecast and therefore, higher consumption for that reason.

I can't point to a number for the company. What I was looking for was the numbers from which this was assembled. As you know, we include the single point metered customers in with our residential and we have tried to provide the comparable figure when referring to the company.

Q So in essence, this 1.475 would be an extrapolation of a company number as well as a number that you would have developed on your own?

A No. My recollection, and that was what I was trying to find, that the 1.475 was developed from a number of company references.

Q Doctor, could I refer you to page 178 of

Exhibit WCH-1?

MR. SEGAL: What page was that?

MR. HALL: Page 178.

THE WITNESS: Yes.

BY MR. HALL:

Q Looking at the 1988 line - -

A Yes.

Q - - on that page, would you read to me the average dwelling units which is stated there?

A 2. - - excuse me. 1431.1.

Q And would you read for me the number that is stated right below that for the year 1993?

A 1475.4.

Q Would you agree with me, Doctor, that the 1475 matches that which is stated in your testimony?

A They are numerically the same. I don't believe there's any connection between the two, however.

Q What do you use depicted in the average dwelling unit shown on this page for 1988, Doctor?

A Again, this would require going back and looking for some notes which is what I was doing before. I believe these numbers are to correspond with the customers that are served under the residential rates. So I believe to get from the 1431, you would have to add in those other apartments. Now, what I was looking before was at my demographics folder to see if I have those calculations with me so I can say exactly what we did do.

MR. BURGRAFF: We can supply the calculation.

MR. HALL: Would you do that, Doctor? Supply a calculation which indicates the basis of the 1.475 million households figure which you show for 1988? Now, Doctor, in addition, if you would look at page 176 - - does Your Honor have this exhibit, by the way?

THE ADMINISTRATIVE LAW JUDGE: Not before me.

(The document was handed to the Administrative Law Judge)

BY MR. HALL:

Q Doctor, if you will note on that page, in the upper half of that page, there is listed December 31, 1988, total dwelling units all. Which column is the total of the indicated column for R, RM, both individually metered and single point metered under GS, PD and HT?

A Yes.

Q That number is what, Doctor?

A 1436600.

Q And would you agree with me that that is well below 1.475 and is indeed for the same period and includes single point metered apartments?

A Yes, it is below it.

Q Assuming that what you have just agreed to is so, Doctor, would you agree with me that the difference in household projections is not a major cause or even a cause of any significant difference between the forecasts?

A. As I have said to you, I am not at this moment able to reproduce that number which I have on page 6, and so until I can look at that number, I don't think I can answer that question.

When you are asking me to make an assumption that I would revise that number in the way that you have suggested from those two pages and all I can say to you is that until I have a chance to provide you with an explanation as to how I got that number, I am not in a position to say what I would do upon revising.

Q. I take it, Doctor, you have studied Exhibit WCH-1 and are familiar with its contents?

A. That is correct.

Q. And I take it you are also familiar with Philadelphia Electric Company's rate schedules, are you not?

A. Yes, I certainly am.

Q. You are familiar with the fact that there are single point metered customers in GS, PD and HT, is that not correct?

A. That is correct.

Q. The other rates with the company has under which residential customers would be served are rates R, RH and RM, is that not correct?

A. That's certainly true.

Q. So if you are adding dwelling units which reflect the dwelling units on all of these rates, would you not in fact have a number which is consistent or which should be the same as the number which you state on page 6?

A. I certainly follow your logic. All I can say is that until I can review how I got that number, I am not in a position to go any further with you, other than to agree with what you have said.

Q. Now, another difference in the two residential forecasts, and perhaps before we go further, we should clarify one thing. Doctor, your forecast is made up of four parts, is it not? The first is a residential forecast for residential customers?

A. Right.

Q. The second is a commercial forecast for commercial customers?

A. Yes.

Q. The third is an industrial forecast for industrial customers and the fourth is a transposition of the results of the prior three which are stated in annual kilowatt hour terms to a peak KW basis for use in generating plant planning, is that not correct?

A Well, it is certainly true that those are the four parts. Its use, I think, is Dr. Shakow's testimony.

Q I would agree with that, Dr. Stutz. I didn't wish to mislead you in any way.

A Okay. Right.

Q Now, another difference in your residential forecast versus that of the company which you identify at page 6 is in the percentage breakdown of new residential construction between single family and multi-family units, is that not correct?

A Yes.

Q Could you describe for me what a single family unit is, Doctor?

A Yes. I don't know exactly what you are looking for. Single family unit is basically a single detached house. A multi-family unit would be an apartment.

Q And I take it that is the way you have used them in your study?

A Now that I have to check, there's a townhouse category that I have to check on the disposition of. For example, I believe that we put the townhouses in with the single families, but I just again, this doesn't seem to be my day for having the right notes with me. I do not.

Q I'm sorry. Doctor, I missed your statement.

A I am saying I am not able to find the note on which I noted how we dealt with the townhouses.

Q Don't you know if they would be single family or multi-family?

A I can check and get back to you.

Q Can you make a rough guess at this point?

A I believe they would be in the single family, but I would have to check it to be sure.

Q Now, would you agree with me, Dr. Stutz, that on average, multi-family units, residential units consume less electricity than single family units?

A Yes.

Q Now, referring you to page 67 of Exhibit JS-4, would you agree with me that in 1990, the ESRG forecast, your forecast, assumes that 28.2 percent of all residential dwelling units in Philadelphia Electric Company's system are multi-family units?

A I will have to check the percentage. You said 1990?

Q Yes, I did.

A Yes. That's roughly correct.

Q Now, referring you to page 176 of Exhibit WCH-1, would you further agree with me that in the PECO residential forecast at 1988, there are approximately 28 percent of the total residential dwelling units which are multi-family units?

A. 176?

Q. Yes.

A. Yes. Approximately.

Q. Would you then agree, Doctor, that the difference between or the split between multi-family and single family units in the two forecasts is, again, not a significant cause of difference between the two forecasts?

A. I would agree with that.

Q. Doctor, does your forecast include either in its kilowatt hour numbers or its customer numbers the customers of Philadelphia Electric Company system on Conewingo Power Company?

A. I believe it does.

Q. Do you believe it does?

A. I believe it does. Wait a minute. Let me think about that for a second. All right. I will let that stand.

Q. You believe it does?

A. I believe it does.

Q. Do you care to check on that and get back to us?

A. Okay. I will.

Q. Doctor, referring to Exhibit JS-4, page 66 - -

A Yes.

Q - - I note that you have there failed to compute the growth rate for the PECO population growth forecast for the period 1975 to 1985. Do you have that growth rate available to you at this time?

A No, I don't.

Q Now, do you recall that it was your testimony at page 6 that the PECO population growth rate as compared to the forecasts of the census in the Pennsylvania Office of State Planning and Development, which you have used, the latter source - -

A Yes.

Q - - are relatively high, is that correct?

A I believe so, yes.

Q So it is your testimony that the PECO growth rate is substantially higher than that which you have used? Is that correct?

A Yes. I think I show that in the growth rates to 2,000 column.

Q I would like to focus on the growth rate of 1985, Doctor, since that is closer to the rates which we are setting in this proceeding. Would you turn to page 178 of Exhibit WCH-1?

Now, Doctor, shown on that page, in the first column, is the Philadelphia Electric Company's population

Q Well, Doctor, would you agree with me that on Page 6, you mentioned three principal factors as being the difference between your residential forecast and that other company, that is factors being a difference in the forecast of households?

A A difference in the split between multi-family and single family households and the company's higher population growth projection. That is correct.

Q And according to the figures we have been discussing, at least as they go out to 1975, none of those are so?

A I disagree. I think we have just demonstrated that the forecast is higher for 1985. I think with regard to the others, there is some difference. It is not a great deal of difference, but I don't think even the figures we were discussing earlier which I have to check on, suggest it a very big difference.

However, I do note that in that one area where we come to a conclusion, it was higher, as I said.

Q Three per cent higher?

A Yes, for 1985.

Q Doctor, in your treatment of electric space heating, how have you forecast the conversion of existing electric customers who are existing non-heating customers who chose to become electric heating customers in the future.

A I believe that is included in the forecast.

Q Could you refer me to the location?

A Yes, that is what I am doing now. Yes, if you would take a look on Page 35 of JS-4, you will see the term penetration defined and above that in the paragraph, it states that the concept of penetration is used in developing a number of households and above that is penetration includes both new and switches. In fact, that was how it was done.

Q How have you represented in your analysis the potentiality for existing electric customers with fossil fuel systems switching to electric? What data input have you used and how have you forecast that?

A The basic information that one has is the relative prices of the fuels and the equipment and those were taken into account in developing the estimate of penetration used in the forecast.

Q What did you apply the estimate of penetration to?

A Number of new customers as penetration is defined.

Q Well, if we are talking about applying estimates of penetration to new customers, how does that account for existing customers who will switch?

A Through the percentage?

Q In other words, you have merely arbitrarily increased it as applied to new customers.

A You don't arbitrarily do anything. You do increase the percentage of your estimate of those who will switch.

Q How did you make your estimate of those who would switch?

A As I explained it, it is a matter of form used based on such factors as the cost of equipment and the cost of fuels and any increases over time and previous experience in the service territory.

Q And would you cite for me the source of the previous sources in the previous territory that was available to you?

A I believe all the information that we gathered from looking at WCH-1 and discussions that we had.

Q And would such data be available or separately considered in the company's forecast, Dr. Stutz, at Page 168?

MR. BURGRAFF: 168 of what?

MR. HALL: Exhibit WCH-1.

THE WITNESS: Yes, that is correct. That information is considered separately at that point or presented separately at that point.

BY MR. HALL:

Q Dr. Stutz, at the back of your testimony in Exhibit JS-1, you list a number of proceedings in which you have testified on load forecast matters, is that not correct?

A Yes, it is.

Q And a number of those are in Pennsylvania, is that not correct?

A I believe only one is in Pennsylvania. The previous case involving Philadelphia Electric.

Q I see a Duquesne Light Company forthcoming.

A That is forthcoming. It has not taken place.

Q And am I correct that other members of your firm have testified at other cases in Pennsylvania, however?

A That is correct. One member of our firm has testified in a Penn Power case.

Q And I take it that was on behalf of the Office of Consumer Advocate?

A That is correct.

Q Now I notice that you have testified in a number of Detroit Edison cases, is that not correct?

A Two.

Q And who did you represent in those cases, Doctor?

A Michigan Citizens Lobby.

Q And who are Michigan Citizens Lobby?

A They are a private intervenor group in the State of Michigan.

Q Are they a consumer group?

A I don't know that I would particularly characterize them that way. They are a Citizen Intervenor Group.

Q Do they generally oppose or support utility increases?

A My only dealings with those particular people was in those cases.

Q Doctor, have you recently represented the Sierra Club in New York proceedings?

A The Sierra Club is a coalition of 26 other groups, yes.

Q Doctor, in these cases that we have been speaking about and which you have presented load forecasts, have your results generally fallen below that of the utility forecasting group?

A Generally, yes.

Q Doctor, how have you applied your estimates of thermal integrity?

A Is the question how the estimates of thermal integrity are used?

The modern estimates of thermal integrity are used to decrease the amount of energy used to heat a home or to air-condition it as appropriate.

Q Is it a flat percentage that begins in the first year or a percentage that goes over time?

A Let me just check. Is the question about space heating?

Q Yes.

A Excuse me. I have to check the computer program for a second. The reason I have to check this is, we changed it recently and I want to answer it exactly as we have done it.

Q Fine, Doctor.

A I believe it is a flat percentage, but I would really have to check that in more detail.

Q You believe that is a flat percentage. Does that mean you apply the same flat percentage from the beginning of the year one through the entire period?

A As I said, I would like to check that but I believe that is my interpretation.

Q Doctor, referring you to Page 78 of Exhibit JS-4, you there state that the fraction of existing ESH, and that means electric space heat, does it not, Doctor?

A Yes.

Q The fraction of existing electric space heat for customers with heat pumps was set using company provided data at 55 per cent for single family unit?

A Yes.

Q Now am I correct that that means that in your analysis you accepted that the company's current residential heating customers were 55 per cent heat pumped?

A 55 per cent for single family. Zero for multifamily.

Q Can you explain the source of that company information that led you to that conclusion?

A Again, I believe it is developed from material in WCH-1, but since we still have a question as to the disposition of townhouses, perhaps I should give you that in writing along with the information of how we treated townhouses.

Q It would suit my purposes for you to develop it, Doctor, now, if you can. It would facilitate matters.

A I am afraid I can't develop that number for you right here, but I will explain it later on in writing.

Q Thank you, Doctor. To eliminate your suspense, I will note that the Company's figures do show a different set of figures.

A You may note that in preparing this forecast, I do receive assistance from other members of the firm. I do supervise it. I can't bring all the work papers with me. That is the reason for this check and having to go back to the office to look for the derivations.

Q Doctor, in projecting further population in the company's service territory, did you begin first off, Doctor, you have developed, have you not, as the factor to indicate the growth population, the projection made by the Pennsylvania Office of State Planning and Development, is that correct?

A Yes.

Q And how have you applied that factor? Have you applied that to the company's indicated population in the service territory at 1975 as shown on Page 78 of Exhibit WCH-1?

A I believe so, sir.

Q Are you certain of that, Doctor?

A I am just checking the notes on population development in front of me. Yes, I believe that is how it was done, took their growth rate and applied it to a company number for the past year.

Q Looking at Page 66 and 67 of your JS-4, can you calculate for me the population of your high cast for 1988?

A I would have to do it by interpolation between 1985 and 1990.

Q I am sorry, Dr. Stutz, it was 1990 that we would like. It is a calculation of Dr. Stutz total population using his assumption of the population growth and starting point for the year 1990.

A You want it in high case?

Q In the high case, yes.

A Yes, I have a figure. I get 3,847,950 approximately.

Q And what would the population be using your low ratio?

A. Essentially the same, 3,847,250.

Q Now, for your high forecast, Dr. Stutz, as indicated on page 66 of your Exhibit JS-4, you have employed a value of 2.55 people per household, have you not?

A. That's correct.

Q And where have you obtained that value?

A. I believe it says on the page. From census projections.

Q And these are census projections by the Department of Commerce?

A. Yes.

Q Doctor, I have an excerpt from the Bureau of Census document from which this material was taken that I would like to hand to you. I will show it to your counsel first. I only have one copy of it at this time. I don't intend to introduce it.

MR. BURGRAFF: Could we have a second so he can read it?

MR. HALL: Sure.

(Pause)

BY MR. HALL:

Q Now, Doctor, you will note at the bottom of the page there is listed three numbers of which the 2.55, and you have employed that as one, is that not correct?

A. Yes.

Q And this is under household series B?

A. Yes.

Q Now, the number that is the 2.55, that is bracketed by two other numbers, is it not?

A. That is correct.

Q What are they?

A. The figure above base is 2.69 and below base is 2.45.

Q Do you agree that that means that the 2.5 as employed by this Bureau of Census study is the middle range or the base forecast?

A. I can't tell that from this document.

Q What else would you need to tell that?

A. I would have to go back and review what the definitions of the three series were and what assumptions they made.

Q Doesn't it normally indicate to you, Doctor, when you have three separate projections and one is in the middle in terms of numerical quantity,that that is the base case forecast?

A. I usually look and see how the scenarios are defined, which is what I would do in this case before answering that question.

Q Would you agree with me, Doctor, that you have used that number as part of your high case and not your base case?

A That is correct. That's how I use that number.

Q Now, Doctor, you have forecasted, have you not, two cases, a high case and a low case, is that not correct?

A Yes.

Q That is both for your commercial and your industrial forecast, is that not correct?

A No. I don't believe that is correct.

Q Where is it incorrect?

A The portion of the projection that is sensitive to high and low is the number of persons per household and I believe that's only relevant in the residential forecast.

Q You have only forecast a high and a low case in the residential forecast, is that your testimony?

A I thought the question was concerning whether or not the population forecasts were reflected in those three energy forecasts and what I was trying to convey to you was they weren't connected to two of them.

Q I understand that, Doctor. The question was whether you have made a high and low and what is termed a base forecast in both the residential, the commercial and the industrial sectors of the company's load?

A That's certainly correct.

Q Is it not true that your base case is simply the mathematical average of your high and low case forecasts?

A. That is true.

Q In other words, you have not independently, for that particular case, chosen the variables to determine the kilowatt hours that are there shown?

A. No. That represents the middle. As determined by numerical average.

Q Now, Doctor, on page 8 of your prepared statement, you discuss another area of difference between your forecast and that of the company, which is in the forecast which is made for refrigerator and freezer consumption, is that correct?

A. That is correct.

Q And you there state various saturation percentages, is that not correct?

A. That is correct.

Q Now, the saturation percentages which you have stated for your case includes single point metered apartments, is that not correct?

A. That is correct.

Q And the saturation percentages that you have stated for the company's case do not, is that not correct?

A. That is correct.

Q Would you agree with me, Doctor, that if single point metered apartments were included in the saturation percentages stated for the company's case, those percentages would be decreased?

A. No. I'm not sure why they would.

Q. Would you agree with me, Doctor - - and I believe you state that somewhere in here - - that apartment residents generally have less refrigerators and less freezers than do single family house owners?

A. That's correct. But I believe I state saturations separately for single and multiple family dwellings.

Q. And in which of those categories do you place single point metered apartments?

A. I put them in multi-family dwellings.

Q. Now, on page 10, Doctor, you refer to dehumidifiers and your disagreement with the company over the projected load for dehumidifiers, is that not correct?

A. Here I am simply - - allow me to step back for a second. As you know, we do not prepare a separate forecast for the dehumidifier as an end use. It is included in our miscellaneous category. The company does prepare a separate forecast for the dehumidifier. I was commenting on the reasons that the company gave for an increase in saturation for that appliance.

Q. Would you agree with me, Doctor, that dehumidifiers constitute approximately three-quarters of the percent of the 1980 residential load?

A. In the company forecast?

Q. Yes.

A. I will accept your calculation.

Q. Doctor, how do you forecast miscellaneous load? First off, would you define in your answer what that is, so the Judge and the parties know?

A. Certainly. We attempt to forecast all end uses which we feel are A, a significant portion of the load and B, we have sufficient data to prepare a separate forecast for. I'm speaking of residential end uses, here. Miscellaneous is a residual category. It is seen to contain all other usage, that is residential usage for which we cannot account directly and explicitly in our forecast. It is developed in the base year as a residual and it is forecasted future years high and low by applying fixed percentage growth.

Q. In other words, you don't seek to disaggregate the usage of the different types of end uses which would be in miscellaneous load?

A. No.

Q. No. But rather you forecast that on an aggregate basis, is that not correct?

A. That is correct.

Q. How do you determine the percentage which you apply to that total usage?

A. We develop a range of percentages reflected in a high and low case, by reviewing the wide range of appliances which are presently contained in miscellaneous categories and which those studies which we are conversant with and felt will be in a miscellaneous category in the future. And then we attempt to seek, through simple calculations, what growth would be like, assuming different things about peoples' use of those appliances.

This allows us to develop a percentage and it is that percentage we apply.

Q Do you read various journals which are published in this field and from those, decide what sort of a percentage to use, that is the basic process?

A. Journals. Yes. Studies developed by others, such as the California Energy Commission, Lawrence-Berkeley Laboratories, but generally yes, we review the literature and then make an informed judgment.

Q Dr. Stutz, on page 11 of your statement, you speak of supplementary heating units as being equivalent to baseboard electric units, and as such, are more expensive sources of heat than either the gas or oil units. I'm somewhat confused as to what you are referring to there. Are you referring to gas and oil portable heating units?

A. No.

Q What are those units?

A What are the supplemental units about which I am speaking of there? Portable electric?

Q The supplementary gas and oil heaters you are speaking of here.

A No. That's not what I'm speaking of. Perhaps I can clarify what is being said. What I'm saying is the supplemental heating units with which I am familiar are simple resistance units. In that case, they are similar in physical operation to simple resistance units which would be connected to the baseboard and as such, it is my understanding that they are more expensive than other types of fixed heating units such as gas heating units and electric heating units, so the comparison is a two step.

From the portable resistance type to the fixed resistance type. From the fixed resistance type to the other types of heating with which it is compared.

Q What does that have to do with forecasting the usage in the future of supplemental heating units?

A I think I have explained that at page 11.

Q Would you consider supplemental heating units to be in competition with fixed whole house gas or oil heating systems?

A No. By their very nature, they are supplemental. Let me just explain what I have said. Perhaps it is really not very clear. All I said was this. That it appears that a person using such a supplemental unit in a bedroom or bathroom would be doing so because they wanted to keep their normal fuel house heating system at a low setting. Such a person, I would assume, was an energy conscious person or at least that is the assumption that made sense to me.

Then I go on to explain how their behavior ought to be reflected in the forecast. Behavior here with respect to the use of that supplemental unit.

Q You don't forecast those units independently in your forecast?

A No. As in the previous page, this is a discussion of what I have found in the company forecast, basically my reaction to it.

Q Now, your discussion of the company's assumptions at line 9 refers to a one thousand hours per year use of these supplementary heating units.

A Yes.

Q Could you refer me to the spot in the company's presentation where you see that particular value?

A Okay. I appear to have made an error. I was referring to the statement on page 127 of WCH-1 where I see 600 hours rather than the thousand I have indicated.

Q And the thousand is the average wattage, I take it, is that correct, Doctor?

A. Yes. It is a typographical error.

Q Now, Doctor, does your forecast assume at any time the appearance of the electric car?

A. I would have to repeat there what I said before, since I do not disaggregate miscellaneous, I can't say to you that it does or does not adhere. What I would say is that I have given the electric car load very low probability of appearance. In other words, I have to look and see what are going to be the significant determinants of that aggregate and/I have given it a very low rate as you might gather from what I have said on page 11 and 12.

Q Referring to schedule A., Doctor, which is in Exhibit JS-2 of your testimony.

A. Yes.

Q Have you included in your average usage for residential customers from the column under ESRG, single point meter departments?

A. Yes.

Q Have you included those same apartments in your PECO column?

A. Yes. Let me - - I'm sorry. That's it.

Q Would you care to consider further?

A. No. I would - - I was simply going to say that the column under kilowatt hours per year which developed PECO forecast material, my assumption, I have not explicitly developed those figures so as to include single point metered apartments. They are developed from figures that are provided in the company forecast. The company forecast doesn't have that in those figures. So I guess the answer would be that they are not reflected in the PECO as far as I am aware.

Q So it would be your understanding that the single point metered apartments are reflected in your column but not in the company's column?

A. Yes.

Q Would you agree, Doctor, that the reflection of single point metered apartments in your column, but not the company's column, would reduce your column, therefore, making the difference greater?

A. It would certainly have some effect in that direction.

Q Referring to answer 22 in your responses to the company's interrogatories to you, Doctor, do you have that before you?

A. Yes.

Q And noting the miscellaneous column in the high case and in the low case, I note - - well, first off, Doctor, the column 1977, that column reflects, does it not, a calculation of historic data, does it not?

A. Yes.

Q And would you not expect, Doctor, that all of the figures in that column relative to each of the different types of appliances which are shown down there, each of those figures would be the same?

A. No.

Q You would not?

A. I think I let you go away with the historic figure too quickly. Base year data is developed as a best estimate of consumption by a given appliance in the base year so you have a base year usage for refrigerators, for example. But I don't have any direct knowledge of the base year usage of refrigerators as I might, for instance, from the information supplied by the company concerning peak.

There are some appliances, particularly televisions, where there is an effect that I take into account which makes it impossible for me to zero in on a single base year usage.

Q And would that effect require that in your low case, you have a different base year usage than you have in your high case?

A. It does and I do.

Q Okay. That's correct. You do. Why do you?

A. Oh, it's the effect of the use of the second television. It has been observed that if a family owns a second television, the second television is used less than the first television. But there's no real agreement as to how much less that might be. There is some notion of what the range might be. Now, these are use per unit. However, they take into account these different kinds of units.

So if you have a different assumption, even if you have the same saturation - - how can I say this clearly for you? That assumption will affect your unit usage figure for the base year. It is quite possible you could have differences in other appliances, too, depending on how uncertain you are concerning the data. We don't show that except for the television.

(Transcript continues on next page)

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Q Yes, I do notice that, and why is that?

A It has to do with the methodology. It has to do with our willingness to accept certain data as a starting point for our calculation. In the television we feel there is an apparent element of uncertainty.

Q And that element is the estimate to which people use the second television?

A That is correct.

Q But you are not certain with respect to the extent they use air-conditioning?

A There is always an uncertain amount of uncertainty in a forecast. When you make a forecast, you have to put in those things you feel most important and the way you feel it most appropriate.

Q Now the effect of what you have done in the effect of the uncertainty in the second television is to state a higher value of the kilowatt hours used for average customer during 1977 and in subsequent years shown on this page for television in your high case, which is offset precisely by a lower usage in your miscellaneous category?

A That is correct.

Q But then in your low case, you have a lower television usage for customer and a higher miscellaneous usage for customer.

A That is correct.

Q I take it miscellaneous is what is left over at the bottom? Is that correct?

A That is certainly true in 1977.

Q Now, Doctor, in your high case, you reflect a growth in miscellaneous usage from 332 up to 497 between 1977 and 1997, but in your low case, you remain entirely constant from a 454 level in 1977 to a 454 level in 1997.

Now I take it that has nothing to do with the uncertainty to television?

A That is correct.

Q What does it have to do with?

A It has to do with my best estimate of growth in miscellaneous under those years. Miscellaneous is determined as a residual, as I said much earlier, in the first year and then grows as a fixed percentage.

In the low case, it does not grow at all. It is zero percentage and the top case, it has grown.

Q Doctor, at Page 83 of your Exhibit JS-4, you indicate that in your high cast miscellaneous use per customer during the forecast period has been increased 100 per cent, is that not correct?

A Yes. That is a typo, however.

Q But I take it you agree that is not, in fact, what has happened?

A No. I can tell you exactly what has happened.

What page are you on?

Q I am on Page 82 which is a one-sentence typo.

A Okay. Let me just tell you, I have the data that was actually fed into the computer with me and I can check that.

Q Can't we check the 332 value for 1977 versus the 497 value for 1997 and determine that there has not been a 100 per cent increase in the high case?

A Yes, you can determine that that way. If you like, I can determine exactly what was put in.

Q In terms of the percentage increase?

A Yes.

Q Well, I can calculate that.

MR. HALL: Your Honor, I am at a changing of the guard here. Could we have a short break?

THE ADMINISTRATIVE LAW JUDGE: Yes.

(Whereupon, at 11:40 o'clock a.m., the hearing recessed until 11:55 o'clock a.m.)

THE ADMINISTRATIVE LAW JUDGE: Are we ready to proceed?

MR. HALL: Yes, Your Honor.

BY MR. HALL:

Q Dr. Stutz, moving now to your commercial forecast --

A Yes.

Q -- am I correct that the first step in the commercial forecast is to establish clerical floor space in the Philadelphia Electric Company's service territory by commercial customer type, shall we call it, for the year 1975?

A Yes.

Q And do you obtain that data by employing various general data applicable to the Statewide Pennsylvania? In other words, let's deal with it this way, Dr. Stutz. What data have you used to derive that?

A The data is derived from two factors, one of which is employees per square foot which is general data and the other is employment which is specific to the service territory.

Q Now by general data, you mean this is a national study?

A There are a variety of studies used.

Q And do they use the data which is drawn on a national plan?

A Yes.

Q And none of them are drawn specifically from studies in the Philadelphia Electric service territory?

A No.

Q And the second source that you have mentioned is employees in the Philadelphia Electric Company service territory, is that not correct?

A Yes.

Q I take it that is commercial employees?

A Yes.

Q And is that a document which is put out by the State government?

A That is County Business Patterns, I believe. It is from County Business Patterns. I am going to check it now.

Q Sure.

A Yes.

Q Doctor, will you be able to confirm that source of information?

A Yes, it is listed as reference nine, County Business Patterns data, 1979.

Q So what we are beginning with in the commercial model, is a calculation of the 1975 commercial floor space broken down by different types of commercial customer which is based on specific employee data from the Philadelphia Electric Company service territory?

A Yes.

Q And also data as to the number of commercial square feet per employee which is based on a national study unrelated to the service territory?

A That is correct.

Q Now from there I take it, Doctor, what that gives us is our base of checking commercial customers, is that not correct?

A Commercial square feet, yes.

Q Square feet, from there, Doctor, I take it we increase the commercial square feet, is that correct?

A That is correct.

Q Do we do that on the basis of projection as to the increase of commercial employees?

A That is correct.

Q And we use in that projection, I take it, the same national study with respect to the number of commercial employees per square foot?

A Square feet per employees, yes.

Q What is the source of that projection we use for the increase of commercial employees?

A It is a composite projection. It is a separate projection for employees per dollar of earnings and a projection of earnings.

Actually, the absolute size of the projection is irrelevant the way the model works. Only the ratio of those quantities are employed.

Q Is that data specific to Philadelphia Electric service territory or Statewide data?

A Statewide.

Q How do you move that down from the Statewide level to the Philadelphia Electric service territory?

A The same statewide data is employed for the service territory. The way in which it is connected with the service territory is through the base year estimate which has the service territory specific information embedded in it.

Q Is it a growth rate that is being projected?

A Yes.

Q Now having obtained your 1975 data and having obtained your data for an increase in commercial square feet, Doctor, you check this data against the utility's actual commercial usage, do you not?

A Yes.

Q And that is a one-year check, is it not, in 1977?

A Yes.

Q And what do you do in that check?

A We re-normalize.

Q What does re-normalize mean?

A We adjust the energy intensities in this particular case across the board. Perhaps I should explain to get from square footage to usage, you have to have numbers which give kilowatt hours per square foot. We have those separately for new buildings and existing buildings in various categories. Those numbers were in this case adjusted to bring us into line with the 1977 total.

Q I take it the ultimate adjustment is to your square footage numbers, is that correct?

A No. In this case the ultimate adjustment was on the intensity numbers because we were fairly happy with the square footage. It is a departure from our usual procedure. Normally we feel we are less confident about the square footage for a variety of reasons. This time we felt resonably confident about the base year square footage.

Q Why was that?

A Because we got good agreement from data we received from the company.

Q Now you have adjusted the energy intensity number. Now energy intensity number, am I correct, is in essence the number of kilowatt hours of which a square foot of particular commercial type would use during any one year, is that correct?

A That is correct.

Q How did you decide how to adjust those numbers?

A We have those numbers based on studies which were performed by Arthur D. Little. We have them by virtue of their incorporation in reports prepared by Brookhaven National Laboratories.

We felt having discussed the development of those numbers with Arthur D. Little in this particular case, that we believed that the relationships between the numbers were solid for our use here, but we were going to adjust their overall level so we were going to bring them all down by a fixed percentage.

Q So you applied a fixed percentage to all of them, just dropped in?

A Yes, we did.

Q How much was the fixed percentage?

A That I would have to dig up for you.

Q Would you do that please?

A I am sorry. I thought I brought the raw data with me, but I didn't, so I can provide you with the size of the adjustment, but I don't have it on me.

Q Fine. I would appreciate that.

A As I understand it, it would be a flat adjustment and it might differ depending whether you were in the high or low case, but you want to know the size of the adjustment from the original to the intensities that were used?

Q Yes, as a percentage factor.

A It will be stated as a decimal but you can convert it to a percentage as part of the output.

Q So, Doctor, what we have got now, then, is the picture of commercial square footage for existing customers which was drawn originally from 1975. We have a projection of employees on a Statewide basis, commercial employees, projection of growth in employees by category.

A Yes.

Q Now the next thing we need then is, as you have indicated, the intensity of use of the extent to which for a given commercial square foot one would find a certain amount of kilowatt hour use?

A Right.

Q Now I take it what is done in your forecast, forecasts forward the amount of square footage increasing it along with the growth rate of employees, there is a one to one relationship, is there not, Doctor?

A What is actually done is this. You develop the number of new square feet from the growth rate and that is brought in at the intensity appropriate to the new square feet.

Q And the intensities which are appropriate to existing square feet and new square feet are drawn from a study which is done by Arthur D. Little Company, is that not correct?

A Yes. The numbers are actually presented in a report published by Brookhaven Laboratories. They were developed by Arthur D. Little for use in that report, among other things.

Q Now, Doctor, as you recall, an associate of yours by the name of Mr. Rosen testified with respect to a similar energy forecast in Philadelphia Electric's last rate case, is that not correct?

A That is correct.

Q And if you recall, at that time, Dr. Stutz, your colleague, Mr. Rosen, employed in his commercial forecast at that time he was responsible for that forecast and analysis which I believe is identical to yours, is that not correct, or very similar?

A It is quite similar.

Q And Mr. Rosen at that time relied, did he not, upon an A.D. Little study for his study of intensity of usage, did he not?

A Yes, I believe he did.

Q And this was the same A. D. Little study that you and I are discussing with respect to your study?

A It is an updated version of what he relied on, yes.

Q If you recall, Dr. Stutz, was it not true that you initially submitted your testimony in this company's last electric rate proceeding based upon an initial version of that A. D. Little study, is that not correct?

A That is correct.

Q And during that prior case, the study changed and was amended and, therefore, the numbers were amended and your testimony had to be amended to reflect that, is that all not also true?

A That is correct.

Q One other question with respect to the prior case --

A Can I interrupt you for a second? I don't believe the amended had to do with the A.D. Little portion. I think it had to do with other features of the forecast.

Q I would disagree, but we do not argue about it now.

A Okay.

Q Is it not true, Dr. Stutz, that in fact at the time of that prior study, at the time of the prior rate case, this A. D. Little study that you relied on was not a public available document, is that not correct?

A Yes, that is true.

Q And you were requested to provide that study to the company but were unable to do so as it had not been approved or released by the Department of Energy at that time?

A That's correct.

Q Now with respect to the updated version -- first off, with respect to the original A. D. Little study, Dr. Stutz, would you agree with me that is still not a published document and you have still been unable to provide a copy of that even at this late date and despite its revisions for the company to review?

A Yes, A. D. Little has chosen to publish part of the data in a report I did provide to the PECO representatives, but they have not provided the data we were particularly interested in.

(Testimony continued on next page.)

Q Now, would you further agree, Dr. Stutz, that with respect to the new and updated A. D. Little study that you are relying upon, that new study has in addition, not been published. It is not publicly available?

A I think somehow in the - -

Q Could you answer my question?

A The answer is I relied upon the numbers in the published Brookhaven study, as I indicated in my testimony.

Q Well, is the study published or not?

A There is a document published by Brookhaven National Laboratory, which contains all the information with respect to energy entities upon which I have relied and that document has been furnished in this case.

Q And that document, I take it, merely takes figures from the A. D. Little study which has not been furnished in this case?

A That is correct.

Q What is the date of the Brookhaven study?

A January, 1978.

Q And could that Brookhaven study, Dr. Stutz, be the same Brookhaven study that you provided in the last case to this company?

A I believe it is an updated version.

Q Dr. Stutz, you were cross examined when, in the last case? I can refresh your recollection that it was May.

A. Why don't you do so. I don't have the exact date.

Q. May, 1978?

A. Yes. I don't believe we had this particular form of the study at that time. I could be wrong, but my recollection is that we provided you with a preliminary copy of the study that we have furnished you with in this case.

Q. I would take it you would have to agree that the revised A. D. Little study would not be reflected in that January, '78 Brookhaven study, is that not correct?

MR. BURGRAFF: May I interject? I think we have had some testimony from Dr. Stutz saying that he believes the '78 document was dated. We can check on that. You are referring to the report as if it is not dated.

MR. HALL: I take it Dr. Stutz has referred to a single report of January, 1978. I can go to the transcript here and demonstrate that we did, in fact, get such a report in the last case. Now, what I'm trying to demonstrate, and I believe that Dr. Stutz will agree, is that if this Brookhaven report is the January, '78 report, then in fact it does not include the revised A. D. Little study. Or any numbers therefrom. That's got to be true.

THE WITNESS: The problem with the A. D. Little numbers is not that they are - -

MR. HALL: I would like an answer to my question.

I have not asked the problem with the A. D. Little study.

MR. BURGRAFF: I think the witness should be allowed to answer the question in the way he sees fit. We have gone through this with company witnesses, when someone has tried to get a yes or no answer. At that point in time, the answer was what was worked out was you can answer yes or no, but you also have the latitude to explain. What's fair to the company witnesses is fair to everybody else's witnesses.

MR. HALL: I would certainly agree with that. But I did not hear a yes or no.

THE WITNESS: Could I hear the question again and I will try to give you a yes or no if I can.

BY MR. HALL:

Q The question is, Dr. Stutz, is it not true that this January, 1978 Brookhaven Laboratory's report which you have referred to does not contain the revised A. D. Little study which you have relied upon in this case? In this case meaning this electric rate proceeding?

A I think I have to state again that the numbers that I used in my forecast are the numbers that are reflected here. What will subsequently appear in the A. D. Little documentation which is supposed to be forthcoming shortly, I believe is the underlying calculations for the numbers that I have used. Now, I have spoken to Mr. Glesk at A. D. Little who is writing it. That is the impression he has given me. I can't answer any more fully until I see the documents myself.

MR. HALL: Your Honor, at this time, I would make a motion to strike the commercial portion of Mr. Stutz' testimony with regard to the commercial forecast of this A. D. Little document and the numbers which are in it. It is a very important part of Mr. Stutz' testimony. It is, in fact, the document which provides the energy usage or the kilowatt hour usage which he projects forward for this commercial forecast.

This is the most important piece of information in it. Now, in the last case, we requested of Dr. Stutz or in fact his associate at that time, Mr. Rosen, that this information be provided to us. At that time, it was indicated that this was draft information.

Mr. Rosen had access to it through his connection with Brookhaven Laboratories and it could not be provided to us. We have now come through two separate changes in that information. The study is apparently still not available, still can't be provided to us.

We cannot examine the study. We can't determine how Dr. Stutz is using the data from this study, whether he is using it correctly or incorrectly and I think the company is denied its ability to rebut and its ability to cross examine Dr. Stutz with respect to this particular forecast.

The most important single piece of information cannot be provided to the company and this is the second case in a row that that is true.

MR. BURGRAFF: I would like a word with the witness, if I could, before I respond.

(Counsel and the witness conferred)

THE ADMINISTRATIVE LAW JUDGE: We will have a three minute break.

(A brief recess was taken.)

THE ADMINISTRATIVE LAW JUDGE: Let's go back on the record.

MR. BURGRAFF: Yes. I think our comments would be essentially along these lines, Your Honor. Dr. Stutz has relied on the numbers as shown in the Brookhaven report. These numbers have all been provided to the company. His views of those numbers or why he has chosen to treat those numbers as he has has been the proper subject of discovery.

Clearly, Dr. Stutz has not misrepresented any of the numbers. If that's the allegation at all, then of course, that's just not the case. I don't see any problem with what has been presented, what has been relied on. Obviously, if the company chooses not to agree with the treatment of them, then that's entirely up to them.

I don't see what the point of it is, when the numbers, themselves, have not been misrepresented. And now we are talking about taking a report that is unknown and changing the numbers as a starting point in dealing with them, I think that's one thing. But that is not the case.

They have come from the Brookhaven report. We haven't done anything to them. I think it is entirely appropriate. The company obviously would disagree with Dr. Stutz' perhaps viewpoint, treatment, but as a starting point, I don't see any problem with them.

MR. HALL: Obviously, the company doesn't disagree with Dr. Stutz' use of the numbers because the company does not know how the numbers were derived. The company does not know how Arthur D. Little went about doing its analysis. We don't know the limitations which Arthur D. Little believes exist on these numbers or their usefulness.

We have not seen that report, which it is my understanding has been seen at least by some in Dr. Stutz' organization. We have not had access to Arthur D. Little to discuss with them. We can't even call and discuss them. We have tried that. There's no way we can adequately examine Dr. Stutz' use of these, merely because they have appeared in some other report published by some other agency.

They do appear on that report, as numbers, but other than for that, there's nothing else there, and that provides us very scant information with respect to an evaluation of this very important feature of one-third of the company's system as forecasted by Dr. Stutz.

MR. BURGRAFF: I'm sorry to interrupt. It is our view that the company can examine these numbers. I don't think the A. D. Little matter has really any relevance at all to the admissibility of the testimony. I think that the company's argument, more or less, goes to perhaps the weight or the way the numbers have been used.

But once again, I fail to see how they can't examine the use of the numbers. They had every opportunity to do that.

MR. HALL: Your Honor, we took every opportunity. We called Arthur D. Little. We called the Department of Energy. We asked Dr. Stutz and all of those sources told us we could not have that study and could not request it.

MR. BURGRAFF: I'm referring to the use of the numbers by Dr. Stutz.

MR. HALL: We have no way of knowing whether he has used the number right or wrong other than what he tells us. The purpose of cross examination or discovery is to check on what the witness tells us. We are denied the ability of cross examination and discovery and I believe due process of law as to this particular portion of Dr. Stutz' testimony.

My motion to strike is limited to the commercial portion of that testimony.

MR. BURGRAFF: Well, we have, I think pretty much covered the ground. I don't - - once again we don't think the motion is appropriate. Certainly to the admissibility of the evidence.

MR. BOCK: I would join in that, Your Honor. It is a question primarily of weight and not admissibility in this Administrative proceeding.

MR. HERSHEY: I would also point out, Your Honor, that in objections posed by intervening parties in this case or motions to strike, in several cases, the motions to strike were put off until the end of the case and in one case, where we were attempting to inquire into the background of I believe it was Mr. Mallard, we were not allowed to do that or in decisions that he had made which would have reflected on the testimony that he was bringing to this case, and I think the situation is very parallel here.

MR. HALL: I think the decision there was that the request was irrelevant which is certainly not the case with respect to this motion. It is totally different. I would note that the argument that this only goes to the weight is always the bromide that is advanced in these situations. How you can give weight to testimony that cannot be examined by cross examination or discovery escapes me entirely and such testimony should not be permitted into the record.

MR.HERSHEY: I think that was exactly the problem with Mr. Mallard's testimony as it related to his previous experience in New Jersey, and in this case, we were not allowed to inquire into what he had done in New Jersey.

MR. BURGRAFF: And also cross examination as to the use of the numbers is available in this case.

MS. BUSH: Mr. Mallard was allowed to rely on an audit of a Virginia Electric and Power Company project, of which we parties did not have the right to cross examine.

THE ADMINISTRATIVE LAW JUDGE: I think the only reference to that was in the Theodore Bary audit. I don't think there was any reference in that.

MS. BUSH: Excuse me.

MR. HALL: The audit was - -

MS. BUSH: Excuse me. I'm responding to the Judge. That referred to the Hope Creek Project maintenance and referred to the percentage figure he used as the appropriate percentage for rework and the audit he referred to done by Theodore Bary on another project.

MR. HALL: I would note that you were permitted to see the audit, to examine it and before you continued your cross examination. I would note also that there was an audit done by your own witness which was available to you from him had you asked.

MS. BUSH: It was a percentage figure. We had no way of investigating what it related to, what particular factual situation was referred to.

THE ADMINISTRATIVE LAW JUDGE: Before I rule on this motion, I want to review Mr. Stutz' testimony again. We will get an answer back to you as soon as possible.

MR. BURGRAFF: Thank you. I might note for the record, Your Honor, that Dr. Stutz is suggesting when you are reviewing his testimony, you also review a section of the Brookhaven report which in essence, explains how to use the data in question and we will furnish copies of that to you and to all parties of interest.

I believe the company already has it.

MR. HALL: I would note that the Brookhaven people, of course, are not the people that put the study together. That is not the study.

MR. BURGRAFF: That's where the numbers come from.

MR. BOCK: That's what the witness is relying upon.

BY MR. HALL:

Q Dr. Stutz, you were present during cross examination of Mr. Rosen in the last case, were you not?

A. Yes, I was.

Q And you and I recently just had a colloquy with respect to whether or not the Arthur D. Little numbers changed during the course of the last case, is that not correct?

A. Yes.

Q I'm going to ask you if you recall this following exchange between myself and Dr. Rosen from the last case with respect to that particular item.

A. Yes.

Q The question is"well, Dr. Rosen, do you have a copy of the study which you refer to page 25 of your prepared statement?" And that study was the A. D. Little study.

A. I am just looking at page 25, if you don't mind.

Q Excuse me?

A. I'm looking at page 25 of the last testimony, if you don't mind.

Q Okay. Fine. Mr. Rosen answered me by saying "A final copy of the MOPS report is not available. The data that I received to enable me to perform my study was received by colleagues of mine at the Brookhaven National Laboratories, who were working on the MOPS study. This data that went into the supplemental testimony, some of the numbers were changed from the earlier testimony and a few changes were made because we did receive final numbers from Arthur D. Little." Do you recall that exchange?

MR. BURGRAFF: Could I show this to the witness?

MR. HALL: Yes. Sure.

MR. BURGRAFF: Is that the extent of the quote?

MR.HALL: Just this. (Indicating)

(The document was handed to the witness)

THE WITNESS: Yes.

BY MR. HALL:

Q So with respect to this A. D. Little study which I believe is reference eight in your exhibit JS-4, is that not correct?

A Yes.

Q And it is listed as forthcoming there, is that not correct?

A Yes.

Q Now, with respect to this A. D. Little study, when you filed your initial testimony in the last case, you used a set of A. D. Little numbers, is that not correct?

A Yes.

Q And those numbers changed during the course of the case, is that not correct?

A That is apparently correct.

Q And during that entire period the A. D. Little study was at that time forthcoming, was it not?

A. That is correct.

Q. Now, we are in a second case some year and a half later and there is an A. D. Little study still forthcoming, is that not correct?

A. Yes. As I indicated, one portion has appeared and we supplied that. The other portion is still forthcoming.

Q. The portion that is still forthcoming is the one which contains the numbers and the analysis which you have employed in your commercial forecast, is that not correct?

A. No. As I said before, the numbers I have employed are in the Brookhaven report. I have employed them as described in my testimony. The document we are discussing is a background document that supplies information concerning the derivation of those numbers, information which I have received through contacts directly with A. D. Little and Brookhaven National Laboratories.

Q. The document we are discussing, is it not, Dr. Stutz, is the document from which the Brookhaven Laboratories presumably got those figures?

A. No. Since it doesn't exist yet, it isn't the document they got it from.

Q. Well, perhaps you could enlighten me, Dr. Stutz. You have used what you term the A. D. Little data from the Northeast United States.

A That's correct.

Q Am I correct in assuming from that that the A. D. Little data must be divided by Northeast, Northwest, Southeast, Southwest? Is that correct?

A Yes.

Q What is the A. D. Little data from the northeast?

A Specific data you are talking about is energy intensity data. It is data on energy consumption per square foot for different types of buildings in the commercial sector. That's the data.

Q How many commercial buildings did they use in the northeast?

A Five. Five different types.

Q Five different types, five different buildings?

A Yes. I should point out that one of the operations we haven't discussed, which is described on page 85 of JS-4 is an adjustment.

Q Dr. Stutz, I don't have a question pending at the moment.

A Okay.

Q I don't mean to cut you off, but I do have another question that I want to ask.

Q Okay.. I just realized I had gotten myself in a situation where I didn't mention something, so it had been omitted from the discussion. It might be misleading if it weren't entered.

Q Perhaps we will get back to it. Dr. Stutz, the northeast United States as used in the A. D. Little study, is that Philadelphia or is that some other area?

A It certainly includes Philadelphia.

Q You made an adjustment to apply that data to Philadelphia?

A Yes.

Q And these are stated in your testimony, aren't they?

A Yes. On page 85.

Q Those are weather adjustments, I take it?

A That is correct.

MR. BURGRAFF: For clarity of the record, page 85 of what?

THE WITNESS: JS-4.

MR. BURGRAFF: Thank you.

BY MR. HALL:

Q Now, you indicate a .5 percent commercial growth rate on page 4 of your testimony, do you not?

A Yes.

Q Does /That growth rate or does the commercial class upon which it is based include, in addition to what one might normally think of as commercial, i.e. stores, commercial office buildings, and others such as pipelines, transportation utilities and Government accounts or such as the Navy Yard and the Mint? The Government Mint?

A Yes.

Q Would you refer to Table 1.3 at page 5 of your Exhibit JS-4, Dr. Stutz? There's a column there headed Other Sales. I have calculated from the change in numbers in that column - - well, first off, what is other sales?

A Sales not included in the residential, commercial and industrial categories.

Q And what generally would that be?

A Oh, street lighting, other miscellaneous things of that sort.

Q I have calculated the increase which you show on an average annual basis from 1978 through 1987, and then separately from 1988 to 2000. Now, during the first ten year period, I get an average million kilowatt hour increase of 42. During the second ten year period, I get an average million kilowatt hour increase of 114. Can you explain for me why the vast difference between those average annual increases?

A I would have to go back and look as to how we developed those. My recollection is we were developing them from company data. But I will have to look to be sure. According to my notes and also my recollection, we developed this from company data. I would have to go back and look at my data development to tell you why there is that break. We include in that, as you will note on page 93, the number of categories, losses, et cetera. I would have to go back and review my notes to tell you exactly how I obtained those numbers.

Q Doctor, you don't mean to suggest, do you, in your prior response, that in fact these numbers are taken directly from the company's exhibits, do you?

A As I explained, they include a number of categories of use by the company. Line losses, et cetera. They are a developed figure. I can certainly indicate in writing how they were developed.

Q Okay. That would be fine. Thank you.

A Let me just indicate preliminarily that they are developed by a linear interpolation, so I will give you the three values that we interpolate to in the years they correspond to. How those were developed.

(Transcript continues on next page)

Q Now, Doctor, I would like to move now to your industrial information account. Doctor, am I correct that the only significant difference between your industrial forecast and that of the company is in your treatment of cogeneration?

A That is correct.

Q And in your treatment of cogeneration, do you rely for your data upon a study which was done by the Thermo Electron Corporation for the Federal Energy Corporation in June, 1976?

A That is one of many things I relied upon, yes.

Q What additional things did you rely upon?

A I relied upon other studies done by the industry such as a study by Resource Planning Associates. I relied upon information supplied by the company concerning studies of cogeneration done by the Electrical Association of Pennsylvania.

I relied upon a study which my company completed for the New York State Energy Office concerning cogeneration.

I relied upon various articles in journals, energy-related publications which I subscribed to concerning cogeneration.

Q Now in making your adjustment for cogeneration, Doctor, how have you developed the number of megawatt hours which you have assumed that the industrial customers can cogenerate?

A That is developed as a fraction of the total processed energy requirement by two digit SIC. Do you want me to go into the development of that fraction?

Q Yes, where did you get that fraction from?

A If you take a look at Page 92, you will see a description of how I did it.

MR. BURGRAFF: Is that JS-4 again?

THE WITNESS: I am sorry. I keep referring to the exhibit. I think that the testimony describes it completely.

BY MR. HALL:

Q And I take it Table 818 provides the percentages which you have assumed could be employed in cogeneration by different industries by type of industry, by SIC code, is that correct?

A 819 contains the fractions, yes.

Q What is 818?

A It is energy intensity.

Q Oh, I see. With regard to No. 24-SIC-24, I see a fraction of .343. That is for the past year in the high cast and the low cast. What type of industry is that?

A I have to get out my SIC list. I am sorry, I don't have a memory for those kinds of things. I have to look it up before you can supply me with it.

Q Would you agree that we don't have any lumber manufacturing locations in Philadelphia? Let's try 33. Now, in the high cast, you show approximately 15 per cent and in the low cast, approximately 27 per cent?

A Yes.

Q Where do you get the 27 per cent?

A As I said, it is described there. It is the largest of two numbers. If you want, I will see if I have the data which tells you which of the two numbers I used.

As you can see, the procedure is very, very simple though. I don't think I have that list, but I will look for it.

Q Well, Doctor, referring to Page 92, you say that for the low case, we assume historic state levels, is that correct?

A That is correct.

Q That is historic State of Pennsylvania?

A Yes.

Q And this is from census data?

A Yes.

Q Do you know how old that census data is?

A I would have to go back and check the data.

Q Could you provide that to us?

A The age of the data on which the base year fraction was determined?

Q Yes.

A Yes.

Q Now you say reachieved by 1985. I take it that means we are not achieving the level you have assumed at this time?

A Yes, that is correct.

Q And I take it another input into your load cast has been the Thermo Electron study?

A That is one of the inputs.

Q In other words, you either assume this census data or the Thermo Electron data depending on which is lower?

A No, that is another item. Potential generation levels by the Pennsylvania Electrical Association, there are three candidates. We examined those three and chose among them in the way described.

Q You picked whichever of the three is higher?

A That is correct. It is designed to be a high-low split. In the high case, which was least amount of cogeneration assumed, you will notice we leave everything constant and the low case, which has the largest amount. We picked the larger of the three.

Q In other words, for the high case, you assumed the same cogeneration level as the company, is that correct?

A Yes, base year levels are maintained as indicated in Table 819.

Q Okay. Doctor, are you aware of the historic growth of cogeneration in the Philadelphia Electric service territory in recent years?

A I am aware that we received information that it had not grown.

Q Has it, in fact, been negative growth?

A I don't recall that. I recall something to the effect of it being flat for ten years.

Q Doctor, are you familiar with the Department of Energy's current position on cogeneration with oil plants?

A In general, yes.

Q What is that position?

A I believe the Department of Energy is interested in decreasing oil consumption as much as possible so it does not look to that kind of cogeneration very favorably.

Q Doctor, would you agree with me that cogeneration through coal plants would not be a feasible alternative in the Philadelphia area?

A That is my impression.

MR. HALL: That is all the questions I have, Your Honor.

MR. BOCK: No questions.

THE ADMINISTRATIVE LAW JUDGE: Let's break for lunch. We will come back at 1:55.

(Whereupon at 12:55 p.m. a recess was taken and the hearing reconvened at 2:05 p.m. the same day.)

THE ADMINISTRATIVE LAW JUDGE: Okay. Back on the record. Mr. Burgraff, do you have any redirect?

MR. BURGRAFF: Yes, we do, Your Honor.

JOHN K. STUTZ, the witness on the stand at time of recess, resumed the stand and testified further as follows:

REDIRECT EXAMINATION

BY MR. BURGRAFF:

Q Dr. Stutz, we have had some cross examination earlier today concerning a group of numbers that are present in the Brookhaven report. What are those numbers?

A The numbers referred to are numbers which give the energy consumption per square foot for specific building types and end uses.

Q Okay. And what do you do in your analysis with those numbers?

A The numbers, the enregy consumption per square foot by building type is multiplied by our estimate of square footage to get an estimate of consumption for a given year.

Q And do you use those numbers strictly as they are found in the Brookhaven report?

A No. There are a number of adjustments made for the numbers as they are found in the Brookhaven report. They're initially represented in terms of BTU's per square foot. We convert to kilowatt hours. We then adjust for temperature, heating degree days and cooling degree days and then we make an initial scaling based upon information we have about base year consumption.

It is only the final intensities, kilowatt hours per square foot that are used as input data for our commercial model.

Q And do you test the resulting KWH per square foot figures which you use as input data?

A Yes, we do. We don't simply take the output of that procedure and put it into our model. We do endeavor to check the numbers that we obtained in this fashion against other model output, against other studies. In particular, we use output that we have used received from Trinsis model. It is a computer model. We also check it against output that we have received from other studies.

For instance, Dubel, Mindel and Bloom, a planning firm in New York has put out a book recently in which they show energy consumption per square foot. We check it against such a source. We have also endeavored to check it against any information we can obtain concerning company estimates for the same quantities. We did receive some information from the company in response to one of our interrogatories concerning the electric heating consumption for new buildings.

We checked it against the numbers that we were putting in to our computer based on the procedures I have described and found them to be in the same range. So the general procedure, then, is to check it against any other model output, any other studies we have available and certainly any information we can obtain from the company.

Q Were you asked to derive your energy intensity by the company?

A No. We were not asked specifically if we could provide any independent derivation of the numbers nor were we asked to go over our reasons for choosing those numbers. We were asked for general background information and input to the Brookhaven model of which those are the numbers. That was we supplied the Brookhaven report which I have referred to and that was as far as the discussion went.

MR. BURGRAFF: That's all we have at this time, Your Honor.

THE ADMINISTRATIVE LAW JUDGE: Mr. Hall?

MR. HALL: Just a second.

(Brief pause)

RECROSS EXAMINATION

BY MR. HALL:

Q Dr. Stutz?

A Yes.

Q With regard to the Trinsis model?

A Yes.

Q That's a model that you now indicate that you have used to check the A. D. Little data, is that correct?

A What I indicated I do is precisely this. I have information about energy usage in the commercial sector from a variety of sources. One source is the output of this model. I do, in the course of selecting the data to be put into the commercial sector, check it against various sources. That is one of them.

Q Is that a model that you have developed?

A No, it is not.

Q Who developed that?

A That, I believe, was originally developed by the California Energy Commission.

Q How long ago was that?

A I would say about a year and a half ago.

Q Do you cite that anywhere in your testimony?

A No, I do not.

Q Do you explain this checking procedure anywhere in your testimony?

A I believe I do. I don't indicate it in the section dealing specifically with the electric intensities.

The general procedure, however, is mentioned, oh, actually it is related. Closely related and in the same subsections, on page 86, we discuss the use of cross checking for our estimates on saturation.

Q Where is this?

A. This is on page 86, first paragraph.

MR. BURGRAFF: Once again, that is Exhibit JS-4?

THE WITNESS: This is Exhibit JS-4. We talk about the commercial saturations in the first sentence and we talk about referring to a variety of other works in particular, here, to check on an assumption to make concerning the saturation models.

So I said it does not refer directly to the intensities, but in fact is a similar procedure as used in all of our inputs.

BY MR. HALL:

Q It refers only to saturation?

A. That's what I said.

Q Would you agree that's considerably different than intensity?

A. Actually, they're very closely related in terms of the way the model operates.

Q In terms of the intensities being the actual kilowatt hours being used by the square footage and saturation being the number of customers or the number of square feet which possess a certain electric consuming appliance, is that not correct?

A. It is certainly correct that they are different.

Q. Those are the different concepts that are involved?

A. That is certainly correct.

Q. You don't mean the Dubel, Mindel and Bloom material, either, do you?

A. No, I don't.

Q. Dr. Stutz, what was involved in the A. D. Little report? These weren't figures that they picked off the wall somewhere. They had to come from some study.

A. No. Certainly it was not. What is involved is this. They developed the set of prototype structures for which they assumed thermal integrity results, results on degree of penetration, degree of their transfer between the interior and exterior of the building, lighting levels for different mix of tasks.

In other words, all of the parameters that one would need to describe the building from an engineering standpoint. Once they have had these parameters, they then check the computed building loads against actual building loads which they had from places like the Jack Faucet studies or the FEA. Once that was completed, they had calibrated by weather and by section of the country, building loads. They then used these as a basis for estimating commercial consumption by building category. That information is then transferred to BNL on the form you see.

Q I take it there were a number of judgments made in the compilation of this data and I believe you stated a number of assumptions made in the compilation of this data?

A. That is certainly true.

Q Now, could you provide me with the source of company data that you used to cross check these energy intensities?

A. Certainly. The only item I was able to cross check directly is from the response to the Consumer Advocate question number 23 in which the company provides information with respect to kilowatt hour per square foot usage in 1984. This is the answer to 23-B-2.

Q Now, have you ever seen a copy of a written document, Dr. Stutz, entitled the ADL Report or the draft report?

A. I have seen written output memoranda through Brookhaven which I was told originated with ADL.

Q But you, yourself, have never seen a full copy of that report?

A. I don't think a full copy of the report in the sense you mean the term exists. It is in bits and pieces.

Q Or have ever existed?

A. As I say, bits and pieces exist in the form of informal communications.

Q But a full and final copy of the report or even a full and final draft of the report has never ever existed?

A. I have not seen such a thing.

MR. HALL: That is all that I have, Your Honor.

THE ADMINISTRATIVE LAW JUDGE: Thank you. You are excused.

THE WITNESS: Thank you.

(Transcript continues on next page)

BEFORE THE

PENNSYLVANIA PUBLIC UTILITY COMMISSION

*** *** ***

PENNSYLVANIA PUBLIC UTILITY COMMISSION

VS.

PHILADELPHIA ELECTRIC COMPANY

R.I.D. R-79060865

*** *** ***

Direct Testimony of

Don M. Shakow

as to

Generation Planning and Reliability

November 13, 1979

E S R G

Q. Please state your name and your current position.
A. My name is Don M. Shakow. I am currently a Senior Economist for Energy Systems Research Group, Inc. of Boston, Massachusetts, and I am employed by Clark University, Worcester, Massachusetts, as an Assistant Professor of Economics.
Q. Would you please describe your educational background?
A. I graduated from the Massachusetts Institute of Technology with a Bachelor of Science degree in Humanities and Sciences. I hold a Ph.D. degree in Economics from the University of California, Berkeley.
Q. Please describe your relevant work experience.
A. Over the past five years I have done considerable research and have acted often in a consultive capacity in the areas of electric utility systems planning, energy usage and demand forecasting.

In 1975, as Senior Economist for Mathematical Sciences Northwest of Bellevue, Washington, I directed a loads and resources forecasting study for the City of Seattle entitled, "Energy 1990." This study involved the construction of an econometrically estimated load forecasting model coupled to a financial funds-flow model which determined future utility rates endogeneously. The study and a subsequent two months of oral testimony which I presented before the Seattle City Council was cited repeatedly as a decisive factor in a decision by this body regarding the municipal system's supply expansion program. The study was also cited and described at some length in a recent report by the House Committee on Government Operations entitled Nuclear Power Costs (Report No. 95-1090).

In 1976 I directed a regional all-energy demand study for the Northwest Energy Policy Project. This study involved the development of a large scale econometrically estimated model with major end-use components describing future regional demands for electricity, natural gas, petroleum products, and coal in the Pacific Northwest.

I have been called upon frequently to evaluate load forecasts and to provide estimates of the probable magnitude and direction of forecast error. Over the past three years I have undertaken evaluations for utility systems located in the Northeast, the Midwest, California, and the Pacific Northwest.

I have also conducted simulations of a number of forecasting models assessing the impact of conservation oriented scenarios on future loads.

Within the past year I have twice acted as expert witness and have submitted written testimony on the issue of load forecasting methodology for the Federal Energy Regulatory Commission.

I have also maintained an active interest in other aspects of electric utility system planning, most notably generation expansion and reliability analysis. In conjunction with Energy Systems Research Group, I have developed a prototype model which assesses the social cost associated with alternative reserve margins given a minimal cost, generation expansion scenario. This model has already been applied in rate proceedings. I have also prepared a study for the City of Seattle which compares the costs of underestimating versus the costs of overestimating loads, assuming alternative lead-times associated with the perception of forecasting error.

Q. What is the subject of your testimony today?

A. My testimony concerns an independent analysis of optimal generation expansion plans and reliability criteria for the Philadelphia Electric Company system, and an assessment of the current Company planning strategy and its probable impact on customer costs of electricity.

Q. Please summarize your major conclusions.

A. The Philadelphia Electric Company (PECO) has developed its construction program based on methodologies which exhibit palpable biases. In particular, outcomes are biased toward:

1. An excessive proportion of baseload relative to cycling and peaking facilities;
2. Within the baseload category, a preponderant emphasis on nuclear plants;
3. For the later years within its present planning horizon, excessive levels of reserve capacity.

These biases emerge when comparison is made between the PECO construction program and an optimal generation expansion program for PECO based on the criterion that the overall social cost of generation be minimized.

As a consequence of these planning biases:

1. Electric rates are likely to be excessive if the PECO construction program is implemented, relative to rates under an optimal program.
2. In particular, ratepayers are being asked to support the construction costs associated with Limerick units 1 and 2, neither of which would be built in a cost minimizing construction program. Under a range of cautious assumptions

on current and forecasted economic and technical parameters, I find that the Limerick units, totaling 2100 Mw, are not cost effective. Even assuming PECO's own forecast of demand growth rates, I find that by 1992 only three small 300 Mw coal-fired units totaling 900 Mw are required in the place of the two Limerick units, in addition to the 600 Mw of coal plants that PECO tentatively plans for 1992.

3. The reserve margins of 27-28% being advocated by the Company for the late 1980's are excessive, and are, moreover, not required to ensure reliable service. To achieve a partial blackout reliability of less than one day in ten years by 1987, reserve margins of 14-22% will likely be adequate.

Q. What is the basis for these conclusions?

A. These conclusions emerge on the basis of a model developed principally by myself in conjunction with staff from Energy Systems Research Group and Clark University.

Q. Could you please describe this model.

A. Exhibit A describes the structure, methodology, and assumptions of the model in detail. The ESRG Electrical Systems Generation Expansion Model (ESGEM) attempts to locate an optimal generation mix for an electrical supply system over a defined planning horizon. An annual social cost, representing the least cost plant expansion sequence, is calculated for a series of minimum reserve margins. The model selects that sequence where the overall expected levelized cost of generation is minimized under specified load conditions.

The calculation of total social costs as a function of reserve, once plants have been selected, is performed by the dispatch, reliability, and production cost segments of the model. These consider all facilities currently in operation, plants under construction, "generic" supply options ranging from nuclear to combined cycle facilities, energy imports via existing interconnections, and alternatives for controlled, mandatory, and/or voluntary load curtailment. The model allows for present maintainance practices, the possibility of random forced outages, and the possibility of random variations in demand. In essence, the optimal sequence reflects a correct balancing among capital costs, fuels costs, curtailment costs, and purchased power costs. The model is, of course, similar in some respects to generation planning models used by many utilities. Unfortunately, I cannot compare it in detail to the generation planning model actually used by PECO and the PJM Power Pool to determine the PECO construction program, since the Company refused to provide me with a description of this model through discovery requests.

It should also be noted that for the purposes of this testimony, the model was run only for target reserves of 6, 14, 22, and 30 percent. The optimal levels referred to below are, therefore, only approximations to the actual optima. Some computer output from sample runs can be seen in Exhibit C.

Q. Is PECO's current generation expansion plan economically rational given its reliability criteria?

A. No, it is not. I have calculated the expected social cost* of generation for the years 1981, 1987, and 1992 under the present

*See definition under Table I

PECO expansion program and have compared them to costs implied by our own optimizations. Independently of the Company, I have selected two sets of economic assumptions regarding fuel inflation rates, interest rates, power plant costs, etc., which I believe bracket the plausible range that these variables will have for the next 15 years. I have labeled these two sets of assumptions the ESRG LOW and the ESRG HIGH scenarios, which stand, respectively, for the low and high extremes of the range of the ESRG inflation and cost assumptions.

Even the ESRG LOW set of assumptions involves higher fuel and power plant capital costs than the PECO assumptions, and are based on an inflation rate of 7.5% for the post-1981 period. The ESRG HIGH set of assumptions consists, then, of still higher prices, and is based on an inflation rate of 9% for the post-1981 period. All economic and technical parameters will be described in much greater detail below. In comparison to the ESRG assumptions, the Company's inflation forecast seems quite unrealistic, since they predict that the rate of inflation will drop suddenly to only 5% after 1981, for the remainder of the planning horizon.

When the ESRG model is run with either set of more realistic economic assumptions, I find that the PECO plant construction program is far from economically optimal, as can be seen in Table I. In all runs the full capital costs of all plants are included. In order to derive a single quantity as a basis for comparison, we have extrapolated costs for each year from 1981 to 1992 to get the total cost to the PECO customers of each scenario in 1979 dollars for the entire twelve-year period. The results are very clear and simple.

TABLE I

COMPARISON OF TOTAL SOCIAL COST†
UNDER ALTERNATIVE FORECAST ASSUMPTIONS AND SUPPLY EXPANSION PLANS

Forecast Assumption: Demand	Forecast Assumption: Cost	Plant Construction Plan	Year	Real 1979 Cost (10^6 $)	Mixed Current Dollars†† (10^6 $)
PECO	PECO	PECO	1981	$ 739.7	$ 862.8
			1987	940.3	1,740.3
			1992	914.0	2,485.0
			Total*	10,515.8	19,674.1
ESRG**	ESRG-LOW	PECO	1981	669.6	817.7
			1987	1,077.6	2,395.4
			1992	831.1	3,043.3
			Total*	10,881.0	24,842.6
PECO	PECO	ESRG	1981	665.4	776.1
			1987	756.0	1,399.3
			1992	807.6	2,196.5
			Total*	8,883.9	16,603.4
ESRG	ESRG-LOW	ESRG	1981	595.1	726.7
			1987	577.7	1,284.0
			1992	542.9	1.988.2
			Total*	6906.3	15,218.0

† Defined as total production and curtailment costs plus capital cost of new plants (net of return and income taxes).

†† Based on yearly cost stream, unadjusted for inflation.

* Interpolated cumulative totals, 1981-1992.

** As presented in the testimony of John K. Stutz in this proceeding.

With the PECO plant construction program, using PECO's cost assumptions, the social costs (as defined in Table I) to customers could be about $10.5 billion 1979 dollars, even without considering income taxes and profits. (See row #1 of Table I.) In contrast, we see from row #4 that in the ESRG optimal construction program which excludes Limerick, the social costs to PECO customers would be only $6.9 billion 1979 dollars, even though the ESRG capital and fuel prices levels exceed Company forecasts, as we shall see in detail later in this testimony. In addition, from Row #3 we see that even with PECO's own demand forecast and cost assumptions, the ESRG construction program is considerably less expensive ($8.9 billion 1979 dollars) than that of PECO. Thus, the remarkable conclusion that emerges is that the ESRG construction program of only building small 300 Mw coal units after Salem #2 is cheaper for PECO customers under both ESRG cost and demand assumptions as well as under PECO cost and demand assumptions, as long as full capital costs for Limerick are included in the analysis.

Q. Is it not prudent to ensure against the possible incidence of unanticipated massive electrical supply shortfalls by the construction of what the Company proposes as sufficient generation capability?

A. The selection of a generation mix and an associated level of revenues can be likened to the purchase of an insurance policy. The rational consumer optimizes by balancing the cost of insurance in the form of premiums to the risks of casualty loss. Our calculations show that the economic risks in the form of social costs of curtailment associated with insufficient generation are relatively insubstantial as compared to the massive fixed obligations incurred as a consequence of overexpansion. PECO is, in effect, vastly overinsuring the ratepaying public through its capacity expansion program. This is illustrated in Table II which shows the fuel, O & M, curtailment, and incremental capital costs for a sample scenario. This table shows that the dominating factors in the aggregation of total social cost are capital and fuel costs, respectively. Costs associated with curtailment reflecting the risks of under capacity are relatively minor, and in fact are probably overestimated, as will be discussed below.

Q. How sensitive are model outcomes with respect to blackout costs?

A. The generation mix which is optimal at a given reserve margin will be unaffected by changes in blackout costs because curtailment options are not included as supply options for generation planning in Module #1. Moreover, my computer analysis shows that the optimal reserve margin for PECO will be relatively insensitive to this parameter. This is shown in Table III where the total social cost of generation is calculated assuming a blackout cost of $5.00/Kwh and $2.50/Kwh, respectively. For each of the two test years, the optimal reserve margin remains approximately the same despite the decrease in the blackout cost parameter.

Q. How were the per Kwh costs of blackouts estimated?

A. I undertook a thorough review of recent studies in which the social costs of energy unserved was estimated. The results of these studies range from $1.23 Kwh (Telson, 1975) and $1.27 (1985 $) (Kaufman, 1975), to $1.00/Kwh (SRI,1977; EPRI, 1978). However, very recent studies indicate that the costs of catastrophic blackouts exceed these estimates by a factor of as much as 2 or 3 (e.g., Corwin, 1978). For

TABLE II

A SAMPLE BREAKDOWN OF COSTS*
BASED ON ESRG LOAD AND PLANT COST ASSUMPTIONS

Cost Factor	1981	1987	1992
	(Costs in millions of levelized 1979 dollars)		
Fuel	314	277	263
Variable O & M	46	46	42
Carry Charges	69	81	73
Incremental Capital	-	61	37
Imports	143	95	120
Curtailment	4	3	4
Total	576	563	539

Source: ESRG Model

* Based on reserve margin of 14%.

TABLE III

SENSITIVITY OF MODEL RESULTS TO BLACKOUT COSTS
(SOCIAL COSTS* IN MILLIONS OF 1979 DOLLARS)

Reserve Margin	Blackout Cost	Years 1981	1987
6%	High	622.2	571.6
	Low	(603.2)	(563.0)
14%	High	576.4	563.2
	Low	(574.6)	(561.7)
22%	High	576.9	555.7
	Low	(576.4)	(555.6)
30%	High	587.0	575.0
	Low	(587.0)	(574.6)

* Estimates are based on ESRG load forecast and ESRG-LOW plant cost forecast.

this reason, we have chosen the highly conservative value of $5.00/Kwh in our base case. It should be noted that the incidence of catastrophic blackouts is extremely rare and is most often caused by inadequacies in transmission and distribution rather than generation plant.

Q. Apart from the issue of outage costs and reliability, aren't high reserve margins justified as a means of displacing high cost oil facilities with lower cost coal and nuclear plants?

A. This is a question over which there exists a great deal of confusion even among active professionals. Basically, it is incorrect to view the issue of oil displacement savings within a reliability context. This means that changing the reserve margin to improve reliability for an optimal set of generating plants, will generally not affect the economics and thus the desirability of building new plants for oil substitution purposes. These two goals are, in general, quite independent. The persistence of opinion to the contrary within the utility industry has led to much of this confusion.

Given a specific load configuration for some year in the future, results from the ESRG model indicate that there are no conceivable circumstances where it is economical to employ a baseload plant only for the purpose of achieving higher reserve margins. Instead, there exists an optimal configuration of baseload plants that will be employed at any target level of reliability. Higher reliabilitity target levels lead, in fact, to the introduction of increased numbers of peaking rather than baseload facilities. These results, of course, are quite logical since only the amount of baseload should determine the economic tradeoffs of baseload fuel switching.

Thus, more concretely, our model suggests that under most of the load and cost assumptions considered here, baseload demand is optimally served through the 1980's by the combination of the nearly completed Salem #2 facility and the introduction of several medium-sized coal burning facilities. At higher levels of reserve, the retirements of older oil-fired facilities are postponed and in later years some additional oil-fired combustion turbines are introduced.

These results (summarized in Table 4) show that the question of oil displacement is, indeed, independent of the issue of optimal reserve margins. It is correct that given rapidly rising oil prices (as well as national security consideration), baseload oil-fired plants should not be employed. This is demonstrated by the ESRG base case in 1990 for a 6% reserve margin, where large-size oil-fired facilities such as Eddystone units 3 & 4 show capacity factors of 4.8% and 6.9%, respectively, while coal-fired facilities -- e.g., Eddystone units 1 & 2, and the two new generic coal units are all baseloaded.

Thus, the imposition of higher reserve requirements in no way alters the optimal baseload configuration. It merely affects the retirement dates for oil-fired units. In fact, at 30% reserve, a host of older oil-fired units are re-introduced into the optimal supply configuration, whereas at lower reserve margins they would have been retired. The optimal reserve margin is thus determined on the basis of a tradeoff between the costs of curtailment on the one hand, and the capital costs and carrying charges of old oil units and new peaking plants on the other.

TABLE IV

INCLUSION OF SELECTED PLANTS IN THE 1990 OPTIMAL PLANT MIX*
AS A FUNCTION OF RESERVE MARGIN

("YES" indicates that the plant enters the optimal mix at the specified reserve; "NO" indicates that the plant is excluded from that mix.)

	Plant	Rated Capacity (MW)	RESERVE MARGIN 6%	14%	22%	30%
PEAKERS	Cromby 2	183	NO	NO	NO	YES
	Salem 3	16	NO	NO	YES	YES
	Richmond 91	51	NO	YES	YES	YES
BASELOAD	Eddystone 1	381	YES	YES	YES	YES
	Eddystone 2	311	YES	YES	YES	YES
	Limerick 1	1055	NO	NO	NO	NO
	Limerick 2	1055	NO	NO	NO	NO
	Generic Coal	300	YES	YES	YES	YES
	Generic Nuclear	1200	NO	NO	NO	NO

* Based on ESRG load Forecast and ESRG-LOW plant cost Forecast.

Q. Please comment on responses that are available to PECO to alleviate situations of supply-demand imbalance, other than generation expansion.

A. A result demonstrated by our model is that optimal reliability levels are determined by a comparison between the costs of curtailment and the costs of facilities likely to be brought into service on peak. In analyzing curtailment costs, it is essential to distinguish between major loss-of-load events and episodes of shortfall which do not result in widespread blackouts. The model, for example, disaggregates eight distinct curtailment regimes other than blackouts (noted in exhibit A) ranging from emergency imports to voltage reductions. A majority of these involve some limited curtailment of service and/or a reduction in the quality of service.

While these options are decidedly inferior to that of continuous high quality service, their occasional use need not be uncritically avoided. In fact, the ultimate judgment concerning such "soft-curtailment alternatives depends heavily on the costs imputed to these options. There is reason to believe that these costs fall considerably short of costs associated with massive blackouts. Costs of emergency power, for example, range about 10% above the operating costs of peaking plants. Controlled service loads for residential hot water heaters and interruptable contracts impose costs of a similar order of magnitude, insofar as the costs of transferring energy from on-peak to off-peak periods are minor.

In our model we have assumed that all curtailment options short of blackouts exhibit costs ranging from \$.10 to \$.20 per Kwh, as compared to \$5.00/Kwh for blackouts. As a consequence, any increase in the availability of such "soft" curtailment options results in a significant reduction in the overall costs of curtailment relative to blackouts, and hence, a reduction in the cost minimizing reserve margin. In Table V, for example, we show that an increase in the availability of emergency imports by 1000 Mw results in a significant reduction in outage costs and hence in the optimal reserve margin. At a 6% reserve margin, for example, the total social cost of the curtailment options only in 1987 (discounted to 1979 dollars) equals $27.7 million for the normal import situation as compared to $.53 million in 1990 in the presence of additional import availability. (All results assume ESRG-LOW cost escalation assumptions.) A similar result holds for increased availability of curtailment options other than emergency imports, but short of partial and rotating blackouts.

Q. In general, are there additional means of lowering reserve requirements aside from increasing the availability of curtailment options?

A. One promising approach is expansion in the range of centrally dispatched power pools. A study undertaken for the California Energy Resources Conservation and Development Commission showed that under full coordination of all California utilities within the framework of a power pooling arrangement and subject to the loss-of-load probability (LOLP) criterion of one day in ten years the necessary reserve margin dropped to 15%, as compared to target margins presently as high as 30.4% in absence of a power pool (Kahn, 1977).

PECO is a member of the PJM pool and thus benefits from enhanced system reliability at lower reserve margins as a result of this relationship. The possibility of additional benefits over present arrangements has not been explored in this study.

TABLE V

COMPARISON OF OUTAGE AND SOCIAL COSTS*
USING NORMAL AND HIGH IMPORT ASSUMPTIONS
(Millions of 1979 dollars)

Reserve Margin:	6%		14%		22%	
Year:	1987	1990	1987	1990	1987	1990
Import Assumption:	Normal	High	Normal	High	Normal	High
Outage Cost:	17.2	.4	3.0	.01	.8	-
Total Social Cost:	571.6	540.7	563.2	550.8	555.7	555.9

* Based on ESRG load Forecast and ESRG-LOW plant cost Forecast.

Q. Please summarize your position regarding the necessity of PECO's capacity expansion program from the standpoint of system reliability.

A. PECO's expansion program envisages expansion almost entirely in terms of baseload capacity. My results show that additional baseload capacity is not essential to ensure reliability. For all scenarios explored by the Model, baseload units are employed at capacity factors which are virtually unchanged under LOLP's ranging from zero to 50.8 days in ten years. These results obtained even for scenarios defined entirely on the basis of PECO planning assumptions.

The baseload mix indicated by the model at low target levels of reliability did not alter as reliability targets were increased.

I conclude that PECO's construction program will have no positive impact on reliability. Any possible justifications for this program must be evaluated solely on the basis of generation cost.

Q. Does the PECO capacity expansion program represent a Least Cost supply option?

A. No. In my opinion, based on the ESRG Forecast, the Least Cost plant configuration over the 1980's would warrant the introduction of two 300 Mw coal units, the retention of Salem unit #2, and the cancellation of Limerick units #'s 1 and 2. Under an LOLP constraint of .2 days in ten years this would imply no retirement among facilities presently in operation. Less stringent reliability (e.g., 6-8 days in ten years) would imply retirement of a limited number of existing peaking facilities. (If PECO's own forecast of demand growth had been assumed, an additional 900 Mw of baseload coal would be required, as we shall see.)

Q. How sensitive are these results to the underlying assumptions of the model?

A. The general tenor of these conclusions obtain for scenarios reflecting a wide range of assumptions. However, two exceptions to this assertion should be noted.

By ESRG "Base Case," we mean henceforth that PECO load growth occurs at a rate determined by the ESRG load forecasting model and that plant cost assumptions are derived from the ESRG LOW cost case.

Additional assumptions necessary for the application of the ESRG Base Case are as follows:

1. Load is assumed to grow at a constant rate with no change in the shape of the original (1978) PECO load curve.
2. Assignments of capacity are made on the basis of discrete plant units for periods of no less than one year.

For this Base Case, the optimal plant mix calculated by the model implies only two new facilities: two 300 Mw coal plants. Table VI summarizes outcomes under varying load growth and cost assumptions.

Load growth assumptions affect primarily the total capacity of coal units brought on line. Major qualitative differences in model outcomes lie in the cost assumptions. Where PECO cost-escalation rates are assumed and capital is valued only at the incremental (future) cost for plant construction, the model indicates the introduction of Limerick units #'s 1 and 2. This we shall term the PECO Planning Case. Otherwise, Limerick units are never introduced.

TABLE VI

OPTIMAL 1992 BASELOAD PLANT CONFIGURATION UNDER ALTERNATIVE ASSUMPTIONS

Case #	Load Growth	Plant Cost	Capital Cost	Optimal New Capacity	Optimal Reserve Margin (Approximate Ran
1	PECO	PECO	Full	2400 Mw,Coal*	14 - 22%
2†	PECO	PECO	Incremental	Limerick #1 Limerick #2 600 Mw, Coal	30%
3	PECO	ESRG-HIGH	Full	1500 Mw, Coal	14 - 22%
4	ESRG	ESRG-LOW	Full	600 Mw, Coal	14 - 22%
5	PECO	ESRG-LOW	Full	1500 Mw, Coal	14 - 22%
6	PECO	ESRG-LOW	Incremental	1500 Mw, Coal	14 - 22%
7††	ESRG	ESRG-LOW	Incremental	600 Mw, Coal	14 - 22%
8	ESRG	PECO	Incremental	Limerick #1 Limerick #2	30%

Source: ESRG Model

* All coal units listed in this column are 300 Mw units.

† PECO Planning Case

†† Base Case

Q. Does this suggest that the economic justification for the entire Limerick project hinges on the merits of using the incremental cost assumption?

A. No. Again, the model only outputs the Limerick facilities when it is assumed - both that incremental rather than total costs are the appropriate measure and that PECO's cost escalation assumptions are valid. In addition, all ESRG scenarios assume that a realistic capacity factor for new nuclear plants is .6, in contrast to the PECO assumption of .7.

Q. Could you comment further on the use of incremental versus total cost in assessing the cost-competitiveness of the Limerick units?

A. First of all, the use of incremental rather than full costs implies among other things that the assignment or cancellation of a plant under construction would not result in any credits applied to construction costs already expended. In the case of capacity assignments this is clearly untrue. The assignee would undoubtedly compensate PECO for part of or more likely all costs of construction. In addition, cancellations would imply book losses which could be applied against expenditures in the form of tax credits. Thus, for plants under construction, the application of full rather than incremental cost is a more realistic, more informative assumption in that it reflects the total cost of those plants to PECO customers.

The PECO plant cost assumptions are described in detail later. Here, I would like to stress that one of the primary differences with ESRG assumptions is in future nuclear capital costs. As I will indicate , the Company assumptions are, in my judgement, optimistic.

Q. How does the ESRG model deal with the possibility of limited term assignments of energy, that is, firm energy sales?

A. The ESRG model can accommodate a variety of specifications in regard to plant assignments. In the first place, it can assess the costs of a specific supply expansion plan, including assignments. For example, it can make a cost comparison between the case where a given assignment is made to the alternative case where it is not. This involves a decoupling of the optimal generation module (Module I, in Exhibit A) from the dispatching segment of the model.

Furthermore, the model can assess the status of assignments under conditions where a vigorous market for energy imports and exports is available. Under these circumstances, the optimal generation module selects for each year the optimal megawattage appropriate to a given technology within a continuous band bounded only by plant capacity. (This upper bound would reflect the case when PECO retained the entire capacity of the plant for its own use).

Finally, we can assess the desirability of "lumpy" assignments by assuming that capital costs include both incremental costs and costs expended plus a penalty for foregoing any potential profits that the utility can anticipate as a result of assignment. Under these assumptions, where the optimal generation module excludes such plants from the mix, the implication is that assignment is preferred to the retention of the plant for the year in question.

Q. Can the proposed assignment of Salem II to GPU for the years 1980-84 be assessed within this framework?

A. Yes. Under the assumption that GPU pays for the assigned capacity on the basis of the full cost of generation, the model indicates that Salem II should nevertheless be retained by PECO for the years 1981-85. Where the price payed exceeds full generation cost, the assignment may be expedient from the PECO standpoint.

We have also compared the social costs of generation under the current PECO supply plan to the alternative where the only change relative to the PECO plan is that the assignment of Salem II is excluded, i.e., all 474 Mw are retained by PECO. Table VII indicates a comparison of these two cases. Under these assumptions, the assignment of PECO cannot be recommended, as the social cost under assignment exceeds that of no assignment for each of the years 1981-85. It should be noted, however, that this table reflects a comparison of two sub-optimal cases.

Q. How would optimal social costs be affected by a moratorium on the completion of all nuclear plants under construction?

A. Under the ESRG Base Case, the optimal generation expansion plan excludes Limerick units I and II. Thus, a moratorium on nuclear construction would have no effect on optimal costs.

Q. Does the above conclusion apply to a moratorium on the operation of existing plants?

A. No. Salem units 1 and 2, for example, both enter the optimal mix. Their peremptory exclusion from the mix would raise generation costs. This is due to the presence of rapid escalation in the capital costs associated with any new (coal) plants as compared to the embedded cost of existing (nuclear) plants whose construction costs had not been as heavily inflated.

TABLE VII

A COMPARISON OF THE SOCIAL COSTS OF SALEM II ASSIGNMENT RELATIVE TO THE NO ASSIGNMENT OPTION UNDER THE ASSUMPTION OF COMPENSATION AT COST
(In Millions of 1979 Dollars)

Year	Assignment	No Assignment
1981	735.0	717.0
1982	810.4	750.2
1983	847.2	796.5
1948	891.9	846.1

Source: ESRG Model

Given PECO cost assumptions, for Salem II energy, the cost penalty of such a moratorium in 1987, say, would amount to roughly 36 mills/kwh and would incur additional expenses for PECO (and ultimately the PECO consumer) in the neighborhood of $100 million per year.

Q. Assuming that the ESRG rather than the PECO load forecasts are realized, would this imply a delay in the optimal on-line dates of Limerick units #1 and #2?

A. We have not identified any circumstances which would warrant a construction delay for Limerick units #1 and #2. As noted above, the introduction of the Limerick units is sensitive primarily to generation cost rather than to load growth assumptions. Under PECO cost assumptions the Limerick units are warranted at their earliest possible on-line dates. This applies to rates of load growth ranging from the ESRG base case to the PECO case. However, under the entire range of ESRG cost assumptions, a cancellation of the units, not a delay, is warranted as they do not enter the optimal mix at least through 1992.

Q. Please comment on the relative magnitude of baseload versus peaking facilities in the present PECO supply plan.

A. Our model suggests an unjustifiable preponderance of baseload plants in the PECO projected mix. Under the ESRG Base Case forecast and the ESRG LOW cost scenario, the optimal mix incorporates all existing baseload plants plus 600 megawatts of coal. The PECO mix by contrast includes 2110 Mw of additional (nuclear) baseload. The effect of this additional baseload is to force the operation of non-nuclear baseload plants at capacity factors which are inappropriately low.

This implies the presence of substantial idle baseload capacity. Since the fixed costs of baseload are high relative to those of peaking capacity, this situation implies that the utility incurs unnecessary costs. Table VIII illustrates the existence of idle non-nuclear baseload capacity in the PECO case, where costs are accounted in full. The 600 Mw of coal which are brought on line in 1992 to supplement Limerick units 1 and 2 are operated only 41.4% of the time. In no case do capacity factors exceed even 60% for these non-nuclear baseload plants.

Q. Can you estimate the cost impacts of this overemphasis on baseload by comparing expected costs for the PECO plan as compared to those of the optimal expansion plan?

A. Excessive baseload is likely to engender severe cost impacts. For example, estimated social costs for the PECO expansion case total $3043.3 million in 1992 (current dollars). In the optimal expansion case, at an equivalent level of reliability, costs total $2006.1 million, a discrepancy in current 1992 dollars of over one billion dollars. Idle baseload plant imposes costs of considerable magnitude indeed.

Q. Please comment on projected PECO reserve margins.

A. PECO anticipates reserve margins for the late 1980's of the order of 27-28%. Our model indicates that under the very unrealistic PECO Planning Case, 30% reserve margins are in fact optimal (note case #'s 2 and 8 in Table VI). In other words, given PECO's assumptions, including that of incremental capital costs, PECO's anticipated reserves are consistent with optimal reserves calculated by the ESGEM Model relative to a social cost minimizing objective. As noted,

TABLE VIII

1992 CAPACITY FACTORS: PECO SUPPLY EXPANSION VERSUS OPTIMAL EXPANSION*

	Plant	Capacity	Capacity Factor: Optimal Expansion (%)	Capacity Factor: PECO Expansion (%)
NUCLEAR BASELOAD	Limerick 1	1055	N.A.	57.8
	Limerick 2	1055	N.A.	57.9
	Salem 1	468	68.8	67.7
	Salem 2	474	58.7	59.3
	Peach Bottom 2	447	69.4	68.3
	Peach Bottom 3	439	69.4	68.6
NON NUCLEAR BASELOAD	Generic Coal	600	80.6	41.4
	Eddystone 1	301	58.7	44.2
	Eddystone 2	311	61.3	25.0
	Delaware 7	126	75.1	19.4
	Delaware 8	124	81.2	22.9
	Schuylkill 1	158	68.6	22.3
	Conemaugh 1	176	60.2	56.7
	Conemaugh 2	176	63.8	55.3
	Keystone 1	179	64.4	56.3
	Keystone 2	179	72.1	56.4

* The latter assumes ESRG load growth and ESRG cost scenario.

however, we believe PECO's assumptions lie outside the reasonable range of expectation, both in regard to load growth and in regard to plant cost and performance. If, instead of PECO's demand growth rates, we introduce the ESRG load forecast together with the PECO construction program, the reserve margin for 1992 would be 52.4%. This compares to an optimal target reserve level of 14% in the ESRG Base Case. In other words, there is likely to be a discrepancy of over 30% between the optimal reserve margin target and the realized margin.

Q. You have established that an increase in baseload capacity will not enhance the reliability of the system in a cost effective way. But what of reliability in general? An electric utility has a legal mandate to provide customers with service of a high and consistent quality. Does your model and the results it implies take sufficient account of this objective? Does it monitor reliability?

A. Most definitely. There exist a number of alternative methodologies current in the industry to ensure technical reliability in an electrical supply system: 1) the contingency outage, reserve criteria (e.g., a requirement that the system have sufficient reserve to meet load in the event that the largest unit in the system experiences outage), 2) the capacity reserve percentage, i.e., the prior specification of a reserve margin, and 3) the LOLP (Loss of Load Probability) method, which specifies a reserve margin, such that the probability of shortfall not exceed a given value (see Kaufmann, 1979).

There is a virtual consensus among workers in this area that among these alternatives only the LOLP method is analytically consistent. For example, consider a system with peak load of 1000 Mw and a supply system consisting of a single facility, a baseload unit of 3000 Mw. The LOLP in this case is equal to the outage rate for this facility, say 1,000 days in ten years, well in excess of even the most lax of standards. However, the reserve margin is 200%, which would normally be considered very high. This example, while exaggerated, is not altogether fanciful as utilities become increasingly baseloaded and the size of individual units continues to increase. It shows, moreover, that the reserve margin is in itself not a reliable indicator of reliability. *Some quantitative measure of the risk of shortfall* must be imposed so as to imply a lower bound on the level of reserve. This will be dependent on the remaining supply configuration and its performance characteristics.

Recently, the LOLP method has been generalized (e.g., Shoengold, 1978) in the form of excess capacity analysis. This method specifies a continuous probability function which associates a probability with each level of capacity shortfall or excess. The traditional LOLP occurs as a single value of this function corresponding to a level of capacity excess equal to maximum import availability.

The ESRG model has been developed to calculate the probability function referred to above. This is necessary in light of ambiguity surrounding the LOLP concept. As noted, LOLP has been traditionally employed to monitor the probability of load in excess of capacity, plus imports, i.e., the probability of service interruptions, load control, voltage reduction and blackouts. In fact, though, we have determined that curtailment responses can be disaggregated into two very different categories: 1. "Soft" curtailment" regimes, with associated costs in the neighborhood of $.10-$.20/Kwh at most: and 2. blackouts, either controlled or uncontrolled, with costs in excess of $.50/Kwh and in our very conservative Base Case assumptions, $5.00/Kwh.

From the economic standpoint, the objective of reliable service should focus on the probability of blackouts, rather than on the probability of curtailment in general.

For this reason, we have specified for each scenario in our model three different values of the excess capacity probability distribution.

I. The probability of curtailment overall.

II. The probability of blackouts.

III. The probability of system-wide blackouts.

In my view, the most appropriate single measure of technical reliability is II, rather than I.

The implications of this revised reliability parameter or index are very great. Table IX shows reserve levels implied by each of these two measures. The use of the revised criterion results in reserve levels approximately 8% less than those implied by the traditional "one-day-in-ten-years" LOLP criterion.

In summary, the ESRG model monitors reliability through the calculation of an excess capacity probability function. This enables it to explore alternative reliability criteria more suitable to the assessment of the genuine risks of system failure, as compared to traditional LOLP analysis.

Q. Can you recommend a particular reserve margin for PECO based on this modified LOLP procedure?

A. The procedure described above pertains exclusively to <u>technical</u> reliability. The major focus in our model is on <u>economic</u> rather than

TABLE IX

RESERVE LEVEL SUFFICIENT TO MEET DESIGNATED RELIABILITY LEVELS AT FULL COST

ESRG Base Case

	Traditional LOLP (Probability of curtailment) 1 day in ten years	Revised Criterion (Probability of Blackouts) 1 day in ten years	Social Cost Minimization Criterion
1981	30%	22%	14%
1987	22%	22%	22%
1992	22%	14%	14%

PECO Cost and Load Growth Assumptions

	Traditional LOLP (Probability of curtailment) 1 day in ten years	Revised Criterion (Probability of Blackouts) 1 day in ten years	Social Cost Minimization Criterion
1981	30%	22%	30%*
1987	30%	14%	14%
1992	22%	14%	14%

* This is a consequence of historic overexpansion.

technical reliability. In other words, the objective in our model is to choose a level of reserve, so as to balance optimally the costs of curtailment and blackouts with the costs of additional capacity. Curtailment and blackouts are not considered negative per se in the Model, but are undesirable only insofar as they impose substantial costs on society at large.

A technical criterion such as LOLP, or the proposed modified LOLP, constrains the probability of blackout with reference to a fixed probability criterion, without considering economic consequences. Implicitly, therefore, this method assumes that socially desirable outcomes can be identified purely on the basis of a technical probabilistic analysis.

Preliminary investigation suggests that this assumption is invalid. Referring back to Table IX, it is clear that significant differences exist between outcomes using, say, traditional LOLP and cost minimization criteria. This demonstrates the inadequacy of purely technical solutions to this problem. Just as the designation of a reserve margin a priori is an inadequate characterization of the probability of system failure, the a priori specification of a probability constraint neglects to incorporate the social cost dimension and is, thus, in the last analysis just as arbitrary as the reserve margin criterion, albeit more analytically precise.

Q. What are the implications of this discussion in assessing operative and anticipated PECO reserve margins?

A. As noted above, PECO margins of 25-30% only appear justified from the standpoint of social cost minimization assuming:

1. that consideration is made only of incremental rather than full costs of capital for Salem unit #2 and for Limerick units #1 and #2,
2. that PECO forecasts are assured, and
3. that PECO cost and plant performance assumptions are employed.

The issue in regard to my conclusions about the PECO reserve margins is not one of methodology, however, since the results from our model largely support the PECO supply plan under the PECO Planning Case, including the choice of reserve margins. My disagreement is primarily with the adequacy of these assumptions. When the assumptions are altered, the optimal reserve margins are reduced substantially from the 25-30% range to 12-20%.

In other words, PECO reserve margins are excessive because of the inadequacy of the Company planning assumptions, not necessarily because of its analytical procedures. The biases introduced into the reserve margin analysis are a consequence of these faulty assumptions.

Q. What are the likely consequences of load control and load management procedures for reliability and social costs?

A. For a fixed reserve margin, both load management (i.e., policies designed to raise the load factor assuming a fixed energy constraint) and load control (i.e., measures to clip peaks above a specified level of load) are likely to have a favorable impact on costs. Both measures may result in a significant reduction in peak load. Insofar as required capacity is defined as (Peak Load) x (1+ reserve margin), the costs of fixed generation are reduced relative to the reduction in peak load.

However, these measures are, in fact, also likely to have an unfavorable impact on reserve margins. Consider, for instance, the case of a perfectly flat load (100.0% load factor). Note that any incidence of shortfall, at any hour of theyear, will require reserve capacity so as to forestall curtailment. For a more typical system, reserve is required in practice only during peak hours, which represent a relatively small proportion of total hours. Thus, the reserve requirements under a regime of load management and load control are likely to be greater than under a more typical load regime. This offsets to some degree the savings engendered by load management and/or control.

There is, moreover, a further circumstance whose effects may be still more unfavorable to these options. A flat load shape implies an optimal mix weighted heavily in favor of base load, relative to peaking capacity. This would imply the early retirement of many of PECO's existing generators and the construction of new baseload. However, given the cost of baseload under the escalation assumptions suggested by the ESRG cost scenarios, the overall generation costs associated with this modified load shape may be almost as high as would be the case with no change in the load shape. On balance, therefore, the net impact of load management/control is not certain to be cost effective, when account is taken of the costs of program implementation or the other social costs of load shifting. Thus, "peak-clip-valley fill" in particular might not result in a net decrease in social cost. But the key fact for the PECO system is that, as we have shown, the LOLP for blackouts under an optimal construction program is quite low. Thus, probably first consideration for improving reliability should be given to implementing additional active load control technologies, e.g., ripple controlled commercial air-conditioning. (See Table IX.)

Q. Would you please explain the sources and bases for your selection of input assumptions and parameters for the generation expansion, dispatch reliability and social cost analyses you have performed with the ESGEN model in this case?

A. The general approach was to use Company data when this was made available to us. Where there were gaps in this data, I worked with the ESRG staff of scientists to perform calculations, review the industry literature, and make estimates of the relevant parameters.

For parameters associated with the future (e.g., costs, and technical and performance characteristics of new generation options) estimates were made based upon industry experience, industry and related literature, and ESRG staff expertise. Future trends (e.g. load growths, costs, inflation rates, cost escalation rates) were handled by establishing scenarios. The PECO scenario embodies all of the Company's assumptions. The ESRG LOW and ESRG HIGH scenarios embody ESRG estimates regarding future cost and load trends. Estimates of the magnitude and costs of the various curtailment regimes were based upon examination of the PECO system and review of the recent literature.

In general, my own estimates of various parameters were made conservatively. Various sensitivity analyses were performed.

Q. How was the load data used in your analyses obtained?

A. The detailed hourly loads on the PECO system for the year 1978 was obtained from the Company and used as the basis for my analyses.

Q. What were the ESRG load growth assumptions?

A. These were obtained from the detailed analyses performed by ESRG staff in this case (see Testimony of John Stutz, R.I.D.R-7906086). These were approximately 1.3 percent per year from 1978 to 1992. During the same period PECO forecasts about 2.7 percent per year.

Q. Would you please provide more detail regarding your input assumptions?

A. Most of these are tabulated in the Table in Exhibit DS-B. It would probably be useful to explain the various sets of assumptions separately.

Q. Please describe your assumptions regarding the available supply options for the PECO System, their forced outage rates, and their capacity factors.

A. The supply options consist of all existing plants expected to be on-line by 1981 (including Salem 2, and excluding Cromby 5 and 6) according to Attachment I-B-4 of a Company document in this proceeding (Ref. 8) plus the Limerick 1 and 2 plants, and generic new supply options including 1200 Mw nuclear units, 300 Mw, 600 Mw and 1000 Mw coal units, 300 Mw oil cycling units, 400 Mw coal combined cycling units, and combustion turbines in sizes of multiples of 10 Mw.

The units' capacities have been obtained from various Company documents (including Company Exhibit VSB-1). For all units the capacity assigned was the summer rated capacity. This embodies conservatism since rated capacity can be expected to be higher during the rest of the year. Forced outage rates (FOUTR in Exhibit DS-B) were obtained from the Company (Attachment I-B-4 in Ref. 8). Forced outage rates for new units were developed by comparison with those of existing PECO units and by examination of the literature and industry experience (e.g., Refs. 9, 10, 11).

The variable CAPFAC in Exhibit DS-B is used in two ways in the ESGEN program, as discussed in Exhibit DS-A . In the capacity expansion module (Module I), CAPFAC is used as the expected annual capacity factor for each unit in order to compare expected costs for ranking. In the dispatch module (Module II) only the CAPFAC for hydro units is invoked, and there in order to conform to the Comapny's expected hydro operation. The expected capacity factor for all existing steam-electric units is obtained by subtracting the sum of forced and planned outage rates from 100 percent. For combustion turbines we have chosen 30 percent for CAPFAC based upon ESRG's discussions with various utilities in work for the Department of Energy (Ref. 12) and familiarity in previous work with utility operations. For hydro units (Muddy Run and Conowingo) CAPFAC was estima on the basis of actual usage of these facilities according to Company data. For new units (Salem 2, Limerick, and the generic supply options) CAPFAC was estimated based upon a review of the literature and industry experience. The large coal facilities were assumed to have CAPFAC's of 75 percent and 70 percent for 600 Mw and 1000 Mw units, respectively. EPRI (Ref. 9) has estimated 73 percent for 800 Mw coal units (with scrubbers). Our choice brackets this estimate, thus taking into account in a modest way the relative advantage of smaller units (see, e.g., Refs. 10, 13, 14). For 300 Mw coal units we assume an additional advantage in an 80 percent expected capacity factor. New combustion turbines were assumed to have a CAPFAC of 30 percent. New oil cycling plants were assumed to have expected capacity factors of 85 percent (EPRI in Ref. 9 assumes 84 percent), and new coal combined cycle plants were assumed to have expected capacity factors of 80 percent (EPRI in Ref. 9 assumes 80 percent).

The remaining CAPFAC to be discussed is that assumed for new nuclear units (Salem 2, Limerick, and new generics). The Company has assumed 70 percent capacity factors for its new nuclear units. Recent research, including my own, in the area of nuclear power plant capacity factors leads me to conclude that this is an insupportably optimistic assumption for large nuclear plants, especially BWR's. I have chosen 60 percent to represent nuclear plant capacity factors. In my judgement, this is a reasonably conservative estimate, given my study of the experienced operating behavior of nuclear power plants as a function of size, type, manufacturer and other characterists (Ref. 15). In the research (Refs. 15, 16, 17, 18) I have found that large nuclear plants operating in the years 1968 through 1978 had the following capacity factor experience:

	Average Capacity Factor	Reactor Years in Sampl
Large (800+Mw) BWR's	54 $\pm$ 2 percent	46
Large (800+Mw) PWR's	57 $\pm$ 2 percent	78

On a yearly basis, beginning the first full year of operation, one finds:

Year	Large (800+MW) BWRs Capacity Factor (Percent)	Reactor Years	Large (800+Mw) PWRs Capacity Factor (Percent)	Reactor Years
1	51 ± 4	12	57 ± 3	23
2	49 ± 5	10	55 ± 4	19
3	53 ± 5	10	53 ± 4	16
4	58 ± 6	7	63 ± 5	11
5	59 ± 6	4	63 ± 5	6
6-7	69 ± 9	3	57 ± 9	3

For units over 1000 Mw the average experienced capacity factors have been 50 percent (14 reactor years) for BWRs, and 53 percent (16 reactor years) for PWRs. These are even lower than the 54 percent and 57 percent for 800+Mw BWR's and PWR's, respectively. While the experience with large (1000+ Mw) nuclear power plants is still limited, it certainly does not support the Company's assumption of 70 percent capacity factor for its new nuclear units. In fact, in choosing 60 percent for my present analyses, I am being conservative, even when this is compared with the results of the much larger (800+Mw) sample, which embodies capacity factor experience better than the 1000+ Mw units.

Q. How were economy imports, emergency imports, pumped storage hydro, and conventional hydro options taken into account?

A. Here, again, I will distinguish between the capacity expansion module (Module I) and the dispatch and costing modules (Modules II and III) of the ESRG ESGEN program.

The hydro options are included in the capacity expansion optimization model, where the least cost mix of supply options to meet expected load is developed. The import options are added (along with the curtailment options) only in the dispatch, reliability, and costing modules where economy purchases and the various insufficiency procedures are invoked based upon costing as well as supply and demand fluctuation conditions.

The capacity factors (CAPFAC) for the hydro options were established on the basis of Company projected usage for 1981. Economy imports were also established on the basis of Company data. The Company's net purchases (after subtracting sales) in 1981 was used assuming an expected capacity factor of 50 percent to arrive at a reasonably conservative estimate of available economy import capacity for the future. A conservative estimate of available emergency import capacity (500 Mw) was established judgementally, based upon the magnitude of capacity and large number of units in the PJM system as well as the large number of transmission lines. Costs of emergency imports (listed in Exhibit DS-B under FUEL) were based upon the Company's interrogatory response, A.GLF.8.

Q. Please describe your assumptions regarding fuel costs.

A. Fuel costs for the 1979 base year, expressed in 1979 dollars, were obtained by examining mid-year (May-July) fuel prices. These prices, and their source are listed below.

nuclear	$ .35	per MMBTU	(Company Response A.GLF.4)
coal	$1.44	"	(Ref.19)
residual oil	$3.65	"	(Ref.20)
distillate oil	$4.14	"	(Ref.20)
natural gas	$1.91	"	(Ref.20)

We have increased base year oil prices over those estimated by the Company in order to adequately incorporate recent price increases.

Fuel costs for each unit in the PECO system were then calculated using the above prices and the plant-specific heat rates. Plant-specific heat rates were obtained primarily from 1977 Monthly Power Plant Reports (FERC Form 4) which give generation and fuel consumption data, and from FERC Form 12 reports. Fuel costs are given by:

$$\text{FUEL COST (\$ per Kwh)} = \text{HEAT RATE (MMBTU per Mwh)} \times \text{FUEL PRICE (\$ per MMBTU)} \div 1000$$

Q. How were fuel costs escalated for the years beyond 1979?

A. In order to describe my fuel cost escalations I must describe my inflation assumptions as well. Fuel costs were escalated by an annual rate which is the sum of the inflation rate and the real price escalation rate (specific to each fuel).

Exhibit DS-D summarizes the inflation rate, escalation rate, and discount (interest) rate assumptions for three sets of scenarios. We have developed three categories of cost related scenarios. The first (PECO) is designed to incorporate the Company's assumptions. The other two incorporate ESRG assumptions. These are designated as ESRG LOW and ESRG HIGH for low and high cost scenarios respectively.

I have pegged all cost escalation rates to the underlying rates of inflation in the ESRG scenarios; that is, all escalation rates are assumed to have a "real" (or constant dollar) component which is added to the inflation rate in the ESRG LOW and ESRG HIGH scenarios.

The Company has assumed annual inflation rates of 6.5 percent in 1980, 5.5 percent in 1981, and 5.0 percent thereafter. In my judgement, these assumptions are unreasonably low. The inflation rate for the last two years has averaged over 10 percent per year. I do not expect this to drop substantially or quickly over the next decade. The impact of the energy industry and energy prices alone within the overall economy is significant in sustaining high inflation rates.

I have therefore constructed two sets of escalation rate assumptions based upon inflation rates of 8.5 percent (1980), 7.5 percent (thereafter in the ESRG LOW case, AND 10.0 percent (1980) and 9.0 percent (thereafter in the ESRG HIGH case. I believe this range of inflation rates adequately represents the likely rate of inflation over the next ten years, given the uncertainties involved in making such forecasts.

Having said this, I would like to note that the main results of my analysis are not very sensitive to the inflation rate assumptions since all cost estimates and comparisons are ultimately made in constant (1979) dollars, by applying a discount rate. Since both the ESRG and the PECO discount rates are 3% plus underlying inflation rate, the latter does not affect the comparisons to first order.

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