ELECTRICITY DEMAND PROJECTIONS AND

UTILITY CAPITAL REQUIREMENTS

by

T. D. Mount and L. D. Chapman*

September 1974 No. 74-24

*Presented at the Conference on Energy Investment Requirements at the Brookings Institute, Washington, D. C., September 5, 1974. Both authors are Assistant Professors in the Department of Agricultural Economics, Cornell University, Ithaca, New York.

ELECTRICITY DEMAND PROJECTIONS AND
UTILITY CAPITAL REQUIREMENTS

by

T. D. Mount and L. D. Chapman

INTRODUCTION

The emphasis of our analysis will be concerned with the projections of electricity demand presented by the A. D. Little Company.1/ It is our contention that the anticipated future generation levels upon which the A. D. Little report is based, and therefore, the associated investment requirements for new generating capacity are too high. This overestimation of future capacity needs stems to a large extent from an inadequate assessment of the effects of higher energy prices on the growth of demand for electricity.

A major part of our research efforts over the last four years has been directed to estimating demand relationships for electricity, and to using these models to evaluate projections of future capacity requirements in the electric utility industry.2/ This type of analysis leads us to conclude that the constant growth of electricity generation that was experienced in the past will not be maintained in the future. The analysis not only implies that future growth rates will be lower than past rates, but also that future growth rates may, in fact, gradually decline over time. In the context of the energy crisis, we believe that the current situation in which electricity sales are well below anticipated levels is indicative of an important change in the demand characteristics facing the electric utility industry, and that this change will continue to manifest itself in future years. We do not believe that current low electricity sales have resulted solely from temporary and reversible conservation efforts made by the public in response to their concern over the energy crisis. In other words, we do not expect things to return to "normal" in a couple of years, and consequently, if the electric utility industry attempts to grow at the rates suggested in the A. D. Little report, we conclude that this will lead to serious overexpansion of generating capacity.

THE A. D. LITTLE PROJECTIONS

The low demand projections presented by the A. D. Little Company are based on the assumption that total energy consumption will remain constant until 1975 and then will resume an exponential growth path of over three percent per year which corresponds to about three-quarters of the growth rate experienced in the past.[3/] Even with this low demand scenario, the consumption of electricity is expected to increase by 5.3 percent per year from 1975-1980 and 6.1 percent per year from 1980-1985. The growth rates for the high demand scenario are 7.8 percent per year and 7.0 percent per year, respectively.[4/] These latter rates are consistent with doubling the consumption of electricity every 10 years. In contrast, the low demand scenario implies a 66 percent increase of consumption between 1975 and 1985.

One important characteristic of the A. D. Little projections is that the difference between the growth rates of generating capacity for high and low demand is not nearly as marked as the difference between the corresponding growth rates of consumption. Using the two extreme capacity projections for 1975 as the base, the corresponding capacity levels projected for 1985 are equivalent to annual growth rates of 5.71 percent as opposed to 5.48

percent for high and low demand, respectively.[5/] This implies that there would be a substantial decline in the capacity factor under low demand compared to high demand conditions. It appears, in fact, that the low demand scenario with respect to generating capacity is almost identical to the high demand scenario except that the growth path is delayed for a year or so. The capacity of 878 thousand megawatts projected for 1985 with high demand would still be attained with low demand early in 1987 at the "low" growth rate of 5.48 percent per year.

One serious deficiency of the A. D. Little report is that there is virtually no documentation of the methodology underlying their energy projections. While they acknowledge the existence of and also some of the limitations of studies on the demand for different forms of energy,[6/] it appears that their projections are not directly based on any formal analysis of this type. Therefore, it is impossible to criticize their projections on purely technical grounds. In particular, it is unclear why they expect the capacity factor for electric generation to deteriorate to such an extent under low demand conditions. One possible explanation is implied in their discussion of electricity demand.[7/] This is that commitments for expanding generating capacity between now and 1985 have already been made, and that only slight modifications of these existing plans are practical. Therefore, actual consumption levels will have little effect on capacity expansion.

It is our belief that these assumptions exaggerate the rigidity of future construction programs. Although we have had no direct experience with this particular problem, it appears that the failure to determine the extent to which planned capacity expansion can be reduced is a serious omission from the A. D. Little report. Furthermore, it is an important topic which should be addressed at this conference. If it is feasible to reduce the capacity level projected for 1985 and still cover projected consumption, total investment requirements will also be reduced. Since these marginal capacity reductions will almost certainly involve nuclear facilities, which are highly capital intensive, potential investment savings may well be substantial.

Another possible explanation for expecting the load factor to deteriorate under conditions of low demand is that overall consumption levels may grow more slowly than peak load. This would occur if conservation efforts involved predominately off-peak activities such as lighting and had little influence on peak activities such as air-conditioning. Once again, there is no substantial discussion of this in the A. D. Little report, and maybe it is another topic which should be considered at this conference. There is little evidence available at the present time on the peak loads experienced by electric utilities during this past summer, and it will be interesting to find out whether peak loads have increased substantially from last year's levels even though overall consumption has generally remained constant.

AN ALTERNATIVE PROJECTION OF ELECTRICITY CONSUMPTION FOR 1980

Although the importance of changes in the levels of population, personal income and energy prices on the demand for energy is recognized in the A. D. Little report,[8/] no attempt is made to explicitly assess the relative magnitudes of these relationships for any energy type. However, a number of econometric studies have been published in which estimated demand functions for different energy forms are presented. Most recent studies of electricity demand show that its price elasticity is relatively large, at least in the long run. The work of Anderson,[9] Halvorsen,[10] Houthakker *et al.*,[11] and Wilson,[12] as well as our own work may be cited in this context.[13] If the consumption of electricity is as responsive to price as these studies imply, one would anticipate that the increases of electric rates which have occurred during recent years and which are expected to occur in the future will tend to reduce consumption levels. On the other hand, increases of population, of real income and of the prices of substitute fuels will tend to offset this reduction. Determining the net effect of these different factors on consumption is the main objective of most econometric analyses of electricity demand.

Unfortunately, almost all published demand models for electricity are unsuitable for projection purposes for one or more of the following reasons:

1) The analysis is restricted to the residential sector and therefore accounts for only a third of total consumption.
2) The analysis is based on cross-section data which makes it impossible to distinguish short-run effects from long-run effects.
3) The treatment of substitution effects of alternative fuels such as gas, oil and coal is inadequate.

We have attempted in our own research to overcome these three deficiencies by:

1) Estimating separate demand models for the residential, commercial and industrial sectors which in total account for about 90 percent of overall consumption.

2) Using pooled cross-section, corresponding to states, and time-series data, corresponding to years, and by incorporating a geometric lag structure to account for the adjustment mechanism of demand.

3) Developing compatible data series for the prices of oil and of coal as well as the price of gas.

During the past year, some technical improvements in our models from those previously published have been incorporated into the analysis, and of these, the most important are:

1) The statistical problem of estimating a model containing a lagged dependent variable as a regressor has been approached by using a generalized least squares estimator under the specification that random cross-section effects are present.

2) The economic problem of whether the average or marginal price of electricity is the correct regressor has been approached by incorporating both prices into the model. In this way, the data can dictate which is most appropriate, and in fact, the marginal price is found to add little to the model.

Our basic demand model relates the quantity of electricity demanded to a set of explanatory variables that include the number of customers; income per capita; and the prices of electricity, of three substitute fuels and of electrical equipment. These variables are transferred to natural logarithms in a linear regression framework. In addition, the logarithm of the quantity of electricity demanded in the preceding time period is specified as a regressor to allow for the existence of a geometric lag structure. Since all variables are transferred to logarithms, the coefficient for a particular explanatory variable, such as income, is an estimate of the short-run elasticity of the demand for electricity with respect to that variable. In addition, the coefficient of the lagged dependent variable is an estimate of the proportion of the change of consumption which occurs after the first year, and consequently, indicates how slowly consumption adjusts to changes of the explanatory variables.

Models for the three classes of customer were estimated from data for the years 1963 to 1972 and for each of the contiguous states in the United States, and the results are summarized in Table 1. In addition to the variables discussed above, other factors are specified which include the unit cost of labor, the wholesale price index, the gross national product, the degree of urbanization, the ratio of the average and marginal prices of electricity, and the proportions of all customers in each consumer class. All variables representing money values are deflated into real terms.

The estimated long-run elasticities for six major variables corresponding to the models presented in Table 1 are summarized in Table 2. In general, the results imply close to unit elasticities for the number of customers, except in the industrial sector; inelastic response to income; slightly elastic response to the price of electricity; and varying degrees of inelastic response to the prices of substitute fuels. In the residential and commerical sectors, the prices of fuel oil and coal are combined into a single index reflecting the cost of space heating, as alternative data sources are not readily available.

For the purposes of using these models to forecast future levels of electricity consumption, we have been forced by time limitations to present projected consumption levels for 1980. These projections have already

Table 1. Estimated Demand Models for Electricity

Explanatory Variable[a]	Residential		Commercial		Industrial	
1. Quantity demanded in the previous period	.734	(42.8)[b]	.554	(22.3)[b]	.727	(33.5)[b]
2. Number of customers	.270	(13.3)	.412	(9.4)	.178	(7.0)
3. Real income per capita	.163	(6.4)	.101	(1.9)	.088	(1.1)
4. Price of electricity	-.311	(14.9)	-.544	(11.3)	-.272	(6.8)
5. Price of gas	.008	(.8)	0		0	
6. Price of fuel oil }	.163	(2.7)	.288	(2.1)	.025	(2.0)
7. Price of coal					.030	(1.7)
8. Price of electric appliances or machinery	0		0		-.043	(.2)
9. Unit labor cost	-		.452	(4.1)	.283	(1.8)
10. Wholesale price index	-		1.151	(3.5)	1.399	(3.9)
11. Gross national product	-		-		.137	(1.7)
12. Degree of urbanization	-.003	(4.0)	-.004	(2.2)	.003	(1.8)
13. Price ratio for electricity[c]	.032	(1.9)	.039	(1.1)	-.008	(.4)
14. Proportion of customers in the residential sector	.080	(.3)	2.238	(3.1)	-	
15. Proportion of customers in the industrial sector	-		-4.125	(1.5)	-25.307	(5.0)

a/ All variables in dollar units are deflated. Variables numbered 12, 14 and 15 are not transformed to natural logarithms.

b/ The absolute values of the ratio between the estimated coefficient and standard error are given in parentheses.

c/ This is the ratio between the marginal and average prices.

Table 2. Estimated Long-Run Elasticities for Electricity Demand

Explanatory Factor	Class of Customer: Residential	Commercial	Industrial
1. Number of customers	1.01	.92	.65
2. Income per capita	.61	.23	.32
3. Price of electricity	-1.17	-1.22	-1.00
4. Price of gas	.03	.00	.00
5. Price of fuel oil }	.61	.64	.09
6. Price of coal }			.11
7. Gross National Product[a/]	-	-	.50
Proportion of the response occurring in the first year	.27	.45	.27

a/ Income per capita is a measure of affluence within each state, whereas the gross national product is a measure of national affluence. Both are included in the model for the industrial sector.

been prepared for a task force on conservation which is currently part of the National Power Survey organized by the Federal Power Commission.[14/] The following assumptions for the explanatory variables were used: population and real income per capita projections for each state were taken from the Bureau of Economic Analysis.[15/] These projections imply overall growth rates of 1.4 and 2.9 percent per year for population and real income per capita, respectively, although actual projected growth rates vary considerably between states. The number of customers is specified as a fixed proportion of population in each state. The per capita income growth assumptions correspond to a four percent increase of real GNP per year. The real prices of gas, fuel oil and coal are specified to increase at rates of seven, nine and seven percent per year, respectively, which are in general agreement with the rates anticipated by the recent MIT Energy Laboratory Study.[16/] This in turn will lead to an increase of five percent per year in the real price of electricity. All other variables in the models are held at their 1972 levels. For variables measured in money units such as unit labor costs, this implies that their growth is the same as the rate of inflation.

Under these specifications, consumption levels for the three consumer classes in each state can be projected to 1980. Other consumer classes are accounted for by assuming that this consumption is a fixed proportion of total consumption in each state. A similar assumption is made to cover transmission losses. In this way, the total quantity of electricity generated in different regions or in the whole United States can be forecast.

The projected consumption of electricity for 1980 is about 2.2 trillion KWH for the United States excluding Alaska and Hawaii. This is about 14 percent less than the level given in the A. D. Little report with low demand, and about 26 percent less than the level with high demand.[17/] Consequently, we consider that even the low demand scenario seriously overestimates the future expansion of electricity consumption.

An additional objective underlying our projection for 1980 was to determine the potential for reducing the dependence of the electric utility industry on imported oil. The corresponding breakdown of the primary fuel sources for generation are summarized in Table 3, and in addition, the same breakdown is presented for a projected consumption level of 3.2 trillion KWH in Table 4. This latter value corresponds to the sum of the regional forecasts made by the task force on utility fuels for the current National Power Survey.[18/] It should be noted that this level is over six percent higher than the A. D. Little projection under high demand conditions. The implications of our projected consumption level of 2.2 trillion KWH are obvious. Not only are capacity needs less than anticipated, but considerable savings can be achieved in the use of gas and fuel oil for generating electricity. This in turn will affect investment needs in other energy sectors.

CONCLUSION

Consumption of electricity in the United States has grown steadily from the late forties to the early seventies at rates exceeding eight percent per year. There is still a strongly held belief among industry and government personnel that similar growth rates will be experienced in the future, and most existing plans for expanding generating capacity reflect these beliefs. The projection presented in Table 4 is a typical example.

Table 3. Projected Levels of Electricity Consumption in 1980 by Region, Task Force on Conservation,[a] National Power Survey (Billion KWH)

Region[b]	Generation by Primary Fuel					
	Nuclear	Coal	Oil	Hydro	Gas	Total
NPCC	73.5	0.0	90.1	38.4	5.4	207.4
MAAC	74.3	72.2	10.6	2.3	3.4	162.8
SERC	173.4	238.5	0.0	38.7	0.0	450.6
ECAR	55.1	300.8	0.0	22.4	0.0	378.3
MAIN	59.1	98.1	0.0	2.6	0.0	159.8
SWPP	23.5	87.4	0.0	3.2	68.2	182.3
ERCOT	7.6	51.3	0.0	1.3	86.2	146.4
MARCA	18.7	48.6	0.0	10.7	0.0	78.0
WSCC	47.9	146.8	0.0	205.4	45.0	445.1
TOTAL U.S.	533.1	1043.7	100.7	325.0	208.2	2210.7

a/ Based on the demand models presented in Table 1.

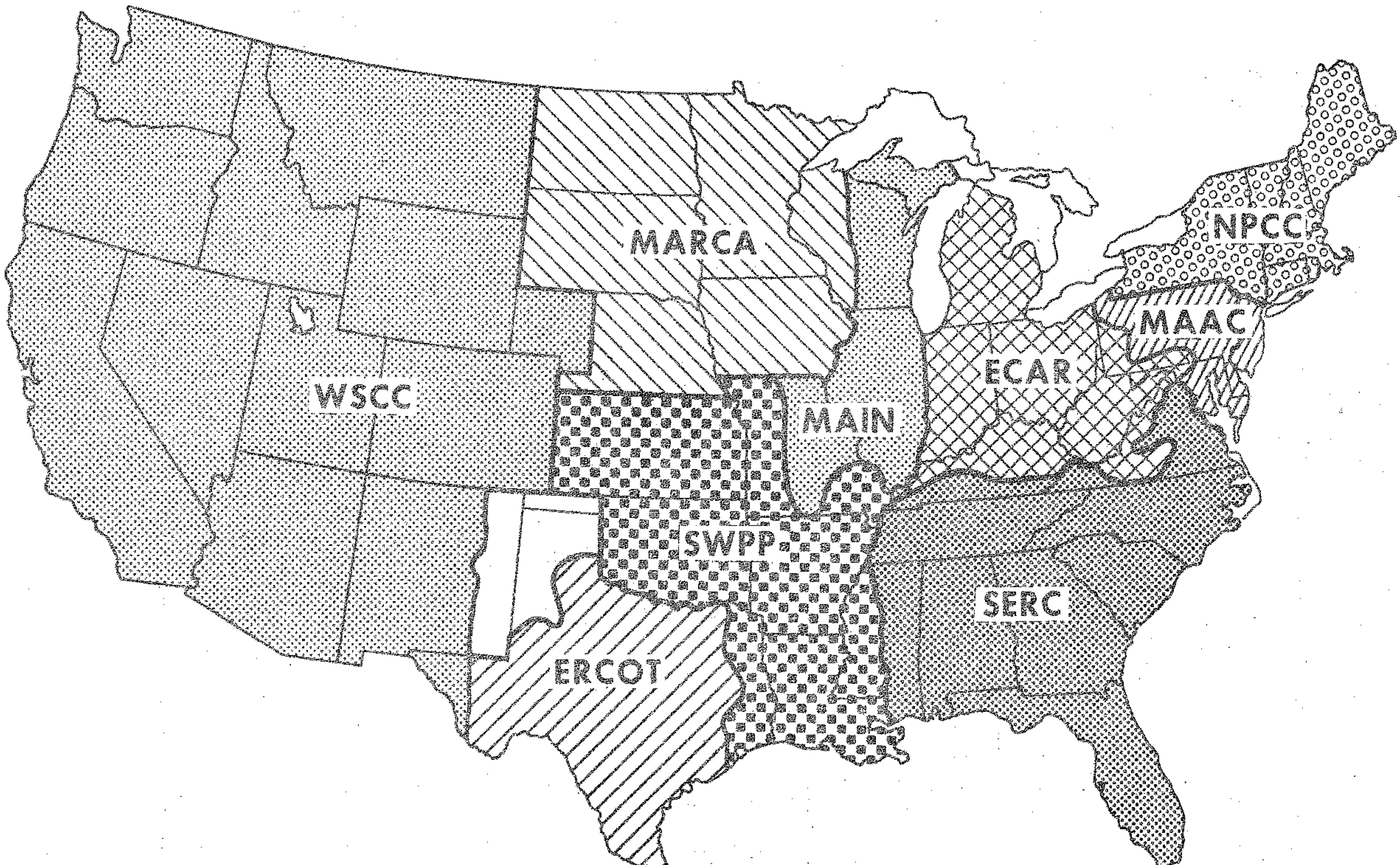
b/ The regions are identified in Figure 1.

Table 4. Projected Levels of Electricity Consumption in 1980 by Region, Task Force on Utility Fuels, National Power Survey (Billion KWH)

Region[a]	Generation by Primary Fuel					
	Nuclear	Coal	Oil	Hydro	Gas	Total
NPCC	73.5	0.0	178.0	38.4	5.4	295.3
MAAC	74.3	72.2	107.7	2.3	3.4	259.9
SERC	173.4	336.2	139.3	38.7	31.0	718.6
ECAR	55.1	417.0	18.9	22.4	9.4	522.8
MAIN	59.1	134.5	21.8	2.6	11.4	229.4
SWPP	23.5	87.4	18.7	3.2	140.7	273.5
ERCOT	7.6	51.3	1.4	1.3	141.9	203.5
MARCA	18.7	68.1	2.9	10.7	15.9	116.3
WSCC	47.9	146.8	50.8	205.4	115.9	566.8
TOTAL U.S.	533.1	1313.5	539.5	325.0	475.0	3186.1

a/ The regions are identified in Figure 1.

FIGURE I. REGIONAL ELECTRIC RELIABILITY COUNCILS



In addition, the methods frequently used by utility companies to predict future consumption levels in their own service areas reinforce these expectations. Generally, only changes in population growth rates are explicitly considered, and factors that may influence the per capita use of electricity, such as income and energy prices, are not incorporated into their forecasting procedures. In this respect, the A. D. Little projections, especially those for generating capacity, are similar to projections made by other industry and government groups, even though their projections are marginally lower than most of the ones that they cite.[19/]

Most econometric analyses of electricity demand, on the other hand, imply that the past growth of electricity consumption can be attributed mainly to three factors: increases of population and of real income per capita, and also to a decrease in the price of electricity relative to other commodities. It is this latter price effect which has often been ignored when planning future generating needs. Now that a period has been reached in which energy prices are increasing faster than other prices, the growth of electricity is expected to decrease from past rates, as substitution effects are not found to be large enough to offset higher electricity prices. Since demand adjustments are relatively slow, the effect of recent price increases will continue to retard electricity growth into the future. Hence, although we could not have predicted the large price increases that occurred last winter, given these increases, we are not surprised that electricity consumption did not grow as fast this year as it did in previous years. However, the publicity associated with the energy crisis may well have accelerated the rate of adjustment of consumption to higher prices.

The projection of electricity consumption for 1980, which was derived from our estimated demand models and is presented in Table 3, is indicative of these general conclusions. This specific projection represents one of a whole series made under alternative assumptions about policies which may be adopted by the federal government with respect to oil imports, air quality standards and conservation. Consequently, the importance of the projection is not so much its exact numerical value, but rather that it is one of the highest of our projections and yet it is still much lower than any of the A. D. Little projections.

In summary, the current crisis facing electric utility companies is seen by many to be the difficulty that these companies are now experiencing in raising sufficient capital to finance planned capacity expansion. Some consider that these problems warrant federal intervention of various kinds. We believe that a more serious crisis will occur in the future if the industry manages to expand as fast as it considers necessary at the present time. Consumption and revenues will not grow as fast as expected, and consequently, companies will find it difficult to maintain a sound financial basis. With the low operating costs and high sunk capital costs associated with nuclear generation, companies will again find it economically attractive to promote inefficient uses of electricity, such as electric space heating, in order to increase sales. Such policies will undermine any recent gains that have been made to discourage extravagant forms of energy consumption. We conclude that this is the appropriate time to change current plans for expanding generating capacity rather than to introduce extraordinary measures in an attempt to maintain the viability of existing policies.

NOTES AND REFERENCES

1/ All citations to the A. D. Little report refer to the full draft of "Capital Needs and Federal Policy Choices in the Energy Industries" and not to the executive summary. Such citations are identified by; ADL op. cit., p. __.

2/ For example, Chapman, L. D., T. J. Tyrrell, and T. D. Mount, "Electricity Demand Growth and the Energy Crisis," Science 178, 703-8 (1972), and Mount, T. D., L. D. Chapman, and T. J. Tyrrell, "Electricity Demand in the United States: An Econometric Analysis," ORNL-NSF-EP-49, Oak Ridge, Tenn., Oak Ridge National Laboratory, June 1973. This research was supported by the National Science Foundation RANN Program through the Oak Ridge National Laboratory and by the New York State College of Agriculture and Life Sciences at Cornell University.

3/ ADL op. cit., pp. 10-11.

4/ ADL op. cit., Table 40, p. 169.

5/ ADL op. cit., Table 41, p. 170. The requirements for generating capacity are presented for 1975 and 1985, and these quantities are used to compute the corresponding annual growth rates.

6/ ADL op. cit., p. 160.

7/ ADL op. cit., p. 168.

8/ ADL op. cit., p. 158.

9/ Anderson, K. P., "Residential Energy Use: An Econometric Analysis," R-1297-NSF, Santa Monica, Calif., RAND, Oct. 1973.

10/ Halvorsen, R. F., "Residential Demand for Electricity, unpublished Ph.D. thesis, Harvard Univ., Dec. 1972.

11/ Houthakker, H. S., P. K. Verleger, Jr., and D. P. Sheehan, "Dynamic Demand Analyses for Gasoline and Residential Electricity," Am. J. Agr. Econ., May 1974.

12/ Wilson, J. W., "Residential Demand for Electricity," Quart. Rev. Econ. Bus. 11, 7-22 (1971).

13/ The earlier study by Fisher and Kaysen is a notable exception. Fisher, F. M., and C. Kaysen, The Demand for Electricity in the United States, North-Holland, Amsterdam, 1962.

14/ A more complete account of this analysis may be found in "Power Generation: Conservation, Health, and Fuel Supply," by L. D. Chapman et al., Sept. 1974.

15/ Graham, R. E., et al., Survey of Current Business, 52, pp. 22-48, April 1972.

16/ "Project Independence," MIT Energy Laboratory, Policy Study Group, Cambridge, Mass., March 1974.

17/ ADL *op. cit.*, Table 41, p. 170.

18/ This projection is derived from nine regional National Electric Reliability Councils. "Utility Fuel Requirements, 1974-2000," Draft, Task Force on Utility Fuels of the National Power Survey, Federal Power Commission, 1973.

19/ ADL *op. cit.*, Table 41, p. 170.