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THE FUTURE DEMAND FOR ELECTRICITY IN THE NASSAU-SUFFOLK REGION

T. Owen Carroll, Philip F. Palmedo, and Robert Stern

December 1977

Policy Analysis Division
National Center for Analysis of Energy Systems
Brookhaven National Laboratory

Institute for Energy Research
State University of New York at Stony Brook

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EXECUTIVE SUMMARY

Traditional approaches to load forecasting for electric utilities are based primarily upon extrapolation of historic trends and consider the electric sector is isolation from other fuel forms. In more recent years, the Long Island Lighting Company (LILCO) has turned to improved techniques utilizing econometric forecasts of short-range growth in electrical demand, logistic curves for long-term estimates, and a multiplicity of other techniques and specific forecasts prepared by outside consulting groups. However, within such forecasts, it is often difficult to identify specific impacts of conservation, new technology, fuel substitution, and the like both in terms of maximum potential increase or decrease in the demand for electricity and the likelihood that such shifts in the demand for electricity will be realized.

Recognizing this, the Long Island Lighting Company contracted with BNL to establish a new methodology for load forecasting and to prepare independent forecasts of the demand for electricity in the LILCO service area. The method includes three specific objectives. The first are:

- . Demand for electricity should be placed in a total energy perspective so that substitutions between electricity and other fuels can be examined.
- . Assess the impact of conservation, new technology, gas curtailment, and other factors upon demand for electricity.

A detailed analysis of changing levels of demand for electricity, and other fuels, associated with these new developments is founded upon a disaggregated end use characterization of energy utilization, including space heat, lighting, process energy, etc., coupled to basic driving forces for future demand which are population, housing mix, and economic growth in the region. The range of future events covers conservation, heat pumps, solar systems, storage resistance heaters, electric vehicles, extension of electrified rail, total energy systems, and gas curtailment. Based upon

cost and other elements of the competition between technologies, we assess the likelihood of these future developments. An optimistic view toward conservation leads to "low" electricity demands, whereas rapid development of new technologies suggests "high" demand for electricity.

While many emerging technologies represent total energy savings or particular savings in natural gas and oil utilization, they shift demand toward increasing market shares for electricity. The market share for electricity in the LILCO service area is expected to increase from 8% at present to about 18% in the year 2000.

While the construction of the disaggregated forecast clarifies future developments and their individual contributions to demand, the method lacks an important perspective critical to the utility planning function. Though a future scenario can be identified which leads to a large demand for electricity, how likely is it that demand will reach, or indeed exceed, this level? Ideally, planning will be founded upon probabilities that given levels of demand for electricity will be realized. Consequently, our third objective is:

Construction of the probability distribution of the demand for electricity.

Our approach has been to establish approximate probabilities for conservation measures and new technology and combine these into cumulative probability distributions for selected years, shown in Figures i and ii. The results yield distributions skewed to the low side in the short-run, reflecting likely conservation but little new technology, and skewed to the high side in the long-run. More importantly there are substantial probabilities (20-30%) of demand for electricity exceeding the upper bounds of a traditional utility forecast of "high" demand.

Two final points are in order. First, this study was limited to an annual requirements forecast. However, new technologies often may have very different load profiles from devices currently utilized. In some instances, the potential impact upon peak load forecasts may out-

weigh the effects upon annual requirements, and load implications certainly deserve detailed study to complete the projection of future LILCO system electric loads.

Second, this method of energy demand projection is not fully evolved. The basic concepts are established and the resulting forecasts are as valid as any for the region and considerably more enlightening with respect to detailed elements of future electricity demands. However, the method will benefit from greater input from econometric analysis. In addition, the social and utility investment costs associated with under and over-estimating electricity demand would be useful in establishing the sensitivity of capacity expansion planning to the probability distribution.

Figure i. Probability distribution of 2000 electric demands.

Figure ii. Cumulative probability distribution of 2000 electric demand.

I. INTRODUCTION

Until recently, we could feel secure in projecting electrical load growth from past trends and some straightforward assumptions concerning future patterns of energy consumption. Events of the last few years, however, have made the task of predicting the future considerably more uncertain. More precisely, we have become aware of how uncertain our projections of future demand have always been. We have learned that actions taken by oil exporting countries half way around the globe can have a dramatic effect on both the availability and price of all fuels in this country. Three major uncertainties have clouded our crystal ball: the future availability of fuels, the prices of fuels, and the demand for energy at various price levels. The future demand for electricity in a given region is subject to even larger uncertainties than apply to total energy demand since possible substitutions between electricity and other fuels can, at least over the longer term, lead to large differences in electrical demand.

Clearly the traditional approach of electrical load forecasting, based upon historical trends and considering the electrical sector in isolation, must be reassessed. An approach must be developed which is broader and more open to future possibilities. More specifically, there needs to be developed a method of looking at future electricity demand that incorporates three elements:

1. The demand for electricity should be placed in a total energy perspective so that substitutions between electricity and other fuels can be examined.
2. The determinants of future demand (number of houses to be heated, effects of insulation, efficiencies of alternative technologies, miles of passenger transport, etc.) should be explicit so that the results of alternative policies (insulation standards, mass transport construction, etc.) and price structures can be dealt with directly.

3. The basic uncertainty of future energy demand should be explicitly recognized in the projection methodology.

The last element is of particular importance to the use of the projections. Whether estimates of future energy demand are used to formulate public policies or are used as the basis for utility capital investment decisions, an erroneous projection can lead to significant costs to the public. The investment decision process and the analysis of future demand should be looked upon as a single problem, not two separate ones. The projection should be formed to match the uses to which it will be put.

The integration of future energy supply and demand in this study was based on the Reference Energy System approach. This approach was developed at Brookhaven National Laboratory for national energy systems analysis⁽¹⁾ and has recently been applied to the New York City region.⁽²⁾ The level of detail in end use (space heat, etc.) and fuels consumed (oil, etc.) permits assessment of both technological options (heat pump, electric car, etc.) and policy options (space heat conservation strategy, etc.). Both the impact upon total energy demand and the implied trade-offs among fuels are readily determined. This approach thus satisfies the first two requirements for a broader based methodology for electricity demand projection specified above. The third requirement has been satisfied by constructing a probability distribution of future electricity demand. That distribution was created by evaluating the probability of certain actions (such as increased electrification of the railroad) that could increase or decrease the future demand for electricity.

This study has two purposes. It was designed as an exploratory effort at developing a general methodology for electrical demand projection that would satisfy the three criteria noted above. It was also designed to fulfill the immediate needs of the Long Island Lighting Company (LILCO) in obtaining an independent view of the future electrical demand in their service area (basically the Nassau-Suffolk region). It was supported jointly by LILCO and the Energy Research and Development Administration, through the Brookhaven National Laboratory Regional

Energy Studies Program. It has drawn upon work currently under way at Brookhaven National Laboratory and the State University of New York at Stony Brook to develop a model linking land use patterns and energy consumption. The latter work is supported by the Federal Energy Administration.

The methods of energy demand projection developed in this report should not be looked upon as fully evolved. We are convinced that the basic concepts are sound and that the resulting projections are as valid as any others for the region. But there is much further development to be pursued. For one thing, the technological approach used here should be integrated with methods or insights from econometric analysis. We also consider that the use of a probability distribution of future demand is particularly worthy of further extension. In future work one should relate the probability of various levels of demand with the social cost of under- or over-estimating demands and the relevant investment decisions of the electric utility. When this has been accomplished there will be a more sensitive interface between those public and private decisions affecting energy supply and analyses of energy demand.

We must emphasize again the large uncertainties that dominate any consideration of the future in energy at this moment in history. Any analysis which claimed to predict a unique future must be dismissed as naive and useless for decision-making. What is needed is a framework for analysis within which prudent policy can be decided upon. It is in that spirit and toward that goal that this study is directed.

II. BASE CASE FUTURE DEMAND: A TOTAL ENERGY PROJECTION

A. CURRENT ENERGY PATTERNS

From a broad energy perspective, the Long Island region is typical of the Northeastern part of the United States. It is an energy consuming region with no indigenous energy sources currently being exploited.* Its distance from domestic resources and its accessibility by foreign oil sources have produced an unusually high dependence on foreign oil. High energy prices along with other factors have led to a relatively low use of energy by industry and thus a total per capita use of energy which is below the national average.

In quantifying the energy picture for Long Island, we shall take 1972 as a reference year. That is the last year for which a complete picture can be amassed.

Natural Gas

For Long Island, LILCO is the distributor of gas with a net gas supply in 1972 of 56.1 billion cubic ft. (bcf). The major categories of end use were: residential 28.1 bcf, commercial 13.1 bcf and other 2.9 bcf. Presently, new connections to the gas system are not accepted due to the supply shortage of natural gas. Residential users of gas are given the highest priority, meaning they would be the last group to be affected by curtailments of gas.

In 1972, LILCO's principal gas suppliers were Trans-Continental Gas Pipeline Company (TRANSCO), Texas Eastern, and Tennessee Gas. They provided 87% of LILCO's requirements; alternative sources of gas, namely imported liquified natural gas (LNG) and synthetic gas from petroleum

* It is incorrect to say that there are no energy resources on Long Island. The sun that shines on its surface and on the surrounding water, the energy in the waves along its southern coast and in the winds that cross it, and the heat of the earth deep beneath it represent energy resources thousands of times greater than the total energy used by the current Island population.

products represent minor contributions at the moment. Domestic reserves of natural gas have been decreasing since 1970, however, and production is not expected to increase substantially even with anticipated price increases. Thus, expansion of natural gas use in the region will depend on the increased use of alternatives, particularly LNG. A summary listing of LILCO's gas supply requirements and capacity for the year 1972 is given in Table I.

Table II summarizes the retail prices of gas in recent years. Individual sector prices are higher than U.S. average due to greater than average distance from the large gas fields, low load factors, and limited storage facilities. As a result, Long Island residents pay almost twice the national average price for their gas supply.

Oil

Long Island's geography lends itself to waterborne oil shipment. Since the region has neither oil wells nor refineries, all oil is delivered as refined products, as shown in Table III. Tankers and barges deliver 60% of incoming oil, while almost all the remaining supply arrives by pipelines. Port Jefferson harbor receives 45% of waterborne oil, East Rockaway 35%, and eight other smaller ports the remainder.

The East Rockaway terminal is adjacent to New York City, and it is expected that most of the distillate deliveries there (7.7 million barrels) represent flow through the region to other locales rather than a contribution to the Nassau-Suffolk supply. Another 7.8 million barrels of distillate are delivered to Nassau County ports sufficiently near New York City to allow distribution there.

As indicated in Table III the petroleum product mix in the region is 54% distillate (fuel) oil, 19% residual oil (primarily utility fuel), and 21% gasoline. The small supply deficits indicated for residual oil and gasoline might be filled by truck deliveries into the region. Allowing for flow through the region, the distillate oil excess remains large. Because of the difficulties of data-gathering in a highly competitive market, it is not clear whether this excess represents flow-through from other receiving ports and/or a change in the level of storage.

Table I

LILCO NATURAL GAS BALANCE - 1972*

(Billions of cubic ft.)

<u>Supply</u>		<u>Sales</u>	
Purchases	67.221	Residential	28.148
Storage Withdrawal	0.599	Commercial	13.129
Manufactured Gas	0.210	Terminable	1.576
Con Edison Exchange	0.243	Interruptible	6.130
Subtotal	68.273	Subtotal	48.983
Placed in Storage	- 9.109	LILCO Use	4.308
Unaccounted for	- 2.844	Sales to other Utilities	3.029
Subtotal	-11.953	Subtotal	56.320
Net Supply	56.320	Sales	56.320

* Source: Report of LILCO to NY Public Service Commission, 1973.

Table II

SUMMARY OF LILCO AND U.S.AVERAGE GAS PRICES BY CUSTOMER CLASS

(\$/Thousand cubic ft.)

	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>
Average U.S.	0.63	0.67	0.73		
LILCO	1.68	1.73	1.90	1.98	2.20
Residential U.S.	1.06	1.12	1.19		
LILCO	2.04	2.12	2.28	2.35	2.55
Commercial U.S.	0.81	0.85	0.91		
Commercial Industrial LILCO	1.20	1.22	1.39	1.46	1.69
Industrial U.S.	0.38	0.41	0.45		

Sources: 1972 Gas Facts: Sales and Revenue Data by State.

Annual Reports from LILCO to the NY Public Service Commission.

Table III.

NASSAU-SUFFOLK OIL BALANCE - 1972

(Million barrels)

	<u>Distillate</u>	<u>Residual</u>	<u>Gasoline</u>
<u>SUPPLY</u>			
Waterborne	17.7	18.6	26.8
Pipeline (cap. 70.1 bbl/yr)	35.6	-	-
Subtotal	53.3	18.6	26.8
less estimated flow through	7.7	-	-
Total	45.6	18.6	26.8
<u>DEMAND</u>			
End Use	37.4	1.0	28.3
LILCO	1.2	19.7	-
Total	38.6	20.7	28.3
NET SUPPLY UNACCOUNTED FOR			
Excess (Deficit)	7.0	(2.1)	(1.5)
<u>STORAGE CAPACITY</u>			
Oil Distributors	- - - - - 8.2 total - - - - -		
Residential	5.7	-	-
Commercial-Industrial	5.7*	-	-
LILCO	negl.	2.4	-

*Since commercial-industrial annual oil consumption is approximately equal to that of the residential sector, we estimate storage capacity as the same also.

Oil storage capacity on the Island is considerable and is the principal buffer against short term supply perturbations. But it is difficult to estimate both total capacity and normal oil storage. The residential sector alone, in home fuel tanks, has an estimated maximum storage capacity of 5.7 million barrels of distillate, or 26% of all storage capacity. However, it is difficult to say what proportion of this storage is utilized at any time. If all distributors were to hold distillate oil, maximum total storage on the Island for distillate would be 19.6 million barrels. With the supply product mix shown (54% distillate) and homeowner's refill schedule (average storage 3/4 tank), we might anticipate actual distillate storage of about 13 million barrels or one-third the annual demand. This actual storage should fluctuate relatively little from one year to the next.

Regional oil prices appear to remain close to average U.S. prices, probably because of the highly competitive nature of the market for oil sales, unlike the regulated market for gas and electricity production and distribution. Moreover, regional differences in electric generation fuel mix and location with respect to gas sources cause price disparity among fuels. At a time (1974) when natural gas prices were 90% higher than the U.S. average and electricity was 25% higher than the U.S. average, oil was only 4% above the U.S. average price per gallon of 35 cents per gallon. Even with seasonal changes in oil prices, there is seldom more than a 15% spread between regional and U.S. prices. Moreover, there is little difference in price between sales to residential, commercial, and industrial markets.

Oil prices have doubled from 20 cents per gallon in 1972 to 40 cents per gallon in 1974. These price changes and those that will result from the deregulation of natural gas, the uncertainty of world oil prices, and the new development of nuclear power on the Island all serve to emphasize the uncertainty of major determinants of future energy supply-demand patterns.

Electricity

The Long Island Lighting Company is the almost exclusive

supplier of electricity on Long Island, supplying 97% of the population and generating 12,786 million kilowatt hours (kwh) per year. In 1972 LILCO generated all but .2% of its electric sendout, with the remainder purchased from Connecticut utilities, Con Edison, and other New York Power Pool utilities.

As can be seen from Tables IV,V, and Figure 1, LILCO deviates significantly from both national and state patterns in terms of customer sales, revenues, and generation statistics. New York State sales by customer class are spread evenly over three classes: residential 29.3%, commercial 29%, and industrial 29.8%, as compared to 46% of LILCO sales being residential and 51% commercial and industrial. In terms of electric generation, Long Island had no hydroelectric or nuclear generating facilities as of 1972, which deviates more from New York State than the nation as a whole. Added to the very high percentage use of oil is the very large fraction of that oil that is imported; 95% in 1972, compared to a national average figure of 58%. These two factors lead to a high dependence of electricity costs on price increases in the oil sector and also a high vulnerability to cut-off in supply.

1972 Energy Use by Fuel Type

The overall fuel consumption pattern in the Nassau-Suffolk region is compared to that in the Northeast and in the country as a whole in Figure 2. Again, the high dependence on oil is of particular note.

B. APPROACH TO PROJECTING FUTURE DEMAND

Most energy projections are based on an analysis of historical trends and the continuation of those trends into the future. In some projections, but by no means all, an attempt is made to adjust future demand for changing conditions, say increased energy prices, through the use of historically-based correction factors, say price elasticities of demand. When used with sophistication such projection methodologies can be powerful indeed. But for policy analysis they suffer from at least two defects. The first is that historically-based correction

Table IV

ELECTRICITY SALES BY CUSTOMER CATEGORY - 1972

(Percent of Total Sales)*

<u>Category</u>	<u>U.S.</u>	<u>N.Y. State</u>	<u>LILCO</u>
Residential	32.4	29.3	46.5
Commercial	23.0	29.0	51.8
Industrial	40.5	29.8	
Other	2.7	7.6	1.7

* Totals may not add to 100% because of rounding.

Sources: Edison Electric Institute, Statistical Yearbook of the Electric Utility Industry for 1972.

LILCO Annual Reports to the NY Public Service Commission.

Table V

FUEL MIX FOR ELECTRICAL GENERATIONU.S., N.Y. STATE and LONG ISLAND

(Percent)

<u>Fuel</u>	<u>U.S.</u>	<u>N.Y. State</u>	<u>Long Island</u>
Hydro	15.6	26.9	0
Fossil Steam	80.9	66.5	95.2
Nuclear Steam	3.1	6.3	0
Gas Turbine	0.4	0.2	4.8

Note: Totals may not add to 100% because of rounding.

Figure 1. 1972 electricity consumption patterns.

factors may not be applicable to future conditions. For example, price elasticities of demand based on cross-sectional analysis and periods of falling energy prices probably do not form a basis for anticipating the response to rising energy prices. The second shortcoming of conventional energy projection methods is that they do not deal with the specific determinants of demand. With such projections, for example, one does not have the basis for examining the effect of new land use patterns, insulation standards, or fuel substitutions.

An alternative approach to energy demand projection has been used in this work. First, the underlying determinants of demand are specified. These are the numbers of households requiring heating (divided among single and multi-family dwellings), the number of vehicle miles of transportation, etc. Secondly, specific technical assumptions are made regarding the fuels required to fulfill those demands. In the space heating area, for example, this requires the specification of future levels of insulation, temperature levels, the fraction of future space heating demand satisfied by oil, gas, and electricity, and the efficiency with which those fuels are used.

This approach to energy demand projection requires not only considerable technical information but also the exercise of considerable technical judgment. However, it results in a picture of future energy which is transparent with regard to its assumptions and is ideally suited to variational analysis. The basic assumptions used in the projections are as follows:

Residential Sector

Population in 1972 in Nassau and Suffolk counties was estimated at 2,674,362. The growth rate is expected to be 25% between 1972 and 1985, and 22% between 1985 and 2000. The number of households which more accurately reflects residential energy use, was used as a basis of projection for the residential sector rather than the population. The number of households is anticipated to increase from 747,662 in 1972 to 1,010,000 in 1985, and 1,320,000 in 2000.⁽³⁾ The mixture of single and multi-family dwelling units is expected to change from 84% single family

Figure 2. Energy use by fuel type* - 1972.

*Excluding utility use.

homes in 1972 to 80% and 78% in 1985 and 2000; and for multi-family homes from 16% to 20% and 22%.^(3,4) The fuel fraction for electricity is expected to increase for residential water and space heating. By 1985, 22% and 31% of all new single and multi-family dwelling units are anticipated to use electric space heating and 43% of all new dwelling units are anticipated to have electric water heating. Due to supply restrictions, the number of gas customers is expected to remain the same as in 1972.

Commerce and Industry

In the commercial and industrial sectors, non-residential floorspace projections were the primary basis for energy demand analysis. Light industry composes almost all of the industrial activity in the bi-county region with the industrial sector utilizing approximately 15% as much floorspace as the commercial sector. Growth of non-residential floorspace between 1972 and 1985 was estimated at 2% annually and 1.5% annually between 1985 and 2000.⁽⁵⁾ The industrial and commercial fuel mix has been changing and because of restrictions on the supply of gas, demands for gas in 1985 and 2000 have been held at the same level as in 1972. Northeast regional estimates from the 1970 National Power Survey were used to estimate a commercial and industrial growth rate for miscellaneous electric demand of about 6.0% annually from 1972 to 2000. Although this growth rate may appear high in light of the current economic climate, this is the major non-residential demand category in which new uses for electricity can be captured. Total energy demand for industrial process heat was estimated to grow at 2.6% per year.

Transportation

The fuel consumed by automobiles was projected on the basis of the number of vehicle miles traveled in the bi-county region. A continued increase in automobile travel, 3.5% annually, is estimated from 1972 to 1985.^(5,6) The rate of growth is expected to decline and the number of vehicle miles traveled is projected to rise 1.4% annually from 1985 to 2000.^(5,6,7) Projections for fuel consumption by commercial vehicles

(taxi, truck, bus) were based on population growth. Railway use^{*}, and its corresponding energy demand, is assumed to remain constant at the 1972 level, which reflects the past consumption trend between 1960 and 1972. The energy consumption for railway in 1972 is stated as the normal annual demand. In fact, the 1972 rail strike reduced electric consumption below this level.

The key assumptions used in projecting future demand are summarized in Table VI.

C. ENERGY DEMANDS

Given the determinants of future demand cited above we have defined two sets of technological coefficients to derive future fuel needs. The first set of coefficients defines what may be called a "historical growth" case in which future demand is not influenced by recent energy price increases or trends towards conservation. The second case is referred to as the "base case" in which more efficient energy practices (e.g. increased insulation) are brought about by higher energy prices. Such effects have been observed in the region. Notice that for the purposes of this initial analysis, energy price increases are assumed to affect the technological coefficients (e.g. through amount of insulation) but not the underlying determinant of demand (e.g. rate of commercial growth).

Historical Growth

All of the technical assumptions made in going from determinants of demand to energy requirements are specified and referenced in Appendix A. The unit electricity demands per household in the residential sector, and per square foot of commercial-industrial floorspace, are summarized in Table VII. Electric water heat in the region is not common (4% saturation in 1972), but is expected to grow rapidly. The same may be said for central air conditioning, although the effects of

* Electrified railway in the Nassau-Suffolk region will be a point of discussion later in the report.

Table VI

BASIC ASSUMPTIONS FOR PROJECTIONS

	<u>1972</u>	<u>1985</u>	<u>2000</u>
Population ^a	2,674,362	3,343,000	4,078,000
Number of households ^a	747,662	1,010,000	1,320,000
Persons per household	3.58	3.31	3.09
Percent single family dwellings ^{a,b}	84%	80%	78%
Percent New Construction			
using electric heat ^c			
single family	22%	22%	
multi-family	31%	31%	
Commercial and Industrial floorspace, ^d sq.ft.	412,000	513,000	664,000
Automotive vehicle miles Traveled, ^e billion vehicle miles	13.4	20.9	25.6
Railroad use, billion passenger miles (Nassau-Suffolk region)	1.2	1.2	1.2

Sources: a. Reference 3.

b. References 3 and 4.

c. References 8 and 9.

d. Reference 5.

e. References 5, 6, and 7.

Table VII

ANNUAL UNIT ELECTRICITY DEMANDS - 1972Residential

	<u>10⁶ Btu per unit</u>	<u>kwh per unit</u>	<u>Saturation</u>	<u>kwh per household</u>
(Space heat)	(51.2) ^(a)	(15000)		
Water heat	16.4	4800	.04	190
Air conditioning central	11.0	3200	.081	260
room	1.5	440	.73	320
Lighting	4.4	1300	1.00	1300
Range	4.1	1200	.42	500
Refrigerator	5.1	1500	1.00	1500
Major appliances ^(b)	10.1	3000	.39	1200
Miscellaneous ^(c)	4.9	1400	1.00	<u>1400</u>
Total, non-space heat				6670 kwh

Commercial-Industrial

	<u>10³ Btu per square foot</u>	<u>kwh per square foot</u>
Space heat	134.2	39.3 ^(d)
Air conditioning	35.3	3.5
Lighting	22.5	6.6
Miscellaneous electric	17.5	5.1

(a) single family

(b) washer, dryer, dishwasher, freezer

(c) heating plant, tv, small appliances

(d) if supplied by electricity

future electricity prices on that demand are highly uncertain. The "miscellaneous" category includes everything from television sets to electric knives, and it is interesting to note these represent 20% of the total electrical demand of the typical utility customer. From the perspective of the utility, the "Residential-General" customer described in Table VII has a total annual use of 6670 kwh in 1972. The space heat demand represents about 11.5 kwh/sq. ft. for the single-family electrically-heated homes.

In the commercial-industrial sector, space heat represents 65% of the demand whereas in the residential sector about 60% of energy goes into space heat. The annual space heat demand represents about 1.6 gallons/sq. ft. of fuel oil (at 60% efficiency). Lighting is a large component of electrical demand and might be expected to offer substantial opportunity for conservation.

Base Case

The major conservation measures introduced in the base case are summarized in Table VIII and are drawn from Federal Energy Administration estimates,⁽⁸⁾ the RAND study of Los Angeles during the '73-'74 energy crises,⁽¹²⁾ and similar studies.⁽¹¹⁾ Nominal implementation rates for these measures are assumed. The overall energy projections describe no more than recent moderate conservation trends. In addition, new technology seems certain to include the heat pump and the electric car. Consequently, these have been introduced with modest implementation rates. Complete details on the unit demands and conservation measures appear in the fuel mix tables of Appendix A.

D. ENERGY SYSTEM REPRESENTATION

The Reference Energy System (RES) is the basic methodology used in this study for analysis of energy system changes occurring as a result of technological or policy adjustments.⁽¹⁾ This methodology serves basically two functions. It provides an integrated picture of the energy system, the demands satisfied by the system, total resource requirements, and associated environmental impacts. It also provides a framework within which the energy system impacts of policy

Table VIII

CONSERVATION MEASURES IN BASE CASE

Residential

- . Thermostat setback (winter)/advance (summer).
- . Efficiency improvements for water heaters, air conditioners, major and minor appliances.
- . Improved construction and insulation standards.
- . Improved burner maintenance.
- . Some retrofit of insulation, storm windows and doors.

Commercial - Industrial

- . Thermostate setback (winter)/advance (summer).
- . Lighting reductions.

Transportation

- . Improved gasoline mileage in autos.

(conservation, allocation, pricing, etc.) and technological options may be evaluated. Of particular pertinence to this study is the utility of the RES in examining substitutions between electricity and competing fuels. A RES consists of a set of estimated energy demands, the energy conversion technologies, fuel mixes, and ultimately, resources used to satisfy those demands, and a description of the environmental impacts associated with all elements in the system.

The format for the reference system is a network diagram which indicates energy flows and associated conversion efficiencies, along with the reference technologies used to accomplish the energy conversion. The system indicates the reference conversion processes used in the following activities, where each applies to a specific energy resource or form.

1. Extraction
2. Refining and/or conversion
3. Transport of primary energy source
4. Centralized conversion (e.g. electricity generation)
5. Transport or transmission and storage of secondary energy form
6. Decentralized conversion
7. Utilization in an end use device

A single path through the network reflects the application of a specific energy resource to a given demand category. Alternate paths and branches reflect the amount of substitutability that is feasible among different resources. Demand figures are exogeneously estimated for each reference year.

Associated with each link in the RES is the amount of energy flowing through the process and, in parentheses, the energy efficiency of the process or relative effectiveness of the fuel. Environmental emission and capital and operating cost coefficients can also be defined for each link.

Data Analysis and Sources for Reference Energy System

The basic documentation on the data included in the Reference Energy Systems is contained in the fuel mix tables of Appendix A. In the case of each demand category, such as residential space heating, the fuel mix tables contain; (1) the fraction of each fuel used to satisfy a given demand, (2) the efficiency of fuel conversion, (3) the energy input and output for each fuel and reference technology, (4) the basis for determining the consumption level of each demand unit (e.g. Btu/household for space heating), (5) the manner of projection and growth rates, and (6) references for 1-5 above.

Figure 3 is the Reference Energy System for 1972. The figures for energy use (under "Utilizing Device") have been derived from detailed analyses of consuming sectors (see Appendix A). The derived totals for natural gas and electricity consumption are close to figures based on an analysis of supply to the region, within 2% and 3% respectively. The energy supply-demand balance is shown in Table IX. The row in the table entitled R+C+I+T gives the total energy consumed by users in the region including electricity (at 3413 Btu/kwh). The row entitled "Electric Utility" gives the amount of fuel used by utilities. The sum of those two rows, less the amount of electricity consumed (37.4×10^{12} Btu) gives the total amount of fuel consumed to satisfy regional needs (555.9×10^{12} Btu). This does not take into account the inefficiency of the fuel supply system. As shown in the RES, if that is taken into account the total amount of resources consumed is 636.3×10^{12} Btu.

E. FUTURE ENERGY PATTERNS

Figures 4 and 5 are the Base Case RES's for 1985 and 2000, under the assumptions outlined in Section II and specified in the Appendix. Table IX also gives the supply demand balances for those years. The definition of the fuel mix for future electrical generation is not complete and should be carried out in collaboration with LILCO.

In Figure 6, we summarize the projection of total energy demand. In Figure 7, we show the projected electric sales to the Nassau-Suffolk

Table IX
ENERGY SUPPLY - DEMAND BALANCE
NASSAU-SUFFOLK REGION - BASE CASE
(10¹² Btu)

	1972			1985			2000		
	Gas	Oil	Elec	Gas	Oil	Elec	Gas	Oil	Elec
<u>Residential</u>									
Space Ht	19.2	100.9	.4	17.5	110.5	3.4	17.0	132.8	5.9
Wat. Ht	3.6	14.5	.5	3.4	18.1	1.9	3.4	22.0	4.1
A/C			1.5			1.9			3.0
Light			3.3			4.4			5.8
Range	4.7		1.3	4.7		2.4	4.7		3.6
Refrig			3.8			5.0			8.1
Major Appl.			3.0			5.7			9.0
Misc. Elec.			3.7			6.2			8.9
R-Subtotal	27.5	115.4	17.5	25.6	128.6	31.7	25.1	154.8	48.4
<u>Comm & Indus.</u>									
Process Ht*	4.5	6.5		4.5	11.4	-	4.5	18.4	-
Space Ht.	13.6	92.5		12.1	107.3	1.9	12.1	134.2	4.0
A/C			2.8			4.4			7.0
Light			9.3			9.6			12.0
Misc			7.2			15.6			34.9
C+I-Subtotal	18.1	99.0	19.3	16.6	118.7	31.5	16.6	152.6	57.9
<u>Transport</u>									
Auto		123.3			129.5			112.9	4.7
Commercial		22.8			42.1			31.4	
Rail		1.6	.6		1.6	.6		1.6	.6
T-Subtotal	-	158.7	.6	-	173.2	.6		165.9	5.3
<u>TOTAL</u> (R+C+I+T) x10 ¹² Btu	45.6	373.1	37.4	42.2	420.5	63.8	41.7	473.3	111.6
Electric Utility	4.2	133.0	(37.4)		n.a.			n.a.	
Total Fuel Consumed	49.8	506.1							
*Coal Negligable

Note: Includes electricity consumption, excludes utility fuel consumption.

Figure 6. Nassau - Suffolk region, growth of energy demand.

Figure 7. Growth of electric sales to the Nassau - Suffolk region.

region. The derived annual growth rate for electricity is 4.2% from 1972 to 1985 and 3.8% thereafter as indicated in Table X.

Also shown in Figure 7, is the growth of electrical demand as projected by LILCO.⁽¹⁰⁾ The LILCO figures include a small amount of power (0.2×10^9 kwh) sold to portions of their service area outside the Nassau-Suffolk region. Although we have calculated a somewhat lower growth rate in our base case between now and 1985, the projected growth rate between 1985 and 2000 is similar to that estimated by LILCO. The market share for electricity (electrical Btu's sold/total Btu's consumed) is expected to increase from 8% in 1972 to 18% in 2000.

The difference between the LILCO and BNL projections may be expressed also in terms of the year in which a given level of demand is attained. The electric sales estimated by LILCO for 1985 would be realized about the middle of 1986 in the BNL case. Similarly, the 1995 sales estimated by LILCO would be realized instead about 1998. However, these differences of less than 3 years in the projected date for achieving a given electric sales level are quite small in comparison with the overall uncertainties in the time frame for planning and constructing additions to electric generation capacity.

It should be emphasized again that these are not to be construed as predictions of the future. They are tentative reference energy balances that can now be used, along with the associated Reference Energy Systems, to examine the implications of alternative future conditions of supply and demand. That analysis will be the subject of the next section of this report. We will construct a rough probability distribution of future electrical demand and the implications of that distribution for electric generation capacity planning.

Table X

GROWTH OF ANNUAL ELECTRIC ENERGY DEMAND

(Billion Kwh)

	<u>1972</u>	<u>1985</u>	<u>2000</u>
<u>Residential</u>	5.13	9.29	14.18
annual growth rate	4.7%	2.9%	
<u>Commercial-Industrial</u>	5.66	9.23	16.96
annual growth rate	3.8%	4.1%	
<u>Transportation</u>	0.18	0.18	1.55
annual growth rate	0%	15.4%	
<u>Total Electricity Demand</u>	10.96	18.69	32.70
annual growth rate	4.2%	3.8%	

III. THE FUTURE DEMAND FOR ELECTRICITY

A. BASIC APPROACH TO PROJECTIONS

It bears repeating that it is very difficult to predict the implementation rates for conservation measures, new technological developments, and fuel substitution possibilities on the basis of past experience and past data. The cost of energy formed an almost negligible part of personal and business expenditures until very recently. In addition, the relative prices of fuels have not shifted significantly in recent years to properly estimate long-run elasticities of demand for total energy or individual fuels.⁽¹³⁾ Also, except for recent experience, widespread fuel shortages have not been evident. These factors prevent extrapolation of historical trends as a basis for predicting future energy demands. Consequently, in this work we have taken a new approach to electrical demand projection. The approach has two important features. First, as shown above, we have analyzed in some detail, the underlying determinants of energy demand and the actions being taken by consumers in response to higher energy prices. Although this approach places projections on a more firm physical basis, there is still large uncertainty in those projections in the 1985-2000 time period.

The second important feature of our method is designed to deal implicitly with uncertainty. This is accomplished by defining a set of alternative futures which might arise in response to varying future conditions. At the same time, a simple presentation of alternative futures is not enough. Planning for future electricity demand requires that we estimate the likelihood of these alternative futures, in order that we might establish present policies which will assure the ability to satisfy likely levels of future demand for electricity. We must construct approximate probability distributions of the electric demand forecasts. In fact, the most likely future electricity demand may not be the best basis for planning. If, for example, there is a significant

probability that the demand will be, say, 20% higher than the most likely level, planning must certainly take that into account. Planning, therefore, as the development of prudent public policy, must take into account not only the probability distribution of future demand but also the total cost to society of alternative construction programs considering that distribution. In this report our work stops short of those final considerations.

In previous sections, we have described the first two major steps in our approach to the analysis of future electricity demand. These are first, to establish a detailed picture of electricity use in a base year specifying the unit electricity consumption for each end use function (air conditioning, cooking lighting, etc.). Second, a base-case projection of electricity demand is constructed. This is based on projections of the underlying determinants of demand (number of households of various types, commercial floorspace, etc.) and the technical factors which translate those determinants into energy demand (device efficiency, levels of insulation, lighting level, etc.). In uses where electricity competes with other fuels, a base-case fuel mix must also be specified based on relative prices and consumer preferences.

We now describe the third step in the analysis, the construction of the probability distribution of future electric demand levels. This is carried out in five steps:

1. Develop a list of potential developments in conservation, new technology, or fuel substitution which can have impacts upon the demand for electricity.
2. Estimate the determinants of implementation of each development, which should include: a) cost factors such as capital cost, operating cost, and amortization or payback periods, b) engineering aspects such as maintenance problems and reliability, and c) personal convenience items such as ease of use, cleanliness, etc. where appropriate.
3. Establish alternative future implementation levels for each development and estimate the probability that a particular implementation rate will be realized.

4. Determine the impacts of potential developments upon the forecast level of demand for electricity and upon the market share for electricity versus other fuels.
5. Accumulate all impacts into an appropriate probability distribution for the total future electricity demand.

To estimate the likelihood or probability that the various conservation measures, new technology, and fuel substitutions will be realized is not an easy task. Ideally, one would use a Delphi sampling of experts in each of the new developments to be included in the electric sales analysis. However, the inherent uncertainties in even expert opinion of future trends suggests that a less sophisticated approach is appropriate for our first estimate of the probability distribution. For components of the electric demand, we assess the cost, engineering, and personal convenience implications and literature in the field which describes future trends and fuel substitution. These are combined into a qualitative statement of high or low likelihood. For construction of the probability distribution, these likelihoods are assigned a probability range relative to the base case. Both traditional high-low demand scenarios and the probability distributions are compared to show the degree to which the latter are more responsive to the needs of utility planning.

Our analysis is one in which individual components of electricity demand are identified for analysis. This should clarify discussion of the demand forecast. There will always be disagreement about projected futures and their likelihood and this method provides a mechanism for examining the implications of alternative assumptions.

For the moment we assume that the relative cost of fuels remains about the same into the future. For those end uses which might utilize a variety of fuels, natural gas generally offers the lowest operating cost; oil has a somewhat, but often not significantly, higher cost; and electricity is generally the highest cost option. Of course, capital cost of the end use device is also crucial. And perhaps most important is whether costs are a significant fraction of person or business expenditures. In general, we will find that our decisions regarding the imple-

mentation of new developments are not highly sensitive to the cost picture, and that large changes in relative fuel prices and/or the total cost of energy would be required to prompt a shift in the projected probability of success of the conservation measures, technology, or fuel substitutions considered.

In the residential sector, only heating and air conditioning seem to represent sufficiently large costs to the homeowner to attract his interest in cost reduction. Even here, air conditioning is not large in terms of annual expenditure but only monthly expenditure during the cooling season.* Consequently, there is relatively little economic incentive for changing patterns of use or technology for most household demands, other than heating and cooling.

Recent increases in electricity prices have created a public perception of electric resistance heating as an expensive option, and most builders have responded by virtually eliminating electric heat for new construction in the area.⁽¹⁴⁾ Natural gas is generally unavailable. Heating demand will thus be met by oil burner installations until new technology, shifting prices, or other factors intervene in the marketplace.

In the commercial sector, the overall cost picture is much the same. Space heat remains the largest demand, though often the system is a combined heating-ventilation-air conditioning (HVAC) one and will be a natural focus for potential savings. However, what distinguishes the commercial sector is the economic incentive to achieve savings in all areas of business expenditures. This should encourage interest in new developments in each end use demand and rapid implementation of new heating systems, lighting changes, and the like wherever they demonstrate real savings.

* Peak pricing could have an important effect in this use.

B. CONSERVATION MEASURES

We have considered virtually all conservation measures in constructing our base case. However, the level of implementation of those measures could well exceed what was assumed. Consequently, we must consider maximum potential implementation rates and their likelihood. Table XI summarizes the list of measures considered, and the discussion below will outline briefly the reasoning behind the estimated probability of implementation for each measure in constructing the "conservation case."

Though many of the conservation measures may be unlikely, it is still important to list them. The assigned probability of occurrence can reflect their likelihood. The values for implementation are based upon the following assumptions in the residential sector:

Lighting. Despite somewhat unpleasant color, fluorescent lighting is expected in the kitchen and bathroom and some living areas in new homes. This would reduce lighting demand by 10%.

Range. Microwave ovens have become more popular, but remain expensive. Personal preferences on taste and appearance of foods might be expected to shift slowly. About 50% of homes might have microwave ovens in 2000; and for each such household annual cooking energy might be reduced by 50%.

Water heat. Expenditures for water heat are large enough to generate an economic incentive for improvement. Efficiency increases of 10% can be achieved without excessive increase in cost. But it is not certain how much pressure will be felt by manufacturers to institute improvements. Recent device changes have introduced the 5% energy savings noted in the base case.

Appliances. Design improvements to achieve 10% energy savings are becoming common among new equipment. However, to achieve 20% savings begins to raise the first cost of appliances. Such improvements might be realized if the present emphasis on energy costs remains in advertising. However, the real cost savings to the consumer is

TABLE XI
CONSERVATION MEASURES
(Year 2000)

Item	Description	Basis (million hshld)	Savings Per Unit (kwh per househld)	Total Savings (million kwh)	Estimated Likelihood
. . . Residential Sector. . .					
Lighting	Increased use of flourescents; nominal- ly for kitchen & bath. in all new homes; re- duces lighting demand 10% (base case no reduction).	1.32	130.	170.	high
Range	Microwave cooking in 50% of all homes; reduces electric demand by 25% in such homes (base case no reduction)	.66	300.	200.	high
Water Heat	Improved design reduces energy demand 10% for all homes (base case 5% reduction).	1.32	240.	320.	high
Appliances (Major & Minor except air cond.)	Improved design re- duces energy require- ment by 20% (base case 10%).	1.32	440.	580	low
Thermostat heat setting	68°F day/60°F night; reduces demand by 20% in electric resistance and heat pump homes (base case 8% reduction)	.15	1380	200.	low
Refrigerator	Manual defrost in all homes; improved design. Reduces energy demand by 15% (base case no reduct.).	1.32	230.	300.	low

TABLE XI (Continued)

Item	Description	Basic (million hshld)	Savings Per Unit (kwh per household)	Total Savings (million kwh)	Estimated Likelihood
Air Con- ditioning setting	Set to 82°F (approx. 4°F above present setting) in all homes with A/C; reduces demand 20% (base case 10% reduction).	.24 (centr.) .79 (rm)	320. 90.	80. 70.	low low
. . . Commercial Sector . . . (million sq.ft)					
Lighting	Reduced lighting by 40% thru lower light levels & eliminate unnecessary light. (base case 20% re- duction)	664.	1.32	880.	low
Space condition- ing (HVAC system)	Improved new construct- ion & heat management systems reduces energy demand by 50% (base case 10%, thermostat only). Improved exist- ing heat management systems reduce energy demand by 20% (base case 10% thermostat only)	103.	18.	1900.	low
	Half of commercial floor- space utilizes HVAC systems Primary electric demand impact is reduced air con- ditioning loads.*	230.	7.	1600	low

* Since light industry has space conditioning demands similar to commercial, total non-residential floorspace is included.

small, and a 20% reduction in energy consumption seems somewhat unlikely.

Thermostat setting. The 68°F day setting for household heat is somewhat lower than present comfort preferences, but might be acceptable if dress changes. The 60°F night setting appears well below the present comfort level and seems unlikely to be widely adopted.

Refrigerator. The manual defrost refrigerator is an energy conserver. However, there seems little economic incentive and considerable inconvenience associated with it. A return to manual (or cycle) defrost units is unlikely.

Air conditioning. Efficiency improvements of 40% are assumed in the base case. Beyond this, first cost increase begins to offset operating cost decrease, and there is little net incentive to obtain EERs above 10. Settings as high as 82°F seem somewhat outside the range of comfort for most persons. Both these measures seem unlikely.

In the commercial sector, the major possibilities for conservation reflect these assumptions:

Lighting. Commercial space has traditionally been lighted in excess of minimum requirements. ⁽¹⁵⁾ Studies show 20% savings are achievable through better lighting management. With the addition of improved lighting systems and building design much larger savings should be achievable.

Space Conditioning. A number of mechanical systems engineering firms have instituted new designs for energy-conserving heating-ventilating-air conditioning (HVAC) systems and have also shown substantial savings through re-configuring existing systems.

It should be noted that the combination of most likely residential sector conservation measures is about 1000 GWH, which is relatively small compared to total annual electricity sales of 32,000 GWH in the year 2000. On the other hand, space conditioning conservation in the commercial sector holds the promise of some 6000-8000 GWH savings. But strong economic and institutional measures would be necessary to realize such savings, and consequently, it is not clear whether these savings can be achieved.

C. NEW TECHNOLOGY

The discussion of new technology is, by its very nature, an area of uncertainty. The implementation possibilities can vary depending upon the state-of-the-art for each technology, its costs, comparative convenience with respect to existing technologies, and public interest in the new development. Consequently, the potential impact upon electric demand varies widely. For utility planning purposes, it becomes important to assess all the factors which influence implementation in order to form an estimate of the likelihood of an impact from these new technologies.

The number of new technologies which might have to be included in this study is quite large. We choose to limit consideration to those new developments which may have significant impacts upon the demand for electricity, and for which there is a present basis, in either engineering design or working devices, for reasonable discussion of the long-range potential of the technology. The developments included are the heat pump, solar energy, electric vehicles, extensions of electrified rail transport, and total energy systems. Of course, there may be significant interfaces between some technologies which are competitive - electric vehicles versus electrified rail - and/or complementary - heat pump and solar heat - and these interfaces might play an important role in establishing implementation potential for either or both of such technologies.

The implementation rates for new technologies will be determined by costs, engineering qualities, and consumer aspects, as noted earlier. To define the costs, we will assume the relative costs for fuels remain more or less as they are now. Engineering reliability is a critical factor in acceptance of new technology. Low maintenance cost is often far less significant than reliability. That is, for new technology, maintenance cost and reliability do not directly trade off against one another. Personal aspects are also critical. For example, as power loss occurs in electric vehicles, how far is the nearest

recharge and how long does it take? Such factors will form the basis, which must be highly judgmental, for our estimates of the likelihood of realizing and implementing new technological developments.

Before we turn to individual technologies, we should briefly note the technology content of the base case. Only the heat pump and electric vehicles were assumed to have important impacts upon electricity demand in the year 2000. The heat pumps were not utilized in the commercial-industrial sector. The total annual electric sales to heat pump units was 230 million kwh, or about 0.7% of year 2000 sales. Electric vehicles were assumed to fulfill second personal car needs only, and to comprise 10% of vehicle miles in the year 2000. The electric sales to satisfy this demand were 1.4 billion kwh, or about 4% of year 2000 electric sales. Under conditions favorable to the growth of these technologies, their electric demand might increase substantially.

It is also important to note the amount of electric resistance heating in the base case. The use of electric resistance heating was assumed to increase following past trends. This led from relatively small fractions of electric energy now to 1.4 billion kwh and 1.2 billion kwh in the residential and commercial-industrial sectors, respectively, in the year 2000. These values are each about 4% of the total projected electric sales. Recent price increases for electricity appear to have virtually eliminated electric resistance heating in new construction. However, the recent introduction of electric resistance heaters with storage capability may lead to future interest in resistance heating. In the discussion which follows, we shall see that the heat pump is also an important determinant of demand for resistance heating.

With this brief reminder of technology contained in the base case, let us turn to more detailed study of individual technologies.

Heat Pump

A heat pump transports heat from a source to a sink. Often the sink is a higher temperature than the source and some external work must be supplied to cause the heat to flow "uphill." A working

fluid or refrigerant provides the means for transporting energy in the heat pump, and the external work is most generally supplied by a compressor driven by an electric motor. During the cold months, the building interior becomes the heat sink by placing the condenser indoors while the evaporator is placed out outdoors. In the warm months, the building interior becomes the heat source, and the evaporator and condenser are reversed. It is not necessary to physically switch the evaporator and condenser, but only to redirect the flow of refrigerant.

Heat pumps have some obvious advantages over oil, gas, and electric resistance heating. From an architectural point of view, they require little space, eliminate the need for a chimney, and operate without the potential hazard of an open flame. High heat output per unit of electricity purchased and a combined heating and air conditioning system make heat pumps attractive, and their clean, quiet operation has always been a key selling point.

However, there are currently a number of disadvantages to the use of heat pumps. Heat pumps have a high initial cost. Maintenance costs for heat pumps are, at this time, high, but this is due to lack of experienced service personnel. Right now, the coefficient of performance for heat pumps in the Long Island region is about 2. A coefficient of 3 appears to be the economic breakeven point.

Dealers also mention several problems with heat pumps. Various sections of a house have different requirements for space heat than for air conditioning. For example, the north side of the house needs the most intense space heat in the winter and the least air conditioning in the summer. A heat pump with a single ducting system for both air conditioning and space heat distributes one or the other efficiently over the house. Separate ducting is expensive, while ducting adjustments are inconvenient. Normally heat pump capacity is sized to the cooling load. On Long Island, under such an arrangement, the heat pump can fulfill heating requirements down to outdoor temperatures near 30°F. Below this point auxiliary heat must be supplied, usually through electric resistance heating. In addition, low outdoor temperatures have always been a deterrent to heat pump use. The problems

encountered are frost on the coils, and the large spread in operating temperatures in the Northeast which causes compressor failure, the single greatest contributor to short heat pump life.

Installation of heat pumps will depend upon real and perceived cost, tempered by other factors. Total cost over time, or first cost plus annual operating and maintenance cost, for various alternative forced air heating systems are shown in Figure 8.⁽¹⁶⁾ The low first cost of electric resistance heating was a critical factor in its past popularity among builders.

The high first cost for the heat pump shown in Figure 8 would discourage its use. However, two important factors may change this picture. First, technological progress seems likely to yield coefficients of performance of about 5, or double present values.⁽¹⁷⁾ Although the operating cost would then be cut in half, the resulting breakeven point between oil and the heat pump would still considerably exceed the 3-5 year ownership period typical of much of our society. Nevertheless, the cleanliness and convenience of an all-electric system might argue in favor of the heat pump for some consumers.

Secondly, any realistic comparison between heat pumps and other systems must include central air conditioning which is typically available with pump installation. The relative costs of residential heating/air conditioning systems are shown in Figure 9. The first cost of the heat pump installation is only about \$1000 above the oil-fired heating/electric air conditioning system. Operating costs are about the same. Consumer preferences might easily favor heat pump installation under these conditions.

A realistic future for the heat pump should acknowledge the large research and development effort under way in both the private and the public sector. Operating costs seem likely to decline as efficiency improves. Reliability should improve with engineering design changes to facilitate operation in colder climates. Even at present, the best pump is almost cost-competitive with oil for heating/electric air conditioning systems. Under these circumstances, the heat pump might

Figure 8. Residential space heating comparisons over time (new construction).

Figure 9. Residential heating/air conditioning.

displace oil burners for all new construction which includes air conditioning. This is shown in Table XII as a development with high probability.* Of course, a substantial overall increase in the cost of energy which discourages central air conditioning and/or an increase in the relative price of electricity which would inflate heat pump operating costs would inhibit widespread utilization of the heat pump in residential installations.

In the commercial sector, heating-ventilation-air-conditioning (HVAC) systems are well-suited to heat pump installations. The pump encounters less problems associated with frost on coils and compressor failure. And the heat pump is cost-competitive with oil-fired and gas fired systems, as shown in the cost comparisons in Figure 10. Indeed, the heat pump is becoming increasingly popular and might be expected to capture a large part of the commercial HVAC system market. In Table XII we estimate the maximum implementation of commercial heat pumps to include its use for all floorspace which is air conditioned that is constructed after 1977.

Solar Energy

Two quite different types of solar systems should be distinguished: 1) Thermal systems which utilize blackened panels and circulating fluids to collect and transmit heat directly for space and water heat; and 2) photovoltaic systems which use a solid state material to convert sunlight directly to electricity. Photovoltaic systems remain very expensive, though in the long run they might eventually become competitive.

* An additional factor might be considered. Long-term national policy is to discourage the use of oil wherever fuel substitutions are possible for various end use demands. Since additional natural gas is presently unavailable in the Long Island region and expected to continue to be so, electric heating is the viable option. Should federal tax policy or other means be used to drive oil use down, the heat pump would become the popular alternative for this region. A heat pump which works well could then be expected to capture the total market in new construction. This would increase heating-only demand for electricity by 810 million kwh above the heating/air conditioning demands noted in Table XII.

Figure 10. Commercial & industrial HVAC systems.

Figure 11. Residential water heat.

TABLE XII

POSSIBLE IMPLEMENTATION OF NEW TECHNOLOGY

POSSIBLE IMPLEMENTATION OF NEW TECHNOLOGY

Item	Description	Basis (thousands of hshlds)	Energy Per Unit (kwh per hshld)	Net Energy Growth (million kwh)	Estimated Likelihood
. . . Residential Sector. . .					
Solar/electric water heat-new construction	Solar/electric water heating systems in all new construction after 1985; provides 75% of energy requirements.	total 340	-3600	-500	high
	(Base case includes 45% electric water heat after 1985).	b.case 140	+1200	+200	high
		net 170			
Heat pump - new construction	Installed in 50% of new construction after 1977.(Base case 36,000 units).Includes all projected central air after 1977 plus fraction of rm air market.Total percent of homes with heat pump in yr 2000 is 15%	total sf 165			
		b.case 21			
		net sf 144	8100	+1160	high
		mf. 70			
Solar-assisted heat pump	Solar energy systems used in conjunction w. heat pump in new construction after 1985	s.f. 165	4050	+670	low
		m.f. 70	2250	+160	low
Storage electric resistance heating	Development of this new technology will replace electric resistance heating in the base case.	s.f. 72	-	-	high
		h.c. 72			
		net 0			
		m.f. 41			
		b.c. 41	-	-	high
		net 0			
. . . Commercial Sector. . .					
		(million square feet)	(kwh per sq. ft)	(million Kwh)	
Heat pump - new construction	Installed in all new a.c. floorspace constructed after 1977	206.	20.	+1100	high
	(Base case contained no heat pump).*				

*Since industry has heating demands similar to commercial, total non-residential floorspace is included.
 NOTE: s.f.= single family; m.f.=multi-family; b.c.=base case

TABLE XII (Continued)

Item	Description	Basis (million sq. ft)	Energy Per Unit (kwh per sq.ft)	Net Energy Growth (million kwh)	Estimated Likelihood
Solar-assisted pump	Solar energy systems used in conjunction w. heat pump in new air-conditioned floor- space constructed after 1985.*	133	10.	+1330	low
Storage electric resistance heating	Development of this new technology will replace electric resistance heating in the base case.	33 <u>b.c. 33</u> net 0	-	-	high
Total Energy systems	Primarily useful in large office/mall complexes which would have oil or gas-fired HVAC. Replaces various electric loads (lighting, etc.).	80	22	-1760	low

* Since light industry has heating demands similar to commercial, total non-residential floorspace is included.

For now, only the thermal system is sufficiently developed to assess accurately its potential role in the local energy system.

Implementation will again be determined by the combination of cost, convenience, etc. We will distinguish carefully between space heating applications and water heat. The magnitude of the first cost investment for each is quite different. Consequently, the possibilities for widespread utilization of solar technology differ significantly between the two. Investment costs argue against conversions to solar heat, so we are primarily concerned with installations in new construction.

Using existing technology for residential solar space heating requires collectors which cover from perhaps half to all of the roof area of a single home. To reduce the need for electric resistance backup, a several day heat storage capacity must be installed. Duct work in the home suffers from some of the problems of air flow balance mentioned for heat pump systems. These factors head to high first costs for solar energy systems and, as in the case of heat pump technology, would suggest solar not for heating alone but rather for heating-air-conditioning systems.

The combination of solar energy with the heat pump as the supplemental system is feasible now, but at the high costs shown in Figure 9. We assume that because of collector limitations the solar system is designed to supply 50% of heating demand.⁽¹⁸⁾ The break-even point with ordinary heat pump and/or oil installations is about 12 years, though this could decrease as the solar system supplies larger fractions of the heating load. At present, these solar costs are probably less an inhibition to its use than its uncertain reliability. There has simply not been sufficient time to study the real lifetime of components of solar energy systems, particularly collector coatings.

Should solar energy costs remain about as at present, there will be little incentive for widespread use of solar energy in residential space heating - air-conditioning systems. On the other hand, if first costs decrease substantially, and/or there are substantial increases in the cost of all fuels, the incentive for solar space heating

would rise. In the summary Table XII, we suggest that the testing period for large solar systems will be long, but there is a small probability of their widespread utilization by the year 2000.

In the commercial sector, the outlook for solar energy systems is much the same. There are some existing commercial installations, but these are primarily experimental. Again, the outcome of these experiments will suggest whether solar is well suited to widespread utilization.

Solar water heating differs from space heating in one significant aspect: first cost. Systems are available on the market for less than \$1000. The comparison between alternatives for water heating is shown in Figure 11. Solar can be considered competitive with electric. In many cases, homes with gas- or oil-fired space heat will, or already do, utilize electric water heat to provide larger storage capacity, and again solar would be competitive. The relatively low first cost also reduces the impact of uncertain reliability. Failure of components of the system represents less financial risk to the homeowner. Collector areas are relatively small and storage tanks are not excessively large. Since water heat is second only to space heat in total energy consumption in the home, there is a significant economic incentive to achieve savings. These factors all suggest a relatively high probability for solar water heating in new construction.

Storage Heating

While the problem of obtaining energy storage capacity of several days required for solar energy systems is quite difficult, sufficient storage to allow off-peak electric resistance heating appears tractable.⁽¹⁹⁾ Units available commercially utilize thermal storage cores with recharge periods of eight hours. Full heating loads can be sustained over both discharge and recharge cycles. The units for heating small spaces are roughly the size of room air-conditioners and do not disrupt the design of living and working space in homes or offices. Though not widely used in domestic installations, these storage heaters are finding a broad market in commercial buildings in Europe.

The cost comparison between these storage heaters and other space heating technologies is shown in Figure 8. Again, because capital or first cost is high, these storage units are cost-competitive only when heating plus air-conditioning systems are considered. At present utility rates, the storage heaters have comparable operating costs to ordinary electric resistance heating. However, since the 8 hour recharge could be scheduled as an off-peak demand, utility rates would probably be reduced for such customers. With a rate differential of two cents per kilowatt-hour (off peak rate \$.03/kwh), storage heat plus electric air-conditioning is competitive with existing heat pump installations and considerably cheaper than ordinary electric resistance systems.

An implementation rate for storage resistance heating is difficult to estimate. Present units are designed for relatively small space, which would limit their use. The storage heater appears to face stiff competition from heat pumps in all heat plus air-conditioning applications. However, the storage heater should become less costly in the future. It would then become a cost-effective substitute for ordinary electric heating. Whereas the heat pump would satisfy a market for heat-cool applications, the storage heaters would probably be directed to heating systems only. In this instance, the past trends in the installation of electric resistance heating in the base case analysis would be retained, as noted in Table XII.

Electric Vehicles

Electric automobiles will have an importance place in the transportation field when an economical energy storage system of high specific energy and high specific power is available.⁽²⁰⁾ The minimum requirement for a viable electric storage system is one that can power an electric vehicle 100 miles with a performance capability comparable to that of a small gasoline-powered car. Unfortunately, existing energy storage devices

fall far short of even this modest requirement.

The most promising developing in electric energy storage for automobiles is the lithium-sulfur high-performance battery. Until lithium-sulfur batteries or their equivalent are commercially available, electric cars will find little market as replacements for internal combustion engine (ICE) cars. Approximately 1000 lbs of lead acid batteries store the amount of energy contained in a gallon of gas. However, lithium-sulfur batteries with 80% less weight provide the same power. Also, it is expected that the cost of the lithium-sulfur battery will be significantly less than an equivalent lead acid battery. Lithium-sulfur batteries being developed at the Argonne National Laboratory are expected to meet performance goals and be ready for production after 1980.

Whether electric cars will replace automobiles powered by internal combustion engines depends on their relative economic and environmental merits. An important consideration is the overall energy efficiency in the process of converting energy from the primary source into useful transportation: primary conversion, transmission and distribution, storage in the vehicle, and secondary conversion in the vehicle's engine or motor. Because of the uncertainty in the efficiencies for each energy conversion step, high and low estimates are given in Table XIII. The electric car has greater overall efficiency; the gasoline car requires 20% more fuel (heating value) than the electric car. Where petroleum savings are essential, electric cars may prove even more appropriate since they can be powered by electricity derived from coal or nuclear energy.

Electric cars would have a high initial cost relative to gasoline powered cars. However, over the life cycle of the cars, the cost difference between the two would appear to be small as shown in Table XIV. In addition, time-of-day electric rates which give price incentives to electric users at off-peak hours might significantly decrease the cost of powering the electric car.

The electric car is expected to make its greatest short-run penetration in the automobile market as a second car. Typically, the second car is utilized for short trips, generally to work or for family business. It requires a much smaller range than the primary family car which is used for both short trips and occasional long trips and recreation. As a secondary car in a two-car household, a 100-mile range could be adequate for over 98% of driving days.⁽²²⁾ Finally, the second car is generally older, smaller, and less luxurious than the primary car. Short range, small size, and sparse accommodations then make the electric car a good substitute for the gasoline powered secondary family vehicle.

However, electric cars also may be expected to replace a certain number of primary cars in households with only one car. Urban dwellers and those who seldom take long trips by car may find it advantageous to own only an electric car. For urban and suburban households, an automobile with a range of 100 miles would be adequate for more than 90% of all trips.

The overall growth in the number of autos and trucks in the Long Island region is shown in Table XV. Increases in the number of automobiles follow population growth in the region, and it is assumed that the proportion of trucks to automobiles will remain constant at about 8%.⁽²³⁾ Within the overall growth in the number of personal vehicles are both replacement⁽²⁴⁾ purchases for households owning autos and first purchases of vehicles by new drivers, who are primarily single persons and young marrieds. Since our earlier discussion suggests the electric auto will find a wider market for second car use than for primary, the percentages of electric vehicle purchases shown in Table XVI are larger for two-or-more car households. The number of electric autos in service in the year 2000 could be 25% of the total number of automobiles. In the base case it was assumed that electric cars would account for 10% of vehicle-miles in 2000. The percentage of trucks purchased that are electric could be 33% throughout the period 1985-2000 so that electric trucks represent 33% of local trucks on the road in the year 2000.

TABLE XIII

COMPARISON OF THE ENERGY CONVERSION EFFICIENCY
OF AN ELECTRIC CAR WITH A GASOLINE POWERED CAR (20)

ENERGY CONVERSION EFFICIENCY %

Energy Conversion Step	<u>Electric Car</u>		<u>Gasoline Car</u>	
	Low	High	Low	High
Generating Plant	30	40		
Electrical Transmission	90	95		
Battery				
Charge	85	95		
Discharge	75	85		
Electrical to Mechanical	75	85		
Crude to Gasoline			80	85
Internal Combustion Engine			15	25
Transmission ^a			85	95
Gear Reducer			92	97
Overall Efficiency	13	26	9.4	19
Avg. Overall Efficiency	1	19.5		14.3

a - based on manual transmission. Automatic transmission may be 5-10% less efficient.

TABLE XIV

COMPARISON OF LIFE CYCLE COSTS
BETWEEN AN ELECTRIC CAR AND A GASOLINE POWERED CAR

(Cents per Mile)

	<u>Electric Car</u>		<u>Gasoline Car</u>	
	Low	High	Low	High
Fuel ^b	2.5	3.5	2.0	4.0
Pollution Control		0		.9
Upkeep		1.2		2.5
Vehicle Depreciation		2.6		2.4
Battery Depreciation	1.3	2.2		0
Financing		2.4		1.6
Taxes, etc.		4.5		4.3
TOTAL	14.5	16.4	13.7	15.7

b- Fuel costs are 60¢/gal gasoline & 5.0¢/kwh electric. Cost of temperature control not included.

TABLE XV
AUTO AND TRUCK STOCK

	<u>1960</u>	<u>1970</u>	<u>1985</u>	<u>2000</u>
Population	11,967,000	2,556,000	3,343,000	4,078,000
Households	522,000	700,000	1,010,000	1,320,000
No. of Households Owning Autos				
One car	327,000	303,000	455,000	663,000
% of households	62%	43%	45%	50%
Two or more cars *	154,000	340,000	485,000	590,000
% of households	30%	49%	48%	45%
no car	41,000	54,000	71,000	66,000
% of households	8%	8%	7%	5%
Total Autos +	650,000	1,017,000	1,474,000	1,902,000
Trucks °	52,000	82,000	118,000	152,000

* % With three or more cars are less than 7%.

+ Based upon average of 2.1 autos per "two or more car households."

° Constant ratio trucks/autos of 8%.

TABLE XVI
ELECTRIC VEHICLE STOCK

<u>Autos per Household</u>	<u>1985-1990</u>		<u>1991-2000</u>	
	<u>Total</u>	<u>Electric</u>	<u>Total</u>	<u>Electric</u>
<u>REPLACEMENT AUTOS</u>				
One	304,000	10% 30,000	814,000	20% 163,000
Two or more	375,000	25% 93,000	850,000	33% 282,000
<u>FIRST PURCHASE AUTOS</u>				
One	140,000	10% 14,000	280,000	20% 56,000
Primary Electric Auto				219,000
Second Electric Auto				<u>282,000</u>
Total Electric Auto				501,000
Total Purchases				1,944,000
% Electric				25%
Truck*		<u>Total</u>	<u>Electric</u>	
		156,000	33% 52,000	

* Constant ratio of trucks/autos of 8%.

Under these conditions, the electric consumption for vehicles becomes substantial by the year 2000. From Table XVI, there are 219,000 primary cars, 282,000 second cars, and 52,000 trucks which are assumed to travel 12,000 mi/year, 6,000 mi/year, and 12,000 mi/year respectively. Using an average energy consumption of .5 kwh/mi for autos and .75 kwh/mi for trucks,⁽²⁵⁾ the total electric sales to these vehicles will be 2590 million kwh.

Total Energy Systems⁽²⁶⁾

The total energy system for commercial or residential applications uses a prime mover for on-site generation of electricity and provides other equipment for useful application of the waste heat from the prime mover. Total energy systems generally serve a building or building complex within a single site. In these systems, fuel-burning turbine generators provide electricity, with waste heat used for hot water or space heating and cooling. Under favorable conditions, the electric energy requirements and the uses of the waste heat of a given system are so proportioned that the total amount of energy utilized by the total energy system is significantly less than would occur if electric energy was taken from a central utility system and the other energy requirements were supplied by fuel-burning equipment at the site. About one half of the energy that would be wasted in the combustion gases and condenser of a conventional electric power plant can be reclaimed for useful application. To the extent that this favorable balance of load occurs, there is good potential for energy conservation which yields savings in fuel costs, and in some cases, overall annual cost for energy.

Nearly all total energy plants are custom designed and most of the components are made to order by producers of equipment designed for other applications, e.g. construction or transportation equipment. The mechanical engineering firms which design total energy plants often choose components, systems, and controls that emphasize reliability at some expense in cost and thermal efficiency. As a result, actual performance

of many total energy plants has been below optimum levels. At the same time, other total energy systems presently in operation do function efficiently.

Since 1958, about 600 systems ranging in size from 0.2 to 20 megawatts have been installed in the United States. Only 5% of the total are residential applications, probably because of the low electric load factor in residences. More recently, the number of new total energy plants installed annually has decreased sharply with reductions in the level of promotional activities by the gas industry, the decline in construction of large, multi-purpose developments, and natural gas shortages. The aggregate electrical energy generation of presently installed total energy plants is between 0.1 and 0.2% of the total national electrical energy generation at this time. Significant numbers of smaller total energy systems have been removed from use after a few years service because of high maintenance costs, poor reliability in electrical service, inadequate supervision, and other causes. Most of the reasons why total energy systems have not gained wider application in the past decade are traceable to the fact that the total energy concept has not as yet emerged as an industry in itself nor has it been embraced as a part of the energy utility industry.

A total energy system is not usually considered to be economically feasible for less than about 200 dwelling units. Groups of single-family dwellings are generally not appropriate because of institutional restrictions against crossing public thoroughfares. Therefore, residential installations will be restricted to large apartment buildings and apartment complexes. However, no land on Long Island is presently zoned in county or town master plans for townhouse or apartment complexes of more than 200 units. The construction of such units would require rezoning.

Associated with population growth in the Nassau-Suffolk region, commercial floorspace is projected to increase by 250 million square feet. In hospitals, commercial and industrial complexes, and large institutions with more than 100,000 square feet of floorspace, total energy systems would be a technically viable energy option. Some

30% of new floorspace would fall into this category. However, in light of continuing institutional problems of ownership and maintenance of systems and the engineering requirements for balanced load, widespread utilization of the total energy system is not likely.

D. OTHER DEVELOPMENTS

In this section, we discuss briefly two other future developments which might increase the demand for electricity: plans for the conversion of diesel rail lines to electrical service and the possibility for significant shifts from natural gas to electricity.

Electrified Rail

There are three main rail lines of the Long Island Railroad (LIRR) system in the Nassau-Suffolk region. The North Shore line runs to Port Jefferson and is currently electrified to Huntington. The Main line runs through Lake Ronkonkoma to Greenport and is electrified to Hicksville. The South Shore branch runs to Montauk and is electrified to Babylon. Plans for the extension of electrified service⁽²⁷⁾ include all lines except that from Patchogue to Montauk, which would remain diesel. This electrification would require large capital investments. In light of the failure of recent state transportation bond issues incorporating funding for electrified rail, the unlikely prospect for future bond issues as well, and the long planning horizon for such projects, electrification of service is not anticipated within the time frame of this study. However, it is necessary for planning purposes to have some idea of the potential electric demands for rail service.

Passenger movements on the Long Island Railroad are shown in Table XVII. The overall passenger's average trip length is estimated at 25 miles, or about 35 miles for passengers boarding on the diesel lines and 20 miles for passengers boarding in the electrified sections. Total annual ridership is 67 million passengers, split about 20% and 80% between diesel and electric service respectively. Estimated total annual passenger miles for the railroad is 1.52 billion passenger-miles, or about a third of total regional passenger-miles for work purposes.

Electricity consumption data for the rail system are shown in

Table XVII. LILCO supplies power to all lines in the Nassau-Suffolk region, whereas Con Ed (New York) supplies LIRR lines into Penn Station. Total electrified system consumption per passenger-mile is 0.24 kwh. However, much of this is buildings, switching yards, and other supporting services. To determine energy associated with car movements, we combined LIRR data on length and number of trains moving over selected sections of track with LILCO hourly consumption at substations which supply the track sections. The specific consumption of 4.4 kwh/car-mile is comparable to nationally-averaged light rail system electricity requirements of 4.1 kwh/car-mile.⁽²⁸⁾ Using the car occupancy of 35 passengers, gives 0.13 kwh/passenger mile. Thus the total system electricity use is about twice that associated with direct passenger movements.

Since the Patchogue-Montauk service is mostly seasonal resort traffic, additional electrification would encompass almost all current diesel passenger-miles. Using current total electrified system needs per passenger mile, the annual electricity sales to additional electrified rail would be 50 million kwh, less than 0.2% of projected year 2000 requirements to the base case. Thus the implications of the extension of electrified rail can be neglected in our projections.

Fuel Substitution

There are a number of complicating factors which make it difficult to assess accurately the prospects for long-term stability of the natural gas supply to the Long Island region. Some contracts for natural gas extending over 20 year periods are now expiring and will be subject to renegotiation. At the same time, the national debate over price deregulation contributes to a hesitancy to establish fixed prices or quantities over long contract periods. Also, the availability of Liquified Natural Gas (LNG) imports or the price of such imports is hard to establish.⁽²⁹⁾ In recent years, such problems combined with shortages of natural gas led to interruptable gas service for many commercial and industrial customers. Overall, we face an uncertain future for natural gas supply.

TABLE XVII
RAIL SUMMARY

	<u>Total System</u>	<u>Diesel</u>	<u>Electric</u>
<u>PASSENGER MOVEMENT</u>			
Annual Passengers(boarding/exit.)	67 million	12 million(18%)	55 million (82%)
Annual passenger-miles	1.52 billion	.21 billion(14%) ⁽¹⁾	1.31 billion (86%)
Occupancy rate	35 passenger/car	-	-
<u>ELECTRICITY CONSUMPTION</u>			
Total system		LILCO	176 million kwh
		Con Ed	<u>145 million kwh</u>
total	321 million kwh	-	321 million kwh
	-	-	.24 kwh/passenger-mile
Car Movement	-	-	4.4 kwh/car-mile
(traction load)	-	-	.13 kwh/passenger-mile
<u>ADDITIONAL ELECTRIFICATION</u>			
Total system	370 million kwh	50 million kwh ⁽²⁾	320 million kwh
Car Movements	200 million kwh	30 million kwh ⁽²⁾	170 million kwh

(1) Average trip length for boarding passengers: diesel 35 miles, electric 20 miles. Passengers boarding in diesel sections make half their trip by diesel, then transfer to electrified service.

(2) Remaining Patchogue-Montauk diesel service not shown.

As natural gas supplies diminish, it becomes important to examine the likely fuel substitutes in the region, particularly the potential increase in demand for electricity. Pessimistically, we might anticipate the gas supply decreasing to half its 1972 base case level. This decline in gas availability is similar to that expected in other regions of the country which, like our own, rely upon natural gas imports. The two questions which arise concerning the impact upon the local area are: what fuel substitutions are likely? and can an orderly transition to the new fuels be made?

To provide for an equitable distribution of natural gas during times of storage, the Federal Power Commission has issued notices establishing user priorities for receipt of gas. Of the 77 priorities based upon end use purpose and daily maximum demand, gas customers in the Long Island area fall almost entirely into the first two priority groups:

- . residential and commercial customers with peak daily requirements less than 50 Mcf.
- . Commercial customers with peak daily requirement greater than 50 Mcf and specified use as plant protection (no alternate fuel available), feedstocks, process needs, and injection (storage gas returned to lines).

Under gas curtailment conditions, the large commercial customers would be expected to shift to alternate fuels first, followed by small commercial users and residential customers.

Estimated gas consumption by commercial-industrial and residential sector customers is shown in Table XVIII. The largest fraction of commercial use is for space heat. In the event of gas cutbacks, most gas-fired burners could be shifted to oil-fired, probably at little capital cost. Most process heat needs could also be met with oil-fired systems. However, where there is a specific requirement for "clean heat", natural gas would be retained under current utilization guidelines. To the extent that such natural gas use continues, additional shifts from gas to electric in the residential sector might be expected. We assume in

TABLE XVIII
FUEL SUBSTITUTION EFFECTS
(10^{12} Btu)

	<u>Natural Gas Use</u>	
	<u>1972</u>	<u>1985-2000⁽¹⁾</u>
RESIDENTIAL		
Space Heat	19.2	17.5
Water Heat	3.6	3.4
Range	4.7	4.7
COMMERCIAL-INDUSTRIAL		
Process Heat	4.5	4.5
Space Heat	<u>13.6</u>	<u>12.1</u>
Gas Sales	45.6	42.2
Gas Available(50% of '72 level)		-22.8
Fuel Substitution required		<u>19.4</u>
Oil for commercial space heat		12.1
Oil for process heat		4.5
Electricity for residential range		2.8
		<u>19.4</u> (310x10 ⁶ kwh)

(1) Because of supply limitations, natural gas use is frozen at 1972 levels or declines through conservation measures.

Table XVIII that all commercial-industrial gas for space heat use shifts to oil.

In the residential sector, the most convenient substitution for the homeowner, though not necessarily the lowest cost, is purchase of an electric range. We note in Table XVIII, that to respond to a 50% reduction in gas consumption from its 1972 level would not require a change to all electric ranges in the region. The increase in electric sales prompted by electric ranges would be 310 million kwh. However, in the real world of interruptable service and intermittent gas shortages, some customers would be expected to shift from gas to oil or electric for space and water heat. Others might be expected to trade gas ranges for electric. If all gas ranges were replaced by electric, the maximum electric demand increase is 530 million kwh.

E. PROBABILITY DISTRIBUTION OF THE DEMAND FOR ELECTRICITY

In this section, we discuss the implications of the conservation measures, new technologies, and other factors discussed earlier for the total demand for electricity. In order to relate the various measures discussed to each other and to the base case projection, we must assign a quantitative likelihood to each. In the discussion of conservation measures, new technologies, and other factors, we emphasized the qualitative nature of estimates of future trends and the difficulty of assigning specific implementation rates and the level of impact for the different components of future electric demand, including those dealing with population, housing mix, retail floorspace, and like. Consequently, while we might construct probability distributions and estimates of high-low impacts upon future electric sales, we should guard against too formalistic an application of statistical techniques.

To provide an overview of the more significant future developments, particularly those which should be of particular concern to LILCO, we summarize the impact of conservation and technology upon electric sales in Tables XIX and XX, for the years 1985 and 2000 respectively. The most significant difference between 1985 and the year 2000 is, of course, in the level of development of new technology. Most of the new

technologies are not realized until after 1985. That is, in examining the impacts listed in Table XX for the year 2000, we note that the largest impacts are associated with the development of the new technologies such as the heat pump, solar energy, and the like. It is important to note that the development of these new technologies conserves energy in an overall sense. That is, the heat pump even at present is twice as efficient as electric resistance heating. Similarly, the introduction of solar energy systems reduces heating demands. However, the development of many of these new technologies would utilize electricity as the primary, or in other cases supplementary, fuel. Consequently, while overall conservation is achieved, the demand for electricity may increase.

To measure where a given level of impact is significant, we look to the base case projection of electric sales considered earlier. The growth in projected electric sales was about 4 percent per year in the year 2000, or about 1.2 billion kwh annually. Consequently, the addition of 1.2 billion kwh to the base case sales forecast for the year 2000 would mean achieving that level of demand one year earlier, in 1999. Differences of up to a year in the projected dates for achieving the level of demand are small compared to the overall 25 year planning horizon mentioned here and in terms of their basic uncertainties. Thus, only impacts greater than about 1 billion kwh are significant in a planning sense.

To simplify computation of a probability distribution, we first group events from Tables XIX and XX, which are likely to occur together. This grouping is shown in Table XXI.

TABLE XIX

SUMMARY TABLE OF IMPACTS UPON ELECTRIC SALES
1985

<u>High Probability</u>	<u>10⁹ kwh</u>	<u>Low Probability</u>	<u>10⁹ kwh</u>
Commercial heat pump	+1.50	Commercial solar/heat pump	-
Residential heat pump	+0.29	Residential solar/heat pump	-
Electric vehicles	-	Electric-gas substitution	+0.31
Storage resistance heating	-	Electrified rail	-
Residential lighting	- .13	Residential appliances/thermostat	- .89
Residential range	-	Commercial total energy system	-
Residential solar/electric water	-	Commercial space conditioning	-2.25
Residential water heat	.24		
Commercial lighting	- .70		
	(total + .72)		(total -2.83)

TABLE XX
SUMMARY TABLE OF IMPACTS UPON ELECTRIC SALES
(2000)

<u>High Probability</u>	<u>10⁹ kwh</u>	<u>Low Probability</u>	<u>10⁹ kwh</u>
Commercial heat pump	+ 4.10	Commercial solar/heat pump	+ 1.33
Residential heat pump	+ 1.41	Residential solar/heat pump	+ 0.83
Electric vehicles	+ 1.26	Electric-gas substitution	+ 0.31
Storage resistance heating	-	Electrified rail	+ 0.05
Residential lighting	- 0.17	Residential appliances/thermostat	- 1.23
Residential range	- 0.20	Commercial total energy systems	- 1.76
Residential solar/electric water	- 0.30	Commercial space conditioning	- 3.50
Residential water heat	- 0.32		
Commercial lighting	- 0.88		
	(total + 4.90)		(total -3.97)

TABLE XXI

<u>"Events"</u>	<u>Event Groups & Impact</u> (Gwh)		<u>Probability</u>
	<u>1985</u>	<u>2000</u>	
A Heat pumps (residential & commercial)	+1790	+5510	high
B Electric Vehicles	-	+1260	high
C Residential-commercial conservation, & storage heating	-1070	-1870	high
D Solar/Heat pump	-	+2160	low
E Commercial space cond. and total energy	-2250	-5260	low
F Appliance efficiencies/ gas substitutions/rail electrification	-580	-870	low

The figures given in the Table for impacts represent the change in electricity demand if the groups of events actually occur. We must now multiply those impacts by their probability of occurrence.

We can view the assignment of probability in two ways. Having calculated the maximum impact of a future development, we are now estimating the most probable level of implementation or impact. Alternatively and equivalently, we can view this step as assigning a probability to the development itself and its implementation at the maximum level. Thus far we have assigned only "high" and "low" probabilities. Now we must quantify these. We do so, by assigning a probability of 0.3 to low likelihood events and 0.7 to high likelihood events. In the construction of the probability distribution, it matters little whether the probabilities vary within ranges of 0.6-0.8 and, 0.2-0.4, since these will lead to relatively small shifts in the cumulative probability distribution which is the basis for planning decisions.

In calculating the probability distribution of future demand one must consider combinations of the events shown in Table XXI. In 1985 for example, the most probable combination of events shown is

$$P_1 = P_A \cdot P_C \cdot P_{-E} \cdot P_{-F}$$

where P_x is the relative probability of x occurring and P_{-x} is the probability of x not occurring ($1-P_x$); that is,

$$P_1 = (0.7)(0.7)(0.7) = 0.240$$

The probabilities of the other combinations are shown in Table XXII. We also assign a probability to the occurrence of the base case demand of 18.69 billion kwh equal to the most probable combination P_1 above. The normalized probabilities are shown in column 4 of Table XXII. The final column in the table gives the electricity demand that corresponds to each combination of events.

The discrete probability distribution in Table XXII is shown graphically in Figure 12. Since the selection of "events" used to construct this distribution was somewhat arbitrary and there are significant uncertainties in a number of elements of the estimates of implementation rate and impact, a representation that better reflects those uncertainties can be produced by aggregating the probabilities into larger demand categories. The result of such an aggregation is shown in Figure 13. For 1985 we see that the probability distribution is spread out on the low side, reflecting the potential influence of conservation in the short term.

As noted earlier, a cumulative probability distribution which shows the probability that demand for electricity will exceed a specified level is, perhaps, the most useful display of information. The distribution for 1985 is shown in Figure 14. There is probability only 0.4 that demand will exceed the base case estimate of 18.7 billion kwh; that is, since conservation measures can be implemented in the short term, there is 60% chance that demand for electricity in the year 1985 will fall below the base case forecast. The range of demand between probabilities of 0.1 and 0.9 is 15 to 20 billion kwh.

TABLE XXII

PROBABILITIES OF COMBINED EVENTS - 1985

<u>CASE</u>	<u>COMBINATION</u>	<u>RELATIVE PROBABILITY</u>	<u>NORMALIZED PROBABILITY</u>	<u>ELECTRICITY DEMAND (10⁹ kwh)</u>
Base		0.240	0.200	18.69
1	A,C, -E,-F	0.240	0.200	18.90
2	A,C,E,-F	0.103	0.086	16.65
3	A,C,-E,F	0.103	0.086	18.83
4	-A,C,-E,-F	0.103	0.086	17.11
5	A,-C,-E,-F	0.103	0.086	19.97
6	A,C,E,F	0.044	0.037	16.58
7	-A,C,-E,F	0.044	0.037	17.04
8	A,-C,-E,F	0.044	0.037	19.90
9	-A,C,E,F	0.044	0.037	14.86
10	A,-C,E,-F	0.044	0.037	17.72
11	-A,-C,E,-F	0.019	0.016	15.93
12	-A,-C,-E,F	0.019	0.016	18.11
13	-A,C,E,F	0.019	0.016	14.79
14	A,-C,E,F	0.019	0.016	17.65
15	-A,-C,E,F	0.008	0.007	15.86
		1.196

Figure 12. Discrete probability distribution of 1905 electricity demand.

Figure 13. Probability distribution of 1985 electricity demand.

Figure 14. Cumulative probability distribution of 1985 electricity demand.

The electricity demand analysis for the year 2000 parallels that above, and the results are summarized in Figures 15 and 16. Unlike the situation in 1985, in 2000 the probability distribution (Figure 15) is skewed to the high side of the base case estimate of electricity sales at 32.7 billion kwh. From the cumulative distribution in Figure 16, we note there is probability of 0.7 that demand will exceed the base case forecast with 50% of the probability distribution itself falling within $\pm 8\%$ of the base case. Developments such as the heat pump and electric vehicles have strong potential for producing higher demands for electricity and are not offset by the conservation actions.

The actual range in estimated demand for electricity in the long run probably exceeds the values noted above. It is very difficult to identify all possible eventualities, particularly new possible uses of energy and national or regional economic possibilities. The demand probability distributions have been derived under the assumption of a "surprise-free" world. However, one can readily identify a number of international or national "surprises" that could create a demand well below (or above) the extremes of this distribution. Such surprises were not considered, however, in the type of planning for which the present analysis is designed.

To relate the probability distribution above to more traditional forecasts of "high" and "low" scenarios for future electricity sales, the assigned probabilities should be interpreted as average levels of implementation. For example, in Table XXIII the event groups in Table XXI are reorganized by conservation measures, which represent decreases in demand, and technology, which generally increases demand. We then interpret the probabilities as the effective percentage implementation which might be expected and determine the weighted average contribution to the sales forecast. Whereas in 1985 the lower and upper bounds are plus and minus about 8%, by the year 2000 there is still only a small potential percentage drop in demand but an upper bound which is 16% above the base case forecast. This simply emphasizes that future developments are likely to lead to increasing demands for electricity in the region.

These "high" and "low" scenarios are noted in Figures 14 and 16

Figure 15. Probability distribution of 2000 electric demand.

Figure 16. Cumulative probability distribution of 2000 electric demand.

TABLE XXIII
Electricity Sales (GWH)

	<u>1985</u>	<u>2000</u>
BASE CASE	18700	32800
High Likelihood (.7)		
conservation	-1070	-1570
technology	+1790	+6470
Low Likelihood (.3)		
conservation	-2830	-6130
technology	-	+2160
Weighted Average Contribution to Electricity Demand		
conservation	-1600	-2940
technology	<u>+1250</u>	<u>+5180</u>
LOW CASE (Conservation)	17100 (-8.6%)	29860 (-9.0%)
HIGH CASE (Technology)	19950 (+6.7%)	37980 (+15.8%)

representing the cumulative probability distributions for 1985 and 2000 respectively. The general difficulty in interpreting scenario results is apparent. For example, in the year 2000 there is 20% chance of exceeding what would be a traditional high estimate of demand for that year, and that represents a substantial chance of exceeding the upper bound on the forecast.

The projected electricity sales distributions provide far more planning information than traditional approaches to forecasting. They display the total range of potential levels of electricity sales. More importantly, since they also show the likelihood demand will exceed specified levels, they can be used for contingency planning around the issue of generating capacity expansions required to assure reasonable chance of meeting the public's need for electricity.

F. FUTURE USE OF PROJECTIONS

As for any projection, the estimates of future demand for electricity that we have presented here should be the subject of continuous review and revision. The method developed for this study has the advantage of indicating those future developments that are the most important to monitor in terms of their potential impact on future electrical demand. As revealed by the analysis of the preceding sections these include: heat pumps for residential and commercial use, including solar driven heat pumps, changes in commercial lighting standards or practices, major substitutions for appliances and electric vehicles.

As mentioned in the introduction, we view the probability distribution method developed for this study to be a starting point for future elaboration. Thus not only should the basic assumptions and judgments used in this work be scrutinized and revised, but the basic approach should be extended. The next major step in the development of the methodology is to extend consideration to the policy decisions that are based on such demand projections. One now has a basis for estimating the probability that the actual demand will be higher or lower than any particular demand used for investment decisions. That demand need not be a "base case" or the most probable future demand. Indeed, the intent of the next phase in methodology

development should be to determine, on the basis of the costs of over- and under-estimating generating capacity, the appropriate demand assumption to use for optimum investment strategy.

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APPENDIX A

ENERGY DEMAND & FUEL MIX ANALYSIS

Projections of energy demands in this report have been made in a detailed end use, or disaggregated manner. This approach is required in order to evaluate technologies or energy policies that may apply to very specific end uses. It is recognized that projections made in this disaggregated manner may well underestimate the total energy demand in the future because of unanticipated new uses of energy. Some allowance for new uses is made in projections for categories such as commercial and industrial miscellaneous electric use.

The projections of energy demand and the fuel mix for the reference years are developed on the worksheets below. Before describing the assumptions underlying these projections, it is useful to define several parameters.

1. Basis B = the land use/economic projection variable; i.e. households, vehicle-miles, etc.
2. Saturation S = average fraction of the basis which has a specified end use; i.e. the fraction of households with air-conditioning of a single room. When S is greater than 1, some of the basis utilizes multiples of the defined end use; i.e. more than one room is air-conditioned.
3. Unit Demand E_u = energy demand per basis for a specific end use; i.e. Btu per household for air-conditioning a single room, Btu per square foot for commercial lighting.
4. Basic Energy Demand E = the total energy demand for the specific end use, which is independent of the technologies selected to meet the demand. The Basic Energy Demand is

$$E = B \cdot S \cdot E_u$$

5. Fuel Fraction f_i = Fraction of the Basic Energy Demand that is satisfied by using the i'th fuel

$$f_i = \frac{e_i D_i}{E} \quad \text{and} \quad \sum_i f_i = 100\%.$$

6. Relative Effectiveness e_i = the relative effectiveness with which fuel, i, is used in a demand category. This parameter depends on the utilization technology employed. In most cases e_i corresponds to the technical efficiency of the device used in the activity in question, but may include other factors. In space heating, for example, e_i for electric space heating includes the effect of different insulation and usage patterns from oil and gas heating.
7. Fuel Demand $\sum_i D_i$ = the quantity of the i'th fuel actually consumed in a specific demand category, such as space heating, automotive transport, or industrial process heat. The Basic Energy Demand is written in terms of Fuel Demand as $E = \sum_i e_i D_i$.

The specific assumptions for energy projection in each demand category and the basis for individual end use projection are given in each case on the fuelmix tables.

BASE CASE

Sector: Residential

Category: Single Family
Space Heat

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
<u>Methane</u>									
Existing	.19	.34	18.0	.13	.40	14.5	.10	.42	13.5
Retrofitted				.02	.50	1.8	.02	.47	2.4
<u>Distillate</u>									
Existing	.80	.28	92.2	.54	.33	73.2	.43	.35	69.9
Retrofitted				.08	.40	8.9	.06	.42	8.1
New-Improved				.16	.42	17.0	.28	.42	37.9
New-FHA-MPS				.01	.54	0.8	.03	.54	3.2
<u>Electric</u>									
1300 ft ²	.01	1.00	0.3	.01	1.17	0.4	.01	1.17	0.5
1600 ft ²				.05	1.00	2.2	.06	1.00	3.4
<u>Heat Pump</u>									
1600 ft ²				-	-	-	.02	2.00	0.6
Basic Energy Demand, E (x10 ¹² Btu)		32.2			44.2			52.0	
Basis, B (x10 ⁶ households)		.63			.81			1.03	
Saturation		1.00			1.00			1.00	
Unit Demand (x10 ⁶ Btu/household)		51.2			55.2			55.2	

Notes on Projections: see p. A-4.

End Use Technologies - Fossil fuel Burners
Electric resistance heating
Heat pump technology

Data Sources = E_u - 2,5,7,8,14,40,41,44.

e_i - 5,42,43.

B_i - 10,5,12

f_i - 10

Single-Family
NOTES ON PROJECTION

Historical growth: Existing single family homes remain at 1300 sq. ft. New homes are 1600 sq. ft. The unit demand for existing single family homes remains constant. Homes built between 1972 and 2000 have larger unit demands due to size. The inventory of single family homes increases 2% per year to 1985 and then 1.5% a year to 2000. It was assumed that the number of gas homes remained constant. It was also assumed that 22% of all new homes would be electrically space heated. Between 1985 and 2000, 50% of new electrically-heated homes will utilize heat pumps. All 1972 fossil fuel burners will be replaced by 2000.

Base Case: a reduction in unit demand by 8% due to thermostat setback from 72° to 70°F, day and night. New homes may be built to either a) new improved insulation standards or b) FHA-MPS standard. Improved insulation requires 27% less energy than existing homes. New fossil fuel burners will be 5% more efficient than present. Of the existing housing stock, 1% per year from 1972 to 1985 will be retrofitted with ceiling insulation, storm windows and doors, and recaulking, which will reduce their energy demand by 15%. It is assumed 1% of existing burners per year from 1972-1985 will have improved maintenance resulting in a 5% efficiency improvement.

Base Case

Sector: Residential
Category: Multi-family
Spaceheat

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
<u>Methane</u>									
Existing	.14	.43	1.2	.08	.43	1.1	.05	.45	0.9
Retrofitted				.01	.52	0.1	.01	.52	0.2
<u>Distille Oil</u>									
Existing	.84	.36	8.7	.45	.36	7.1	.31	.38	6.7
Retrofitted				.05	.42	0.7	.04	.42	0.8
New-Improved				.26	.50	3.0	.37	.50	6.1
New-FHA-MPS				.02	.62	0.2	.01	.62	0.1
<u>Electric</u>	.02	1.0	0.1	.14	1.0	0.8	.14	1.0	1.2
<u>Heat Pump</u>							.05	2.0	.2
Basic Energy Demand E ($\times 10^{12}$ Btu)		3.8			5.8			7.8	
Basis, ($\times 10^6$ households)		.12			.20			.29	
Saturation, S		1.00			1.00			1.00	
Unit demand, E_u ($\times 10^6$ Btu/household)		31.0			28.5			28.5	

Notes on Projection: See A-6.

End Use Technologies - Fossil Fuel burners
Electric Resistance heating
Heat pump technology

Data Sources - E_u - 2,5,7,8,13,14,40,41,44.

B - 10,5,12.

e_i - 5,42,43.

f_i - 10.

MULTI-FAMILY
NOTES ON PROJECTION

Historical Growth: Between 1972 and 1985, multifamily households will increase 4% per year and 2.5% per year between 1985 and 2000. It was assumed that 31% of all new multifamily homes will be electrically heated. All fossil fuel heated new construction will be of superior quality, which will reduce fuel demand by 28%. Heat pumps for multifamily homes will be introduced in 50% of new electric-space heated homes constructed between 1985 and 2000. The number of gas homes is kept the same for 1985 and 2000 as in 1972. By 2000, all existing 1972 fossil fuel burners will be replaced by new burners which will be 5% more efficient.

Base Case: A reduction in unit demand by 8% due to thermostat setback from 72° to 70°F, day and night. New multifamily homes may be built to either a) new improved insulation standards or b) FHA-MPS standards. Improved insulation in new construction requires 26% less energy than existing units. It was assumed 10% of the new construction is the FHA-MPS standard which requires 41% less energy than existing units. New fossil fuel burners will be 5% more efficient than present. Of the existing multifamily housing stock, 1% per year from 1972 to 1985 will be retrofitted with ceiling insulation, storm windows and doors, and recaulking, which will reduce their energy demand by 13%. It is assumed 1% of existing burners per year from 1972 to 1985 will have improved maintenance resulting in a 5% efficiency improvement.

BASE CASE

Sector: Residential

Category: Water Heat

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane	.22	.75	3.6	.16	.79	3.4	.13	.79	3.4
Distillate Oil	.74	.63	14.5	.72	.66	18.1	.67	.66	22.0
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	.04	1.00	.50	.12	1.05	1.9	.20	1.05	4.1
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		12.3			16.6			21.5	
BASIS, B ($\times 10^6$ households)		.75			1.01			1.32	
SATURATION, S		1.00			1.00			1.00	
UNIT DEMAND, E_u $\times 10^6$ Btu/household		16.4			16.4			16.4	

END USE TECHNOLOGIES: Gas and oil Burners

Electric Resistance heating

DATA SOURCES: E_u : Ref. 8 e_i : Ref. 9 S: Ref. 9,16

B: Ref. 5,10,2 f_i : Ref. 5

NOTES ON PROJECTIONS:

Households increased 2.3% per year to 1985 and then 1.8% per year to 2000. It was assumed that between 1972 and 1985, 35% of new homes will install electric hot water and between 1985 and 2000, 45% of new homes will install electric hot water systems. The number of gas customers will remain constant. BASE CASE: New water heaters will increase in efficiency by 5%.

BASE CASE

Sector: Residential

Category: Air Conditioning

	1972			1985			2000		
	f _i	e _i	D _i	f _i	e _i	D _i	f _i	e _i	D _i
DIRECT FUEL USE									
Methane									
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY									
Central									
Single-Family	1.00	2.5	.627	1.00	3.50	.694	1.00	3.50	1.029
Multi-Family	1.00	2.5	.029	1.00	3.50	.227	1.00	3.50	.451
Room A/C	1.00	2.0	.821	1.00	2.80	1.00	1.00	2.80	1.527
BASIC ENERGY DEMAND									
E, (x10 ¹² Btu)		1.5			2.7			4.3	
BASIS, B									
10 ⁶ Households		.75			1.01			1.32	
SATURATION, Single		.076			.097			.110	
Multi		.005			.046			.070	
Room		.730			1.03			1.20	
UNIT DEMAND, E _u									
x10 ⁶ Btu/Household									
Single Central		27.5			24.8			24.8	
Multi-Central		19.0			17.1			17.1	
Room A/C		3.0			2.7			2.7	

END USE TECHNOLOGIES: Vapor Compression Cycle

DATA SOURCES: E_u: Ref. 34 S: Ref. 8, 35
e_i: Ref. 9 B_i: Ref. 10, 5, 2

NOTES ON PROJECTIONS:

The number of households increased by 2.3% per year from 1972 to 1985 and 1.8% from 1985 to 2000. BASE CASE: The relative effectiveness of all air conditioners has been increased 40% by 1985 and remains constant thereafter. A decrease in unit demand of 10% has been applied to reflect thermostat advance and improved home insulation.

BASE CASE

Sector: Residential

Category: Lighting

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane									
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	1.00	1.00	3.3	1.00	1.00	4.4	1.00	1.00	5.8
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		3.3			4.4			5.8	
BASIS, B 10^6 households		.75			1.01			1.32	
SATURATION, S		1.00			1.00			1.00	
UNIT DEMAND, E_u $\times 10^6$ Btu/house= hold		4.4			4.4			4.4	

END USE TECHNOLOGIES: Conventional Lighting Technology

DATA SOURCES: E_u : Ref 15

B: Ref 1, 5, 10

NOTES ON PROJECTIONS:

The number of households increased 2.3% between 1972 and 1985 and 1.8% between 1985 and 2000.

BASE CASE

Sector: Residential

Category: Range

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane	.58	.38	4.7	.43	.38	4.7	.33	.38	4.7
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	.42	1.00	1.3	.57	1.00	2.4	.67	1.00	3.6
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		4.6			6.2			8.1	
BASIS, B $\times 10^6$ households		.75			1.01			1.32	
SATURATION, S		1.00			1.0			1.00	
UNIT DEMAND, E_u $\times 10^6$ Btu/household		4.1			4.1			4.1	

END USE TECHNOLOGIES: Gas burners and electric resistance cooking

DATA SOURCES: f_i : Ref. 5 e_i : Ref. 9 S: Ref. 9, 10

NOTES ON PROJECTIONS:

The number of households grew 2.3% between 1972 and 1985 and 1.8% between 1985 and 2000. The Number of gas customers was held constant. It is assumed 100% of the new homes have electric cooking.

BASE CASE

Sector: Residential

Category: Refrigeration

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane									
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	1.00	1.00	3.8	1.00	1.00	5.8	1.00	1.00	8.1
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		3.8			5.8			8.1	
BASIS, B $\times 10^6$ Households		.75			1.01			1.32	
SATURATION, S		1.00			1.13			1.20	
UNIT DEMAND, E_u $\times 10^6$ Btu/refrig.		5.1			5.1			5.1	

END USE TECHNOLOGIES: Vapor compression cycle

DATA SOURCES: e_i : Ref. 9 E_u : Ref. 8 B: Ref. 10, 5, 2
S: Ref. 8

NOTES ON PROJECTIONS:

The number of households grew 2.3% between 1972 and 1985 and 1.8% between 1985 and 2000. Unit demand increased 10% for 1985 and 2000 due to larger refrigerators. BASE CASE: Increased efficiency of all new refrigerators by 10%. Therefore, no net change in unit demand for 1985 and 2000.

BASE CASE

Sector: Residential

Category: Major Appliance

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane(gas dryers) ¹		.38	.65						
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	1.00	1.00	3.0	1.00	1.00	5.7	1.00	1.00	9.0
BASIC ENERGY DEMAND E , ($\times 10^{12}$ Btu)		3.3			5.7			9.0	
BASIS, B $\times 10^6$ households		.75			1.01			1.32	
SATURATION, S		.39			.62			.75	
UNIT DEMAND, E_u $\times 10^6$ Btu/household		10.1			9.1			9.1	

END USE TECHNOLOGIES: Dishwashers, clotheswashers, dryers.

DATA SOURCES: S: Ref. 8

NOTES ON PROJECTIONS:

Number of households increased 2.3% per year from 1972 to 1985 and then 1.8% per year from 1985 to 2000. Unit demand decreased 10% for 1985 and 2000.

1. represents only gas dryers in 1972 - Gas dryers negligible in 1985 and 2000.

BASE CASE

Sector: Residential

Category: Miscellaneous Electric

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane									
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	1.00	1.00	3.7	1.00	1.00	6.2	1.00	1.00	8.9
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		3.7			6.2			8.9	
BASIS, B $\times 10^6$ households		.75			1.01			1.32	
SATURATION, S		1.00			1.36			1.50	
UNIT DEMAND, E_u $\times 10^6$ Btu/household		4.9			4.5			4.5	

END USE TECHNOLOGIES: A/C induction motors, Electronic devices

DATA SOURCES: E_u : Ref. 5, 15 S: Ref 5, 9, 10 B: Ref 10, 5, 1

NOTES ON PROJECTIONS:

The number of households increased by 2.3% from 1972 to 1985 and then by 1.8% from 1985 to 2000. BASE CASE: A reduction of 10% of unit demand for residential miscellaneous electric was applied in 1985 and 2000.

BASE CASE

Sector: Commercial-Industrial

Category: Process Heat

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane	.38	.64	4.5	.27	.64	4.5	.19	64	4.5
Distillate Oil	.15	.68	1.7	.24	.68	3.8	.42	68	9.5
Residual Oil	.43	.68	4.8	.49	.68	7.6	.39	68	8.9
Coal	.05	.68	0.5						
Gasoline									
Other									
ELECTRICITY									
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		7.6			10.6			15.4	
BASIS, B									
SATURATION, S									
UNIT DEMAND, E_u									

END USE TECHNOLOGIES: Fossil Fuel Burner

DATA SOURCES: f_i : Ref. 30 E: Ref. 35,9,30 e_i : Ref. 19

NOTES ON PROJECTIONS:

The total demand was increased at an annual rate of 2.6%. Gas demand for 1985-2000 was held constant. It was assumed that the demand satisfied by coal will decrease by 10% annually. The demand for distillate oil will increase 10% annually.

BASE CASE

Sector: Commercial-Industrial

Category: Space Heat

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane	.13	.53	13.6	.10	.53	12.1	.08	.53	12.1
Distillate Oil	.87	.52	92.5	.87	.52	107.3	.87	.52	134.2
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	-	-	-	.03	1.00	1.9	.05	1.00	4.0
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		55.3			64.1			80.2	
BASIS, B $\times 10^6$ Ft ²		412			531			664	
SATURATION, S		1.00			1.00			1.00	
UNIT DEMAND, E_u $\times 10^3$ Btu/ft ²		134.2			120.8			120.8	

END USE TECHNOLOGIES: Fossil Fuel Burners, Electric resistant heating.

DATA SOURCES: E_u : Ref. 35,38 f_i : Ref. 30 B: Ref. 2,36 S: Ref. 9
 c_i : Ref. 7,9

NOTES ON PROJECTIONS:

Floorspace will increase by 2% for 1972 to 1985 and then 1.5% from 1985 to 2000. BASE CASE: A 10% decrease in unit demand due to thermostat set back.

BASE CASE

Sector: Commercial-Industrial

Category: Air Conditioning

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane									
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	.57	3.00	2.8	.79	3.00	4.4	1.00	3.00	7.0
BASIC									
ENERGY DEMAND									
E, ($\times 10^{12}$ Btu)		2.8			4.4			7.0	
BASIS, B									
$\times 10^6$ ft ²		412			531			664	
SATURATION, S		.57			.79			1.00	
UNIT DEMAND, E									
$\times 10^3$ Btu/ft ² of									
non-residential									
floorspace		35.3			31.8			31.8	

END USE TECHNOLOGIES: Vapor Compression Cycle

DATA SOURCES: E_u : Ref. 9, 35, 36, 37, 38 f_i : Ref. 9 e_i : Ref. 9
 S: Ref. 9 B: Ref. 2, 30

NOTES ON PROJECTIONS:

Floorspace will increase at 2% per year from 1972 to 1985 and then 1.5% from 1985 and 2000. Unit demand for A/C remains constant. The saturation increases 2.5% per year from 1972 to 1985 and achieves 100% by 2000.
 BASE CASE: A 10% savings due to thermostat advance and reduced demand through better construction.

BASE CASE

Sector: Commercial-Industrial

Category: Lighting

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane									
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	1.00	1.00	9.3	1.00	1.00	9.6	1.00	1.00	12.0
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		9.3			9.6			12.0	
BASIS, B $\times 10^6$ ft ²		412			531			664	
SATURATION, S		1.00			1.00			1.00	
UNIT DEMAND, E_u $\times 10^3$ Dtu/ft ²		22.5			18.0			18.0	

END USE TECHNOLOGIES: Conventional Lighting System

DATA SOURCES: E_u : Ref. 9 e_i : Ref. 7,9 S: Ref. 9 B: Ref. 2

NOTES ON PROJECTIONS:

Between 1972 and 1985, floorspace will increase by 2% annually and then by 1.5% to 2000. A 20% reduction in Commercial and Industrial lighting by 1985 is projected.

BASE CASE

Sector: Commercial-Industrial

Category: Miscellaneous Electric

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane									
Distillate Oil									
Residual Oil									
Coal									
Gasoline									
Other									
ELECTRICITY	1.00	1.00	7.2	1.00	1.00	15.6	1.00	1.00	34.9
BASIC ENERGY DEMAND $E, (x10^{12} \text{ Btu})$		7.2			15.6			34.9	
BASIS, B $x 10^6 \text{ ft}^2$		412			531			664	
UNIT DEMAND, E_u $x 10^3 \text{ Btu/ft}^2$		17.5			29.3			52.5	

END USE TECHNOLOGIES: AC induction motors, Misc. electric energy uses

DATA SOURCES: e_i : Ref. 2,9 B: Ref. 2 E_u : Ref. 36, 37, 38

NOTES ON PROJECTIONS:

Between 1972 and 1985, floorspace will increase by 2% annually and 1.5% between 1985 and 2000. Unit demand was assumed to grow 4% annually. Overall growth rate of miscellaneous electric demand is 6.1% annually from 1972 to 1985 and 5.5% from 1985 to 2000.

BASE CASE

Sector: Transportation

Category: Automobile

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane	-	-	-	.02	.36	1.5	.04	.36	2.8
Distillate Oil	-	-	-	-	-	-	-	-	-
Residual Oil	-	-	-	-	-	-	-	-	-
Coal	-	-	-	-	-	-	-	-	-
Gasoline	1.00	.20	123.3	.98	.20	128.0	.86	.20	110.1
Other	-	-	-	-	-	-	-	-	-
ELECTRICITY	-	-	-	-	-	-	.10	.54	4.7
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		123.3			26.1			25.6	
BASIS, B $\times 10^9$ vehicle mile		13.4			20.9			25.6	
SATURATION, S		1.00			1.00			1.00	
UNIT DEMAND, E_u $\times 10^3$ Btu/vehicle mile		1.84			1.25			1.00	

END USE TECHNOLOGIES: Internal Combustion Engine, Diesel Engines, Electric Cars

DATA SOURCES: E_u : Ref. 2,3,39 e_i : Ref. 7,9 E: Ref. 2 B: Ref. 2
 f_i : Ref. 2

NOTES ON PROJECTIONS:

Total fuel consumption is directly proportional to total vehicle miles traveled in the region. Between 1972 and 1985 total vehicle miles traveled will increase 3.5% per year and 1.4% between 1985 and 2000. Electric cars will be introduced for use after 1985 and comprise 10% of new car sales. Electric cars used for 10% of vehicle miles in 2000. Average ICE miles per gallon increases from 13.6 in 1972, to 20 in 1985 to 25 in 2000, diesel miles per gallon increases from 36 in 1972, to 40 in 1985 to 50 in 2000, which is reflected in lower unit demands.

BASE CASE

Sector: Transportation

Category: Commercial

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane									
Distillate Oil	.24	.20	8.3	.24	.20	10.1	.24	.20	12.3
Residual Oil									
Coal									
Gasoline	.76	.20	25.5	.76	.20	32.0	.76	.20	39.1
Other									
ELECTRICITY									
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)	6.7			8.4			10.3		
BASIS, B 10^6 GAL	262.8			328.5			400.8		
SATURATION, S									
UNIT DEMAND, E_u									

END USE TECHNOLOGIES: Internal Combustion Engines

DATA SOURCES: B: Ref. 2 f_i : Ref. 2 e_i : Ref. 7,9

NOTES ON PROJECTIONS:

Projections are based on the assumption that total fuel consumption is directly proportional to population growth. Between 1972-1985, population growth was 1.7%/yr. Between 1985-2000, population growth was 1.3%/yr.

BASE CASE

Sector: Transportation

Category: Railway

	1972			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Methane									
Distillate Oil	.06	.30	0.2	.06	.30	0.2	.06	.30	0.2
Residual Oil	.38	.30	1.4	.38	.30	1.4	.38	.30	1.4
Coal									
Gasoline									
Other									
ELECTRICITY	.56	1.00	0.6*	.56	1.00	0.6	.56	1.00	
BASIC ENERGY DEMAND E, ($\times 10^{12}$ Btu)		1.1			1.1			1.1	
BASIS, B $\times 10^9$ Pass. Miles		1.2			1.2			1.2	
SATURATION, S		1.0			1.0			1.0	
UNIT DEMAND, E_u Btu/Pass. Mile.		918			918			918	

END USE TECHNOLOGIES: Diesel engine and electric motor propulsion on conventional tracks

DATA SOURCES: E_u : Ref. 31,33 B: Ref. 31 f_i : Ref. 16 e_i : Ref. 9

NOTES ON PROJECTIONS:

Energy demands for 1985 and 2000 are assumed to be at the same level as 1972.

*Actual consumption in 1973 due to strike in 1972. For 1985, 180×10^6 kwh or 0.6×10^{12} Btu was projected due recent consumption patterns in non-strike years.

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