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ELECTRIC UTILITY FORECASTING IN NEW JERSEY

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ELECTRIC UTILITY FORECASTING IN NEW JERSEY

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TABLE OF CONTENTS

Chapter Page

List of Figures

ACKNOWLEDGEMENTS

This report has been prepared as part of our responsibility to assess the performance of New Jersey's electric utilities. This report contains a description of each of the methodologies (models) used by the State's major generating utilities in forecasting their energy and peak demand requirements. This report will be updated annually to identify any changes made to the models upon which each corporate forecast is based.

We wish to thank the forecasting personnel at the three companies surveyed, especially:

ATLANTIC CITY ELECTRIC

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Special thanks are due Joan Delli Santi, of our own Office, for typing the numerous drafts as well as the final report.

EXECUTIVE SUMMARY

This report has been prepared in response to the growing concerns over the forecasts of electrical consumption and peak demand requirements upon which generating capacity plans are made by the three New Jersey electric utilities.

Load growth in the 1950's and 1960's due to price stability was easy to predict, and the consequences of being wrong were relatively minor. However, the 1970's was a decade of turmoil in the energy field in general, and the 1980's and 1990's are assumed to be equally tumultuous.

Ever since the oil embargo, with its subsequent skyrocketing prices, the then adequate time series forecasting method fell into disfavor and was replaced by more sophisticated techniques. Some of these new techniques are econometric models, end use models, geographic models, and customer surveys. Recently, however, it has been recognized that time series forecasts can still be useful, and now both new and old methods are used where appropriate.

This report contains a compilation of the latest forecasting techniques being used by New Jersey utilities, including modeling concepts and the demographic, technological, and economic factors which influence the development of the annual forecasts for the three major New Jersey utility companies: Atlantic City Electric (ACE), Jersey Central Power and Light (JCP&L), and Public Service Electric and Gas (PSE&G).

Some of the information used in this report was obtained from the testimony and exhibits presented in the New Jersey Board of Public Utilities (NJBPU) Construction Practices hearings, Docket No. 762-194.

From those hearings it was learned that as of 1976, Atlantic City Electric Company had contracted with National Electric Research Associates (NERA) to provide a completed forecast, which it subsequently modified; General Public Utilities (GPU), parent company of JCP&L, developed its own residential model and contracted consultants to develop its commercial and industrial models; and Public Service Electric and Gas Company had developed its own models. Since that time the GPU forecasting group has developed its own industrial model which is being applied to JCP&L data.

Since New Jersey utilities are part of the Pennsylvania-New Jersey-Maryland (PJM) grid and members of the Mid-Atlantic Area Council (MAAC), the energy requirements of the State must also be looked at on the larger scale of the interchange system which currently, in the aggregate, has an installed capacity of over 48,500 MW, versus New Jersey's installed capacity of approximately 13,000 MW.

This report is part of a comprehensive and continuing study of the forecasting of electricity requirements in New Jersey. It must be revised and updated to assure its accuracy and reflect the dynamic nature of the forecasting techniques and energy situation.

In order for the State of New Jersey to maintain its economic strength and quality of life, sufficient electrical energy is essential. The psychological impact of an energy shortage was demonstrated quite vividly in the recent gasoline crisis where some motorists, forced to wait on long lines, resorted to bribery and violence to circumvent regulations or just as a response to the deprivation of what some considered an essential commodity.

In the electrical field brownouts, due to insufficient generating capacity, affect equipment as well as people, causing damage or discomfort. The most recent blackout in New York City, with its attendant rioting, was an event of catastrophic proportions which the State of New Jersey must avoid if at all possible. Certainly, however, new capacity should only be built if necessary, and only through accurate and up-to-date forecasting can this be determined.

Demand for electricity must be met without excessive construction in order to provide affordable electric service. However, the various regulatory agencies whose standards must be followed make it extremely difficult to catch up with need once a utility falls behind. No longer can a plant be placed on line in two or three years, since economics and legislation, specifically the Fuel Use Act (FUA), preclude the use of oil or natural gas-fired units. The only viable options for new baseload capacity are coal or nuclear. Current estimates indicate that a coal plant must be started eight to ten years ahead of need and a nuclear plant twelve or more years prior to going on line, with more than half the time required to meet all regulatory licensing procedures.

Siting of electric generating plants is becoming ever more difficult in New Jersey, since it is a small state with its most desirable plant locations already taken up by the existing major industries, such as recreation and petrochemicals. Water supplies in New Jersey are not sufficiently abundant inland for large nuclear or coal stations and most land near the shoreline comes under the Coastal Area Facilities Review Act (CAFRA), which has established stringent land use standards to prevent deleterious environmental impacts.

Transmission and distribution facilities must also be built to distribute the power from new generating stations or from increased generation at existing sites. As population shifts occur, rights-of-way for totally new transmission and distribution lines must be obtained and built upon. The aesthetics of the power lines and towers and the environmental requirements placed on rights-of-way make siting of these facilities as difficult as for new plants. Land purchases for utility purposes often require the intervention of the Board of Public Utilities, with its powers of eminent domain and exemption from existing zoning laws for the convenience and necessity of the State at large. In newly developing areas of the State, distribution lines must go underground requiring substantially more utility personnel than overhead lines; thus restricting these workers from assignments involving expansion of capacity or transmission.

Based on the foregoing, it can be seen that the primary purpose for an electric utility forecast is to assure an adequate supply of energy and peak load capacity. However, it also serves many other uses and purposes. Internally, the utility uses the forecast to project operating and maintenance expenses, fuel purchases, load management possibilities, generation mix, interchange energy needs and maintenance scheduling. Externally, the utility uses the forecast for rate case documentation and justification of capital expenditures to investors. Regulatory agencies use the forecasts submitted annually by the utilities for such things as rate setting, legislative recommendations, statewide energy planning and compliance with federal regulations. Since the forecasts are available to the general public, lobbyists, concerned citizens groups, business and industry can make decisions based on the information presented.

The use of any forecast must be made with an understanding that it is a dynamic tool with which to work and its accuracy is dependent on the underlying assumptions remaining valid. Various types of historical data are used as a basis for the models used to predict the future. The forecaster must choose the data which, used singly or in combination with other information, most closely approximates the historical electric consumption and demand requirements. However, no forecast can predict or account for catastrophic events, such as wars or nuclear accidents. In addition, social changes of a drastic nature, such as oil embargoes, extortionate price escalations, changes in regulatory philosophy, or depressions must be ignored in preparation of a forecast, despite the possibility that they could occur. Even cyclic trends, although recognized, are not considered when the forecasts are developed.

As can be seen from the preceding, forecasting is an extremely complex subject. Therefore, the remainder of the Executive Summary will be devoted to the analysis of each company's techniques and our assessment thereof. A detailed discussion of the generic concepts of forecasting and the techniques used by ACE, JCP&L and PSE&G are contained in the main body of this report.

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0.1 Analysis

In order to properly analyze and evaluate the various forecasting methodologies used, we had to become familiar with how the corporate forecasts were developed and what is considered to be the state-of-the-art. The Construction Practices Docket of the NJBPU was used as a starting point, since it contained the most complete documentation of the forecasting methodologies available, albeit somewhat dated. Numerous topical books and magazine articles were perused for information concerning current techniques and experts' opinions thereon. Further, meetings with the forecasting staffs of the three utilities were held to determine how the latest corporate forecasts were developed. An analysis of the forecasting techniques of the individual companies follows:

0.1.1 ACE

The methodology used by ACE was originally developed by NERA, an organization which is considered expert in the forecasting field. Forecast techniques were developed for residential, commercial and industrial sales and peak demand.

The residential sales are forecast using a hybrid model that is both econometric and end use in nature. The total residential sales are obtained by adding competitive usage and net usage. The competitive usage equation relies on appliance saturations and average-use-per-appliance data. The appliance saturations are calculated based on electric price, gas price and heating degree days (HDD), along with a housing and demographic parameter. Average-use-per-appliance data are obtained either from Edison Electric Institute (EEI) for non-heating appliances or from HDD equations for space and water heaters. The net usage equation is based on appliance saturations (only for air conditioning), income levels and a housing and demographic parameter.

The commercial sales are forecast using an approach which is primarily econometric. The starting point is actual commercial sales in the latest year adjusted for electric price and weather effects. The final forecast equation then uses each prior year's forecast to develop the next year's number. The variables used are income per capita, residential customers, housing starts and marginal price of electricity.

The industrial sales are developed in two steps, a 1 to 5 year short-term forecast and a 6 to 15 year long-term forecast. The short-term is based on an annual survey and average load factor. The long-term econometric model was developed using 1975 cross-sectional data of employment, electric price and competitive fuel price.

The peak demand forecast starts with the current peak, breaks it down by rate classes, and reconstructs it based on weather adjustments and sales growth by rate class.

The two portions of the residential forecast are done differently. In fact, the two components of competitive usage are developed in different manners. Consumption-per-appliance is obtained by end use analysis while the econometric approach is used in developing the appliance saturation equations. Coefficients for non-heating appliance saturation were calculated from cross-sectional, 1970 census data which the company plans to update when the 1980 census is released. Meanwhile, these coefficients could lead to forecast inaccuracies. The net usage equation was developed from different cross-sectional data contained in a 1976 ACE survey which should also be kept current.

The data for the commercial forecast was historical in nature. The elasticity for marginal price was a NERA number based on national statistics verified for ACE territory. However, strong dependence of the equation on prior year's sales could tend to compound any error present in the base year's data.

The short-term industrial forecast should predict accurately, barring the emergence of a totally new major industrial customer within the 5 year span. The long-term industrial forecast used cross-sectional data from 1975 to develop the equation, but forecasts using projections from New Jersey Department of Labor and Industry, ACE itself, and NERA. Re-calculation of the coefficients may be indicated once 1980 data are available.

The peak forecast is strongly tied to the current level and sales growth, ignoring for the most part future price and efficiency improvement effects directly related to peak demand requirements. For each of the above forecasts alternative methods of forecasting should be developed to provide greater assurance of forecast accuracy.

Although the cross-sectional approach for calculating coefficients was originally adopted because of a paucity of other data, it may now be possible to develop forecasts based upon actual historical information. However, it must be noted that the use of cross-sectional data is a standard statistical technique which is acceptable for forecasting purposes.

Company personnel have refined the NERA models as actual energy consumption and demand data have become available for comparison with previous forecasts. Thus, ACE is developing the necessary expertise to carry on the forecasting responsibility. In addition, a recently issued report contracted for by the company discusses the population growth associated with casino development. The report was researched and written by Data Resources Inc. (DRI), another well-known forecasting organization. The information received will be incorporated in future forecasts.

Thus, the techniques employed by the company are state-of-the-art, though updating and expansion would be desirable. Additional sales and peak models for each sector should be developed, since only if the forecasts are found to track actual sales and demand into the future can they be considered adequate.

0.1.2 JCP&L

GPU Service Corporation (GPU) forecasts for JCP&L as part of the GPU Corporate Forecast. Data specific to the JCP&L service territory are used in GPU models.

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Models were developed for residential, commercial and industrial sales sectors and for peak demand. A special input model called the Economic/Demographic Model (Eco/Demo) was also developed.

The Eco/Demo Model provides forecasts of variables used in some of the other models, the number of residential customers and commercial employees being the two most important. Data for this model come from company records, the U.S. Census Bureau, New Jersey State agencies and the National Planning Association (NPA). The model was originally developed by Booz-Allen and Hamilton, Inc. (Booz-Allen).

The residential sales are forecast on a quarterly basis by rate classes, i.e., all-electric, water heating and residential. The two components of the residential model are a use/customer model developed by DRI and the Eco/Demo Model. The use/customer model is a hybrid (end use/econometric) incorporating appliance saturations, electricity price and seasonal effects both weather and non-weather related. The appliance saturations are based on GPU models for eleven specific appliances. Price is actual JCP&L quarterly bills in 1977 dollars.

Commercial sales are forecast on an annual basis. Booz-Allen's energy-per-employee model multiplied by the number of commercial employees from the Eco/Demo model yields the annual commercial sales. The energy-per-employee model has baseload, summer and winter components which are modeled on the basis of electricity price, income and prior year's weather adjusted sales. GPU forecasts the electricity price while NPA does the income component.

The industrial model is new, GPU having just developed it to replace the one by DRI which the company had been using. Industrial sales are now forecast on a quarterly basis using econometric techniques with industrial output index, price of electricity and price of natural gas being the variables. DRI still, however, provides forecasts of the industrial production index and natural gas price while GPU forecasts electric price based on JCP&L data.

Peak demand is forecast based on historical load ratio and energy sales forecasts by rate class. Adjustments are made, however, for curtailable loads and load management.

The Eco/Demo Model appears to be a reasonable method of obtaining predictions for the input variables modeled.

The residential model being a hybrid (econometric/end use) can account to some extent for both price and efficiency effects. However, since the coefficients of regression are based on data from 1965 to 1977, more up-to-date information is ignored. The coefficients should therefore be re-run for each subsequent forecast.

The commercial model, which is econometric, would have difficulty tracking efficiency and non-price conservation effects. Breaking the model into summer, winter and baseload components is a good idea, since each component may respond differently to changes in the independent variables. The use of a lagged variable tends to tie future consumption to current levels and may not adequately recognize a new trend. However, this model is being replaced and in the interim the existing 1977 forecast is being manually adjusted using the same growth rate but the current sales level. Certainly, the new model should be developed as soon as possible since reliance on a 1977 forecast, even one being adjusted, may not reflect current conditions.

The industrial model is a brand new econometric model using the latest available data. It contains lagged variables so that an error that appears early in the forecast is magnified as the projections go out further. It may be advantageous for the company to run both its new model and its old model as a check, thus allowing the forecaster to use his judgment in selecting the final figures.

The peak demand model relies on the sector sales models and, as such, would be unable to adequately predict an improvement in load factor. An independent model in addition to the above technique should be developed for comparison with the current model.

Development of two models for each sector and peak should be done by the company to reinforce its forecasting effort. It must be recognized that this company has unique problems associated with the Three Mile Island accident which have caused manpower and financial shortages. Despite this situation, the forecasting methodology, though not as complete as PSE&G's, does come up to the general level of utility industry forecasting.

0.1.3 PSE&G

PSE&G has a very sophisticated system of forecasting relative to the utility industry in general. The company uses a multi-method approach to obtain a group of forecasts for residential, commercial and industrial consumption and for peak load. The final corporate forecast is arrived at judgmentally from within the common range of the forecasts developed.

To begin the forecasting process, a variety of input data is collected and forecast. Demographic information is obtained by running the Cohort-Component Population Model. Merrill, Lynch Economics, Inc., provides data on the consumer price index, gross state product and personal income. Political and regulatory influences are also taken into consideration. All sales and peak demand historical data are weather-normalized. All price and income data are adjusted for inflation based on 1972 dollars. In addition, customer use surveys are made to get first-hand information about customer preferences and plans for new electrical usage in the residential, commercial and industrial rate categories.

Residential sales are forecast by rate categories: Residential service plus water heating (RS + WH), and residential heating service (RHS).

RS + WH is forecast using econometric (total use and use-per-customer), appliance saturation, geographic area and base/weather-sensitive models. The econometric total sales model is based on RS electric price, oil price and New Jersey disposable personal income (NJDPI). The econometric use-per-customer model has a summer component based on summer electric price, oil price, and air-conditioning saturation, while the winter component is based on winter electric price and NJDPI. The appliance saturation model relies on the annual customer use survey, and information from Merchandising Weekly Magazine, the Edison Electric Institute, and the Association of Edison Illuminating Companies. The geographic area model is simply a trend analysis by local service territories. The base/weather-sensitive model is also trend analysis done separately for base sales and weather-sensitive sales.

RHS is forecast using econometric (total use and use-per-customer), physical and base/weather-sensitive models. The econometric models are the same as the RS + WH models except that RHS parameters are used. The physical model is unique and relies on the number of new and converted RHS customers and the consumption associated with the various electric heating options available. The base/weather-sensitive model is the same as the RS + WH model.

Commercial sales are forecast using econometric, market area, end use, business group and weather-sensitive models. There are three econometric models for the commercial portions of rate categories: General Light and Power (GLP), Large Power and Light (LPL), and High Tension Service (HTS). The GLP model covers small commercial sales with

GLP electric price, NJDPI and oil price as independent variables. The LPL and HTS models are totalled for large commercial sales. The LPL model is based on LPL electric price, oil price and number of residential customers. The HTS model depends on HTS electric price, oil price and NJDPI per capita (NJDPIPC). The business group model is a series of mini-econometric models each tailored to a particular type of commercial customer. The market area model uses trend analysis to analyze commercial sales based on various characteristics of each local service territory. The end use model also uses trend analysis to combine projections for new electrical equipment with growth in commmercial floorspace, as does the base/weather-sensitive model to project a base component and a weather-sensitive component on a monthly basis.

Industrial sales are forecast using econometric, Standard Industrial Classification (SIC), end use and major customer/econometric hybrid models. There are three econometric models similar to the commercial ones by rate category. However, GLP and LPL are small industrial sales while HTS is large industrial sales. The independent variables for the GLP model are GLP electric price, NJDPIPC and number of residential customers, while those for the LPL model are LPL electric price, manufacturing value added per manufacturing employment, and oil price. The HTS model is based on HTS electric price, the product of the industrial production index times capacity utilization factor and oil price. The SIC model forecasts for 22 industries located in PSE&G's service territory with mini-econometric equations plus an estimate for the remainder. The end use model uses market and load research data to forecast electric consumption for specific industrial equipment. The major customer/econometric hybrid model forecasts the 30 largest industrial customers based on surveys with the remainder done econometrically.

Peak demand is forecast using a base/weather-sensitive model and two macro-econometric models. In the base/weather-sensitive model, baseload is assumed to grow at the same rate as sales while the weather-sensitive load is broken into summer and winter components. End use analysis is applied to the summer component based on residential air-conditioning, commercial floorspace and industrial employees, and for the winter component residential heating replaces air-conditioning. The two macro-econometric models are, a base model with average electric price and NJDPI as independent variables, and a total peak model using NJDPI and equivalent saturation of room air-conditioners.

An important feature of the company's program is its forecast monitoring system. If within the first few months after release the forecast is found to be off, an interim forecast is issued prior to the annual review.

Since PSE&G uses almost all the recognized techniques and checks one against the others in preparing each segment of its forecast, individual critiques of particular models would be irrelevant. Any errors contained in one model would be obvious from comparison with the other models used. In addition, the company has been recognized as being in the forefront of forecasting techniques within the utility industry. The constant attention given to the forecasting process should assure reliable forecasts barring catastrophic world events.

0.2 Assessments

Many changes have occurred in the energy situation since the Arab oil embargo precipitated a crisis. These changes have drastically altered our thinking on energy. Conservation forced by high energy prices has become a way of life for many people. Thus, forecasting energy use has become increasingly difficult and saving money by saving energy is discussed everywhere.

Energy efficiency has become an important aspect of most businesses. Many quick fixes were done in response to the initial jolt of higher prices. Then, long range planning took over and more capital intensive energy saving projects were planned and carried out. Once money is spent on energy conservation equipment, a permanent decrease in energy use occurs. The quick fix, on the other hand, often results in backsliding. As an example, once a company converts from incandescent to fluorescent or High Intensity Discharge (H.I.D.) lighting, consumption and demand will continue at a reduced level for the life of the building. Conversion back to incandescent, even if the real price of electricity stabilizes or comes down, is not a possibility; thus, any model based on the incandescent installation will not produce an accurate forecast.

An approach such as the Delphi technique may provide just as accurate an answer as most modeling techniques. The Delphi technique involves taking everyone's best guess and averaging the results. New generating capacity to reduce our dependence on oil may be desirable, but new capacity to sell more electricity may be unnecessary or undesirable. Utilities earn a profit on capital invested, a substantial proportion of which has always been for new capacity. So, if no new plants are built, the rate treatment privately-owned utilities receive may have to be changed to encourage conservation without destroying the companies.

Many questions arise in trying to forecast energy needs. If the historical data, except possibly very recent data, is useless how do we forecast? What if we already have enough capacity with efficiency improvements and rate restructuring offsetting any need for new capacity? How do you develop a forecast that does nothing? If every year the relationship between standard indicators, such as income and gross national product, fluctuate or no longer track with energy, what kind of model, if any, works? We don't have the answers, but some kind of forecast is necessary. How do we account for socioeconomic changes, such as the large increase in the percentage of full-time working wives, which may have significantly altered historic appliance use patterns? Washers, dryers, irons, air-conditioners, which once were used on peak, may now be used off peak or not at all.

The noted economist Charles Hitch stated in the May 1980 EPRI Journal "...projecting the relations that held good before 1973 is not going to work in the future....(A)ll the econometric projections based on the relations before 1973 have led to gross overestimates for energy demand." He goes on to recommend the adoption of end-use analysis. Fortunately, all three New Jersey companies do a forecast by end-use for residential customers. However, the appliance data for annual usage may be inappropriate if it lags behind conservation improvements or actual replacement rates.

A recent article in the EPRI Journal entitled "Electricity Growth: Part Trend, Part Cycle?" raised the issue of whether the forecaster can reasonably ignore cyclic effects if they change the rate by as much as 2 or 3% per year. The article complemented PSE&G as a company which "...is known for its careful planning and sophisticated analysis...." Yet PSE&G's order for and subsequent cancellation of 4 baseload units may not have occurred had the cyclic effects been considered. Certainly, if nothing else, the article points up the necessity for constant vigilance over the forecasting process so that money is not wasted in ordering unnecessary plants while at the same time assuring that adequate supplies of electricity are provided.

In general, the three companies are making a legitimate effort to forecast energy requirements. They are using state-of-the-art techniques in their forecasting programs. The econometric, end-use and trend models will all provide reasonable estimates from available data barring major upheavals. However, short-term patterns seem to indicate that much of the available information prior to 1974 is unusable. Thus, all three companies show overestimates in their load growth. However, in the short run, the addition of new coal and nuclear capacity, even if reserves become too high, will be advantageous in displacing oil-fired capacity. So, though the basic bias of the three companies may be to have too much capacity, it will not be detrimental to the customer through the 1980's. Therefore, the load growth we must try to get a handle on is from 1990 on. Will there be any increase in load after 1990, or will sufficient capacity exist at that time for the foreseeable future? Certainly, increased efficiency in lighting and appliances will offset some growth and, as the cost of electricity goes up, usage of typical appliances may go down.

So, though we may disagree with the load growth projections, we cannot recommend that any units currently planned be delayed. As new units are proposed, however, stringent review of the need for them should be made before the utility commits any money to them. One area which should be addressed with respect to new capacity is storage of off peak coal and nuclear, whether by pumped storage, batteries, or thermal storage to displace even the intermediate and peak use of oil. The benefits to society in general plus the environmental advantage of pumped storage over burning oil should be considered so that less expensive electricity can be made available to everyone.

At the same time as new plants are being brought on line, conservation efforts designed to reduce load growth should be implemented. Concentration on summer peak reductions in the PJM area will be most beneficial since summer peak substantially exceeds winter, plus due to operating characteristics, winter capacity exceeds summer. Better maintenance of existing equipment and purchase of the most reliable equipment, in general, can also reduce the requirement for new capacity. New transmission lines which allow maximum intra and interpool transfers of power can also provide adequate reserves without new plants.

CHAPTER 1

FORECASTING - GENERIC

As we get deeper into this subject of forecasting, we can show that it is taking on ever-increasing importance, especially in the area of regulatory affairs. Regulatory agencies are now scrutinizing more thoroughly utility forecasts which are used as proof for construction programs considered necessary by the utility to meet anticipated growth in consumption and demand. Since a basic responsibility of a utility is to provide its customers with reliable electric service at the lowest price, a utility must determine whether the increased energy consumption and demand should be met by building base, intermediate, or peak load facilities; or reduce the rate of growth of energy consumption and demand via appropriate load management techniques.

Each option has inherent advantages and disadvantages which have to be taken into consideration. A baseload facility is generally more efficient and produces electricity using cheaper fuels like coal and nuclear, but requires a long lead time to license as well as huge capital outlays to construct. A peak load facility utilizes less efficient equipment (such as combustion turbines) which use more expensive fuels (such as natural gas or distillate oil). However, they can be licensed quickly, barring FUA or CAFRA restrictions, at lower capital expenditures and with less impact upon the environment. Depending on the effectiveness and cost of a load management program, new construction may or may not be preferable.

Therefore, a utility's forecast helps to identify the level of installed capacity required. As an example, consider the case in which a utility forecast indicates increasing growth in electric consumption; the utility would then probably embark upon a construction program to meet this projected growth. Should the projected growth rate not materialize, the utility will in all likelihood have on its hands (and books) an under-utilized plant.

Worse than overcapacity would be undercapacity since in today's climate of tight money, regulatory philosophy and environmental constraints, a utility could not respond appropriately to this situation. Since it takes eight to ten years to license and build a fossil-fuel plant and even more time for a nuclear plant, the utility would be forced to meet the planned for energy consumption either using less efficient equipment such as combustion turbines, purchasing expensive energy from a local power pool such as PJM/MAAC, or embarking upon an ambitious load management program. Problems such as localized brown-outs or voltage reductions or, even worse, catastrophic blackouts, can result if a condition of undercapacity is allowed to exist.

Forecasting is done not only on a long-term basis, but is also used to predict the immediate future. Forecasts of peaks for each week of the upcoming calendar year are prepared by November of each year to aid in planning maintenance and repair of existing equipment as well as anticipating purchases from the grid.

In addition to forecasting energy sales and peak load, a utility will generally carry out a demographic analysis to determine which individual areas within its franchised territory are growing. This demographic analysis allows the utility the time to prepare plans to construct transmission and distribution systems to meet an area's increased need for electrical energy.

Over the years, various modeling techniques have been developed. Independent of the technique, however, we must realize that a forecast attempts to predict future trends based upon historical relationships: what held in the past will continue to hold in the future. Also, a forecast ignores catastrophic events such as; wars, depressions, oil embargoes, gas curtailments, strikes affecting delivery of fuel, drastic changes in regulatory philosophy and/or nuclear accidents, though such things may occur. Furthermore, it is a principle of forecasting that accuracy improves as a function of the smoothness, quality, and quantity of the historical data. Yet, no matter how good the data is, an accurate forecast depends upon the judgment used by the forecaster in assessing the numbers developed and presenting the information in an understandable manner.

Some of the factors (called independent variables in mathematics) that have been used to predict the dependent variables, electric energy consumption and peak demand are:

1. Disposable Personal Income
2. Electricity Price
3. Other Fuel Price
4. Appliance Saturation
5. Number of Customers
6. Time
7. Gross State Product

8. Gas Price
9. New Jersey Population
10. Company Territory Population
11. Manufacturing Employment
12. Non-manufacturing Employment
13. National Industrial Production
14. Industrial Capacity Factor
15. Oil Price
16. Gross National Product
17. Taxes

However, the critical element is choosing the correct independent variable or variables that most closely reflect the way the electrical dependent variable has responded in the past. The future must then be predicted on the basis that these relationships will remain the same. In order to predict the future, a forecast of the independent variables is necessary, whether developed by the utility or an outside organization. The electric dependent variables are normally broken out by rate categories or subcategories such as; residential, residential-heating, small commercial, large commercial, small industrial and large industrial, or combinations thereof where approriate.

There are numerous techniques used by electric utilities to forecast, which are listed below and will be addressed in turn:

1. Econometric
2. End Use
3. Survey
4. Trend
5. Geographic
6. Hybrid

1.1 Econometric

Modern econometric forecasting techniques involve the use of mathematical modeling of historical data to determine the future electrical needs of a company or region. There are various sources for historical data including, but not limited to; utilities, the federal and state governments, banks, and poll-taking organizations.

In econometric modeling, the dependent variable is assumed to be a function of one or more independent economic variables. A variety of independent variables which may have an effect on the dependent variable are identified. Those whose historical data demonstrate the closest relationship with this dependent variable are chosen for the econometric model.

A typical equation may be expressed as:

$$E = f\ (X, Y, Z) \tag{1.1}$$

where:

E = the dependent variable representing either energy sales or peak demand;

X = the first independent variable;

Y = the second independent variable; and,

Z = the third independent variable.

Appendix A discusses multiple regression analysis used to develop the above equation, which is then the basis for the forecast. A forecast of the independent variables is used in this equation to forecast the dependent variable E.

However, econometric modeling is not a panacea because it is extremely sensitive to the growth rates predicted for the economic independent variables which themselves are speculative owing to the influences exerted by regional, national and world economic situations. Further, econometric models do not capture non-price related conservation nor equipment efficiency improvements. In addition, no matter how well the model fits historical data, if there are significant economic changes, such as that precipitated by the oil embargo, historical relationships may no longer be valid to predict the future. Therefore, other forecasting methods should also be used to verify the reasonableness of the projection.

1.2 End Use

An end use model depends on the physical quantities, demand and hours of use.

Data concerning the demand, hours of use and saturation of electrical appliances being modeled can be obtained from national electrical organizations or, in the alternative, by direct survey of a utility's customers.

A typical equation for energy consumption may be expressed as:

$$E_i = S_i \times N \times P_i \times H_i \qquad (1.2)$$

where:

E_i = energy consumption for service territory for particular appliance i in KWH;

S_i = saturation in number of appliances i per customer;

N = number of customers;

P_i = power required in KW by appliance i;

H_i = hours of use of appliance i.

Adding together the energy consumption of all appliances will produce the total energy required in the service territory.

The accuracy of the end use model is dependent upon the ability to forecast the effects of conservation and technological improvements in use per appliance and changes in the number of appliances per customer. Additionally, a major drawback of this type of model is its inability to explicitly take economic conditions into consideration.

1.3 Survey

Often the utility's customers know best what plans they have for expansion of electric consumption. Thus, surveys are performed to determine a customer's projected additions of electrical equipment. In this way, the company can forecast electric consumption and demand based on the actual plans of its customers.

In general, these surveys are only useful for short-term projections, since customers' plans are usually not firm for a period over five years.

1.4 Trend

The primary technique which was used prior to the oil embargo was trending, also known as time series modeling. It is still used since certain electric variables respond to time as the driving force. However, it is usually used in conjunction with the newer, more sophisticated modeling techniques.

Trend analysis is used to forecast either energy sales or peak load. When forecasting energy sales, the technique can also be used to develop residential, commercial, and industrial components.

The method consists of the collection of historical data at equal intervals of time. These data are used to derive the relationship between the dependent and independent variables. In this type of model, energy sales or peak load represents the dependent variable and time represents the independent variable. The data can be plotted to form a graph and, through the use of regression techniques, the parameters can be estimated to give a straight line which will best fit the historical data with the least squared error.

The equation that represents this line is called a time series equation. It should be noted that the method is simply a refined form of extrapolation. The model implicitly assumes that the rate of change of events in the past will approximate the rate of change of events in the future. As long as this assumption holds true, this type of model will be representative of what is actually happening. During the late 1960's, these models appeared to work well because there were no serious random impacts. However, the major problem with this type of model is that it has difficulty forecasting a change in direction. For example, if an upturn occurs, the model has difficulty forecasting this upturn. Consequently, these models had difficulty forecasting the downturn in electric sales when the rate of growth decreased from 1974 through 1976. Trending is also unable to explicitly account for economic, efficiency and conservation effects. It is, however, still useful as one weapon in the forecaster's arsenal.

1.5 Geographic

Changing economic conditions may result in particular sections of a company's service territory growing at rates atypical of the whole area. Examples of this effect would be the Meadowlands Sports Complex in North Jersey and Atlantic City gambling casinos in South Jersey. By projecting by geographic area and totalling, the overall growth rate can be forecast.

1.6 Hybrid

Any combination of two or more of the prior five methods is a hybrid model. In reality, most of the actual forecasts made are derived by use of hybrid models. Underlying data is often gathered using one method and forecast using another. For example, in projecting residential sales, it is possible to use the end use model wherein the use per appliance is based on engineering estimates, whereas the number of appliances is forecast econometrically.

CHAPTER 2

ATLANTIC CITY ELECTRIC

ACE serves most of the southern portion of New Jersey. The original econometric forecasting methodology was developed by National Economic Research Associates Inc. (NERA). Forecasts of electric sales and peaks are made for the residential, commercial, industrial and "Other" sectors, which are then added together for service area totals.

2.1 Residential Sales

The company forecasts residential sales by use of an econometric model. The basic approach taken is to obtain values for sales per customer and the number of residential customers, and then multiply them to obtain total residential sales. This is expressed as follows:

$$R = \frac{R}{C} \times C \qquad (2.1)$$

where:

R = residential sales in KWH;

$\frac{R}{C}$ = sales in KWH per residential customer;

C = total residential customers.

The methodology developed by NERA to forecast sales per customer is defined as the sum of competitive usage and net usage or,

$$\frac{R}{C} = \frac{RA}{C} + \frac{RN}{C} \qquad (2.2)$$

where:

$\frac{RA}{C}$ = competitive usage in KWH per customer;

$\frac{RN}{C}$ = net usage in KWH per customer.

Competitive usage is defined as the yearly electric consumption per customer for space heating, water heating, ranges and clothes dryers -- appliances for which alternative fuels are available. Net usage is then defined as the remaining electric usage, which includes appliances where electricity has a monopoly, such as lighting and air conditioning as well as above or below average use of competitive usage appliances.

The competitive usage for a specific appliance can be written as:

$$\frac{RA}{C} = S \times A \qquad (2.3)$$

where:

S = appliance saturation;

A = average yearly KWH usage of particular appliance.

The average annual KWH consumption of ranges and clothes dryers is obtained from the Edison Electric Institute. NERA developed the following two equations to estimate the average annual consumption of space and water heating which are weather-sensitive:

$$A_{SH} = a(HDD) - b(HDD)^2 \qquad (2.4)$$

$$A_{WH} = c + d(HDD) \qquad (2.5)$$

where:

A_{SH} = average annual KWH for space heating;

A_{WH} = average annual KWH for water heating;

HDD = heating degree days for service territory.

Competitive usage, in KWH/customer, is calculated for space and water heating, cooking and clothes drying. The appliance saturations are obtained using relationships which identify the customer's behavior, sometimes called behavioral equations, in purchasing these appliances and can be functionally written as:

$$S = f\ (P_E,\ P_{CF},\ Y,\ HDD,\ H) \qquad (2.6)$$

where:

P_E = real price of electricity in ¢/KWH;

P_{CF} = real price of competitive fuel in ¢/therm;

Y = personal income per household in real $;

HDD = number of heating degree days;

H = collection of housing and demographic characteristics.

Saturations for air conditioning were developed in the same manner as above. The data base used to develop the above saturation equation, Eq. (2.6), was the 1970 Census of Housing supplied by National Planning Data Corporation. It consists of consumption, price, income and other demographic data for 268 Minor Civil Divisions in New Jersey. Since these data are cross-sectional in nature, dummy variables were utilized to estimate the coefficients in the saturation equations.

The equation for net usage includes the air conditioning factors plus income, housing, and demographic variables and is specified as:

$$RN/C = f\ (AC1,\ AC2,\ AC3,\ AC4,\ Y1,\ Y2,\ Y3,\ Y4,\ Y5,\ Y6,\ H) \qquad (2.7)$$

where:

AC1 = percent saturation of central air conditioners;

AC2 = percent saturation of three window air conditioners;

AC3 = percent saturation of two window air conditioners;

AC4 = percent saturation of one window air conditioners;

Y1 = percent unemployed;

Y2 = percent earning \$1.00 to \$6,000 annually;

Y3 = percent earning \$6,001 to \$12,000 annually;

Y4 = percent earning \$12,001 to \$18,000 annually;

Y5 = percent earning \$18,001 to \$24,000 annually;

Y6 = percent earning over \$24,000 annually;

H = selected housing and demographic variables.

The coefficients of the net usage equation are estimated from data contained in the 1976 ACE Residential Appliance Saturation Survey, again cross-sectional in nature. Then, projections of the growth of the independent variables are made to develop the forecasts of electricity sales per customer. The forecasted competitive and net usages are added together, and then multiplied by the number of customers to obtain forecasted total residential sales.

The current forecast considers natural gas as an alternative fuel. ACE purchased NERA's R/G/D Model which allows the company to input gas data in addition to the oil and propane information previously included. Also included are appliance efficiencies mandated by the federal government, as well as other nonprice conservation factors such as weatherization and new building efficiency standards.

2.2 Commercial Sales

Electric sales to the commercial sector are forecasted using the following equation:

$$K_t = (K_{t-1}) \times \left(\frac{I_t}{I_{t-1}}\right)^{a_1} \times \left(\frac{R_t}{R_{t-1}}\right)^{a_2} \times \left(\frac{H_t}{H_{t-1}}\right)^{a_3} \times \left(\frac{P_t}{P_{t-1}}\right)^{-0.4} \qquad (2.8)$$

where:

t = forecast year;

K = commercial sales in KWH;

I = income per capita in \$;

R = number of residential customers;

H = number of housing starts;

P = marginal price of electricity in \$.

In the above equation the constant -0.4 represents price elasticity developed by NERA from national data and validated for the ACE service area. The constant a_1, a_2, a_3 are the estimates of the parameters of the following equation:

$$\ln K^1 = a_0 + a_1 \ln I + a_2 \ln R + a_3 \ln H \qquad (2.9)$$

where:

K^1 = adjusted commercial sales in KWH.

The adjusted commercial sales is obtained from the following equation:

$$\ln K^1 = \ln K + 0.4 \ln (\text{TEB at 40 KW, 10,000 KWH - TEB at 12 KW, 1500 KWH} - 0.05\ CDD_t/CDD_{t-1}) \qquad (2.10)$$

where:

TEB = typical electric bill;

CDD = cooling degree days.

The data used are for the period 1961 to 1978 and the sources are:

1. Commercial sales - ACE Annual Reports
2. Number of residential customers - Federal Power Commission (FPC)
3. Income per capita - U.S. Department of Commerce
4. TEB - FPC
5. Number of housing starts - N.J. Department of Labor and Industry
6. CDD - South Jersey weather stations

Forecasts of the following independent variables; I, R and H are made for a 15 year period by DRI. The forecasted values are subsequently adjusted to account for nonprice conservation based on information from Energy Information Administration (EIA).

2.3 Industrial Sales

In the industrial sector the company looks at two separate forecasts, a short-term 1 to 5 years based upon survey data, and a long-term 6 to 15 years based upon more refined econometric techniques.

The short-term forecast is based on an annual Industrial Load Survey prepared by the company's Commercial and Industrial Department. Sales estimates are then obtained by multiplying the industrial demand times the average load factor times the number of hours in a year.

The long-term forecast uses an econometric approach in which the coefficients are developed from a 1975 cross-section of Standard Metropolitan Statistical Area (SMSA) data for selected major Standard Industrial Classification (SIC) code industries located in ACE's territory.

The coefficients for each SIC code industry were estimated using the following equation:

$$I = f\ (E,\ P,\ F) \tag{2.11}$$

where:

I = sales in KWH consumed by SIC code industry in SMSA;

E = total employment in SIC code industry in SMSA;

P = price of electricity to SIC code industry in SMSA;

F = price of competitive fuel in SMSA.

The historical employment data was obtained from the New Jersey Department of Labor and Industry. ACE projected the annual growth rate for the real price of electricity. The projection for the real price of competitive fuels was done by NERA, based solely upon natural gas which it considered the dominant industrial competitive fuel.

2.4 Peak Demand

The annual peak is forecast as the sum of the peaks projected for each respective rate class -- residential, commercial, industrial, "Other," and Du Pont. The residential and commercial classes are further subdivided into baseload and weather-sensitive portions (summer or winter). Since most service-territory industrial customers use electricity for process rather than space conditioning purposes, no weather-sensitive component is currently attributed to the industrial class.

The initial value used to develop the forecast is the most recent historical system peak. The actual data is adjusted to normal weather conditions using linear regression techniques. A weighted Temperature Humidity Index (WTHI) is used as the weather variable. The formulas used by ACE to calculate WTHI are:

Summer

$$WTHI = 3/4\ THI_0 + 1/4\ THI_{-1} \tag{2.12}$$

Winter

$$WTHI = 3/5\ THI_0 + 2/5\ THI_{-1} \tag{2.13}$$

where:

THI_0 = THI on the day of the peak;

THI_{-1} = THI on the day prior to the peak.

The Temperature Humidity Index (THI) is calculated using the U.S. Weather Bureau formulas (see Appendix D).

The average of all system demands recorded with an associated WTHI between 60°F and 68°F defines the baseload. Due to space conditioning requirements, the demand increases both above and below these threshold WTHI values. The seasonal weather-sensitive demands are determined as the difference between the baseload and the demand at the normal extreme WTHI for the service territory -- 82.8°F summer and 28.8°F winter.

Now the baseload and weather-sensitive portions of the summer and winter peaks are determined. Next, the residential, commercial, and industrial contributions to the baseload and, as previously stated, the residential and commmercial contributions to the weather-sensitive demand are calculated.

Residential summer baseload is projected by applying to the prior year's summer baseload the rate of growth projected for residential sales. Winter baseload is projected by applying the growth in sales for purposes other than space heating to the prior year's winter baseload.

Commercial baseloads are projected by multiplying the previous year's baseload (summer or winter) by the forecast growth in commercial sales. Added to the commercial baseload are the projected peaks of the various casino-hotels as they are scheduled to become operational.

Total summer weather-sensitive demand is forecast by applying to the previous year's weather-sensitive peak the growth in air conditioning saturation and growth in number of residential customers. Annual winter weather-sensitive peaks are projected by applying to the previous year's weather-sensitive peak the growth in sales for space heating purposes.

The annual industrial peak is forecast by adjusting the prior year's industrial peak (summer or winter) by the projected growth in industrial sales. Adjustments, if warranted, are made in the early years for extraordinary customer expansions or deletions.

The "Other" rate class is estimated to be a constant one megawatt demand while the Du Pont demand is obtained via discussions with Du Pont.

CHAPTER 3

JERSEY CENTRAL POWER & LIGHT

JCP&L, which is one of the operating companies of GPU, has its Energy Sales and Peak Demand Forecasts performed by GPU Service Corporation's Forecasting Department using historical data specific to JCP&L's service territory. JCP&L's energy forecast is the sum of the forecasted energy requirements for the residential, commercial, industrial and "Other" sectors.

In general, JCP&L's forecast methodology is based upon econometric or end-use modeling techniques or a combination thereof. The forecasting methodology for the residential, commercial, and industrial sectors will be discussed in subsequent sections. It may be noted that input to some of the sector models is based upon the output of the Economic/Demographic (Eco/Demo) Model which is described first.

3.1 Economic/Demographic Model

The Eco/Demo Model was developed by Booz-Allen and Hamilton, Inc. (Booz-Allen) to forecast certain key variables such as population, employment and income within JCP&L's service territory. The primary outputs of the model provide forecasts of the total number of residential customers and the total number of employees in the commercial sector.

A flow chart of how the Eco/Demo Model is used to obtain the forecasts of residential customers and the number of commercial employees is contained in Fig. 3.1. The inputs to the model are obtained from company records, U.S. Census Bureau, and New Jersey State agency data and forecasts developed by the National Planning Association (NPA).

3.2 Residential Sales

JCP&L forecasts its residential energy sales on a quarterly basis by rate classes, which are comprised of all-electric, water heat, and residential service rate classes. The residential forecast by rate class as developed by DRI and modified by GPU is specified as a function of use per customer times number of customers or:

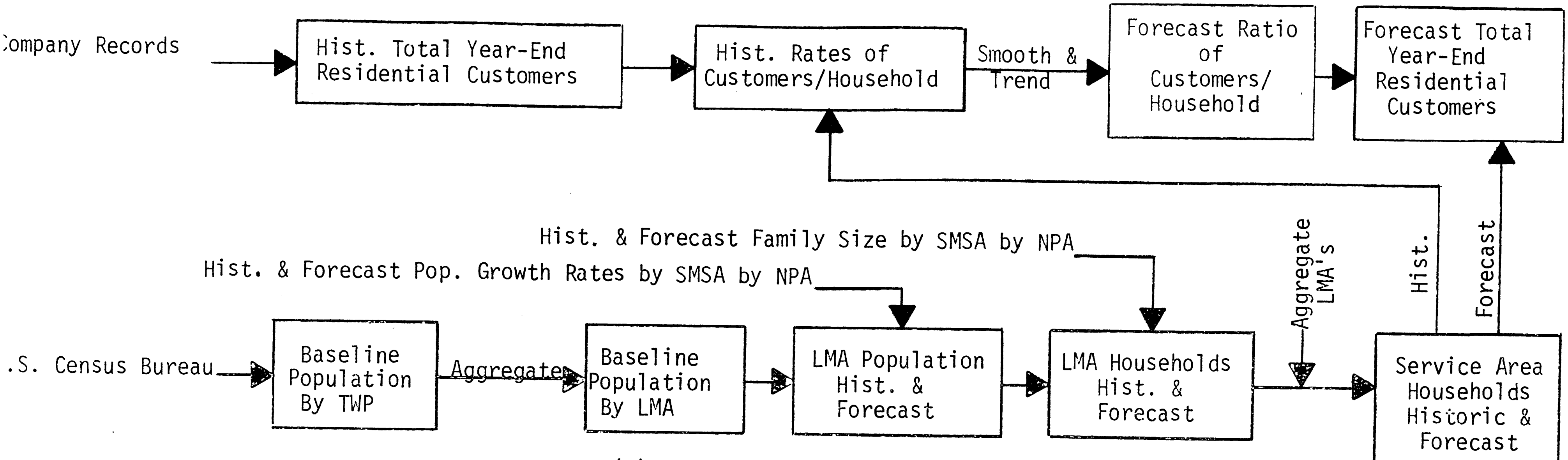
$$\text{Residential Sales} = \text{Use/Customer} \times \text{\# of customers} \quad (3.1)$$

The use per customer is based upon an end use-econometric equation incorporating appliance saturation (end use), electricity price, dummy variables which represent nonweather-sensitive seasonal variations, plus nominal cooling and heating degree days and it is specified as:

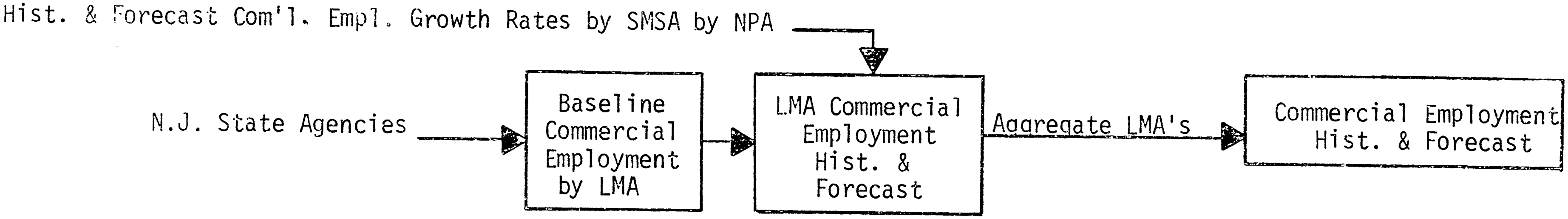
$$\begin{aligned}\ln(\text{use/customer}) - \ln(\text{Stock Index}) &= a_0 + a_1 \ln(\text{Price}) + a_2(\text{Q1}) + a_3(\text{Q2}) \\ &\quad + a_4(\text{Q3}) + a_5(\text{CDD}) + a_6(\text{HDD}) \qquad (3.2)\end{aligned}$$

where:

use/customer = the quarterly energy consumption per customer;



(a) Residential



(b) Commercial

Fig. 3.1 Eco/Demo Model

stock index = the quarterly energy consumption, in KWH per typical customer, for the eleven (11) appliances specifically modeled by GPU. For each typical customer the consumption per appliance equals the products of percent saturation, power requirement per appliance, and quarterly usage in hours;

price = the typical quarterly bill in dollars, indexed to 1977;

Q1 = quarterly dummy representing nonweather-sensitive seasonal variation (= 1, if 1st quarter and 0 otherwise);

Q2 = quarterly dummy representing nonweather-sensitive seasonal variation (= 1, if 2nd quarter and 0 otherwise);

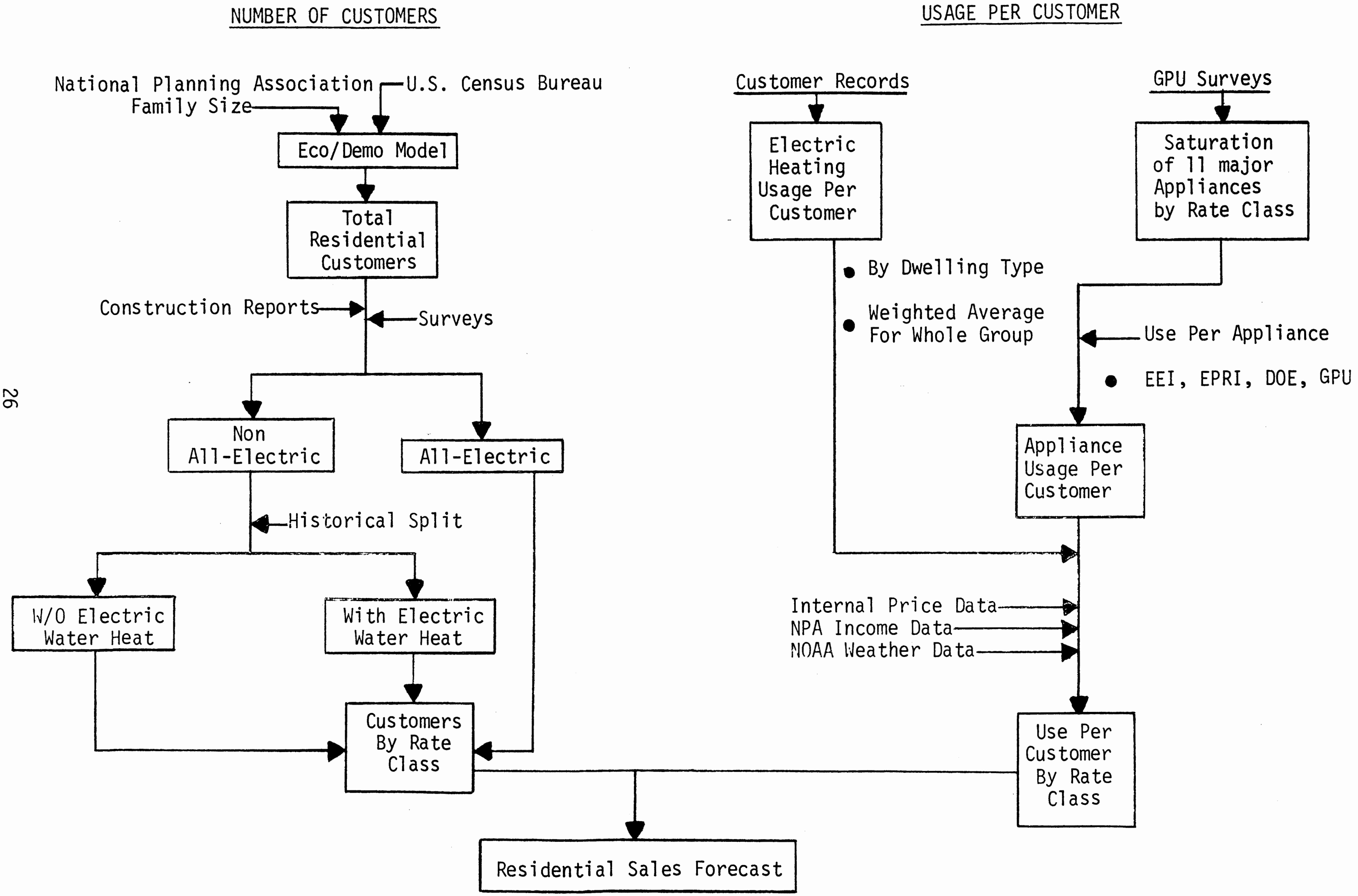
Q3 = quarterly dummy representing nonweather-sensitive seasonal variation (= 1, if 3rd quarter and 0 otherwise);

CDD = cooling degree days for quarter under consideration;

HDD = heating degree days for quarter under consideration.

The coefficients of regression are estimated using historical data from 1965 through 1977.

The basis for the number of customers by rate class is the total number of residential customers provided by the Eco/Demo Model. The total number of residential customers is disaggregated in terms of 1) all-electric customers and 2) non all-electric customers, on the basis of historic relationship adjusted for the forecast period, as shown in Fig. 3.2. Further, the non all-electric customers are disaggregated using historic relationship with adjustment for the future in terms of customers with 1) electric water heat, and 2) without electric water heat.


NUMBER OF CUSTOMERS
USAGE PER CUSTOMER
National Planning Association
Family Size
U.S. Census Bureau
Eco/Demo Model
Total Residential Customers
Construction Reports
Surveys
Non All-Electric
All-Electric
Historical Split
W/O Electric Water Heat
With Electric Water Heat
Customers By Rate Class
Customer Records
Electric Heating Usage Per Customer
● By Dwelling Type
● Weighted Average For Whole Group
GPU Surveys
Saturation of 11 major Appliances by Rate Class
Use Per Appliance
● EEI, EPRI, DOE, GPU
Appliance Usage Per Customer
Internal Price Data
NPA Income Data
NOAA Weather Data
Use Per Customer By Rate Class
Residential Sales Forecast

3.2.1 All-electric Rate Class

The rate class identified as all-electric is defined as those customers who are supplied electric energy for space and water heating, lighting, and other electric appliances. In other words, the only energy form supplied to this particular rate class is electricity.

Based upon historical data specific to the all-electric rate category, the coefficients in Eq. (3.2) are estimated to model historical quarterly sales per customer in this rate category.

The forecast of the number of all-electric customers developed from the residential model and the forecast of the use per all-electric customer developed from Eq. (3.2) are then substituted into Eq. (3.1) to forecast the energy sales to the all-electric rate category.

3.2.2 Water Heating Rate Class

The rate class identified as water heating is defined as those customers who are supplied electricity for water heating, lighting, and electric appliances, but not for space heating.

Based upon historical data specific to the water heating rate category, the coefficients in Eq. (3.2) are estimated to model historical quarterly sales per customer in this rate category.

The forecast of the number of water heating customers developed from the residential model and the forecast of the use per water heating customer developed from Eq. (3.2) are then substituted into Eq. (3.1) to forecast the energy sales to the water heating rate category.

3.2.3 Residential Service Rate Class

The rate class identified as residential service is defined as those customers who are supplied electricity for lighting and electric appliances, but not for space or water heating.

Based upon historical data specific to the residential service rate category, the coefficients in Eq. (3.2) are estimated to model historical quarterly sales per customer in this rate category.

The forecast of the number of residential service customers developed from the residential model and the forecast of the use per residential service customer developed from Eq. (3.2) are then substituted into Eq. (3.1) to forecast the energy sales to the residential service rate category.

3.3 Commercial Sales

JCP&L's commercial energy sales are forecast on an annual basis using econometric techniques. This forecast is further divided into sub-forecasts of baseload or nonweather-sensitive, summer weather-sensitive, and winter weather-sensitive components.

The functional form of the model was specified by Booz-Allen, the consultant contracted to develop the commercial forecast by GPU, and yields energy per employee in the commercial sector in JCP&L's service territory. The output of the model when multiplied by the number of employees projected by the Eco/Demo Model gives the energy sales for the commercial sector, as shown in Fig. 3.3. The resultant equation is specified as:

$$E_t = Q_t \times EMP_t$$

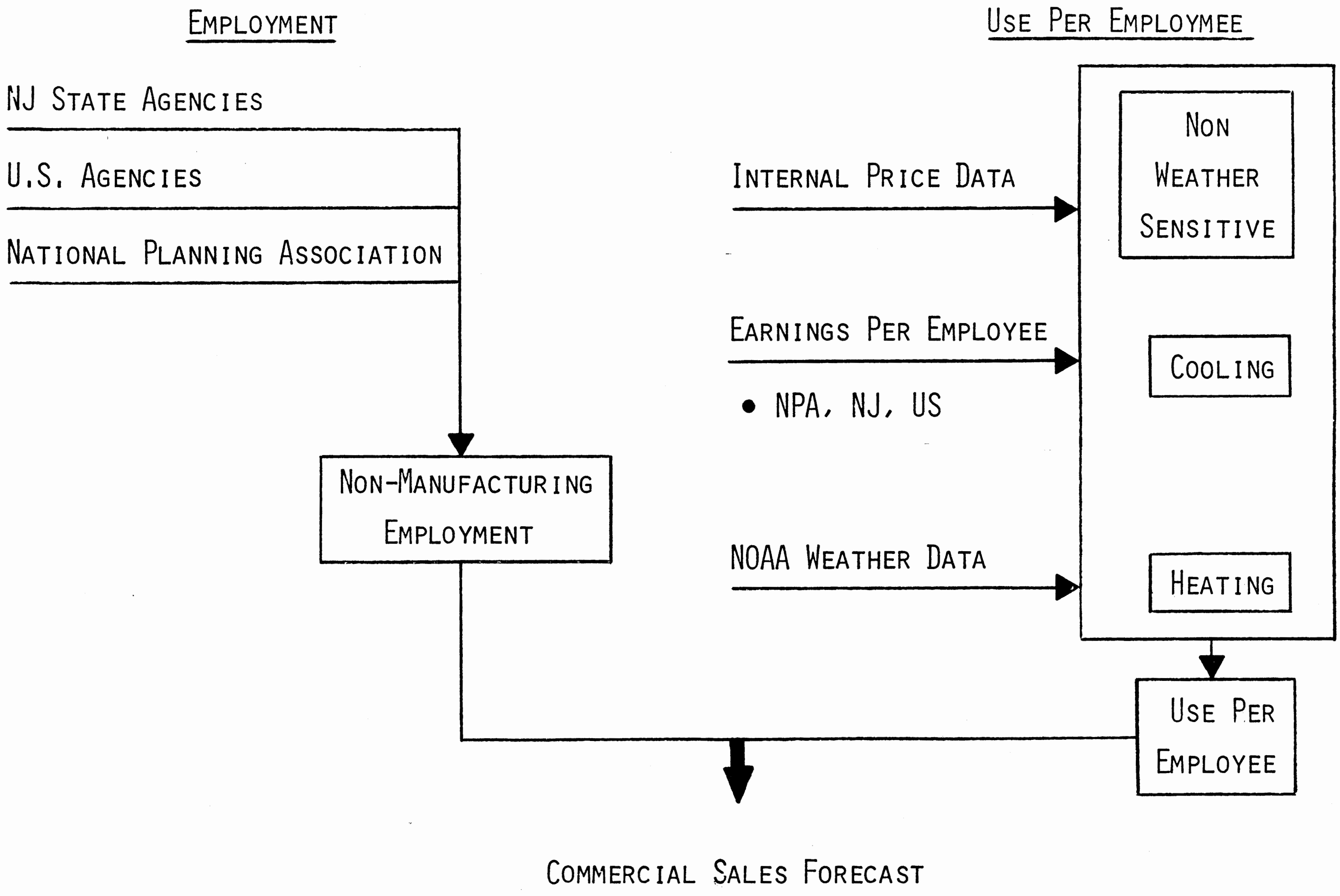


FIG. 3.3 COMMERCIAL MODEL

where:

t = forecast year;

E = annual energy sales to the commercial rate class in MWH;

Q = annual energy sales per commercial employee;

EMP = number of employees in the commercial rate class.

This model has not been run since 1977 and instead is being manually adjusted using the same growth rate, however, the starting point for the projection is the current year's sales level. A new commercial model is being developed to replace this model, however, since the forecast was formulated originally based on this format we will describe the way it is used.

3.3.1 Baseload

The baseload forecast is developed to identify the sales which are unaffected by weather variations, such as temperature and humidity.

The model providing baseload energy sales per employee is specified as:

$$\ln QN_t = a_0 + a_1 \ln(PE_t) + a_2 \ln(INC_t) + a_3 \ln(QN_{t-1}) \quad (3.4)$$

where:

t = the forecast year;

QN = the baseload energy sales per employee;

PE = the price of electricity in ¢/KWH;

INC = the projected income in $;

QN_{t-1} = the lagged dependent variable reflecting prior year's use adjusted for weather. For the commercial forecast, this is always the prior year's forecast and not actual use.

GPU is responsible for the forecast of the price of electricity within the time frame of the forecast while NPA is under contract to develop the forecast of the income.

The output of the Eco/Demo Model in number of employees in the commercial sector times the baseload energy sales (QN_t) results in the annual baseload consumption forecast of the commercial sector.

$$EN_t = QN_t \times EMP_t \tag{3.5}$$

where:

EN = baseload energy sales in commercial sector.

3.3.2 Summer Weather-sensitive

The summer weather-sensitive forecast is developed to identify the sales which result from the effects of high temperature and humidity.

The model providing summer weather-sensitive energy sales per employee is specified as:

$$\ln QS_t = a_0 + a_1 \ln(PE_t) + a_2 \ln(INC_t) \tag{3.6}$$

where:

QS = the summer weather-sensitive energy sales per employee.

The coefficients are estimated using historical summer weather-sensitive sales data.

The output of the Eco/Demo Model in number of employees in the commercial sector times the summer weather-sensitive energy sales (QS_t) results in the annual summer weather-sensitive consumption forecast of the commercial sector.

$$ES_t = QS_t \times EMP_t \tag{3.7}$$

where:

ES = summer weather-sensitive energy sales in commercial sector.

3.3.3 Winter Weather-sensitive

The winter weather-sensitive forecast is developed to identify the sales which result from the effects of low temperature.

The model providing winter weather-sensitive energy sales per employee is specified as:

$$\ln QW_t = a_0 + a_1 \ln(PE_t) + a_2 \ln(INC_t) \tag{3.8}$$

where:

QW = winter weather-sensitive energy sales per employee.

The coefficients are estimated using historical winter weather-sensitive sales data.

The output of the Eco/Demo Model in number of employees in the commercial sector times the winter weather-sensitive energy sales (QW_t) results in the annual winter weather-sensitive consumption forecast of the commercial sector.

$$EW_t = QW_t \times EMP_t \tag{3.9}$$

where:

EW = winter weather-sensitive energy sales in commercial sector.

3.4 Industrial Sales

JCP&L has recently revised its forecast methodology for the industrial sector.

The general structure of the model is graphically presented in Fig. 3.4.

The model is specified as:

$$\begin{aligned}\ln E_t = a_0 + a_1 \ln(E_{t-i}) + a_2 \ln(Q_{t-j}) + a_3 \ln(PE_t) \\ + a_4 \ln(Po_t) + a_5 (S_t)\end{aligned} \tag{3.10}$$

where:

t = forecast year;

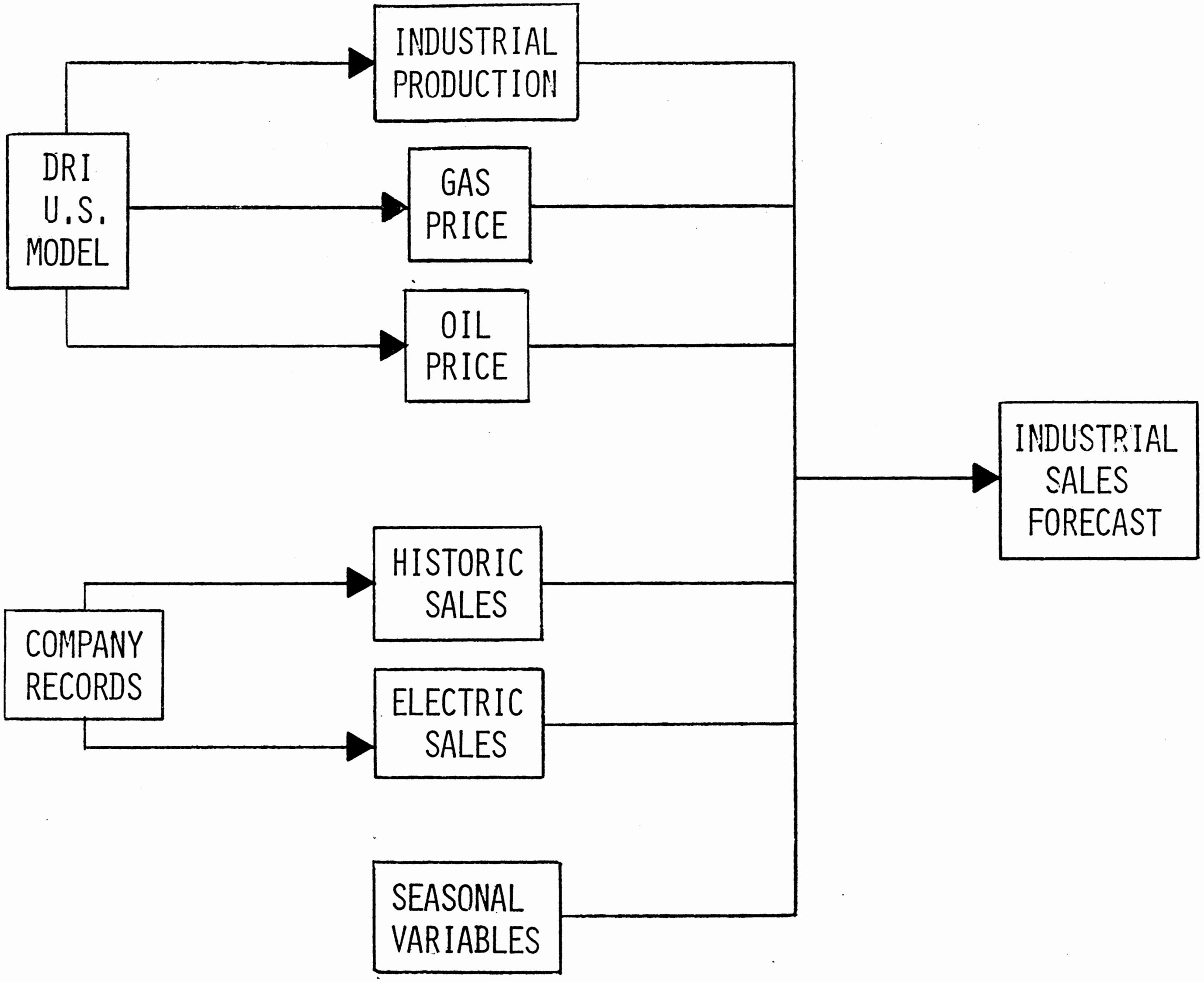


FIG. 3.4 INDUSTRIAL MODEL

i,j = time lag of the lagged variables, i.e., $i = 3$ & $j = 1$, respectively;

E_{t-i} = lagged variable, industrial energy sales in MWH. For the quarter being forecast, its value is the actual or forecast value of industrial energy sales of 3 quarters earlier;

Q_{t-j} = lagged variable, industrial output index. For the quarter being forecast, its value is the actual or forecast value of the industrial output index of the previous quarter.

PE = average price of electricity to the industrial sector in ¢/KWH;

Po = average price of natural gas to the industrial sector in ¢/therm;

S = seasonal dummy (see Glossary).

DRI provides the forecasts of the industrial production index and price of natural gas on a quarterly basis for the time span of the corporate forecast. The price of natural gas is used as a proxy for alternate competitive fuels to the industrial sector. GPU's Forecasting Department develops the forecast of the price of electricity on a quarterly basis for the entire length of the forecast.

To develop the short-term and long-term sales forecasts, values of the independent variables are forecast independently for the quarter under consideration, i.e., 1st, 2nd, 3rd and 4th, and substituted into

Eq. (3.10). For a given year of the forecast, the 1st, 2nd, 3rd and 4th quarter forecasts are then added together to obtain an annual forecast of energy sales to the industrial sector. This procedure is repeated until annual energy sales have been developed for the time span of interest.

3.5 "Other" Sales

The previous sections discussed the forecasting methodologies to predict energy sales to the residential, commercial, and industrial sectors. However, there are other energy sales which make up the total system requirements. These "Other" sales include electrical energy for public street and highway lighting and public authorities, and sales for resale. Public street and highway lighting and sales to public authorities are forecasted using trend analyses and projections. The sales for resale forecast is provided by the resale customers.

3.6 Peak Demand

The Peak Load Model forecasts peak demand as a function of rate class contribution to peak demand. This class contribution to peak demand is arrived at by multiplying the forecast rate class energy sales times the rate class load ratio. The rate class load ratio is defined as the peak demand of that rate class divided by the energy sales of that rate class, or:

$$L.R. = \frac{\text{Peak Demand}}{\text{Energy Sales}} \qquad (3.11)$$

where:

L.R. = load ratio;

Energy Sales = electrical energy to rate class in MWH;

Peak Demand = max. power required by rate class in MW.

The rate class load ratios are developed from Load Research data. These load ratios are calculated using rate class demand which is coincident with the operating company's peak demand.

These load ratios are held constant during the forecast period. The sum of the products of each class' load ratio and energy sales forecasts equates to the unadjusted peak demand for each year.

These results are explicitly adjusted for curtailable loads and load management effects to derive the final peak demand forecast.

CHAPTER 4

PUBLIC SERVICE ELECTRIC AND GAS

PSE&G, the State's largest utility, forecasts the electric consumption and peak demand for the residential, commercial and industrial customer classes through the use of several different methods, most of which have been developed by the company's forecasting group. The rationale for using a multi-faceted approach is to provide a range of forecasts, thus trying to avoid the bias inherent in any one method while providing a cross-check of the various results. Some of the different methods used include: econometric models, customer use surveys, geographic area analysis, saturation model, and SIC number analysis for electric consumption; substation analysis, load factor, and a weather-sensitivity model for peak demand. The use of these methods allows the forecaster to investigate factors which, though unrelated to one another, influence the final forecast. Here is an example of how the various methods are used to develop the forecast: If we have three methods (A, B and C) as shown in Fig. 4.1, the final forecast would be chosen judgmentally from the range common to the three forecasts. All official company forecasts are subject to review and approval by the Energy Forecasting Committee. This Committee consists of eleven management representatives from various disciplines in the company, including marketing, rates and load management, planning, finance, governmental affairs, production, and area development. All forecasts are reviewed and approved by upper-management before adoption for use in corporate planning.

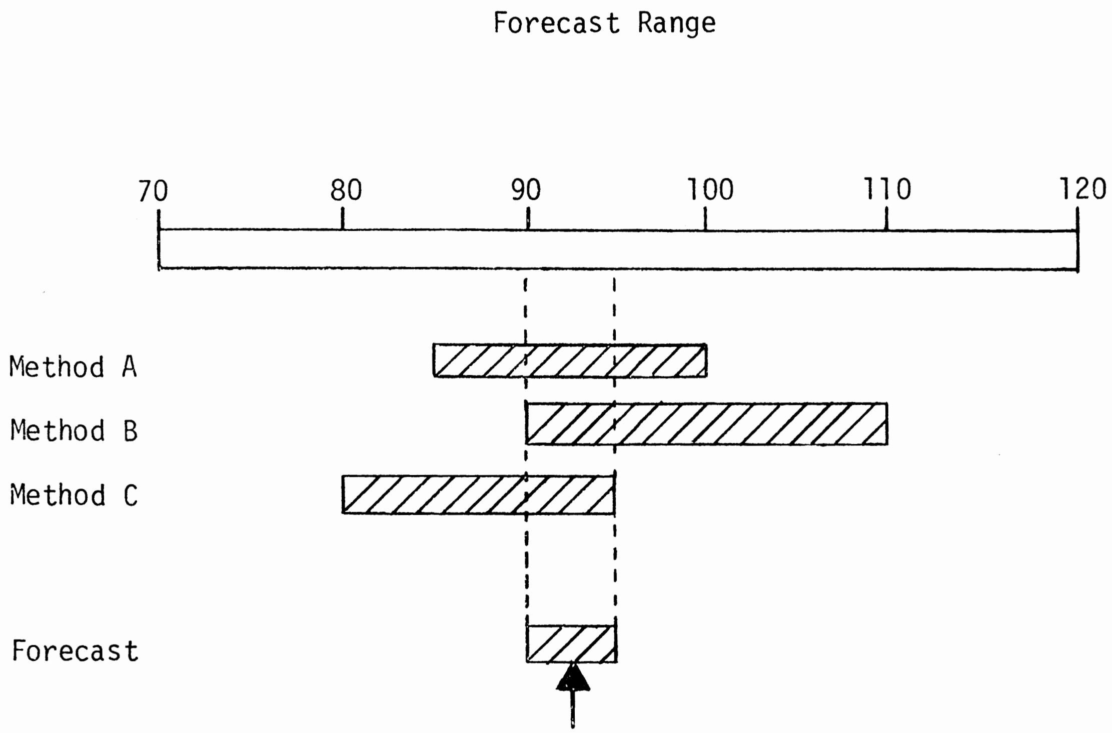


Fig. 4.1 Multi-method Forecast

The corporate forecast is constructed by using a building block approach. The rate category forecasts are developed first, then totalled to obtain the customer class forecasts which are, in turn, totalled to develop the corporate forecast. A block diagram showing this approach is depicted in Fig. 4.2.

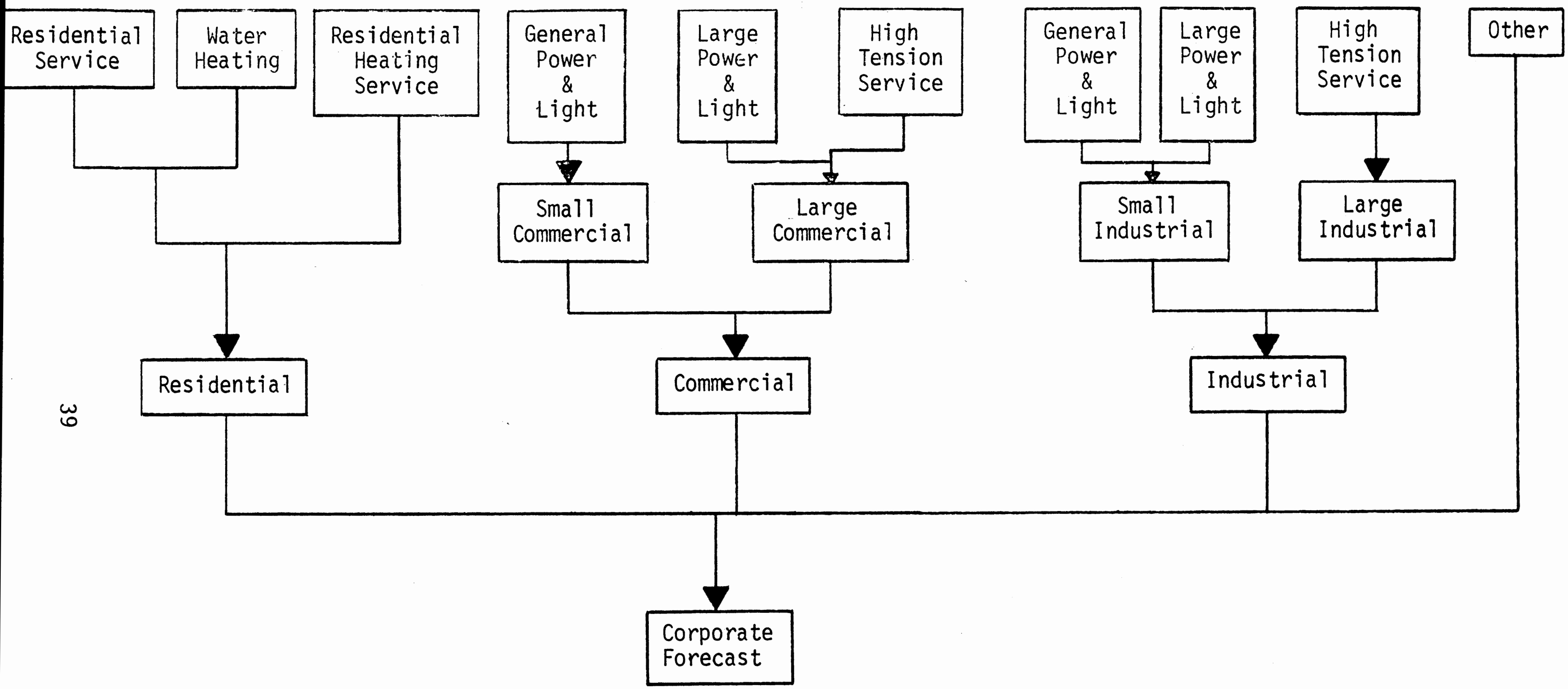


Fig. 4.2 Building Block Approach

4.1 Inputs/Assumptions

Figure 4.3 illustrates the general forecast structure employed by PSE&G to develop its forecast. The first row shows the inputs which are required to initiate the forecasting process. In order to develop its forecast, PSE&G considers the economic situation nationally and locally, population trends, prices of all energy sources, business philosophy, political climate (particularly the regulatory climate) and the available technology and possible advancements.

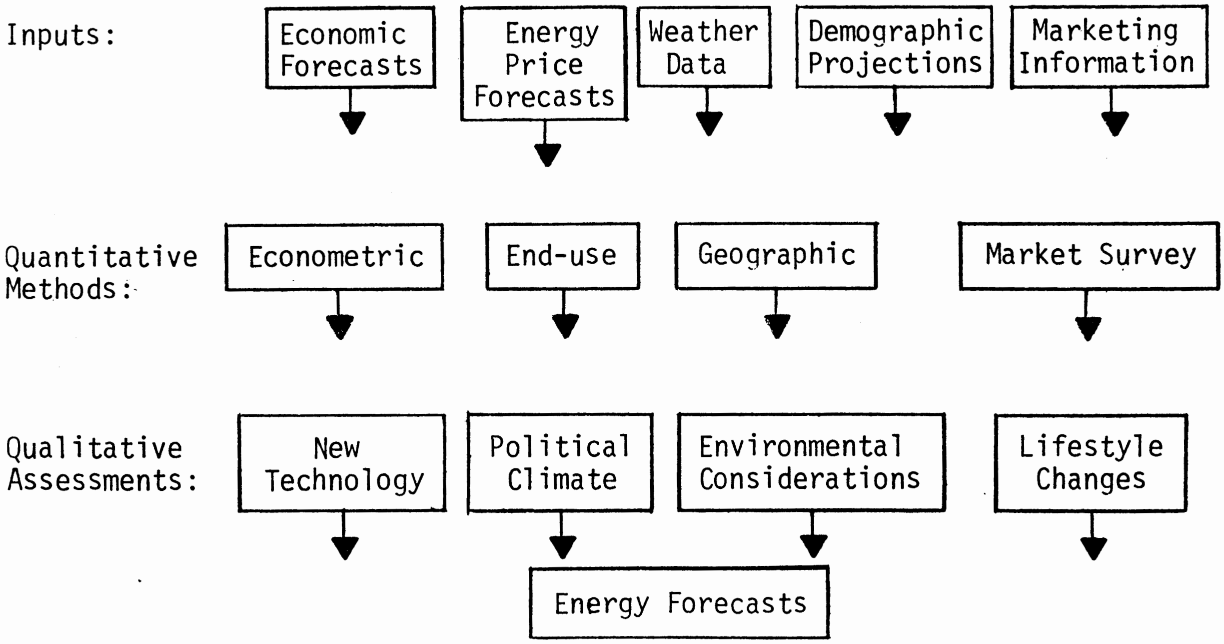


Fig. 4.3 Forecast Flow Chart

PSE&G retains Merrill Lynch Economics, Inc., to develop national, state and service territory economic forecasts. In addition, cross-checks are made by the company of available economic statistics from government and commercial sources.

PSE&G has developed its own demographic model of New Jersey. It is called the Cohort-Component Population Model, which analyzes population mix, survival and birth rates, and migration patterns. A flow chart of this model is shown in Fig. 4.4. Actual historical energy price levels are used as input data modified by recent regulatory or political considerations, which would have a significant impact on the long-term trend. In addition, the company's capital investments and operating plans which would change generation mix are included in the analysis of the energy price trends.

The business considerations which are taken into account revolve around the desire for corporations to locate within PSE&G's franchise territory, based on taxes, labor costs, availability of transportation networks, land for development, and housing.

Political decisions, whether legislative or regulatory, can change the availability of fuel, the type of equipment that can be used and the location for plants. A conservation ethic mandated by legislation or regulation, which causes such tariff revisions as

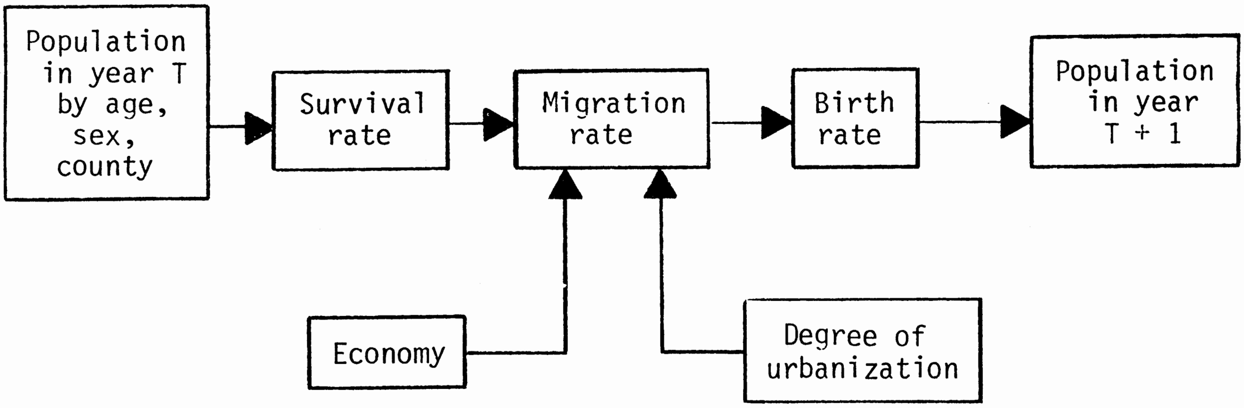


Fig. 4.4 Cohort Population Projection Model

time-of-day rates or load management, can significantly affect consumption and demand for electricity. The BOCA Energy Subcode for buildings affects the heating and water heating loads and the IES Lighting Codes for new and existing buildings will reduce the consumption and demand for electricity for lighting purposes.

The company looks at the effect of implementing existing technology such as appliance efficiency improvements, higher efficiency lighting, and battery-powered automobiles. New technology which could improve heat rates of new or existing plants, higher voltage or DC (instead of AC) transmission lines, electric storage heating, higher efficiency photovoltaic cells or other unknown factors must be considered in beginning any forecast.

All historical data bases used in the forecasting process are corrected to normal weather conditions. This is extremely important in that the use of actual sales and/or peak demands, which are subject to the vagaries of the weather, might provide false indications of growth and serve as an erroneous starting point for the forecast. For example, if a summer is extremely hot, as was 1980, actual sales might be 10% to 15% above a "normalized" level of sales. If the actual data is used as the starting point for an applied growth rate, sales projections for the mid-1990's would be 25% to 30% too high. PSE&G uses THI hours to measure weather impacts in the summer months and degree days to measure weather impacts in the winter months or heating season.

In order to evaluate accurately the true sensitivity of electric customers to the increasing cost of electricity and other commodities, all prices take inflation into consideration. Thus, all price variables used in the forecasting models are real prices i.e., current prices adjusted to reflect the changes in the federal consumer price index for the New York Metropolitan area. Currently, this means that all prices are expressed in 1972 dollars. Historical data and current data both are recalculated to the 1972 level for such things as electric rates, oil price and income.

4.1.1 Customer Use Surveys

4.1.1.1 Residential

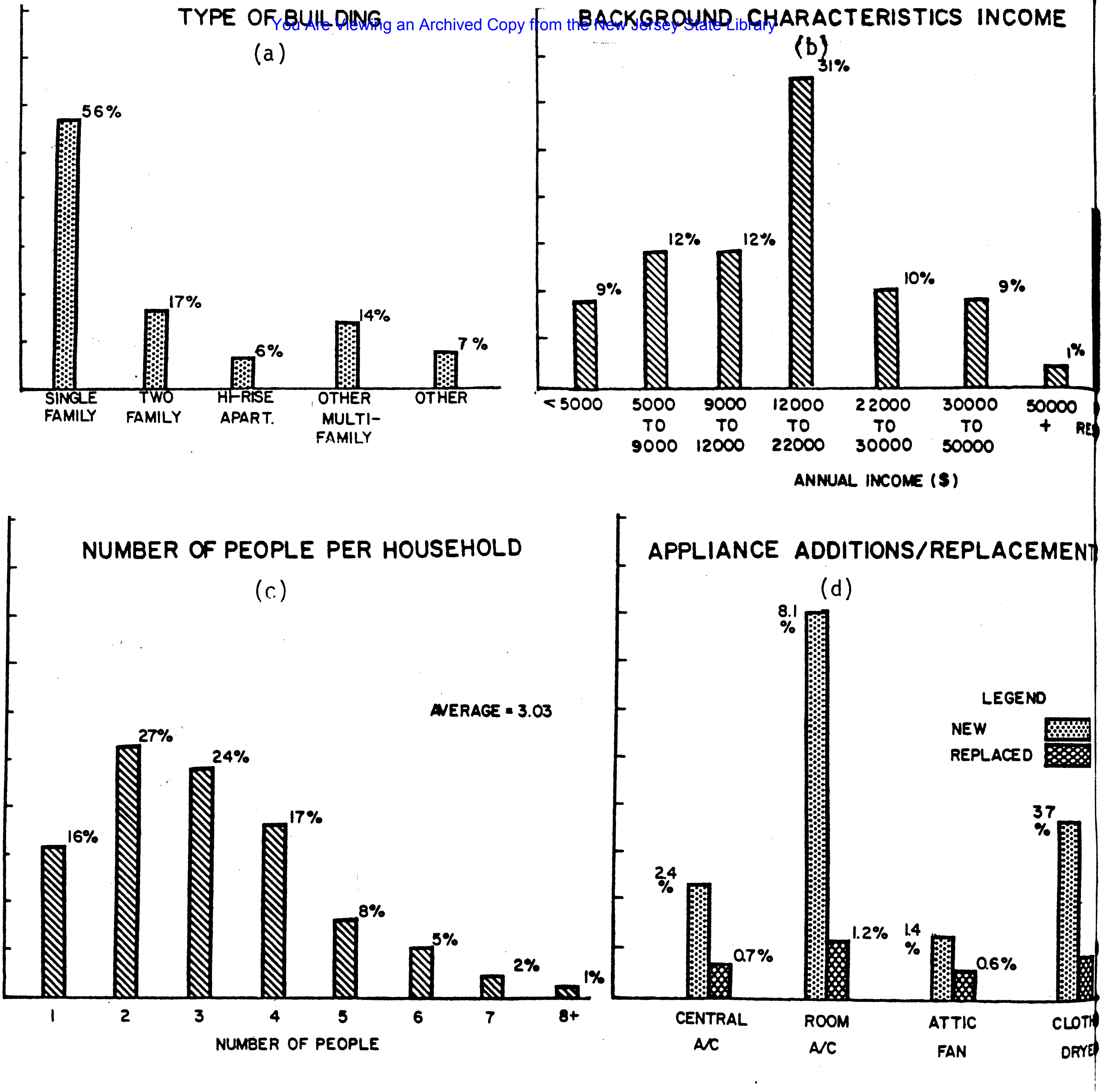
Each year the company surveys a cross-section of all customers from all classes of business by personal interview. The intent of these surveys is to establish for each customer class the key factors which influence customers' use and to determine the potential impact of these factors over the next several years. The following illustrations (Figs. 4.5a through e) are examples of the questions asked and data obtained in the residential area. This marketing information is a key input to all the methodologies employed in the forecasting process.

4.1.1.2 Commercial

Reliance is also placed on the data and information obtained from the commercial section of PSE&G's Energy Use Surveys. Usually about 600 customers are surveyed via personal interview. The primary emphasis of the commercial survey is directed toward determining the extent of the reaction of customers to business conditions and to conservation-related factors such as rising energy prices.

4.1.1.3 Industrial

The emphasis of the industrial customer energy use survey is directed toward determining the impacts of economic conditions and



ENERGY CONSERVATION STEPS TAKEN

(e)

	LOWERED USE SIGNIFICANTLY	LOWERED USE SLIGHTLY	NO CHANGE	INCREASED USE
HEAT	22%	33%	36%	1%
REFRIGERATION	1 %	6%	80%	2%
RANGES/OVENS	1%	9%	77%	1%
AIR CONDITIONING	8%	26%	43%	3%
LIGHTING	10%	33%	50%	1%

Fig. 4.5 Residential Customer Use Survey-Sample Data

conservation measures on sales. Typical questions asked industrial customers involve:

1. Projected changes in employment levels.
2. Reasons for increased use - expansion, extra shifts, working weekends?
3. Type of conservation program in place.
4. Plans for additional conservation programs.
5. Advantages and disadvantages of doing business in New Jersey.
6. Problems faced by your company.

4.2 Residential Sales

Residential sales are forecast by rate categories, residential service plus water heating (RS + WH) and residential heating service (RHS). Sales are forecast using the following methods:

1. RS + WH
    a. Econometric
        (1) Total
        (2) Use per Customer
    b. Appliance Saturation
    c. Geographic Area
    d. Base and Weather-sensitive
2. RHS
    a. Econometric
        (1) Total
        (2) Use per Customer
    b. Physical
    c. Base and Weather-sensitive

The RS + WH and RHS sales are summed to obtain residential sales.

4.2.1 Residential Service and Water Heating

4.2.1.1 Econometric

4.2.1.1.1 Total

The company has determined that the forecast of residential service (RS) along with the water heating service (WH) is primarily dependent on the price of electricity (RS Tariff), the price of #6 oil, which serves as a proxy variable for competitive fuel prices, and the real disposable income for New Jersey.

The econometric equation for this class is specified as follows:

$$\ln\{RSSY(T)\} = a_0 + a_1 \ln\{RSP72(T)\} + a_2 \ln\{OILPR72(T)\} + a_3 \ln\{NJDPI72(T)\} \qquad (4.1)$$

where:

RSSY = Residential service sales in MWH;

(T) = Year for which forecast is being developed;

RSP72 = Average real price of RS electricity in ¢/KWH in 1972 dollars;

OILPR72 = Real price of #6 oil in $/MBtu in 1972 dollars;

NJDPI72 = N.J. real disposable income in millions of 1972 dollars.

4.2.1.1.2 Use per Customer

Other econometric equations examine only use per customer. Use per customer equations separately examine winter use and summer use. These split season equations are used in order to measure the impact of the seasonal rate structure. See Fig. 4.6.

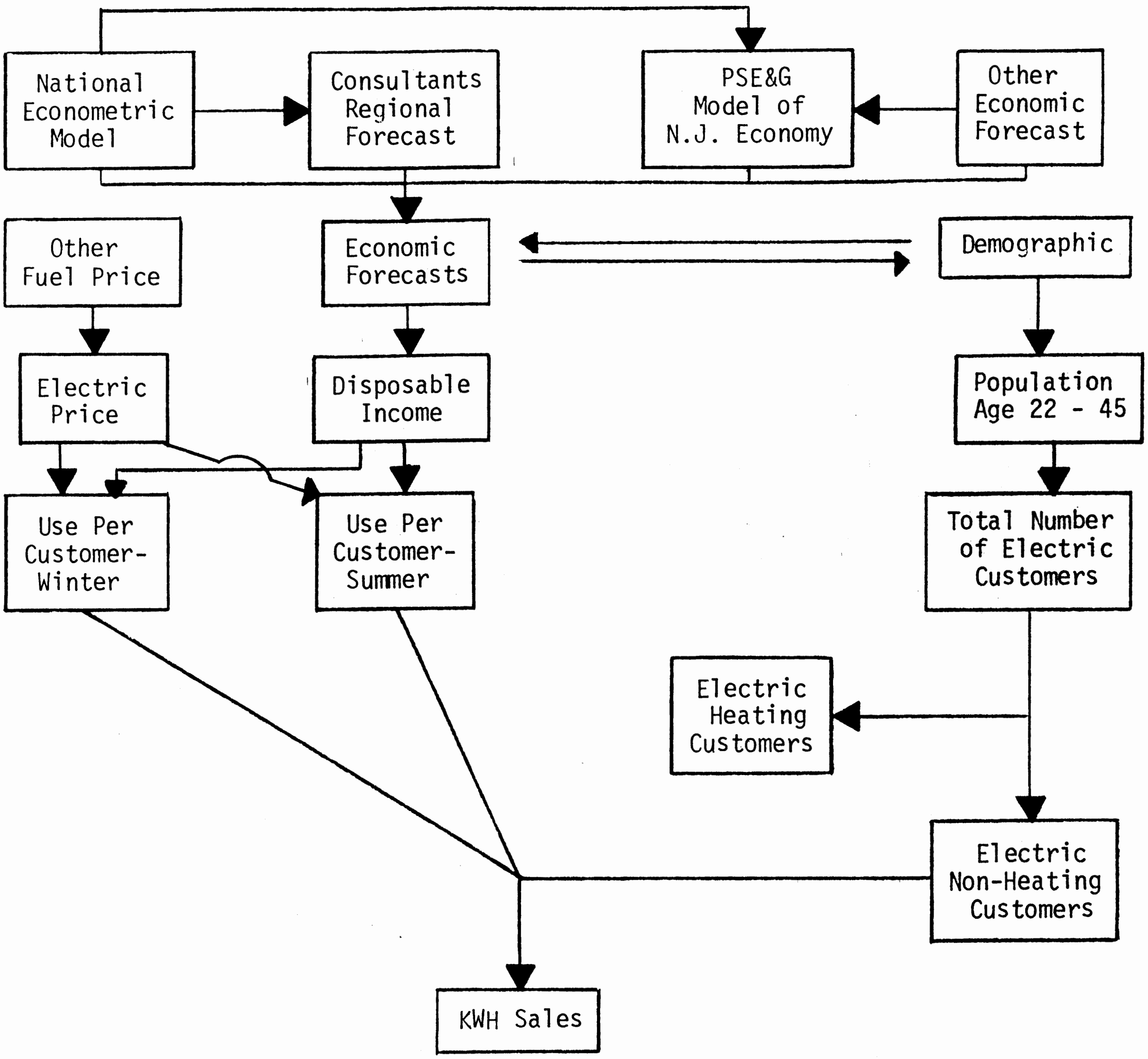


Fig. 4.6 Seasonal Use Per Customer

The summer model is specified as:

$$RSUPC_s = f(RSP_s72,\ OILPR72,\ TOTEQSAT) \qquad (4.2)$$

where:

RSP_s72 = Summer electric price in 1972 dollars;

TOTEQSAT = Room Air Conditioner Saturation + 3.5 x Central Air Conditioner Saturation.

The air conditioning saturation models are:

$$\text{Room AC Sat}' = f\ (NJDPI72,\ \text{Room AC Sat}'_{t-1}) \qquad (4.3)$$

$$\text{Central AC Sat}' = f\ (NJDPI72,\ \text{Central AC Sat}'_{t-1}) \qquad (4.4)$$

where:

Sat' = Adjusted air conditioning saturation.

The adjusted air conditioning saturation is calculated as follows:

$$\text{Sat}' = \frac{\text{Sat}}{\text{Sat}_{max} - \text{Sat}} \qquad (4.5)$$

where:

Sat_{max} = Maximum expected saturation of air conditioning which is:

Room = 1.5

Central = 1.0

The calculation of Sat' is necessary to avoid the problem of ever-increasing saturations being forecast. The maximum expected saturation sets an upper limit on the possible saturations.

The winter model is specified as:

$$RSUPC_w = f(RSP_w72,\ NJDPIPC72) \qquad (4.6)$$

where:

RSP_w72 = Winter electric price in 1972 dollars;

NJDPIPC72 = New Jersey disposable personal income per capita in 1972 dollars.

The average of the winter and summer models times the number of RS customers gives the sales for the forecast year.

4.2.1.2 Appliance Saturation

PSE&G conducts a biannual survey of its customers to determine the types of large appliances they own and the quantities of each. For information about small appliances the company refers to the Merchandising Weekly Magazine. The annual usage per appliance is determined either by testing or by reports from the Edison Electric Institute.

Also included in the residential appliance model is lighting energy usage. A value for KWH/room-person is obtained from a study performed by the Association of Edison Illuminating Companies. This number is then multiplied by the room-person estimates provided by the U.S. Census Bureau to determine the estimated KWH needed for lighting in residences.

Other factors such as unknown appliances, price elasticity and furnace motors are included to modify the basic consumption estimate. On an annual basis, each large and small appliance's future saturation is separately estimated which times the predicted consumption levels, taking improvements in efficiency into account, gives the forecast for the individual appliances. A flow chart of the process is shown in Fig. 4.7.

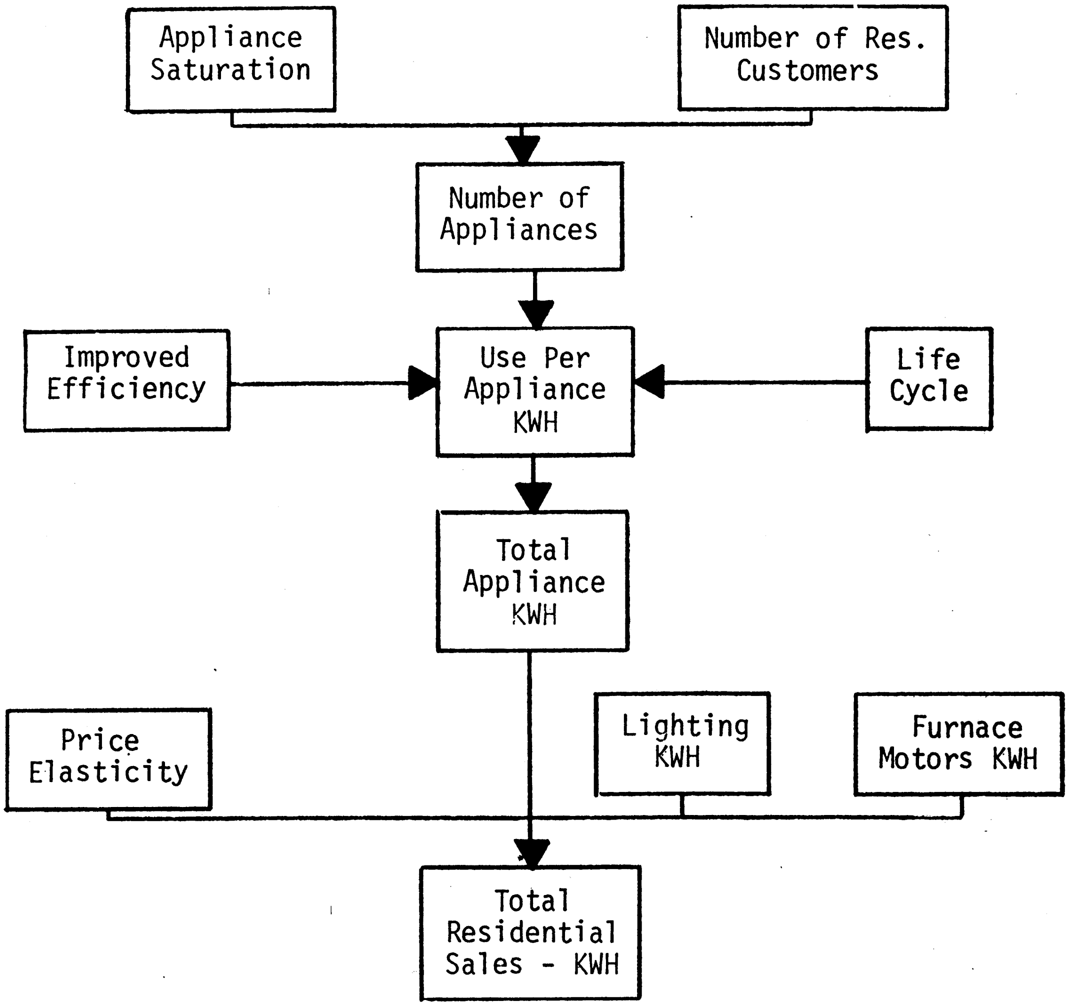


Fig. 4.7 Residential Appliance Model

4.2.1.3 Geographic Area

For each of the company's major marketing areas a growth rate is projected based on the socioeconomic factors characteristic of each district and the historical trends, both near- and long-term. Some of the socioeconomic factors considered are: number of customers, housing types, income and land use. Marketing managers for all areas submit their forecasts which are then added together to obtain the total RS + WH forecast for comparison to the results of the other methodologies.

4.2.1.4 Base and Weather-sensitive

Historical RS + WH sales are separated into base and weather-sensitive sales components on a monthly basis. These components are then projected separately. This methodology allows a detailed analysis of air-conditioning and heating sales which are very sensitive to both weather conditions and price levels. Heating sales are tied very closely to projections of use for heating equipment, since most of the electricity used for heating is by auxiliary support systems such as furnace motors and fans. Air-conditioning use depends on summer rate levels and government required efficiency levels, among others.

4.2.2 Residential Heating Service

4.2.2.1 Econometric

4.2.2.1.1 Total

The forecast for the residential heating service, also known as all-electric service, depends upon the average price of electricity (RHS Tariff), the price of #6 oil, which is used as a proxy variable for the price of home heating oil (#2), and the real New Jersey disposable income per capita.

The model is specified as:

$$\ln\{RHSSY(T)\} = a_0 + a_1 \ln\{RHSP72(T)\} + a_2 \ln\{OILPR72(T)\} + a_3 \ln\{NJDPIPC72(T)\} \qquad (4.7)$$

where:

RHSSY = Residential heating service sales in MWH;

RHSP72 = Average real price of RHS electricity in ¢/KWH in 1972 dollars.

4.2.2.1.2 Use per Customer

There are two models which have been developed to predict RHS sales, one for use per customer and the other for the number of RHS customers. See Fig. 4.8.

The use per customers model is specified as:

$$RHSUPC = f(RHSP72, NJDPIPC72) \qquad (4.8)$$

where:

RHSP72 = RHS price of electricity in 1972 dollars.

The model for the number of RHS customers is specified as:

$$RHS\ Cust = f(RHSP72, OILP72, RHS\ Cust_{t-1}) \qquad (4.9)$$

where:

$RHS\ Cust_{t-1}$ = Prior year's actual number of RHS customers.

4.2.2.2 Physical Model

RHS Sales are also forecast by various types of end use customers and varying use per customer. This allows for analysis of new versus conversion-type customers and various heating techniques, as well as conservation measures. Figure 4.9 illustrates the flow of data in this analysis.

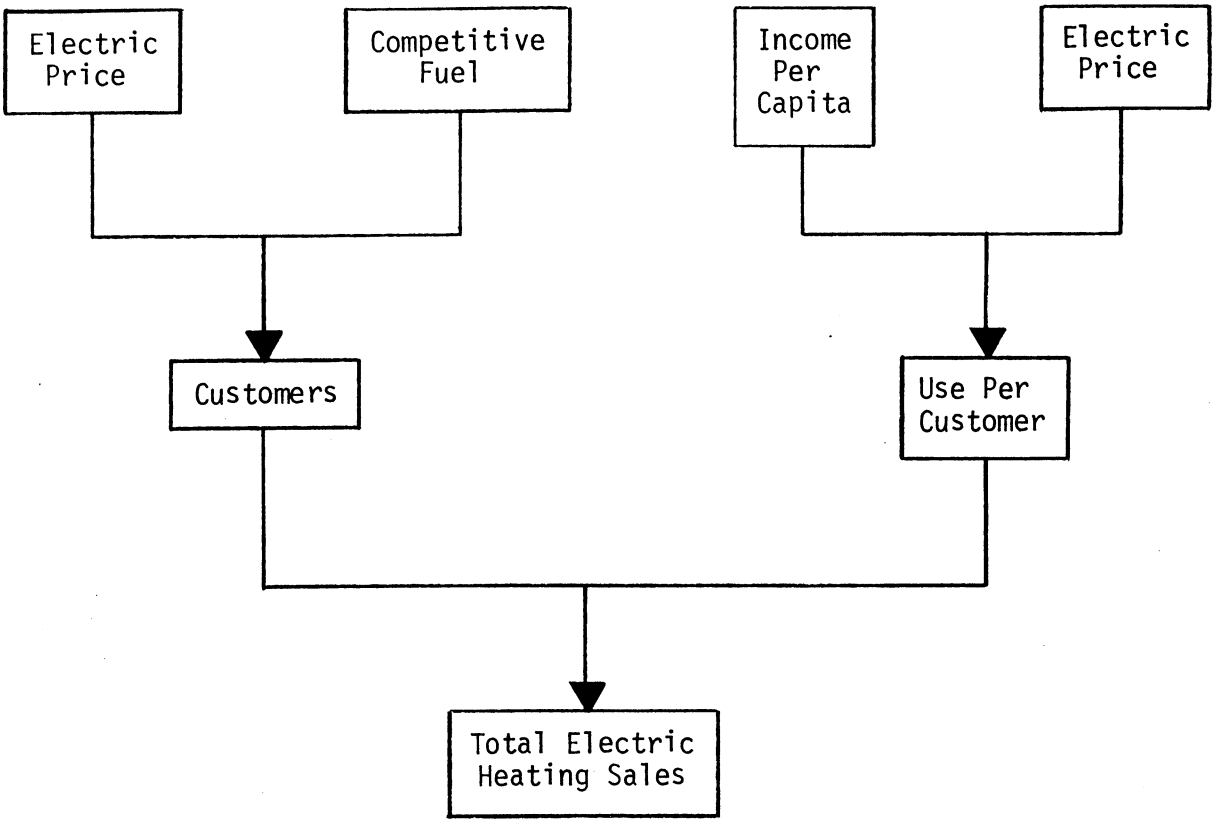


Fig. 4.8 Residential Heating - Use Per Customer Model

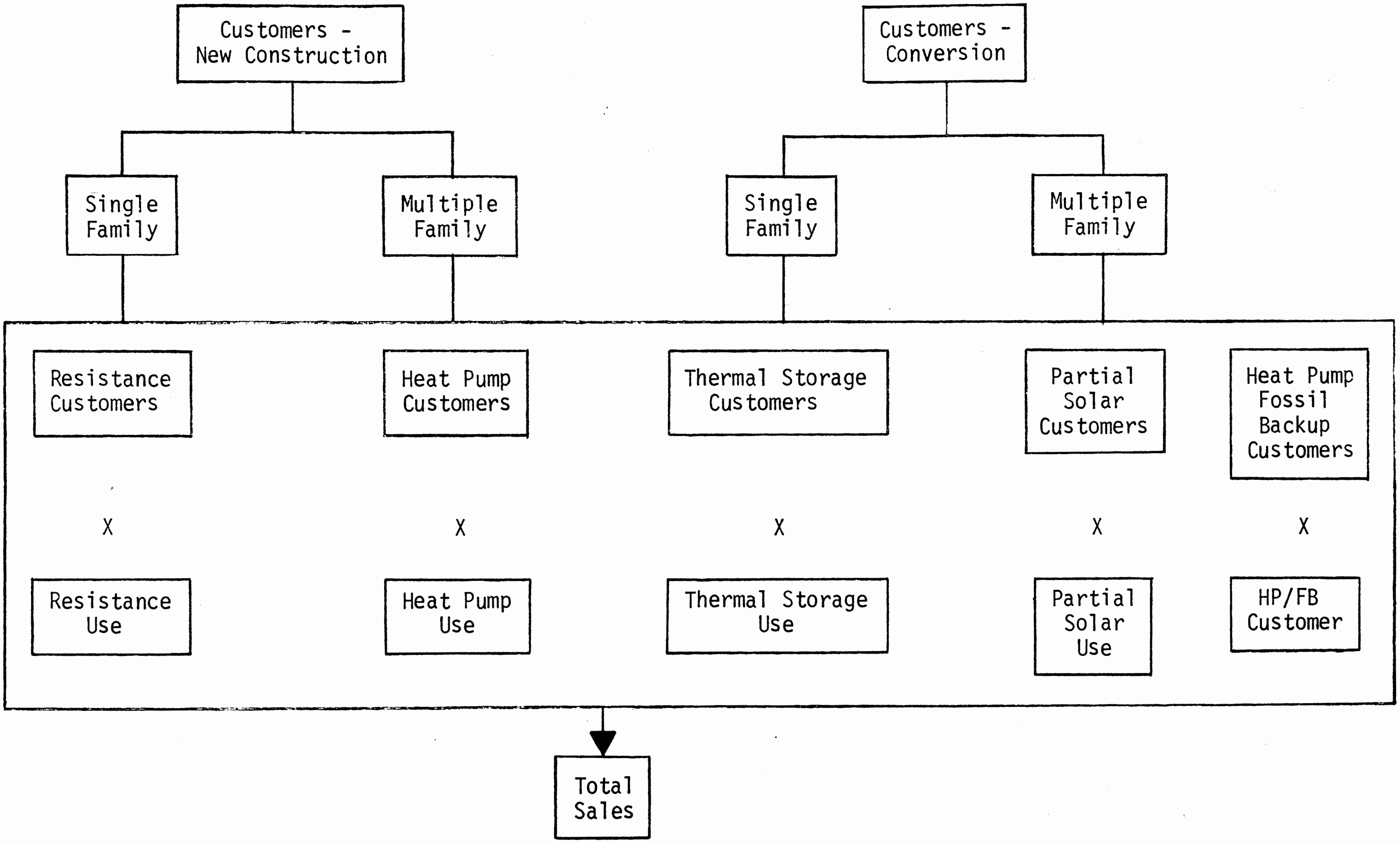


Fig. 4.9 Residential Heating - Physical Model

4.2.2.3 Base and Weather-sensitive

The RHS sales are forecast similarly to RS + WH for base and weather-sensitive components.

4.3 Commercial Sales

The methods used to forecast commercial electric sales are:

1. Econometric
2. Market Area Analysis
3. End Use
4. Business Group
5. Base and Weather-sensitive

4.3.1 Econometric

The forecast of sales by econometric models to the commercial customer class is divided into sales to small and large commercial customers. Small commercial sales are defined as that portion of the General Light and Power (GLP) rate category which can be attributed to the commercial customer class. Large commercial sales are defined as those portions of the Large Power and Light (LPL) and High Tension Service (HTS) which can be attributed to the large commercial customer class.

4.3.1.1 Small Commercial

That portion of the GLP rate category sales forecast which can be attributed to small commercial customers is influenced by the average price of electricity (GLP Tariff), New Jersey real disposable income and real oil price (#6 oil).

The econometric equation is specified as:

$$\ln\{GLPCSY(T)\} = a_0 + a_1 \ln\{GLPCP72(T)\} + a_2 \ln\{NJDPI72(T)\} + a_3 \ln\{OILPR72(T)\} \qquad (4.10)$$

where:

GLPCS = Small commercial customer sales in the GLP rate category in MWH;

GLPCP72 = Average real price of electricity at GLP rate in ¢/KWH in 1972 dollars.

4.3.1.2 Large Commercial

That portion of the LPL rate category sales forecast which can be attributed to large commercial customers is influenced by the average price of electricity (LPL Tariff), real price of #6 oil and total number of residential electric customers.

The large commercial econometric equation is specified as:

$$\ln\{LPLCSY(T)\} = a_0 + a_1 \ln\{LPLCP72(T)\} + a_2 \ln\{OILPR72(T)\} + a_3 \ln\{RESEC(T)\} \qquad (4.11)$$

where:

LPLCS = Large commercial customer sales in the LPL rate category in MWH;

LPLCP72 = Average real price of electricity at LPL rate in ¢/KWH in 1972 dollars;

RESEC = Thousands of residential electric customers.

That portion of the HTS rate category sales forecast which can be attributed to large commercial customers is influenced by average price of electricity (HTS Tariff), real price of #6 oil and New Jersey real disposable income per capita.

The econometric equation for sales to large commercial customers in the HTS category is specified as:

$$\ln\{HTSCSY(T)\} = a_0 + a_1 \ln\{HTSCP72(T)\} + a_2 \ln\{OILPR72(T)\} + a_3 \ln\{NJDPIPC72(T)\} \qquad (4.12)$$

where:

HTSCS = Large commercial customers sales in the HTS rate category in MWH;

HTSCP72 = Average real price of electricity at HTS rate in ¢/KWH in 1972 dollars;

NJDPIPC72 = New Jersey real disposable income per capita in thousands of 1972 dollars.

4.3.2 Market Area Analysis

As with the residential sales, commercial sales are forecast for the major marketing areas by the commercial marketing managers. Here the key factors taken into consideration are: zoning, shopping center development, highway access, population density, available land, urban redevelopment, employment patterns and the near-term economy, especially interest rates which impact on commercial construction financing.

4.3.3. End Use Analysis

Commercial sales are also analyzed for the specific impacts of building codes and regulations on end uses in the buildings. Commercial sales are split into the major end uses, including lighting, air-conditioning, heating, cooking, water heating and mechanical drive (including refrigeration). End use penetrations are projected on a per square foot analysis, as illustrated for air-conditioning:

$$\begin{array}{c}\text{Commercial}\\ \text{Air-conditioning sales}\end{array} = \begin{array}{c}\text{Commercial}\\ \text{Floorspace}\end{array} \times \begin{array}{c}\text{Percent}\\ \text{Penetration}\\ \text{of Air-conditioners}\end{array} \times \frac{\text{KWH}}{\text{Ft}^2} \qquad (4.13)$$

Similar relationships are developed for other primary end uses.

4.3.4 Business Group

Long term projections are made for approximately a dozen individual business groupings within the commercial class. These projections are based on an "a priori" model of the form:

$$Cit = (Cio) \left(\frac{Eit}{Eio}\right)^{e1} \left(\frac{Pit}{Pio}\right)^{e2} (A_{90}) \qquad (4.14)$$

where:

Cit = sales in business group i in year t;

Cio = sales in business group i in the base year;

Eit = the appropriate economic variable for group i in the year t;

Eio = the appropriate economic variable for group i in the base year;

Pit = the price of electricity in year t;

Pio = the price of electricity in the base year;

e1, e2 = elasticities;

A_{90} = an adjustment factor for the impact of ASHRAE-90 building standards.

The major groups analyzed via this analysis include:

1. Office Buildings
2. Educational Facilities
3. Food Stores
4. Health Services
5. General Merchandise
6. Business Services
7. Restaurants

8. Government & Social Services
9. Recreational Facilities
10. Hotels and Motels
11. Transportation Services
12. Utility Services

4.3.5 Base and Weather-sensitive

Similar to residential sales, historical data are separated into base and weather-sensitive sales on a monthly basis. These components are then projected separately. This methodology allows for detailed analysis of air-conditioning and heating sales, which are very sensitive to both weather conditions and price levels. Heating sales are tied very closely to projections of the use of gas for heating, since most of the electricity used for heating is by auxiliary support systems such as furnace motors and fans. Air-conditioning depends on summer rate levels and required efficiency levels, among others.

4.4 Industrial Sales

The methods used to forecast industrial electric sales are:

1. Econometric
2. Standard Industrial Classification Analysis
3. End Use Analysis
4. Major Customer/Econometric Hybrid

4.4.1 Econometric

As with the commercial sales forecast, the forecast of sales to the industrial customer class is divided into sales to small and large industrial customers for econometric analyses. Small industrial sales are defined as those portions of the General Light and Power (GLP) and Large Power and Light (LPL) categories which can be attributed to the industrial customer class. Large industrial sales are defined as that portion of the High Tension Service (HTS) which can be attributed to the industrial customer class.

4.4.1.1 Small Industrial

That portion of the GLP rate category sales forecast which can be attributed to small industrial customers is influenced by the average price of electricity (GLP Tariff) and New Jersey real disposable personal income per capita.

The econometric equation for sales to small industrial customers in the GLP rate category is specified as:

$$\ln\{GLPISY(T)\} = a_0 + a_1 \ln \{GLPIP72(T)\} + a_2 \ln \{NJDPIPC72(T)\} \quad (4.15)$$

where:

GLPIS = Small industrial customer sales in the GLP rate category, in MWH;

GLPIP72 = Average real price of electricity at GLP rate in ¢/KWH in 1972 dollars;

NJDPIPC72 = New Jersey real disposable income per capita in thousands of 1972 dollars.

That portion of the LPL rate category sales forecast which can be attributed to small industrial customers is influenced by average price of electricity (LPL Tariff), real price of #6 oil and a calculated term based on New Jersey manufacturing value added and employment.

The econometric equation for sales to small industrial customers in the LPL rate category is specified as:

$$\ln \{LPLISY(T)\} = a_0 + a_1 \ln \{LPLIP72(T)\} + a_2 \ln \{MFGPRO72(T)\} + a_3 \ln \{OILPR72(T)\} \quad (4.16)$$

where:

LPLIS = small industrial customer sales in the LPL rate category, in MWH;

LPLIP72 = Average real price of electricity at LPL rate in ¢/KWH in 1972 dollars;

MFGPRO72 = Manufacturing value added divided by manufacturing employment.

4.4.1.2 Large Industrial

That portion of the HTS rate category sales forecast which can be attributed to large industrial customers is influenced by the average price of electricity (HTS Tariff), product of industrial production index and capacity utilization rate, and real price of #6 oil in 1972 dollars.

The econometric equation for sales to large industrial customers in the HTS rate category is specified as:

$$\ln \{HTSISY(T)\} = a_0 + a_1 \ln \{HTSIP72(T)\} + a_2 \ln \{IPCAP67(T)\} + a_3 \ln \{OILPR72(T)\} \quad (4.17)$$

where:

HTSIS = Large industrial customer sales in the HTS rate category in MWH;

HTSIP72 = Average real price of electricity at HTS rate in ¢/KWH in 1972 dollars;

IPCAP67 = Product of industrial production index and capacity utilization rate (1967 = 100).

4.4.2 Standard Industrial Classification Analysis

Econometric models were developed for 22 of the 30 major two-digit Standard Industrial Classification (SIC) codes located in PSE&G's territory. The models use combinations of a variety of independent variables including New Jersey employment, U.S. industrial production, electric price, gas price, and oil price. The sum of the models plus estimates for those not modeled becomes the industrial forecast by SIC numbers.

4.4.3 End Use Analysis

Industrial sales have been subdivided into the major component end uses. Market and load research surveys have provided the breakdowns for the following sub-sectors:

Grinding and Crushing
Mixing
Compression
Air Furnaces
Electrolytic Processing
Hot Working of Materials
Welding
Material Cold Working
Separation
Packaging
Refrigeration
Air-conditioning
Lighting
Pumping
Other Mechanical Drive
Pollution Control

Specific end uses can be forecast in light of the growth (or lack of growth) of certain industries, technology changes such as the rapid growth in arc furnace and pollution control consumption, and conservation considerations such as improved motor efficiencies.

4.4.4 Major Customer/Econometric Hybrid Model

Individual long range and short range forecasts are made for the largest 30 industrial customers, which account for about 30% of total industrial sales. Specific expansion or contraction plans of these large customers are factored directly into the forecast. Each forecast is made after marketing personnel consult with the customer. The residual sales, or the remaining 70%, are modeled econometrically in a fashion similar to those described in the previous econometric section on industrial sales.

4.5 Building Heating Sales

The model used for the building heating sales forecast is econometric. Building heating is considered to be primarily commercial with a separate rate category, Heating Service (HS).

The factors which influence the sales to the HS rate category are the average price of electricity (HS sales), the real price of #6 oil and real New Jersey disposable income per capita.

The econometric equation is specified as:

$$\ln\{BHSCISY(T)\} = a_0 + a_1 \ln\{BHSCP72(T)\} + a_2 \ln\{OILPR72(T)\} + a_3 \ln\{NJDPIPC72(T)\} \tag{4.18}$$

where:

BHSCISY = Commercial customer sales in the HS rate category in MWH;

BHSCP72 = Average price of electriicty at HS rate in ¢/KWH in 1972 dollars.

4.6 Peak Demand

The forecast of peak demand, which is the highest instantaneous requirement in megawatts that a utility must meet, is developed primarily using a base/weather-sensitive model with a macro econometric methodology as a check.

4.6.1 Base/Weather-sensitive Model

This model combines econometric and end use modeling techniques. The base load is that portion of the load which does not change in response to seasonal weather variations. For the weather-sensitive portion adding air-conditioning to the base provides the summer peak, and adding heating to the base provides the winter peak.

4.6.1.1 Base

The growth in base demand is assumed to be the same as the base energy sales growth for the industrial, commercial and total residential categories. The base energy sales are calculated as the average of April, May, October and November sales for each rate class, since these four months have the least weather-sensitive loads. The base demand for prior year is then multiplied by growth rate.

4.6.1.2 Weather-sensitive

A residential air-conditioning demand model uses air-conditioning saturation projections and residential customer projections to come up with total equivalent units. A replacement model is used to calculate the demand per equivalent unit which, multiplied by the number of units, gives the residential demand.

A commercial air-conditioning demand model using commercial floorspace, air-conditioning saturation and efficiency assumptions forecasts the commercial demand.

Industrial demand is trended on historic data, resulting in a flat percentage growth rate.

These three results are totalled to determine the weather-sensitive summer peak demand, which added to the base component gives the summer peak forecast.

The model is specified as:

$$WSP = (ACU \times KWPU) + (CF \times KWP1000CF) + (IE \times KWPIE) \tag{4.19}$$

where:

WSP = Weather sensitive peak;

ACU = Air-conditioning units;

KWPU = Kilowatts per unit;

CF = Commercial floorspace;

KWP1000CF = Kilowatts per 1000 ft^2 of commercial floorspace;

IE = Industrial employees;

KWPIE = Kilowatts per industrial employee.

If a winter peak is desired, heating is used in place of cooling as the weather-sensitive component. Since this is smaller than the summer peak, it does not have as great an impact on capacity requirements, but does affect maintenance schedules.

4.6.2 Macro Econometric Models

There are two macro econometric models, a base model and a peak model. The peak model forecasts the total demand of base and weather-sensitive loads with one equation, while the base model only forecasts the nonweather-sensitive loads. These models are used primarily to test the reasonableness of the "Base/weather-sensitive Model."

a. Base

The base model is specified as:

$$BP = f(AEP72,\ NJDPI72,\ BP_{t-1}) \tag{4.20}$$

where:

BP = Base Peak;

AEP = Average Electricity Price in 1972 dollars;

BP_{t-1} = Prior year's base peak;

b. Total

$$TP = f(NJDPI72,\ TOTEQSAT) \tag{4.21}$$

where:

TP = Total Peak;

$TOTEQSAT$ = Equivalent saturation of room air-conditioners.

4.7 Forecast Monitoring System

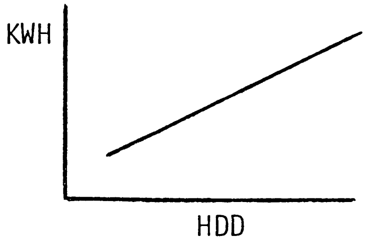
In order to assess the accuracy of its forecasts, PSE&G has developed Energy Sales and Peak Demand monitoring systems. On a monthly basis, the actual energy sold and peak demand achieved, normalized for weather, are compared with the respective forecasts.

Should the difference between the forecasts and actual data be very great, an Interim Corporate Forecast is prepared. This forecast is then normally issued in April, following the annual fall forecast.

4.8 Weather Correction

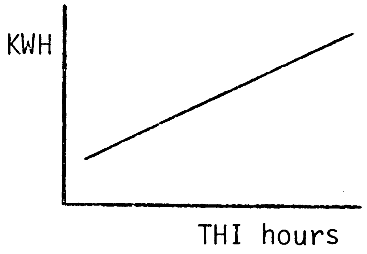
All summer and winter weather corrections are done by rate category. Some are not weather-sensitive while others respond greatly to weather. The winter weather correction is based on heating degree days (HDD) of a normal month or year with respect to the higher or lower amount of

HDD's in the subject month or year. A slope is determined by graphing KWH versus degree days for the normal weather shown below.



If the subject period is 100 HDD higher than normal and the slope is Q KWH/HDD, then 100 Q KWH is subtracted from actual KWH sales in order to weather-correct. If the subject period is lower, an appropriate amount is added to sales to normalize.

The summer weather correction is based on temperature humidity index (THI) hours which PSE&G feels more accurately tracks electric consumption than cooling degree days (CDD). The adjustment is handled in much the same manner as the winter correction. The slope shown below is multiplied times the higher or lower THI hours and the sales are adjusted accordingly.



The THI hour was developed by PSE&G and is based on the standard THI calculations and the number of hours the THI exceeds 66°F.

APPENDIX A - ABBREVIATIONS

ACE - Atlantic City Electric
BOCA - Building Officials and Code Administrators
CAFRA - Coastal Areas Facilities Review Act
DOE - U.S. Department of Energy
DRI - Data Resources Inc.
EEI - Edison Electric Institute
EIA - Energy Information Administration
EPRI - Electric Power Research Institute
FERC - Federal Energy Regulatory Commission
FPC - Federal Power Commission
FUA - Fuel Use Act
GPU - General Public Utilities Corporation
JCP&L - Jersey Central Power & Light
LMA - Labor Market Area
MAAC - Mid-Atlantic Area Council
NERA - National Economic Research Associates
NJDLI - New Jersey Department of Labor and Industry
NOAA - National Oceanographic and Atmospheric Administration
NPA - National Planning Association
PJM - Pennsylvania, Jersey, Maryland Interchange
PSE&G - Public Service Electric & Gas
SIC - Standard Industrial Classification
SMSA - Standard Metropolitan Statistical Area
WTHI - Weighted Temperature Humidity Index

APPENDIX B - GLOSSARY

Appliance Saturation	- The number of each type of appliance in residences expressed as a percentage. In the case of TV's, where there is more than one, the percentage is greater than 100%.
Autocorrelation	- Describes a situation where two or more independent variables move the dependent variable in the same direction with either being sufficient.
Demographic	- Population related data.
Dependent Variable	- The quantity to be determined in an equation. In electric forecasting, it is the sales or peak demand being forecast.
Dummy Variable	- A variable which is either 0 or 1 depending on whether the independent variable is operative in the equation. For this report it is either seasonal or quarterly, and is 0 for all periods except the one being forecast.
Econometric Model	- An equation in which the independent variables are economic in nature, such as price, income, etc.
Eminent Domain	- The State's right to use private property for the good of society in general.
High Intensity Discharge	- Mercury vapor, metal halide and high pressure sodium lamps (HPS) which are suitable for both indoor and outdoor use. The HPS are the highest efficiency of the three.
Independent Variable	- In an equation, the quantities which are known and are used to determine a relationship to the dependent variable. In electric forecasting, they are the economic, physical or time values used to predict the sales or peak demand.
Lag	- A specific time period.
Lagged Variable	- An independent variable which is related to a prior value of itself or other independent variable.
Model	- A representation of the relationship between independent variables and a dependent variable. In electric forecasting, it is an end use, econometric or time series equation used to predict electric sales or peak demand.

APPENDIX C

Econometric Modeling

In order to demonstrate how the technique of econometric modeling is applied, let us use specific variables. The dependent variable will be (E) for electric consumption on a yearly basis. The independent variables will be personal disposable income (PDI) and the price of electricity (EP). Functionally, the equation is written:

$$E = f(PDI, EP) \tag{c.1}$$

In order to simplify the forecasting procedure, this functional relationship is further reduced to a first order equation, i.e., an equation defined as constants times the variables chosen which drive the dependent variable. Therefore, Eq. (c.1) may be written as:

$$\ln E = a_0 + a_1 \ln (PDI) + a_2 \ln (EP) \tag{c.2}$$

where:

ln = natural (Napierian) logarithm

The constants a_0, a_1, and a_2 can then be estimated using the historical data and multiple linear regression analysis techniques. This is where the technique can fall apart if either the historical data are sparse or not very accurate, or if inappropriate independent variables are chosen. Here, statistical analyses are used to determine the validity of the chosen independent variables. The R^2 term is first calculated to assess the statistical significance of the constants estimated and the variables chosen for Eq. (c.2). To be statistically significant R^2 should be reasonably close to 1. This means that, if R^2 is calcualted as 0.98 for Eq. (c.2), the functional relationships will match the historical trend fairly accurately. Once the best fit has been established, a forecaster can trust his assumption with a greater degree of confidence.

In order to further assure that the model not only fits the historical data, but that the independent variables drive the model or cause appropriate changes to the dependent variable (sales), a variety of additional statistical tests are used. After R^2 is used to test the quality of the fit, "$\bar{R}^2$" is calculated to determine if the change in the sales are explained by the independent variables chosen. "$\bar{R}^2$" should also be between 0 and 1, but the closer to 1, the better the fit. A check of the statistical significance of the "$\bar{R}^2$" values is performed using the "F" statistic which indicates whether the independent variables not only fit the curve of the dependent variable, but that it wasn't just luck that they do. Depending on the amount of data available and the number of independent variables, a chance relationship between energy sales and independent variables such as oil price can be ruled out. To test the coefficients or constants which appear after regression analysis, the "T" statistic is used. What this does is show the probability that the coefficient is not zero. The "T" statistic provides information about each independent variable as opposed to the whole equation. If a coefficient were zero, the variable would not impact the equation, yet the overall equation would be accurate with or without the variable being tested. A test which weeds out unnecessary variables is the Durbin-Watson Statistic. If two variables move the curve in the same way at the same time, called autocorrelation, the effect of either is sufficient for accurate forecasting. In fact, if two independent variables drive the model in the same direction, the result may be biased and therefore wrong. This test is designed to determine whether autocorrelation exists through the use of a table of Durbin-Watson statistics. After determining whether the model is statistically accurate, it is then run to forecast the future.

APPENDIX D

Temperature Humidity Index (THI) Calculation

THI was originally derived to indicate a level of human comfort (discomfort) since it reflects the combined effects of air temperature and relative humidity. The THI can be calculated using any of the three (3) formulas listed below which were developed by Mr. J. F. Bosen, Office of Climatology, U.S. Weather Bureau:

$$THI = 0.4\ (DB + WB) + 15 \tag{D.1}$$

$$THI = 0.55\ DB + 0.2\ DPT + 17.5 \tag{D.2}$$

$$THI = DB - (0.55 - 0.55\ RH)\ (DB - 58) \tag{D.3}$$

where:

DB = dry bulb temperature, ^{o}F;

WB = wet bulb temperature, ^{o}F;

DPT = dew point temperature, ^{o}F;

RH = relative humidity, decimal.