ELECTRIC POWER CONSUMPTION FOR THE RAILBELT:

A PROJECTION OF REQUIREMENTS

TECHNICAL APPENDICES

by

Scott Goldsmith
Lee Huskey

Institute of Social and Economic Research
Anchorage * Fairbanks * Juneau

prepared jointly for

State of Alaska
House Power Alternatives Study Committee
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APPENDIX A. METHODOLOGICAL REVIEW

A.1. Types of Forecasting Models

There are three general types of forecasting techniques or models.

Time series or trend models include all mathematical techniques in which the forecast is a function of time. The justification for this approach is that past behavior is the best guide to forecasting the future behavior of a variable. Past trends form the basis for forecasting, and the various techniques used in this form of modeling are concerned with identifying the most significant past movements of the variables being forecast.

A simple example of a trend technique is the classical (past, universally used) method of forecasting electricity consumption growth. During every decade since the turn of the century until 1970, electricity consumption in the United States has doubled. This corresponds to an annual growth rate of 7 percent. This information is enough to formulate a trend model for projecting future electricity consumption growth. Consumption next year is 7 percent greater than this year.

An obvious advantage of this type of model is that it is easy and cheap to construct and use (although some time series models can be very complicated and expensive to develop). If the actual process by which the forecast variable is determined is stable over time, then this technique will work well. In general, the shorter the forecast interval, the more likely it is that the system will be stable. The historical growth of electricity consumption could be interpreted as a reflection of a very stable process. For many decades, a simple trend model worked well to forecast future consumption.

Basically, a time series or trend model is appropriate when

1) cost and time minimization involved in making the forecast is important,

2) the process determining the forecast variable is stable,

3) the forecast interval is short, and/or

4) no information is available on what factors really account for the level of the forecast variable.

Causal models include all mathematical techniques where a specific set of factors is assumed to "cause" or determine the value of the forecast variable and the causal relationship is quantified. The idea behind these techniques is that the identification of cause and effect relationships facilitate our understanding of and forecasting of future events. These modeling techniques thus try to pick out the most important causal relationships and to measure them quantitatively. An example of a simple causal model used to forecast electricity consumption would be based on the idea that the level of population and income determines or "causes" the level of electricity consumption. Thus, as population grows or income grows, electricity consumption is forecast to increase, and vice versa.

The obvious advantage of this type model is that the forecast is based upon the notion of cause and effect, rather than the identification of patterns in the past movement of the forecast variable (as in the time series technique). If there are past or forecasted changes in the process by which the level of the forecast variable is determined, this forecasting technique can accommodate them. Thus, a time series model for forecasting electricity consumption would not be able to respond to a sudden drop in population which would, in all likelihood, "cause" a reduction in consumption. A causal model with population as a causal factor would be able to accommodate this structural change.

Another advantage of causal models for forecasting is that they allow one to do "what if" experiments. Using the causal model of electricity consumption, one could determine what would happen to consumption if population doubled, fell by half, etc. Time series models do not have this capability.

Obvious problems with causal models are the time and cost generally associated with their construction and the requirement that the causal variables must be forecast in order to use the model. For example, forecasts of population and income are necessary to use the causal model for the electricity consumption forecasting discussed here.

The causal model is generally appropriate when

1) the process by which the forecast variable is determined is not constant over time,

2) it is possible to quantify links between causal variables and the forecast variable,

3) the forecasting model will be used repeatedly using varying assumptions regarding the causal variables,

4) the time interval for the forecast is long, and/or

5) sufficient time and money are available to develop the model.

Judgmental models are all nonquantitative or nonmathematical techniques for forecasting. The simplest example is the informed opinion of an expert. A more complex and structured technique is the Delphi Technique, in which a group of experts interact in a formal way to develop a consensus forecast. The rationale for judgmental models is that individuals with an understanding of the process by which the forecast variable is determined can directly interpret a large amount of information relevant to projecting the future level of the forecast variable and on that basis develop a forecast. No specific mathematical or formal techniques are used.

An example of judgmental techniques would be in the forecasting of technological change affecting electricity consumption. It is not possible to forecast by quantitative methods the types and timing of technological change which would either increase or decrease electricity consumption.

This technique is particularly appropriate where the number of potential causal variables is large and they cannot be systematically analyzed for lack of information, resources, etc. Obviously, the longer the forecast interval, the more general are the variables which need to be considered and, thus, the more appropriate judgmental forecasting becomes. A possible drawback of this method is that system interactions (the effect of one variable upon another) may be overlooked in complex systems.

This technique is appropriate when

1) resources for forecasting are limited,

2) the process determining the forecast variable is not amenable to quantification, and/or

3) data are not available to develop a quantitative model.

Each of these general techniques is appropriate in certain situations depending upon the process being analyzed, the desired accuracy of the forecast, the resources available to develop the forecasting tool, the uses to which the forecasts will be put, and an evaluation of what method actually forecasts best.

In any complex forecasting effort, elements of all three methods will likely be present. The forecaster must determine what technique is appropriate at each step in the process of developing the overall forecast. For example, the forecaster may decide that a causal model is the appropriate general approach. He may use time series or trend analysis to forecast the value for an explanatory variable. Finally, he may adjust the forecast derived from the causal model on the basis of information he has which is nonquantifiable in the sense that it cannot be incorporated into the causal model in a formal way.

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A.2. Forecasting Alaskan Economic Activity

The important considerations in choosing a general technique for forecasting Alaskan economic activity for the purpose of projecting electricity requirements are as follows:

1) a thirty-year forecast is required;

2) the forecasting model will be used repeatedly and will be utilized to do "what if" experiments;

3) the Alaskan economy is a complex system with many factors interacting in important but non-obvious ways; and

4) the future growth and development of the Alaskan economy may be considerably different from the past because of a qualitative and quantitative change in the factors determining the state of the economy.

These considerations suggest a quantitative causal model which has the advantages of

1) identifying structural relationships within the economic system, quantifying them, and automatically tracing the effects of these relationships through the system;

2) allowing "what if" experiments to examine alternate futures under alternate assumptions about important future events and variables; and

3) providing a framework within which all forecasting assumptions are explicit.

Arguments against the causal approach are

1) the complexity of the model makes its development and utilization relatively expensive;

2) the quality of the data may not warrant sophisticated causal models;

3) the causal relationships may not be quantifiable; and

4) the causal relationships may not be understood.

In choosing a quantitative causal model, we feel that, although the causal relationships in the Alaskan economy may be only partially understood and the data of poor quality, the advantages of formalizing the relationships that are considered relevant outweigh these problems.

Large elements of trend analysis and judgmental models enter into the causal modeling approach in the development of the projections of some of the most important variables in the economy, and these techniques become more important the further into the future the forecasts are pushed. Currently, twenty years is the limit for the quantitative causal model. Beyond that time, we revert to trend and judgment.

Having decided upon a quantitative causal modeling approach to economic forecasting, there remains the question of choosing among the many types of models available. In fact, there have been at least seven different economic models of the Alaskan economy developed over the last fifteen years, although only three econometric models are in current use. (These are the Man in the Arctic Program [MAP] model, the Alaska Department of Labor model LABMOD, and the Alaska Department of Commerce and Economic Development model AEIRS.)

In choosing a type of causal model, we would want one which is best able to represent the important factors in the workings of the economy itself. Also, since the projection is over a long-time period, we would want a model capable of adequately forecasting the level of economic activity in the long run.

These criteria eliminate both input-output and short-run forecasting models. The first is rejected because it best represents interindustry flows of intermediate goods in manufacturing. There is almost no manufacturing in Alaska and, thus, an interindustry transaction table would be mostly zeros. Short-run forecasting models are designed specifically for that purpose and as such can ignore many important long-run phenomena.

The choice is thus narrowed down to some type of long-run, econometric or simulation model. One advantage of both these model types is their flexibility in terms of the situations they can model and the theories they can represent. The difference between them is that the econometric model uses statistical techniques (such as regression analysis) to identify the quantitative relationships among variables, while the simulation model uses nonstatistical methods (averages, point estimates, judgment, etc.).

Econometric determination of quantitative relationships has the advantage of being able to interpret formally all historical information concerning those relationships although the techniques used can be expensive, time consuming, and on occasion too sophisticated for the Alaskan data. Because of repeated model use, however, we feel the econometric approach is appropriate.

Finally, we want a model that specifically incorporates several important features of the Alaskan economy. These include:

1) the importance of state government activity in determining the level of economic activity;

2) the importance of and potential variability in development of Alaskan natural resources (particularly petroleum) on the level of economic activity;

3) the process of maturation of the economy as it grows in size; and

4) the links which exist between the Alaskan and national economy.

The MAP econometric model includes features which address all of these important relationships but is criticized in the treatment of some of them. Specifically, it is suggested that the "multiplier" is too large and that the method used to determine population is inappropriate.

The "multiplier" is a quantitative measure of the support sector response to changes in basic sector activity. The support sector includes such industries as retail and wholesale trade and services, while the basic sector is made up of those industries which "drive" the economy, such as petroleum, portions of government and construction, etc. In a developing economy such as Alaska, the support sector is growing rapidly, and this is reflected in a large "multiplier" value on increments to basic sector activity.

It is also argued that the "multiplier" is too large because it includes a state government response to increases in economic activity in the private sector. We argue that this type of response has indeed occurred historically (the level of the state government budget has grown partially because private sector growth has increased the demand for public goods and services) and, absent specific state policies to severe the connection, will continue to occur in the future.

The method used in the MAP model to determine the level of net migration to the state, and thus ultimately the level of population, uses the relative Alaskan wage rate and the change in the employment level as explanatory variables. These variables are generally accepted by economists and demographers as being important in the determination of migration patterns. Clearly, other factors are also important, although they are not quantifiable. Neither is it clear how, taken together, they would effect the results obtained using the two economic variables. In the absence of such analysis, the present technique appears appropriate.

A.3. Forecasting Alaskan Electricity Requirements

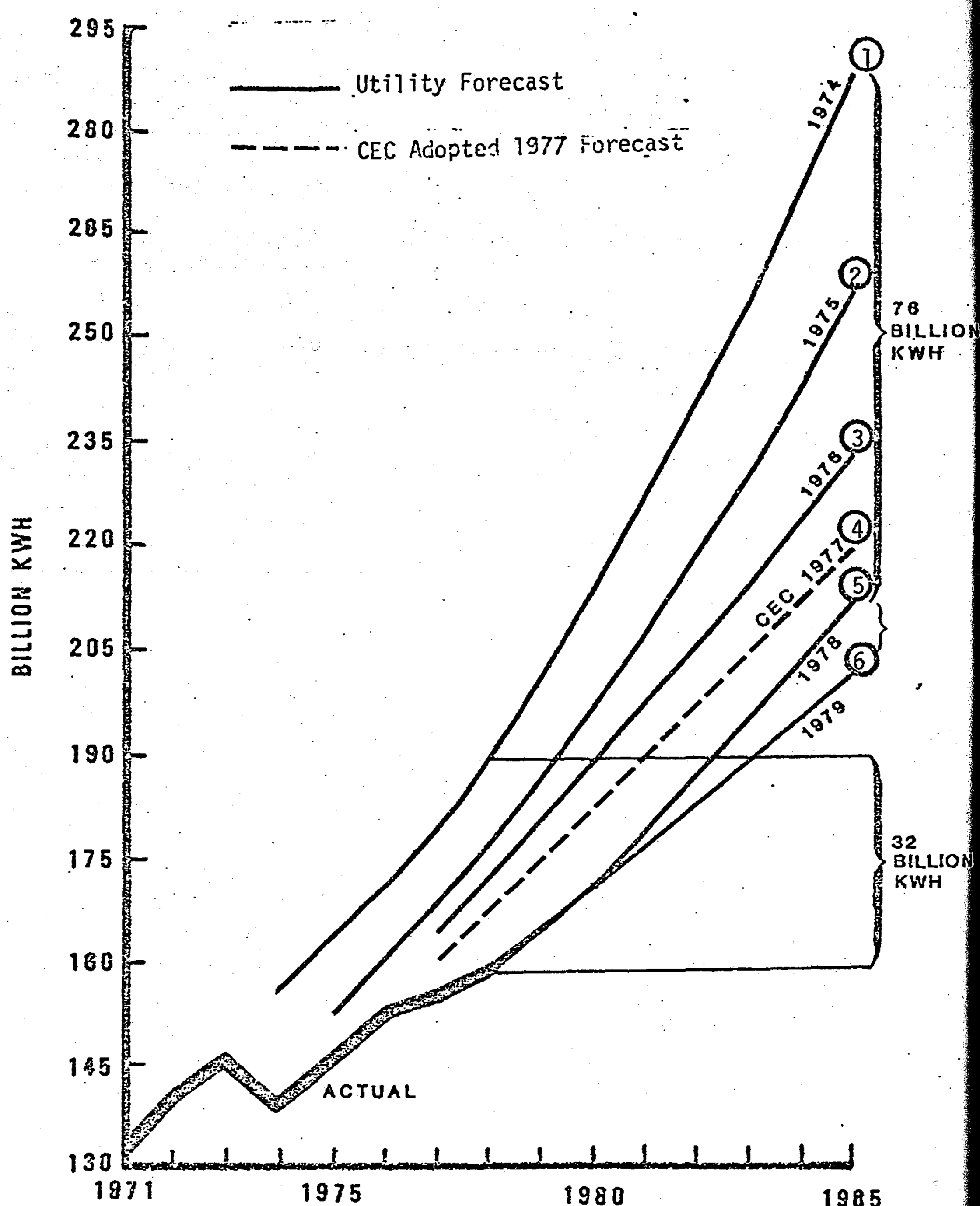
As previously noted, the traditional method of forecasting electricity requirements was the use of trend analyses. In the aggregate, it worked well until the early 1970s. At that time, however, there occurred a sharp break with the past in terms of behavior in all energy markets. Growth in consumption of electricity began to fall short of growth projected by trend analysis. It was clear that the structure of electricity markets was changing in ways that trend analysis was unable to anticipate and adjust to. These changes included a reversal in the long-term trend of declining real prices for electricity, the attainment of high saturation rates for many appliances, the appearance of the conservation ethic, demographic changes, and other factors. Figure A.1 dramatically demonstrates this inadequacy of the traditional forecasting method as applied to California.

It may be that a new long-term trend in growth of electricity consumption may emerge after the electricity market again stabilizes, but it is unlikely that this will occur for some time. In the interim, causal forecasting techniques are necessary which explicitly attempt to identify those factors which are causing change in the basic electricity consumption patterns. In addition, causal models explicitly allow utilities and policy analysts to examine the effects on electricity consumption of policies which effect electricity prices and other causal variables.

Judgemental models have a role in this forecasting task for two reasons. First, the data is often not available with which to develop a quantitative model. Second, there are some relationships which may be difficult or impossible to quantify. Future changes in technology which will alter consumption patterns cannot be forecast quantitatively, for example. Emerging important factors effecting load growth in a particular market for which no historical information is available is another. In all these cases, however, the judgement must come down to

FIGURE A.1.

CALIFORNIA UTILITIES STATEWIDE ELECTRICITY SALES FORECASTS



1, 2 G.O. 131 - Utility submissions to the Public Utilities Commission

3, 5, 6 Utility submissions to the CEC

4 CEC adopted forecast (1977)

Source: California Energy Commission, "California Energy Demand 1978-2000: A Preliminary Assessment," August 1979, p. 10.

a quantitative value which can be used in the analysis because the electricity requirements forecasts are quantitative.

The primary forecasting tool is the quantitative causal model of which there are two basic types: econometric and end use models. Econometric models of electricity consumption use statistical techniques to quantify relationships between electricity consumption or electrical appliance ownership and price, income, and other "explanatory" variables. They are generally quite aggregate in the sense that all residential consumption for all purposes may be lumped together and "explained" by the same price and income variables. These models have been developed by economists who have primarily been interested in identifying the exact strength of the relationship between electricity consumption and the important economic variables price and income. (They often refer to the concept of elasticity, which is the percentage change in electricity consumption in response to a 1 percent change in price or income. Thus, a price elasticity of -.5 would mean that when the electricity price increased 1 percent electricity consumption declined .5 percent.)

End use models disaggreate electricity consumption not only by class of user but also by use. Total consumption is then the sum of all electricity consuming appliances and the average amount of electricity consumed in each. The stock of electrical appliances will be determined by demographic and economic variables and average consumption by those same variables, as well as technology, use patterns, and other variables.

Because of the great diversity observable in electricity consumption, it is necessary to collect large amounts of data in order to construct an end use model. Its advantage is a capability of identifying technological, regulatory, and other policy-related factors which effect demand. Having done this, the model can be used to forecast consumption pattern changes in response to changes in these factors.

Each of these modeling approaches has advantages and drawbacks. The econometric approach uses accepted statistical procedures to develop quantitative relationships for certain variables, but data limitations restrict its ability to analyze specific electricity uses and non-economic-demographic factors effecting consumption. There is concern within the economics profession that the many "demand functions" which have been estimated by researchers over the years really are measuring a relationship between electricity consumption and price and income. We feel there is substantial truth to these arguments. In addition, there is suspicion that relationships estimated using historical electricity prices may no longer be appropriate because of recent and rapid price increases in contrast to the previous long-run secular decline in electricity price. Even if there was agreement that the approach of the econometricians was valid, the substantial variation in results reported by various studies invites caution in the utilization of any particular estimate. One review article cited long-run price elasticities from different studies of between -1 and -2 and long-run income elasticities of between .2 and 2.[1]

End use models are disaggregated and lend themselves to policy analysis but generally are lacking in a strong statistical foundation for the parameters (quantitative relationships) used in the modeling. This is largely because of a lack of adequate data. In many instances, a single data point may be all the researcher has available to work with, and this does not provide a firm basis for quantification of a relationship between two variables.

The best solution, suggested by a recent article in Public Utilities Fortnightly, is to utilize the better features of both modeling approaches to make the modeling sensitive to both the economic factors of price and income as well as to regulatory and technological factors.[2]

In the model developed for this study, this was also the preferred approach with a heavy emphasis on end use because of the anticipated use of the model not only for forecasting but also policy analysis. Relatively little emphasis was placed on econometrics because of the absence of data, the theoretical problems alluded to previously, and earlier unsuccessful attempts by one of the authors to develop econometric models of electricity demand for Alaska.[3]

ENDNOTES: APPENDIX A

1. Lester Taylor, "The Demand for Electricity: A Survey," Bell Journal of Economics, Spring 1975, Vol. 6, No. 1, p. 101.

2. Robert Shaw, Jr., "New Factors in Utility Load Forecasting," Public Utilities Fortnightly, July 19, 1979, p. 19.

3. Scott Goldsmith, "Future Electricity Requirements in Alaska," paper presented at Western Economics Association Annual Meetings, San Francisco, California, June 1976.

APPENDIX B. THE ECONOMIC PROJECTION METHODOLOGY

Introduction

The projections of end-use energy requirements are based on projections of economic activity in the state and its railbelt region. This economic projection provides estimates of employment, population, households, and housing stock for the state and the major regions in the railbelt. These projections are provided for five-year periods throughout the projection period; the projection period is through 2010.

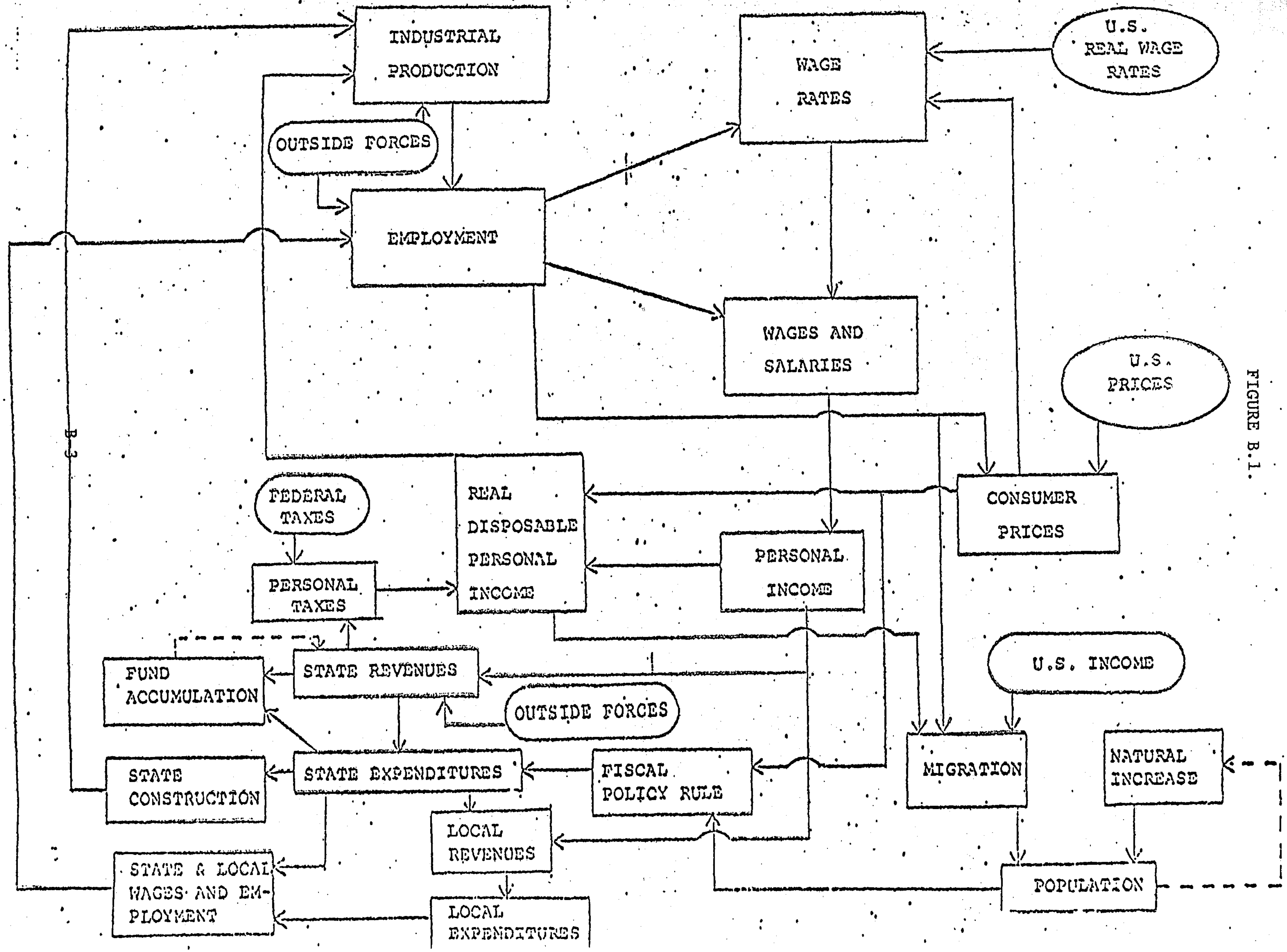
The main component of the economic projection methodology is the Man-in-the-Arctic Program (MAP) statewide econometric model, which is used to project the employment, population, and fiscal variables. In addition to this major component, three new components have been developed for this study: a household formation model, a regional allocation model, and a housing stock model. The household formation model estimates the number of households in the state based on the MAP model population projection. The regional allocation model allocates the major variables--population, employment, and households--to the study regions. Finally, the housing stock model projects the distribution of housing by type for each region of interest. This appendix provides a detailed description of each of these components.

The MAP Economic Model

The statewide econometric model developed by the Man-in-the-Arctic Program (MAP) at the University of Alaska's Institute of Social and Economic Research is the principal model used in the projection of economic activity for the end-use forecast. The model consists of three interrelated components: an economic model, a fiscal model, and a demographic model. The basic structure of the model is shown in Figure B.1.

The economic model divides the economy into exogenous or basic sectors and endogenous or nonbasic sectors. The level of output in the exogenous sectors is determined outside the state's economy. The level of output in the nonbasic sectors of the economy is determined within the Alaska economy since their primary purpose is to serve local Alaska markets. The basic industries in the model are mining, agriculture-forestry-fisheries, manufacturing, federal government, and the export component of construction and transportation. The nonbasic industries are wholesale and retail trade, finance-insurance-real estate, services, communications, utilities, and the remainder of construction and transportation.

Incomes, output, and employment are simultaneously determined in the model. The demand for local economic production is determined by the level of real disposable income in the economy. The level of industrial production determines the demand for labor; employment is that level which is needed to produce the required output. The labor demand is always satisfied since the Alaska labor market is assumed to be open to



INDUSTRIAL PRODUCTION
WAGE RATES
U.S. REAL WAGE RATES
OUTSIDE FORCES
EMPLOYMENT
WAGES AND SALARIES
U.S. PRICES
REAL DISPOSABLE PERSONAL INCOME
FEDERAL TAXES
CONSUMER PRICES
PERSONAL TAXES
PERSONAL INCOME
FUND ACCUMULATION
STATE REVENUES
U.S. INCOME
OUTSIDE FORCES
STATE CONSTRUCTION
STATE EXPENDITURES
FISCAL POLICY RULE
MIGRATION
NATURAL INCREASE
LOCAL REVENUES
STATE & LOCAL WAGES AND EMPLOYMENT
POPULATION
LOCAL EXPENDITURES

FIGURE B.1

migration from the rest of the United States. Because of this, both the supply and price of labor (wage rate) are linked to outside activity; wage rates in Alaska are determined in part by wages outside the state. Once wage rates and employment are determined, aggregate wages and salaries are known. The level of disposable income is estimated by adding an estimate of nonwage income to wages and salaries and reducing this by the level of income taxes. Real disposable income is found by deflating the level of disposable income by a relative price index; the major determinants of Alaska prices are U.S. prices, the size of the economy, and the growth rate of the economy.

The level of population projected is based on a projection of each of its components: births, deaths, and migration. The model uses age-sex-race specific survival rates and fertility rates to project the births and deaths of the civilian population; the number of births net of deaths determines the natural increase in the population. Total civilian population is found by adding net civilian migration to the natural increase. Net migration is determined by the relative economic opportunities in the state. Economic opportunities are described in the model by the change in employment and the Alaska real per capita income relative to the U.S. average. Total population is determined by adding an exogenous estimate of military population.

The final component of the MAP model is the fiscal model. This model describes the activity of the state and local governments. The fiscal model calculates the level of personal tax payments which are necessary for projecting disposable income. The fiscal model, based on an assumed state spending rule, also calculates personnel expenditures, the level of state government employment, and the amount spent on capital improvements. The amount the state government spends on capital improvements partly determines the level of employment in the construction industry. All three model components are linked by their requirement for information produced by the other components. A description of the model can be found in Goldsmith, Man in the Arctic Program Model Documentation (1979).

The model has been updated in connection with the current study. This updating included the reestimation of important economic component equations with data series which included the most recent information. In most cases, this consisted of including the 1978 data in the series; however, some data series were recalculated based on recent information. These data changes had only marginal effects on the equations; however, several equations were respecified. The primary reason for these specification changes was to capture the buoyancy of the economy in the post-pipeline period. Equations describing wage rates in the exogenous sector and output in the endogenous sector were respecified in an attempt to improve the model's description of post-boom periods.

An additional change was made to the fiscal model. The fiscal model was changed to incorporate recent changes in state tax laws which eliminated the state income tax for residents with over three years in the state. The recent permanent fund distribution program was also reflected in model changes.

Household Formation Model

MODEL DESCRIPTION

The primary unit on which projections of residential energy consumption are based is the household. Households are living units. They are distinct from families and can contain more than one family as well as unrelated individuals. This section describes the model developed for this study to project the number of households in the state.

The population projections determine the number of households in the state. The number of households is a function of both the level of population and its age-sex distribution. The age-sex distribution of the population is important because the rate at which people form households differs across age-sex cohorts. The model described below accounts for both of these influences of population on household formation.

The household formation model is an accounting model which depends on a set of assumptions about the cohort specific rate of household formation and changes in those rates. The model is based on the assumption that the social, economic, and life cycle factors which determine the formation of households can be described by a set of household formation rates. Household formation rates describe the probability that a person in a particular cohort is a household head.

The model requires input from the MAP population model in the form of the projected size and age-sex distribution of the population. The total number of households in the state (HH) is equal to the number of households summed across age and sex cohorts.

$$HH = \sum_{ij}\sum HH_{ij} \qquad (B.1)$$

The total number of households in sex cohort i and age cohort j (HH_{ij}) describes the number of households with household head or primary individual in the ith sex and jth age cohort. The total number of households in cohort ij equals the number of civilian non-Native households in cohort ij (CHH_{ij}) plus the number of Native households in cohort ij (NHH_{ij}) plus the number of military households in cohort ij (MHH_{ij}).

$$HH_{ij} = CHH_{ij} + NHH_{ij} + MHH_{ij} \qquad (B.2)$$

The number of civilian and Native households in each cohort is a function of the population and household formation rate for the cohort. The number of households in any cohort equals the cohort specific household formation rate (HHR_{ij} for civilian non-Natives and $NHHR_{ij}$ for Natives) multiplied by the total population ($CNNP_{ij}$ for civilian non-Natives and $NATP_{ij}$ for Natives) net of the population in group quarters ($CPGQ_{ij}$ for civilian non-Natives and $NPGQ_{ij}$ for Natives).

$$CHH_{ij} = (CNNP_{ij} - CPGQ_{ij}) * HHR_{ij} \qquad (B.3)$$

$$NHH_{ij} = (NATP_{ij} - NPGQ_{ij}) * NHHR_{ij} \qquad (B.4)$$

Household formation rates describe the probability that someone in a particular cohort is the head or primary individual of a household. These rates change through the projection period. The initial rates are those found in 1970 (HHR_{ij}^{1970} for civilian non-Natives and $NHHR_{ij}^{1970}$ for Natives).

$$HHR_{ij}^{1970} = CHH_{ij}^{1970}/(CNNP_{ij}^{1970} - CPGQ_{ij}^{1970}) \tag{B.5}$$

$$NHHR_{ij}^{1970} = NHH_{ij}^{1970}/(NATP_{ij}^{1970} - NPGQ_{ij}^{1970}) \tag{B.6}$$

Household formation rates are assumed to change at a constant yearly rate ($CHHR_{ij}$ for civilian non-Natives and $NCHHR_{ij}$ for Natives). So the household formation rate in any year equals the rate in the previous year times the rate of change.

$$HHR_{ij} = HHR_{ij}\ (-1) * CHHR_{ij} \tag{B.7}$$

$$NHHR_{ij} = NHHR_{ij}\ (-1) * NCHHR_{ij} \tag{B.8}$$

Finally, the cohort distribution of military households is assumed to remain constant throughout the projection period. The number of military households (MHH_{ij}) equals the number in 1970 (MHH_{ij}^{1970}) times the percentage of 1970 military population in the state (MILPCT).

$$MHH_{ij} = MHH_{ij}^{1970} * MILPCT \tag{B.9}$$

PARAMETER ASSUMPTIONS

The most important source of variation in the model results is the assumed rates of household formation. These rates have been subject to dramatic changes in recent history. The change in these rates can be judged by examining recent changes in the average household size. Between 1960 and 1970, the average household size in the United States fell by 6 percent from 3.33 people per household to 3.14 people per household. Between 1970 and 1978, the rate of decrease was almost twice as fast as in the previous period; the average household size fell by more than 10 percent from 1970 to 2.81 (Bureau of the Census, Projections of the Number of Households and Families: 1979 to 1995, 1979). Alaska is experiencing a similar trend, the average household size fell by almost 7 percent between 1970 and 1976 (Bureau of the Census, Demographic, Social, and Economic Profile of States: Spring 1976, 1979).

The important recent changes in household formation rates, illustrated by the recent changes in household size, and the lack of agreement by population experts on future changes in these rates make the selection of any particular set of parameters probabilistic. Two sets of parameter assumptions are required by the model, household formation rates and yearly changes in those rates. Table B.1. presents the initial set of household formation rates. These rates are derived from the 1970 census and equals the number of household heads per population in households in the cohort. These rates were adjusted in some cohorts to insure consistency with U.S. rates in 1970.

TABLE B.1. 1970 ALASKA CIVILIAN POPULATION HOUSEHOLD FORMATION RATES (HHR_{ij})

	NON-NATIVE		NATIVE	
	Male	Female	Male	Female
0 - 1	0	0	0	0
1 - 5	0	0	0	0
5 - 9	0	0	0	0
10 - 14	.001	.001	.003	0
15 - 19	.040	.018	.017	.006
20 - 24	.583	.107	.238	.069
25 - 29	.900	.109	.576	.082
30 - 34	.933	.117	.746	.095
35 - 39	.955	.126	.881	.119
40 - 44	.962	.133	.894	.120
45 - 49	.963	.148	.907	.139
50 - 54	.964	.164	.922	.149
55 - 59	.956	.207	.947	.296
60 - 64	.956	.245	.926	.313
65 +	.885	.320	.816	.385

SOURCE: Bureau of the Census, 1970 Census of Population Detailed Characteristics: Alaska, 1972, Table 153.

Table B.2. illustrates the second set of required parameter assumptions, the assumed yearly change in the household formation rates. These changes are based on the changes implicit in the Series B projections of households by age and sex cohorts prepared by the Bureau of the Census (Bureau of the Census, <u>Projections of the Number of Households and Families: 1979 to 1995</u>, 1979). The average yearly change in household formation rates by age-sex cohort for the nation were assumed to hold for the civilian non-Native population. It was assumed that Native household formation rates would not change as rapidly; Native household formation rates were assumed to change at rates which would provide half the change in average household size projected for the nation.

TABLE B.2. YEARLY PERCENT CHANGE IN HOUSEHOLD FORMATION RATE ($CHHR_{ij}$)

	NON-NATIVE		NATIVE	
	Male	Female	Male	Female
0 - 1	0	0	0	0
1 - 5	0	0	0	0
5 - 9	0	0	0	0
10 - 14	1.002	1.045	1.001	1.028
15 - 19	1.002	1.045	1.001	1.028
20 - 24	1.002	1.045	1.001	1.028
25 - 29	1.000	1.045	1.002	1.028
30 - 34	1.001	1.040	1.001	1.024
35 - 39	1.000	1.027	1.000	1.016
40 - 44	1.000	1.027	1.000	1.016
45 - 49	1.001	1.012	1.000	1.006
50 - 54	1.001	1.012	1.000	1.006
55 - 59	1.001	1.000	1.000	1.000
60 - 64	1.001	1.000	1.000	1.000
65 +	1.001	1.000	1.000	1.000

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

Regional Allocation Model

MODEL DESCRIPTION

A method for making substate regional projections was required by this study. The economic and household projections described above are made at the state level. These projections serve as the basis for the energy demand projections; however, the Susitna project will provide energy for only a portion of the state, the railbelt region. This section describes the regional allocation model used in this study to allocate statewide projections to the region of interest.

Methods of projecting substate regional economic activity range from the simple to the complex. The simplest methodology is to allocate state economic activity to the region based on its historical share or to allocate nonbasic activity based on the regional share of basic sector activity. The most complex approach involves the estimation of complete regional models. The first approach suffers from its simplicity; it fails to recognize the importance of changes in the structure of the regional economy over time as the economy grows. The more complex approach requires massive commitments of time and resources to develop. It may also suffer from a lack of consistent data in the regions, particularly in areas like Alaska where many of the regions have small, undeveloped economies.

In choosing a regional projection technique, we were interested in three things. First, we wanted a model which was simple and efficient to use and could be used to project activity in a number of regions. Secondly, we wanted a model which made maximum advantage of the short data series available in the regions. Finally, we wanted a model which provided results consistent with the state projections.

The method used in this study is a regional shares model. In this model, the regional shares of state support sector employment, state and local government employment, and population are estimated econometrically as a function of basic sector activity as well as proxies for comparative advantage and scale of the regional economy. A pooled time series cross-section approach is used to estimate the model. This econometric approach has two purposes. First, it allows us to make use of the short data series in the census divisions. Secondly, it allows us to capture the major variability in the regional shares of economic activity which is across regions rather than over time.

Traditional explanations of regional economic growth explain growth as a function of growth in the region's basic sector. The regional allocation model recognizes that the local support sector response depends not only on basic sector growth but also on the position of the region in economic space. Larger economies will provide a greater support sector response since they offer economies of scale and produce more goods and services locally. Regions may also respond differently if they provide support sector services to regions other than their own. These trade centers have a comparative advantage in producing these goods and services. The scale and comparative advantage effects are accounted for in this model by the use of lagged population and regional dummies in each equation.

The model consists of four equations which estimate the regional share of population, support sector employment (in two categories), and state and local government employment. State and local government employment is assumed to be allocated across regions in the state primarily to serve the population, so the share of state and local government employment in region i ($REGSL_i$) is primarily a function of lagged share of population in the region ($LRPOP_i$). Special characteristics such as the capital in Juneau and administrative centers in larger regions are accounted for through the use of regional dummy variables (D_i).

$$REGSL_i = F_1(LRPOP_i, D_i) \tag{B.10}$$

Support sector economic activity is disaggregated into two distinct sectors: direct support, which includes construction and transportation employment, and other support which includes trade, services, finance, utilities, and communication. This distinction is a function of the assumed relation between these sectors and basic activity and assumed differences in causes of growth in each sector. Direct support sector employment depends not just on the size of the community or its basic sector, but on the growth of the community. This is a result of construction employment serving mainly an investment function. Because of this, the share of direct support sector employment in region i ($RESA_i$) is a function not only of the size of the community ($LRPOP_i$) but also the change in the economy; this change is described by the lagged share of the change in total employment in region i ($L298_i$). Uniqueness of regional economies is captured by the inclusion of a regional dummy (D_i).

$$RESA_i = F_2(LRPOP_i, L298_i, D_i) \tag{B.11}$$

Employment in the other support sector is assumed to be a function of the level of basic sector activity in the region. For our purpose, basic sector is defined broadly to include traditional basic sector industries as well as local and state government, and direct support sector employment in region i ($RESB_i$) may differ from a direct relation to the regional share of basic sector employment ($RR3EB_i$) for two reasons. First, the support sector may not expand immediately because of lags or because the basic sector growth is temporary. Secondly, the region may provide support sector services to a large region and be related to the basic sector activity in those regions. To account for these effects, both the lagged share of population ($LRPOP_i$) and regional dummies (D_i) were included.

$$RESB_i = F_3(RR3EB_i, LRPOP_i, D_i) \tag{B.12}$$

Finally, the regional share of population ($RPOP_i$) was assumed to be a function of employment in the region. In Alaska, workers often travel to jobs in other regions; this is most important in basic sector activities. Because of this, the effects of basic and other support sector employment or population were separated. Population may also differ from employment since a region may house the families of workers who work in other regions, such as Anchorage providing the homes of families of Prudhoe Bay workers. The regional share of population ($RPOP_i$) was assumed to be a function of the share of support sector employment ($RESB_i$), the share of basic sector employment ($RR3EB_i$), and a regional dummy (D_i) which reflects the fact that a region can serve as home to families of workers employed in other regions.

Regional totals are found by multiplying state totals by the shares estimated by the model.

PARAMETER DESCRIPTIONS

These equations were estimated using a pooled time series cross-sectional technique. Data on Alaska labor divisions (similar in most cases to census divisions) from 1965 to 1976 were used in the estimation. A linear form of the equations was estimated; the primary reason for this choice of functional form was the ability to use the set of equations to project the growth of any region defined as an aggregate of census divisions.

Conopsak (1978) identifies both the advantages and problems with using this technique. First, the use of pooled data increases the number of degrees of freedom compared to either cross-section or time-series regressions. Second, pooling techniques limit structural change biases which may occur in time series. Thirdly, by using a time series of cross-sections, it is possible to measure the effect of time and structure on the relationships. This is particularly important when estimating a shares model since examining time series of pooled cross-section provides for ample variation in the data.

Two types of problems may exist when using this approach. There may be systematic bias of the disturbance term because of cross-sectional influences, or the source of bias may be autocorrelation of the residuals. The first problem may be reduced with the inclusion of the regional dummies in the equation. The second problem may be reduced by adjusting for autocorrelation in the regression; both of these corrections were made.

Equations B.13 to B.16 are the equations used in the model. Dummies were included for all regions; however, only those dummies for the regions in this study are shown (DA-Anchorage, DK-Kenai, DS-Seward, DM-Matanuska, DF-Fairbanks, and DV-Valdez). The high R^2 (uncorrected) result from two factors, the inclusion of the regional dummies and the relatively small variability of regional shares in the historical period.

$$\begin{aligned} REGSL = {} & \underset{(3.48)^1}{.246} * LRPOP + \underset{(6.99)^1}{.224} * DA + \underset{(10.07)^1}{.124} * DF + \underset{(3.56)^1}{.025} * DK \\ & + \underset{(3.15)^1}{.021} * DM + \underset{(1.41)}{.009} * DS + \underset{(2.78)^1}{.018} * DV \qquad R^2 = .987 \end{aligned} \tag{B.13}$$

$$\begin{aligned} RESA = {} & \underset{(4.73)^1}{1.357} * L298 + \underset{(3.44)^1}{.744} * LRPOP + \underset{(1.67)^1}{.148} * DA + \underset{(1.27)}{.045} * DF \\ & + \underset{(2.36)^1}{.025} * DK - \underset{(-1.07)}{.008} * DM - \underset{(-.45)}{.003} * DS + \underset{(.45)}{.003} * DV \qquad R^2 = .987 \end{aligned} \tag{B.14}$$

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[1] t statistic in parentheses significant at greater than 95 percent.

$$RESB = .269 * LRPOP + .086 * RR3EB + .409 * DA + .111 * DF \qquad (B.15)$$
$$\quad (3.26)^{1} \qquad (1.31) \qquad (11.46)^{1} \qquad (7.71)^{1}$$

$$+ .017 * DK + .007 * DM + .004 * DS + .006 * DV \qquad R^2 = .997$$
$$(3.74)^{1} \qquad (1.95)^{1} \qquad (1.19) \qquad (1.94)^{1}$$

$$RPOP = .290 * RESB + .157 * RR3EB + .213 * DA + .073 * DF \qquad (B.16)$$
$$(4.70)^{1} \qquad (2.93)^{1} \qquad (5.78)^{1} \qquad (4.58)^{1}$$

$$+ .029 * DK + .022 * DM + .005 * DS + .012 * DV \qquad R^2 = .995$$
$$(7.38)^{1} \qquad (6.81)^{1} \qquad (1.59) \qquad (3.45)^{1}$$

Housing Stock Model

MODEL DESCRIPTION

Regional projections of households and housing stock are the basic components of the residential energy demand projections. This model uses the output of the three components described above to project both the number of households by region and the distribution of those households by housing type. The housing types projected by this model include single-family, duplex, multifamily, and mobile homes. The total housing stock by type is found by adjusting for vacant housing.

Housing stock projections are influenced by three factors. First, the number of households determines the aggregate demand for housing. Secondly, the distribution of households by income, family size, and tenure determines the effective demand for different types of housing. Finally, housing has a long life; once a type of housing is built, it

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[1] t statistic in parentheses significant at greater than 95 percent.

exists for a long time and influences the actual distribution of housing by type. The model described in this section attempts to account for each of these factors.

The number of households in region i (THH_i) is found by dividing the regional population (POP_i) [from the regional allocation model] by a regional population per occupied dwelling units parameter ($PPODU_i$). This provides an estimate of the total number of households in the region. On-base households (BHH_i), which are assumed to remain constant throughout the period, are subtracted from total households to find total off-base households (HH_i).

$$THH_i = POP_i/PPODU_i \tag{B.17}$$

$$HH_i = THH_i - BHH_i \tag{B.18}$$

Once total off-base households (from hereon, total households) are found, the demands for various housing types are projected through the use of housing type demand coefficients. The demand for housing type T (H_i^T) equals the total housing units (HH_i) times the demand coefficient for type T (HD^T). The demand coefficients describe the distribution of households by "preferred" housing type.

$$H_i^T = HH_i * HD_i^T \tag{B.19}$$

The initial stock of housing of type i in any period is equal to last period's housing stock of that type ($S_i^T(-1)$) minus the removals from the stock since the previous period. Removals are due to demolitions, accidental loss (fire, flood, etc.), and conversions to other types of units or uses. The model finds the initial stock of housing of type T ($\hat{S}_i^T$) by multiplying the stock from the previous period times one minus the removal rate (r_T), where the removal rate equals the proportion of the previous period housing lost between the periods.

$$\hat{S}_i^T = S_i^T\,(-1) * (1-r_T) \tag{B.20}$$

Construction of new housing of each type is determined by the net demand for that type (ND_i^T). The net demand equals the demand for housing of type T (H_i^T) minus the initial supply of that type ($\hat{S}_i^T$).

$$ND_i^T = H_i^T - \hat{S}_i^T \tag{B.21}$$

If the net demand for all types of housing is positive, new construction (ND_i^T) equals net demand plus the equilibrium amount of vacant housing. In this case, new construction equals net demand plus the vacancy rate (V_T) times the net demand plus the initial supply of housing type T.

$$NC_i^T = ND_i^T + V_i * [\hat{S}_i^T + ND_i^T] \tag{B.22}$$

If the net demand for a particular housing type is negative, an adjustment is required. The adjustment recognizes implicitly the effect of prices on demand. When net demand for a housing type is negative, this excess supply is assumed to drive down the price of this type of housing relative to others and switch demand. For this adjustment, single-family and mobile homes and multifamily and duplexes are assumed to be close substitutes; when one type has excess supply, it is filled by households with the other type demand. If excess supply continues to exist and the vacancy rate is greater than an assumed maximum rate, the units are filled proportionally from the other types with excess demand. Once these adjustments are made, new construction occurs to meet the excess demand.

PARAMETER DESCRIPTION

There are four sets of parameters which determine the housing stock projections. The assumed people per occupied dwelling unit ($PPODU_i$) determines the number of households in a given regional population. The removal rates (r_T) determine the proportion of last period's housing which has been removed from the housing stock. The vacancy rates (V_T) determine the supply of vacant housing in any period. Finally, the housing demand coefficients (HD_i^T) determine the initial distribution for demand by housing type.

The initial people per occupied dwelling rates were taken from the most recent information found for each region. Table B.3 shows the initial rates used in each region. These rates were adjusted each period to reflect projected changes in the population per household rate on the state level; this adjustment assumed the changes in the state rate were reflected proportionally in each region.

TABLE B.3. INITIAL PEOPLE PER OCCUPIED DWELLING UNITS

Greater Anchorage[1]	Fairbanks[2]	Valdez[3]	Rest of State[4]
3.03	3.01	3.1	3.5

[1] Weighted average of rates found in: Anchorage Municipality, 1978 Population Profile, 1978 (for Anchorage); Kenai Borough, Profile of Five Kenai Peninsula Towns, 1977 (for Kenai and Seward); and Rivkin Associates, Workbook on the Economic and Social Impacts of the Capital Move on Juneau and the Mat-Su Borough, 1977 (for Matanuska-Susitna).

[2] Assumes Fairbanks people per occupied dwelling decreased at same rate as the U.S. average between 1970 and 1977; the 1977 rate was .91 less than in 1970 for the United States.

[3] M. Baring-Gould, Valdez City Census, 1978.

[4] Weighted average for the nonrailbelt area of the state in the 1970 census (3.7) assumed to decline at one-half the rate of the decline for the United States.

An average removal rate is assumed for this report and applied to all types of housing in all regions. Table B.4 shows the rates assumed in this study.

TABLE B.4. ASSUMED HOUSING REMOVAL RATES

1975-1980	1980-1985	1985-1990	1990-1995	1995-2000
1.0%	1.25%	1.50%	1.75%	2.0%

Removal rates are a function of the age of the housing stock and the growth of the region. Older housing may be subject to filtering, and areas with more rapid growth may remove more older housing to make room for new construction. Comparisons of dwelling unit estimates in 1970 and 1979 with building permits data on units constructed during that period show an approximate removal rate of 1 percent per five-year period in Anchorage and Fairbanks. It was assumed that, as the existing stock ages, the removal rate will grow toward the U.S. average which has been estimated to be between two and four percent for a five-year period (deLeeuw, 1974). We assumed the removal rate would reach the lower bound of 2 percent by 2000.

Vacancy rate assumptions are based on U.S. averages and recent Alaska experience. Table B.5 shows the assumed normal and maximum vacancy rates used in the housing stock projection. The normal vacancy rates are the ten-year U.S. averages for owner and renter units (Bureau of the Census, Housing Vacancies: Fourth Quarter 1979, 1980). Single-family and mobile homes have the owner rate; multifamily, the rental rate; and duplexes, the

TABLE B.5. VACANCY RATE ASSUMPTIONS

	Normal	Maximum
Single Family	1.1	3.3
Multifamily	5.4	16.0
Duplex	3.3	10.0
Mobile Home	1.1	3.3

average of owner and renter. Maximum rates are based on recent Anchorage multifamily experience (Anchorage Real Estate Research Report, 1979); single-family, mobile home, and duplexes are assumed to maintain the normal relationship to multifamily vacancies.

The final parameter assumptions concern the housing demand coefficients; these are the most important parameters for determining the housing stock distributions. The assumed housing type demand distributions used in this study are based on the analysis of existing survey information from Anchorage. A 1978 survey of the Anchorage population conducted by the Urban Observatory of the University of Alaska - Anchorage (Ender, 1979) provided information on housing type choice and demographic variables. Regression analysis was used to analyze this information. A linear probability model was estimated for each of three housing types: single-family, multifamily, and mobile home. These regressions estimate the probability that a person would occupy a particular housing type as a function of the age of the household head and family size. Family size and incomes have often been isolated as the major determinants of housing type choice. In reality, current income and wealth influence a household's ability to purchase a home; the age of the household head is a proxy for both wealth and income. Table B.6 shows the results of the Anchorage regressions.

These equations were tested by estimating the 1970 housing type distribution in the Anchorage, Fairbanks, and Valdez regions and with more recent data in Fairbanks and Anchorage. The performance of the

TABLE B.6. HOUSING CHOICE REGRESSIONS

Single Family

$$SF = .461 - \underset{(70.36)^{1}}{.303 * S1} - \underset{(20.52)^{1}}{.175 * S2} + \underset{(1.87)}{.08 * S4} + \underset{(12.24)^{1}}{.182 * A2}$$

$$+ \underset{(47.33)^{1}}{.317 * A3} + \underset{(43.85)^{1}}{.380 * A4} \qquad \bar{R}^2 = .153$$

Multifamily

$$MF = .383 + \underset{(50.75)^{1}}{.225 * S1} + \underset{(6.46)^{1}}{.086 * S2} - \underset{(3.07)}{.09 * S4} - \underset{(19.84)^{1}}{.203 * A2}$$

$$- \underset{(47.96)^{1}}{.280 * A3} - \underset{(49.02)^{1}}{.352 * A4} \qquad \bar{R}^2 = .128$$

Mobile Home

$$MH = .097 + \underset{(7.01)^{1}}{.068 * S1} + \underset{(1.98)}{.039 * S2} + \underset{(.121)}{.014 * S4} + \underset{(.043)}{.008 * A2}$$

$$- \underset{(.366)}{.020 * A3} - \underset{(.151)}{.016 * A4} \qquad \bar{R}^2 = .005$$

Family Size		Age of Household Head	
S1	≤ 2	A2	25-30
S2	3	A3	30-55
S4	5<	A4	55<

[1] F statistic in parentheses significant at greater than 95 percent.

models in these cases suggested that no specific regional adjustment of the equations was required in Anchorage and Fairbanks, and they were used to project housing demand coefficients in each region.

In Valdez, comparison with 1978 housing stock distribution showed a major difference. This was assumed to be a result of the recent rapid growth in the region connected with construction of the Trans-Alaska Pipeline Service (TAPS) pipeline and associated port facility. In Valdez, demand coefficients were assumed to change linearly from the 1978 housing type distribution to the projected 2000 housing demand distribution.

Use of these equations assumes that the existing relationships between housing type choice and non-included variables remains the same. Most important in the case is the effect of housing price. We are implicitly assuming that the relation between housing prices and income will remain constant throughout the period. The importance of housing means there may be some adjustments such as two-income families. The importance of the government in the housing and mortgage markets makes any change impossible to forecast. This approach also ignores the existence of land-use constraints which may prevent actual construction of these units.

The housing type parameters were projected over the period based on assumed changes in household head age distribution in each region and the family size distribution. The state distribution of households by age of household head was used to estimate the regional distribution; each region was assumed to maintain the same relation to the state distribution as in 1970. The family size distribution in each region was assumed to follow a pattern of change which approached the 1977 Western Regional distribution (Bureau of Census, Annual Housing Survey: 1977, 1979). The level of household size in the Western region of the United States was similar to that projected for our regions in 2000. The change from the 1970 distribution to this 1977 distribution was assumed to be at the same rate as the rate of the change in population per household projected by the regional allocation model.

APPENDIX C. ECONOMIC PROJECTIONS

The projections of electricity consumption in the Susitna Hydroelectric Power Project service area are based on a set of projections of economic activity in the state and the railbelt region. This appendix describes those projections. The appendix is divided into three parts. First will be a short general discussion of projections, the reasons for doing them, and general problems with projections. A discussion of the specific sets of assumptions which were used in conjunction with the models described in Appendix B follows the first section. Finally, the projections themselves will be reviewed.

What are Projections?

Projections provide a description of a future level of activity; the economic projections described in this appendix describe possible future levels of important economic variables. Projections cannot be assumed to be an accurate description of what will happen but rather a description of what could happen if the assumptions which determine the projections come true. This means that projections are probabilistic.

The uncertainty of the future, though it may increase the problems associated with making projections, increases the importance of projections. Decision makers in both public and private sectors need information about the future in order to plan their actions since they must make decisions which both are affected by and affect future events.

The more uncertain are the future events, the more important are some projections of them in decision making.

All methods for making projections of future economic activity require assumptions about the future. The simplest projection technique is simply to assume a certain growth for each of the major variables of interest. More complex methodologies employ some form of model to translate assumptions about specific events into projections. Models describe the relationship between variables about which assumptions are made (exogenous variables) and those of which projections are made (endogenous variables); an important assumption when a model is used is that the relationship described by the model remains constant. The use of models makes explicit the assumptions implicit with simpler projection techniques, and it provides consistency between sets of projections.

The major problems with projections is the uncertainty attached to the projections. The uncertainty results because of uncertainty about the future levels of exogenous variables and uncertainty that the relationships will continue to hold as described by the model. There are two major ways to limit the importance of this problem, although uncertainty can never be eliminated from projections. The first measure is to provide a clear, complete description of the assumptions on which the projections are based; this allows users to know exactly what is behind the projections. The second measure involves producing many alternative projections instead of just one; these alternative projections provide an indication of effect of altering major assumptions.

These measures in themselves do not limit the uncertainty of any particular projection, but they allow the establishment of a range of possible outcomes which the researcher expects to have a very high probability of occurrence.

The Approach of the Current Study

In the present study, we present a series of projections which, although of limited number, reflect the range of probable future levels of economic activity. Because these projections may be used in the actual design of the project, it is important to provide a range of futures with a relatively high probability of occurrence. We do not assume that the actual growth in future economic activity will match any of our scenarios in level of activity or timing and magnitude of events. What we assume is that the general level of economic activity described by these scenarios will occur with a high probability.

The projections in this study are for a thirty-year period from 1980 to 2010. Because of the long projection period, there is a large potential for error in utilizing any single technique in developing the projections. Two general techniques have been employed in these projections. The first is scenario building in which the aggregate values are developed by constructing scenarios composed of specific events. For example, the level of total employment in the petroleum industry would be estimated by assuming the development of specific reserves with associated manpower requirements and timing. The scenario building technique reduces the potential for error in the projection by dividing the development of the assumptions into a series of small decisions. This technique allows specific information about future developments to be built into the projection. The most important reason for using the scenario building technique is that it allows for consistency in the forecast. By assuming specific events, we can make sure the growth rate projected is at least possible.

The major disadvantage of the scenario building technique occurs as the projection period is extended in time. Because many of the possible future events are unknown, they may be ignored when developing the scenarios. This myopia may result in a downward bias in the projection as the projection period lengthens.

To attempt to overcome this problem in these projections, a second technique was used in the post-2000 period when information about specific events is undefined. This second technique is a judgmental approach The judgmental technique projects directly the aggregate variables. The judgmental projection is based on an analysis of both the historic period growth and the growth in other regions. This technique fails to provide reality or consistency checks on the assumptions but provides a method of projection when the scenario building technique is impossible to use.

The study combines the scenario building and judgmental techniques to produce the required projections. Each technique is used to project economic activity in the period when it is most appropriate; the scenario building technique is used in the period between 1980 and 2000 when reasonable information about possible economic events is available and the judgmental approach is used after 2000 when there is only limited information on the possibilities.

The Scenarios: 1980-2000

For the period between 1980 and 2000, specific scenarios are developed. These scenarios consist of two major components, an economic scenario and a state government fiscal scenario. The economic scenarios consist of a set of assumptions which describe the special projects and industrial growth in the period. The state government fiscal scenario describes the assumed level of state expenditures; these expenditures result in the creation of jobs in both state government and the construction industry.

Each economic scenario describes the growth in the exogenous industries: mining, manufacturing, agriculture-forestry-fisheries, federal government; and in the exogenous components of construction and transportation. Each state government scenario describes the growth of state operations and capital expenditure which affects the level of employment in state government and construction. The next two sections describe the economic and state government scenarios.

THE ECONOMIC SCENARIOS

The economic scenarios consist of time series on employment and output in certain export base or exogenous industries. These assumptions are organized into three separate scenarios which describe a high, moderate, and low series of economic events which describe what we feel to be a reasonable range of economic events. This does not mean that we are predicting that all or any of these events will occur since there is a highly variable degree of uncertainty with respect to the levels and timing of the events in these scenarios. What it does mean is that with a certain degree of probability, we expect the general level of economic activity to follow these scenarios. We assume that there is a very high probability that the level of activity will be at least as great as that described by the low scenario, a medium probability that the level of activity will be at least as great as that described by the moderate scenario, and a low probability that activity levels higher than those described in the moderate case will occur.

Primarily as a result of the uncertainty attached to the occurrence, magnitude, and timing of any particular event, agreement about particular scenarios is hard to achieve even among those most knowledgeable about the Alaska economy. Emphasizing our concern mainly with general levels of activity and the probabilistic nature of any specific scenario should reduce the disagreement. In an attempt to reduce even further the disagreement, the scenarios were developed based upon existing scenarios which have attained some measure of consensus. The most important source for these scenarios were the scenarios developed in the level B Southcentral Water Study (Scott, 1979).

The individual scenarios are described in Tables C.1 through C.3. The assumptions are described below; these discussions are organized by industry.

Mining

Currently, the mining sector in Alaska is dominated both in terms of employment and output by the petroleum industry. This is assumed to continue in the future in all scenarios.

All three scenarios include production at Prudhoe Bay and in the Upper Cook Inlet. Production from the Sadlerochet formation at Prudhoe is assumed to include both primary recovery and secondary recovery using water flooding. The Kuparak formation is also assumed to be developed with production rising to 120,000 barrels per day by 1984. Employment associated with these developments peaks in the early 1980s with the development of Kuparak and the water flooding project. Upper Cook Inlet employment is assumed to remain at its existing level throughout the projection period. This assumes a rising level of exploration, development, and production of gas in the Kenai fields which would replace employment lost because of declining oil production.

The major new source of petroleum production assumed in these scenarios is Alaska's Outer Continental Shelf (OCS). Alaska is the area of primary importance to future OCS activity. Nearly 60 percent of oil and 40 percent of gas resources which are expected to be found in the United States OCS are expected to be in Alaska waters (Bureau of Land

TABLE C.1. HIGH SCENARIO ECONOMIC ASSUMPTIONS

Special Projects	Description	Dates & Employment	Railbelt Location	Source
Trans-Alaska Pipeline	The construction of the TAPS was completed in 1977. Additional construction of four pump stations is assumed as well as pipeline operations.	1979-1982 - Pump station construction of 90/year 1977-2000 - Operations employment of 1000/yr.	Operations employment allocated: 1/3 to Valdez 1/3 to Fairbanks	E. Porter, Bering-Norton Statewide-Regional Economic and Demographic Systems, Impact Analysis, Alaska OCS Socioeconomic Studies Program, Bureau of Land Management, 1980.
Northwest Gasline	Construction of natural gas pipeline from Prudhoe Bay which includes construction of an associated gas conditioning facility on the North Slope.	1981-1985 - Construction peak employment of 7,823 (1983) 1986-2000 - Operations begin employing 400 petroleum and 200 transport workers	1/2 of construction and transportation employment in Fairbanks	E. Porter, 1980.
Prudhoe Bay Petroleum Production	Primary recovery from Sadlerochit formation, secondary recovery using water flooding of that formation and development of the Kuparuk formation.	1982-1984 - Construction of water flooding project peak employment of 2,917 (1983) 1980-2000 - Mining employment long-run average of 1,802/year		E. Porter, 1980.
Upper Cook Inlet Petroleum Production	Employment associated with declining oil production is assumed to be replaced by employment associated with rising gas production maintaining current levels of employment.	1980-2000 - Mining employment of 705/year	All in Anchorage region	E. Porter, 1980

TABLE C.1. HIGH SCENARIO ECONOMIC ASSUMPTIONS (cont.)

Special Projects	Description	Dates & Employment	Railbelt Location	Source
National Petroleum Reserve in Alaska	Petroleum production in NPRA. Production in five fields with a total reserve of 2.5 billion bbls equivalents of oil and gas. Construction of 525 miles of pipeline.	Leases held between 1983-1990. Development and exploration begins in 1985. Average mining employment of 460/year.		Based on mean scenario under Management Plan 2 in Office of Minerals Policy and Research Analysis, U.S. Department of Interior, Final Report of the 105(b) Economic and Policy Analysis, 1979.
State Capital Move	Movement of the state capital from Juneau to Willow begins in 1983. A full move involving 2,750 state employees.	1983-1996 - Construction - peak employment in 1990 of 1,560/year. Move completed in 1996.	All in Anchorage region	High Scenario in M. Scott, Southcentral Alaska's Economy and Population, 1965-2025: A Base Study and Projections, Economics Task Force, Alaska Water Resources Study (Level B), 1979.
Beluga Coal Production	Major development of Beluga coal reserves for export.	1985-1990; 1994 - Construction with peak employment of 400 (1987) 1988-2000 - production employment of 370/yr. for long-run average	Located in Anchorage region	Pacific Northwest Laboratory, Beluga Coal Field Development: Social Effects and Management Alternatives, 1979.

TABLE C.1. HIGH SCENARIO ECONOMIC ASSUMPTIONS (cont.)

Special Projects	Description	Dates & Employment	Railbelt Location	Source
Outer Continental Shelf Petroleum Production	Production in eleven OCS lease sale areas: Beaufort 1 (1979) Lower Cook (1981) Bering-Norton (1982) St. George 1 (1982) North Aleutian (1983) Beaufort 2 (1983) Navarian Basin (1984) Hope Basin (1985) Chukchi Basin 1 (1985) Navarian Basin 2 (1989) Chukchi Basin 2 (1994)	Peak OCS employment - mining - 9,066/year (2000) - construction - 5,300 /year (1992)	Lower lease sale (68) is in Anchorage region. Headquarters employment averaging 12 percent of mining is in Anchorage	E. Porter, 1980 (for Lower Cook and Bering-Norton lease sales). Employment scenarios for remainder of sales estimated based on N. Gulf (Sale 55) high case adjusted to include LNG plant (Huskey and Nebesky, Northern Gulf Petroleum Scenarios: Economic and Demographic Systems Impacts, Socioeconomic Studies Program, Alaska OCS Office, 1979). Northern Gulf Scenario was adjusted by difference in resource estimates to produce scenarios for specific areas.
U.S. Borax Mining	Development of mining operation.	Exploration and development begins in 1980. Long-run mining employment of 440/year begins in 1993.		U.S.D.A. Forest Service, E.I.S.: U.S. Borax Mining Access Road for Quartz Hill Proposal, 1977.
Alpetco Project	Major petrochemical facility developed as originally proposed by Alpetco.	1982-1986 - Construction - peak employment of 3,500/year (1984-1986) 1987-2000 - Operations employment of 1,925/year	Located in Valdez region	S. Goldsmith and L. Huskey, The Alpetco Petrochemical Proposal: An Economic Impact Analysis, Institute of Social and Economic Research, 1978.

TABLE C.1. HIGH SCENARIO ECONOMIC ASSUMPTIONS (cont.)

Special Projects	Description	Dates & Employment	Railbelt Location	Source
Pacific LNG Project	Construction of current proposal by Pacific LNG	1982-1985 - Construction peak employment of 1,323/year (1984) 1986-2000 - Operations employment of 100/yr.	Located in Anchorage region	E. Porter, 1980.
Forestry/Pulp and Paper Manufacturing	Employment in these industries expands to accommodate an annual cut of approximately 1.3 million board feet by 2000.		Approximately 11% of this activity occurs in the Fairbanks region	M. Scott, 1979
Other Manufacturing	Expansion of existing manufacturing as well as new local manufacturing of locally-consumed goods.	Growth of output at 3% a year	81% in Anchorage region, 15% in Fairbanks region and .4% in Valdez region	Regional distribution based on existing distribution of employment
Federal Government	A doubling of the recent growth rate of civilian federal government. Military government employment assumed to remain constant at 1978 level.	Civilian federal government employment grows at 1% per year	.56% of civilian employment in Anchorage, 15% in Fairbanks, .3% in Valdez. Military employment as in 1978.	M. Scott, 1979.
Fairbanks Petrochemical	Moderate petrochemical facility using the state's royalty gas as feedstock.	1984-1986 - construction of 1,500/year 1987-2000 - operation employment of 600/yr.	Located in Fairbanks region	J. Kruse, Fairbanks Petrochemical Study, 1978.

TABLE C.1. HIGH SCENARIO ECONOMIC ASSUMPTIONS (cont.)

Industry Assumptions	Description	Dates & Employment	Railbelt Location	Source
Other Mining	Assumed expansion of hardrock and other mining opportunities in the state.	Growth of employment at 1% a year. Starting at existing level.	Growth is assumed to be distributed across regions as existing mining employment. (67% in Anchorage and 2% in Fairbanks)	
Agriculture	Major development of agriculture in Alaska. Reflects favorable state and federal policy and favorable markets.	Employment in agriculture reaches about 4,600 by 2000.	Major emphasis in Tanana Valley. 71% of growth in Fairbanks and 18% in Anchorage.	M. Scott, 1979.
Fisheries/ Food Processing	Continued level of employment in existing fisheries. Major development of bottom-fishing, with 100% replacement of foreign fishing effort in 200 mile limit by 2000.	Employment in fisheries increases to 1,350 by 2000. Fish hatchery and processing plant construction employment averaging 150/year. Appropriate expansion of food processing industry.	.14% of existing fisheries and 8% of bottom-fish development in Anchorage; .1% of existing fishery in Valdez.	M. Scott, 1979. M. Scott, "Prospects for a Bottom-fish Industry in Alaska," Alaska Review of Social and Economic Conditions, 1980.

TABLE C.2. MODERATE SCENARIO ECONOMIC ASSUMPTIONS

Special Projects	Description	Dates & Employment	Railbelt Location	Source
Trans-Alaska Pipeline	The construction of the TAPS was completed in 1977. Additional construction of four pump stations is assumed as well as pipeline operations.	1979-1982 - Pump station construction of 90/year 1977-2000 - Operations employment of 1000/yr.	Operations employment allocated: 1/3 to Valdez 1/3 to Fairbanks	E. Porter, Bering-Norton Statewide-Regional Economic and Demographic Systems, Impact Analysis, Alaska OCS Socioeconomic Studies Program, Bureau of Land Management, 1980.
Northwest Gasline	Construction of natural gas pipeline from Prudhoe Bay which includes construction of an associated gas conditioning facility on the North Slope.	1981-1985 - Construction peak employment of 7,823 (1983) 1986-2000 - Operations begin employing 400 petroleum and 200 transport workers	1/2 of construction and transportation employment in Fairbanks	E. Porter, 1980.
Prudhoe Bay Petroleum Production	Primary recovery from Sadlerochit formation, secondary recovery using water flooding of that formation and development of the Kuparuk formation.	1982-1984 - Construction of water flooding project peak employment of 2,917 (1983) 1980-2000 - Mining employment long-run average of 1,802/year		E. Porter, 1980.
Upper Cook Inlet Petroleum Production	Employment associated with declining oil production is assumed to be replaced by employment associated with rising gas production maintaining current levels of employment.	1980-2000 - Mining employment of 705/year	All in Anchorage region	E. Porter, 1980

TABLE C.2. MODERATE SCENARIO ECONOMIC ASSUMPTIONS (cont.)

Special Projects	Description	Dates & Employment	Railbelt Location	Source
National Petroleum Reserve in Alaska Petroleum Production	Petroleum production in NPRA. Production in two fields with total reserves of 1.2 billion barrels equivalents of oil and gas. Construction of 266 miles of pipeline.	Leased between 1995 and 2013. Exploration and development begins in 1998. Average mining employment of 286 (between 1998-2000).		Based on mean scenario under Management Plan 4 in Office of Minerals Policy and Research Analysis, U.S. Dept. of Interior, Final Report of the 105(b) Economic and Policy Analysis, 1979.
Outer Continental Shelf Petroleum Production	Production in six OCS lease sale areas: Beaufort 1 (1979) Lower Cook (1981) Beaufort 2 (1983) Navarian Basin 1 (1984) Hope Basin (1985) Chukchi Basin (1994)	Peak OCS employment - mining - 4,900 (1996) - construction - 3,300 (1992)	Lower Cook lease sale in Anchorage region. Headquarters employment averaging 12% of OCS mining employment	E. Porter, 1980 (for Lower Cook and Bering-Norton lease sales). Employment scenarios for remainder of sales estimated based on N. Gulf (Sale 55) high case adjusted to include LNG plant (Huskey and Nebesky, Northern Gulf Petroleum Scenarios: Economic and Demographic Systems Impacts, Socioeconomic Studies Program, Alaska OCS Office, 1979). Northern Gulf Scenario was adjusted by difference in resource estimates to produce scenarios for specific areas.
Beluga Coal Production	Moderate development of Beluga coal resource for export.	1985-1990 - construction - peak employment of 400 (1987) 1988-2000 - operations employment of 210/year long-run average	Located in Anchorage region	Pacific Northwest Laboratory, Beluga Coal Field Development: Social Effects and Management Alternatives, 1979.

TABLE C.2. MODERATE SCENARIO ECONOMIC ASSUMPTIONS (cont.)

Special Projects	Description	Dates & Employment	Railbelt Location	Source
Alpetco Project	Development of modified Alpetco proposal; configuration is primarily as a refinery rather than petrochemical operation.	1982-1984 - Construction employment of 900/year 1985-2000 - operations employment of 518/yr.	Located in Valdez region	E. Porter, 1980.
Pacific LNG Project	Construction of current proposal by Pacific LNG	1982-1985 - Construction peak employment of 1,323/year (1984) 1986-2000 - Operations employment of 100/yr.	Located in Anchorage region	E. Porter, 1980.
Industry Assumptions				
Other Mining	No expansion of existing non-special project mining.	Employment constant at 1979 level, 2,350/yr.	Regional allocation constant (67% in Anchorage and 2% in Fairbanks)	
Agriculture	Assumes that a relatively low priority is given to agriculture development because of priorities for recreation and wilderness or the lack of markets.	Employment grows to 1,037 by 2000.	71% located in Fairbanks region and 18% in Anchorage region	M. Scott, 1979.
Fisheries/ Food Processing	Maintenance of current levels of employment in existing fishery. Expansion of bottomfishery to replace one-half of foreign fishery in the 200 mile limit.	Employment in fisheries increases to 1,228 by 2000. Construction of hatchery and processing facilities employs 75/ year. Approriate expansion of food processing industry.	14% of existing fisheries and 8% of bottomfishery in Anchorage; .1% of existing fishery in Valdez	M. Scott, 1979. M. Scott "Prospects for a Bottomfish Industry in Alaska," Alaska Review of Social and Economic Conditions, 1980.

TABLE C.2. MODERATE SCENARIO ECONOMIC ASSUMPTIONS (cont.)

Industry Assumptions	Description	Dates & Employment	Railbelt Location	Source
Forestry/Pulp and Paper Manufacturing	Employment expands to accommodate 960 million board feet of lumber.		Approximately 11% of activity in Fairbanks region.	M. Scott, 1979.
Other Manufacturing	Expansion of existing manufacturing of locally consumed goods.	Growth of output at 2% per year.	81% in Anchorage, 15% in Fairbanks, .4% in Valdez	Regional distribution based on existing distribution of employment.
Federal Government	Civilian employment assumed to grow at recent historical rate. Military constant at current level.	Civilian employment grows at .05%/year	56% of civilian employment in Anchorage, 15% in Fairbanks, .3% in Valdez	M. Scott, 1979.

TABLE C.3. LOW SCENARIO ECONOMIC ASSUMPTIONS

Special Projects	Description	Dates & Employment	Railbelt Location	Source
Trans-Alaska Pipeline	The construction of the TAPS was completed in 1977. Additional construction of four pump stations is assumed as well as pipeline operations.	1979-1982 - Pump station construction of 90/year 1977-2000 - Operations employment of 1000/yr.	Operations employment allocated: 1/3 to Valdez 1/3 to Fairbanks	E. Porter, Bering-Norton Statewide-Regional Economic and Demographic Systems, Impact Analysis, Alaska OCS Socioeconomic Studies Program, Bureau of Land Management, 1980.
Northwest Gasline	Construction of natural gas pipeline from Prudhoe Bay which includes construction of an associated gas conditioning facility on the North Slope.	1981-1985 - Construction peak employment of 7,823 (1983) 1986-2000 - Operations begin employing 400 petroleum and 200 transport workers	1/2 of construction and transportation employment in Fairbanks	E. Porter, 1980.
Prudhoe Bay Petroleum Production	Primary recovery from Sadlerochit formation, secondary recovery using water flooding of that formation and development of the Kuparuk formation.	1982-1984 - Construction of water flooding project peak employment of 2,917 (1983) 1980-2000 - Mining employment long-run average of 1,802/year		E. Porter, 1980.
Upper Cook Inlet Petroleum Production	Employment associated with declining oil production is assumed to be replaced by employment associated with rising gas production maintaining current levels of employment.	1980-2000 - Mining employment of 705/year	All in Anchorage region	E. Porter, 1980

TABLE C.3. LOW SCENARIO ECONOMIC ASSUMPTIONS (cont.)

Industry Assumptions	Description	Dates & Employment	Railbelt Location	Source
Other Mining	Assumed reduction in mining employment in the state as a result of land policy or world market conditions.	Mining employment declines at 1% per year from existing levels.	Decline distributed across regions as existing mining employment.	
Agriculture	Unfavorable conditions for agricultural development. These include land policies as well as lack of markets. Agriculture disappears in Alaska.	Employment in agriculture declines to zero by 1992.		M. Scott, 1979.
Fisheries/Food Processing	Existing fishery is maintained but no bottomfish development occurs.	Employment remains at 1000. Moderate growth in food processing to accommodate expanding catch.	14% in Anchorage and .1% in Valdez	M. Scott, 1979.
Forestry/Pulp and Paper Manufacturing	Employment expands to accommodate 960 million board feet of lumber.		Approximately 11% of activity in Fairbanks region.	M. Scott, 1979.
Other Manufacturing	Expansion of existing production for local markets.	Growth in output at 1% per year.	81% in Anchorage, 15% in Fairbanks, .4% in Valdez.	Regional distribution based on the existing employment distribution.
Federal Government	Civilian employment assumed to grow at recent historical rate. Military constant at current level.	Civilian employment grows at .05%/year	56% of civilian employment in Anchorage, 15% in Fairbanks, .3% in Valdez.	M. Scott, 1979.

Management, 1980). The present scenarios are constructed around the present lease schedule, although the projected probability of finding oil in each area is considered. For areas with large reserves, we assumed more than one sale would be held. Table C.4.1 describes the lease sales, their assumed lease date, the assumed level of resources developed, the probability of finding oil or gas, and the scenarios in which they are included. The low scenario assumes no OCS development in the period prior to 2000; this is a result of assumed environmental and legal challenges in the Beaufort Sea, lack of technology and market conditions for the major resource areas in Western Alaska, and only limited resource finds in the Gulf of Alaska. In the moderate scenario, only the most probable areas are developed. The high scenario includes both more areas and a second round of sales in some areas in the moderate scenario. Although five sales are scheduled for the Southcentral region of the state, the probability of finding resources in all of them is extremely low; only the second Lower Cook sale is assumed to be developed in the high and moderate scenarios.

Both the moderate and high scenarios also include petroleum development in the National Petroleum Reserve in Alaska. In the high scenario, five fields are developed beginning in 1983 and extending through the period. These fields contain reserves of 2.5 billion barrels of oil equivalents in oil and gas. Pipelines are constructed to bring the resources to the Trans-Alaska Pipeline Service (TAPS) pipeline and to the Northwest gas pipeline. In the intermediate case, two fields with approximately half the reserves of the high case are developed. This development does not occur until near the end of the period in 1998.

TABLE C.4.1. FUTURE OCS ACTIVITY

Lease Sale Area	Reserves[1]		Risk Factor[1]	Scenario
	Oil (billion barrels)	Gas (trillion cu. ft.)	(Probability of finding no resources)	(H = high, M = moderate, L = low)
Beaufort Sea			.04	
Sale 1 (1979)	.75	1.6		M,H
Sale 2 (1983)	.75	1.6		M,H
Northern Gulf (1980)	.5	1.3	.95	
Lower Cook (1981)	.2	.5	.95	M,H
Bering-Norton (1982)	1.4	2.3	.60	H
St. George			.40	
Sale 1 (1982)	1.4	5.2		H
Kodiak (1983)	.2	5.4	.92	-
North Aleutian Shelf (1983)	.7	2.7	.29	H
Navarian Basin			.33	
Sale 1 (1984)	2.8	9.8		M,H
Sale 2 (1989)	2.8	9.8		H
Chuckchi Sea			.30	
Sale 1 (1985)	2.1	5.2		H
Sale 2 (1994)	2.1	5.2		M,H
Hope Basin (1985)	.43	1.72	.35	M,H

[1] Alaska OCS-Office, BLM

In addition to the petroleum development, some other mining is assumed to take place. Development of the U.S. Borax mining operation at Quartz Hill in Southeast Alaska is assumed to occur in the high scenario. In addition, development of the Beluga coal resources is assumed in both the moderate and high scenarios. In both scenarios, coal is assumed to be produced for export.

The special projects described above do not exhaust the mining employment in the state. Additional employment occurs in the exploration, development, and production of nonpetroleum minerals, as well as a major component of headquarters employment in Anchorage. Market forces and governmental policies are assumed to be such that this component of mining declines in the low case, remains constant in the moderate case, and grows in the high case.

Table C.4 describes the three separate mining scenarios used in this study. In the low scenario, mining rises in connection with development at Prudhoe, but falls after 1983. By 2000, mining employment is almost 275 less than in 1980. Growth occurs in both the moderate and high scenarios throughout the period. By 2000, mining employment is 9,500 greater than in 1980 in the high scenario and 2,900 greater in the moderate.

Agriculture-Forestry-Fisheries

This industry is, in reality, three distinct subindustries which represent Alaska's renewable resource industries. Of the three, the

TABLE C.4. MINING EMPLOYMENT

(thousands of employees)

	Low Scenario	Moderate Scenario	High Scenario
1980	5.075	5.139	5.163
1981	5.163	5.317	5.364
1982	7.322	7.713	7.784
1983	8.096	8.477	8.695
1984	7.624	8.061	8.410
1985	5.134	5.423	6.051
1986	5.097	5.774	6.599
1987	5.075	6.366	7.259
1988	5.054	6.655	7.999
1989	5.050	6.747	8.401
1990	5.011	6.537	9.885
1991	4.990	6.538	10.601
1992	4.969	6.849	11.261
1993	4.949	7.261	11.911
1994	4.928	8.089	12.749
1995	4.908	8.151	13.243
1996	4.888	8.249	13.808
1997	4.868	8.165	13.966
1998	4.848	8.007	14.259
1999	4.829	8.042	14.650
2000	4.810	8.054	14.639

fishing industry is currently the largest in terms of both employment and value of product. Agriculture is currently only a marginal industry employing few people statewide (Scott, 1979). Current state efforts to develop agriculture may lead to its increased importance in the future. Forestry consists of only a small component; the future of forestry is most appropriately discussed with the future of lumber and wood products manufacturing.

The future of agricultural development in the state depends importantly on governmental policies and actions. State and Federal land policies, infrastructure development and loan programs, and marketing programs will determine the future of this industry. In the low scenario, it is assumed that government policies do not favor agriculture. New land is not opened up; old agricultural areas suffer from competition with other land uses (recreation, residential) and from competition for markets from outside producers. In the low scenario, agriculture disappears in Alaska. The high scenario assumes a major positive government effort in support of agriculture with a fifty-fold increase in land in agricultural production by 2000. In the intermediate case, agriculture is assumed to rise only slightly from its current levels of employment. This assumes, as in the low case, that agriculture receives low priorities from government.

Fisheries also hold promise for the future. The major determinant of future increases in fisheries employment will be the expansion of the Alaska bottomfish industry. The creation of the 200 mile limit may support increased Alaska bottomfish activity. In all cases, employment in the existing fisheries is assumed to remain at its current level. Increases in production are assumed to have no effect on employment because of limited entry and labor-saving improvements in the fleet. Employment increases occur in both the high and moderate cases as a result of the development of an Alaska bottomfish industry. In the high case, the Alaska fishing industry is assumed to replace all of the existing foreign fishing effort inside the 200 mile limit; while the moderate case assumes only 50 percent replacement. No bottomfish industry is assumed to be developed in the low case.

Table C.5 illustrates the three agriculture-forestry-fisheries scenarios used in this study. In the low case, employment decreases by about 170 over the period due to the reduction in agricultural employment. The high case shows employment rising by almost 4,700 during the projection period. In the moderate case, employment rises by almost 1,000 between 1980 and 2000.

Federal Government

Federal government employment has always been an important component of Alaska's economy. In recent years, federal government employment has been growing very little; increases in civilian employment have been offset by decreases in military employment. Low rates of growth in federal government employment are assumed to occur in all three scenarios. In all scenarios, federal military employment is assumed to remain constant at existing levels. In the low and moderate cases, federal

TABLE C.5. AGRICULTURE-FORESTRY-FISHERIES EMPLOYMENT

(thousands of employees)

	Low Scenario	Moderate Scenario	High Scenario
1980	1.203	1.303	1.304
1981	1.204	1.314	1.325
1982	1.192	1.312	1.334
1983	1.183	1.361	1.403
1984	1.183	1.395	1.480
1985	1.155	1.429	1.541
1986	1.154	1.459	1.580
1987	1.124	1.488	1.629
1988	1.105	1.551	1.732
1989	1.087	1.612	1.865
1990	1.076	1.675	2.069
1991	1.062	1.737	2.309
1992	1.031	1.799	2.620
1993	1.032	1.862	3.029
1994	1.032	1.924	3.450
1995	1.033	1.986	3.744
1996	1.033	2.048	4.054
1997	1.033	2.110	4.462
1998	1.033	2.171	4.896
1999	1.033	2.233	5.396
2000	1.033	2.295	5.996

civilian employment is assumed to continue to grow at its historical rate of about .05 percent per year. In the high case, this rate of growth is assumed to double to one percent per year. Table C.6 illustrates the three alternative federal government employment scenarios.

Manufacturing

The manufacturing industry in Alaska has four important components: seafood processing, lumber-wood products-pulp, petrochemicals, and manufacturing for the local economy. (Assumptions are discussed in terms of industry product since this is their form of input in the MAP model.)

Production of seafood processing is expected to continue to dominate the food processing industry in Alaska. Growth of this industry is dependent on the growth of the fisheries catch by Alaskans, so these scenarios reflect the fisheries scenarios. In all scenarios, the output of the food processing industry is affected by growth in the catch in existing Alaska fisheries and growth in the bottomfishery. In the high case, output in the food processing industry is assumed to expand by 100 percent between 1980 and 2000 due to increases in the catch of the existing fishery and by an additional 57 percent because of the development of a bottomfish industry. In the moderate case, output expands by 149 percent in existing fisheries and an additional 49 percent because of the bottomfish development. In the low case, no bottomfish industry is assumed to develop, so output expands only because of increased catch in existing fisheries, and a 22 percent increase is assumed.

TABLE C.6. FEDERAL GOVERNMENT EMPLOYMENT

(thousands of employees)

	Low Scenario	Moderate Scenario	High Scenario
1980	43.200	43.200	43.200
1981	43.400	43.400	43.400
1982	43.600	43.600	43.600
1983	43.700	43.700	43.800
1984	43.800	43.800	43.900
1985	43.900	43.900	44.100
1986	44.000	44.000	44.300
1987	44.100	44.100	44.500
1988	44.200	44.200	44.700
1989	44.300	44.300	44.900
1990	44.400	44.400	45.100
1991	44.500	44.500	45.300
1992	44.600	44.600	45.500
1993	44.700	44.700	45.800
1994	44.800	44.800	46.000
1995	44.900	44.900	46.200
1996	45.000	45.000	46.400
1997	45.100	45.100	46.600
1998	45.200	45.200	46.800
1999	45.300	45.300	47.000
2000	45.400	45.400	47.300

The growth of the lumber-wood-paper-pulp sector of manufacturing in the state is determined primarily by two factors. These are the Forest Service allowable annual cut and the Japanese market conditions. In the high case, these industries' growth reflect almost a doubling (over its 1970 level) of the annual cut by 2000. In the low and moderate cases, growth in annual cut is only one-half this amount.

The petrochemical industry in Alaska currently consists of the developments in Kenai. In the low case, there is no expansion of this industry. In the moderate case, the petrochemical industry expands with the construction of the Pacific LNG facility as currently planned, the development of LNG facilities associated in the OCS activity in Western Alaska, and the development of a fuels refinery as the ALPETCO project. The high case contains two additions to these projects. A petrochemical complex is assumed to be established in Fairbanks, using the state's royalty gas, to produce ethylene or fuel-grade methanol. The Alpetco project is assumed to be developed as a major petrochemical facility as originally proposed.

The final component of the manufacturing industry consists of those industries producing for local consumption and other diverse specialized production. It was assumed that this sector would grow in all scenarios because of increased market size, allowing scale economies which make local production viable. This sector was assumed to grow at 1 percent per year in the low case, 2 percent in the moderate, and 5 percent in the high.

Table C.7 shows the three alternative manufacturing scenarios. Manufacturing employment increases continually through all scenarios. It increases by 50 percent over the period in the low case, 83 percent in the moderate, and 137 percent in the high case.

Transportation

The exogenous portion of the transportation industry is that which serves special projects. In all scenarios, this industry includes the operations employment for TAPS and the Northwest gasline. The other major source of transportation employment is the OCS petroleum development. This employment is associated with both supply ships and helicopters used in the OCS development. The difference in transportation employment reflects the difference in the OCS lease sale areas assumed to be developed. Table C.8 illustrates the three transportation employment scenarios.

Construction

The final exogenous industry for which scenarios are required is that portion of the construction industry where the level is determined outside the economy. This sector includes construction employment associated with the special projects described above. This sector does not include capital improvement projects of any level of government or construction activity which supports the local economy; the remainder of construction activity is determined endogenously in the MAP model. In all scenarios, the major development of special projects occurs in the early part of the projection period. The most important project during this period is the construction of the Northwest gasline which is assumed

TABLE C.7. MANUFACTURING EMPLOYMENT

(thousands of employees)

	Low Scenario	Moderate Scenario	High Scenario
1980	12.518	13.266	13.348
1981	12.968	14.061	14.274
1982	13.344	14.741	15.176
1983	13.684	15.355	15.985
1984	14.000	15.924	16.769
1985	14.303	16.983	17.541
1986	14.597	17.541	18.317
1987	15.012	18.135	21.469
1988	15.241	18.535	22.141
1989	15.487	18.944	22.938
1990	15.745	19.359	23.610
1991	16.013	19.781	23.341
1992	16.289	20.207	24.350
1993	16.570	20.643	25.461
1994	16.858	21.354	26.682
1995	17.154	21.870	27.555
1996	17.456	22.328	28.601
1997	17.771	22.799	29.370
1998	18.097	23.281	30.139
1999	18.434	23.776	31.188
2000	18.780	24.282	31.979

TABLE C.8. EXOGENOUS TRANSPORTATION EMPLOYMENT

(thousands of employees)

	Low Scenario	Moderate Scenario	High Scenario
1980	1.500	1.500	1.500
1981	1.500	1.500	1.500
1982	1.500	1.525	1.525
1983	1.500	1.536	1.582
1984	1.500	1.536	1.644
1985	1.500	1.527	1.855
1986	1.700	2.185	2.481
1987	1.700	2.318	2.558
1988	1.700	2.310	2.929
1989	1.700	2.349	2.662
1990	1.700	2.331	2.744
1991	1.700	2.259	2.972
1992	1.700	2.549	3.291
1993	1.700	2.621	3.397
1994	1.700	2.668	3.722
1995	1.700	2.705	3.776
1996	1.700	2.876	3.901
1997	1.700	2.716	3.986
1998	1.700	2.662	3.913
1999	1.700	2.596	3.796
2000	1.700	2.573	3.751

to begin in 1981. This is the only special activity assumed in the low case. The high and moderate cases reflect completion of other projects. Both cases assume Pacific LNG and Alpetco projects will begin in 1982, although a more massive-scale Alpetco development is assumed in the high case. Construction employment is also required in the development of the OCS fields, NPRA, and Beluga. Additional sources of construction employment in the high case are the construction of a new capital at Willow and a petrochemical complex in Fairbanks.

Table C.9 illustrates the three exogenous construction scenarios. In all cases, employment peaks in the early 1980s. This peak is primarily a result of the construction of the Northwest gasline which is a major one-time project. The bunching of other large projects, as well as the beginning of OCS development at this time, also leads to this early peaking.

THE STATE GOVERNMENT SCENARIOS

Past studies of the Alaska economy have indicated the key role state government plays in the Alaska economy. State fiscal policy has been a major determinant of state economic growth. State expenditures determine not only direct government employment, but also through expenditures on goods and services and capital improvements, they will affect all endogenous sectors of the economy. The state government scenarios described in this section attempt to define the most likely range of state government activity.

TABLE C.9. EXOGENOUS CONSTRUCTION EMPLOYMENT

(thousands of employees)

	Low Scenario	Moderate Scenario	High Scenario
1980	.090	.090	.090
1981	0.590	0.714	0.789
1982	2.885	4.335	3.960
1983	7.823	9.889	11.289
1984	7.038	9.583	14.488
1985	1.563	2.355	8.963
1986	0.000	1.027	8.372
1987	0.000	1.139	3.458
1988	0.000	1.138	2.933
1989	0.000	1.083	2.749
1990	0.000	0.482	3.884
1991	0.000	1.909	6.293
1992	0.000	2.519	6.701
1993	0.000	2.701	6.279
1994	0.000	1.084	4.158
1995	0.000	0.307	3.193
1996	0.000	0.252	3.436
1997	0.000	0.152	3.101
1998	0.000	0.305	2.660
1999	0.000	0.400	0.714
2000	0.000	0.545	0.798

Two factors affect our ability to project the future course of state expenditures. First, since the beginning of production at Prudhoe Bay, state revenues have overtaken expenditures; revenues from this production will continue to increase in the projection period. Secondly, the establishment of the Permanent Fund and recent tax reduction and wealth-sharing programs place constraints on the use of certain petroleum revenues. These recent changes in the structure of state spending constraints limit the usefulness of past fiscal policy for determining projected future policy.

For this study, we will assume three separate directions for state fiscal policy, each of which will be defined by the growth of real per capita expenditures. Real per capita expenditures measure the effect of increases in prices and population on state expenditures. Between 1970 and 1972, real per capita expenditures grew at almost 24 percent per year; this was primarily a response to the lease sale bonus of $900 million from Prudhoe Bay in 1969. After 1972, the rate of growth dropped to .5 percent per year.

We will describe the growth of real per capita state expenditures in terms of its relation to real per capita incomes. The relationship between income and state expenditures will be described in terms of the income elasticity of state government expenditures; this elasticity equals the assumed proportionate increase in real per capita expenditures which would result from a one percent increase in real per capita income. The historical pattern of state expenditure growth shows real per capita expenditures as an increasing proportion of real per capita income through most of the period. The proportion increased through 1971 with a rapid expansion between 1969 and 1971 as a result of the Prudhoe lease sale bonus. Between 1971 and 1977, the ratio of real per capita expenditures to real per capita income remained constant (Goldsmith, 1977). The state's present revenue situation makes it hard to forecast how this ratio will change in the future.

Our three scenarios assume that real per capita expenditures consume a growing, constant, and declining portion of real per capita income. The low case assumes that the level of real per capita state expenditures stays constant through the projection period and real per capita state expenditures decline over the projection period as a proportion of real per capita income. The moderate case assumes the real per capita state expenditures proportion of personal income stays constant with real per capita state expenditures increasing at the rate of real per capita income. Finally, in the high scenario, real per capita expenditures increase at one and one-half the rate of real per capita income and increase as a portion of real per capita income.

In combination, these three state expenditure scenarios and the three economic scenarios produce nine growth scenarios for the period between 1980 and 2000.

POST-2000

For the period between 2000 and 2010, a judgmental approach to projecting the level of economic activity was used. The approach used for the post-2000 period was to assume a rate of growth which described the possible continuation of the high, moderate, and low scenarios. In each case, a similar rate of growth was assumed for all three scenarios for the major variables--employment, population, and households. This implicitly assumes changes in household formation and labor force participation assumed between 1980 and 2000 do not continue after 2000. The assumed growth rates describe three possible post-2000 growth paths which are based on examination of growth in other similar areas as well as the historical growth of the Alaska economy. The high case assumes a continued expansion of the Alaska economy as a result of increasing resource development, although a reduced role of state government. The major economic variables are assumed to grow at 3.3 percent per year, which is approximately the rate in the high economic-moderate government scenario in the last part of the period. The moderate scenario assumes slightly slower growth at 2 percent per year, which is slightly less than in the moderate economic-low government scenario. This growth is assumed to result from more moderate resource development and reduced government activity. The low scenario provides only minimal growth at one percent per year, which reflects a self-generated growth from government expenditures.

Projections of State Growth 1980-2000

This section presents the statewide projections of future economic and demographic activity. These projections are the basis for the energy end-use projections. The projections presented in this section are projections of the MAP model and the economic and government scenarios described above. The combination of three economic and three government scenarios produced the nine alternative projections presented here.

Table C.10 describes the projected growth of total employment in each scenario. As would be expected, the combination of high economic and high government scenarios (HH) produces the greatest growth, and the low economic-low government scenario (LL) produces the lowest. In scenario HH, total employment grows by over 300,000 between 1980 and 2000, an average annual rate of growth of 4.5 percent per year. Total employment grows by only 78,000 in the scenario LL, which is an average annual rate of 1.6 percent per year. In all the scenarios, the bunching of major construction projects in the early 1980s results in the most rapid growth occurring in this period.

The effects of the alternative economic scenarios can be seen by comparing three economic scenarios with the same government expenditure assumption. We will examine those scenarios with a moderate level of government expenditure. Total employment grows at an annual average rate of 2.3 percent per year in the low growth case, a growth in employment of 122,150. In the moderate case, total employment grows by 161,420

TABLE C.10. TOTAL EMPLOYMENT, 1980-2000

(thousands of employees)

	LES.GL	LES.GM	LES.GH	MES.GL
1980	210.099	210.099	210.099	210.099
1985	230.916	243.697	251.214	245.098
1990	238.170	254.525	264.528	258.102
1995	259.992	287.476	305.620	292.023
2000	287.810	332.252	366.017	319.972

	MES.GM	MES.GH	HES.GL	HES.GM
1980	210.099	210.099	210.099	210.099
1985	262.624	273.015	269.638	291.414
1990	280.802	294.968	295.785	330.477
1995	329.047	354.070	349.823	404.736
2000	371.520	410.523	384.956	454.648

	HES.GH
1980	210.099
1985	304.017
1990	354.543
1995	445.033
2000	510.292

SCENARIO NAMES:

LES.GL - Low Economic/Low Government
LES.GM - Low Economic/Moderate Government
LES.GH - Low Economic/High Government
MES.GL - Moderate Economic/Low Government
MES.GM - Moderate Economic/Moderate Government
MES.GH - Moderate Economic/High Government
HES.GL - High Economic/Low Government
HES.GM - High Economic/Moderate Government
HES.GH - High Economic/High Government

Note: Values in 1980 adjusted to be the same in all cases; adjusts for minor differences in exogenous series.

between 1980 and 2000, which is 32 percent greater than in the low case and an average annual growth of 2.9 percent per year. Total employment in the high scenario grows by 244,550, which is an annual average rate of 3.9 percent per year.

The effects of the alternative government expenditure scenarios on economic growth can be examined by comparing three alternative projections with the same economic scenario. Examining the projections with the moderate economic scenario and low, moderate, and high expenditure scenarios shows that the effect of varying state expenditure scenarios is similar to altering the economic scenarios. Under the moderate economic growth scenario, total employment increases at an annual average rate of 2.1 percent per year. Total employment increases at an annual average rate of 2.9 percent per year in the moderate expenditure case. This is 38 percent faster than in the low case; when the government expenditure assumptions are held constant at the moderate level, the growth rate in the moderate economic scenario is 26 percent greater than in the low. The average annual rate of growth in the high government scenario is 3.4 percent per year, which is 17 percent faster than in the moderate scenario. This compares with the 34 percent difference in growth rates between the moderate and high economic scenarios.

Examining the effects of altering the government expenditure scenarios shows that in all cases state government expenditure is expected to play an important role in projected future growth. State government employment assumes a different role under each scenario, which reflects the alternate assumption about state government expenditures as a proportion of personal income. State government employment as a proportion of total employment falls in the low scenario, increases slightly in the moderate scenario, and increases in the high scenario. In 1980, state government employment is 21 percent of the total. By 2000, this proportion has fallen to 19 percent in the low scenario, risen to 23 percent in the moderate scenario, and risen to 26 percent in the high scenario.

The importance of state government spending to the projections of total state activity makes it necessary to examine the consistency of these projections. It is necessary to ask whether the state can make this level of expenditures without running out of money or requiring large increases in taxes. One consistency check is to examine the state's fund balance in 2000. The fund balance is where the state accumulates excess revenues; it includes both the Permanent and General Funds. The most important source of revenue for the state during the projection period will be petroleum revenues. The revenue projections used in this study are based on the most recent projections of the Alaska Department of Revenue (Alaska Department of Revenue, Petroleum Production Revenue Forecast: Quarterly Report, March 1980). Based on this assumed growth in revenues, the fund balance is positive and large in all scenarios in 2000. Only in the high economic-high government expenditure scenario has the fund blanace peaked. This scenario has the lowest level of fund balance in 2000, $48.9 billion (in current dollars). Given the petroleum revenue assumptions, all three of the assumed government expenditure scenarios are possible.

Table C.11 describes the growth of the population in each scenario. In the high economic-high government scenario, population more than doubles over the period, growing by 487,000. In the low economic-low government scenario, population is projected to increase by only 36 percent. In all scenarios, population growth follows the pattern of employment growth.

Examining the moderate government expenditure scenarios illustrates the effect of the different economic scenarios on population growth. In the low economic scenario (LM), population grows at an average annual rate of 2.1 percent per year, reaching 635,578 by 2000. In the moderate economic scenario, population grows slightly faster (a rate of 2.6 percent per year); by 2000, population in this case is 10 percent greater than in the low case. Population in the high case reflects the rapid economic growth assumed in this case. Population grows by 97 percent; by 2000, population is 19 percent greater than in the moderate case.

The effects of the alternate government expenditure scenarios provide as great a variance as the economic scenarios. By 2000, population in the moderate economic-moderate government scenario is 12 percent greater than in the moderate economic-low government scenario. The moderate economic-high government scenario projects population in 2000 which is 8 percent greater than in the moderate government scenario. Population growth rates between 1980 and 2000 vary from an annual average of 2.0 percent per year in scenario ML to 2.6 percent per year in MM and 2.9 percent per year in scenario MH.

TABLE C.11. POPULATION, 1980-2000

(thousands of people)

	LES.GL	LES.GM	LES.GH	MES.GL
1980	421.737	421.737	421.737	421.737
1985	467.154	481.343	489.697	484.463
1990	490.316	511.635	524.638	518.496
1995	528.220	565.281	589.303	575.227
2000	574.216	635.578	680.418	627.156

	MES.GM	MES.GH	HES.GL	HES.GM
1980	421.737	421.737	421.737	421.737
1985	503.942	515.437	512.720	536.670
1990	547.996	566.267	570.790	614.965
1995	625.159	658.257	660.043	733.365
2000	700.076	753.448	731.548	831.024

	HES.GH
1980	421.737
1985	550.534
1990	645.251
1995	786.342
2000	908.437

SCENARIO NAMES:

LES.GL - Low Economic/Low Government
LES.GM - Low Economic/Moderate Government
LES.GH - Low Economic/High Government
MES.GL - Moderate Economic/Low Government
MES.GM - Moderate Economic/Moderate Government
MES.GH - Moderate Economic/High Government
HES.GL - High Economic/Low Government
HES.GM - High Economic/Moderate Government
HES.GH - High Economic/High Government

Note: Values in 1980 adjusted to be the same in all cases; adjusts for minor differences in exogenous series.

In all scenarios, population grows at rates slightly lower than employment. This reflects, in part, the increased labor force participation of both Alaska Natives and women and the changing age structure of the population. Total employment as a proportion of population is 49 percent in 1980. By 2000, this proportion is 56 percent in scenario HH, 54 percent in scenario MM, and 50 percent in scenario LL. The difference between scenarios results from the importance of migration in each scenario. Migration brings in fewer dependents per employee than in the existing population. Migration is more important as a source of population growth in the moderate and high scenarios. This is responsible for the greater increase in employment as a proportion of population in these scenarios.

Table C.12 shows the growth of households in each scenario. Household growth reflects two factors, the growth of the population and the changing structure of households reflected in an increased probability that certain sectors of the population will form households. All scenarios follow the same pattern of increasing proportion of households in the population. The pattern of this change can be seen by examining the low economic-low government (LL), moderate economic-moderate government (MM), and high economic-high government (HH) scenarios. In scenario LL, the number of households reaches 210,790 by 2000; this is a 58 percent increase during the projection period. The number of households by 2000 is 24 percent greater in scenario MM than in LL; the number of households has increased by 96 percent over the projection period in MM. In scenario HH, the number of households is 32 percent greater than in MM;

TABLE C.12. HOUSEHOLDS, 1980-2000

(thousands of households)

	LES.GL	LES.GM	LES.GH	MES.GL
1980	133.043	133.043	133.043	133.043
1985	153.357	157.770	160.360	158.948
1990	166.913	174.427	179.002	176.912
1995	186.378	200.040	208.860	203.893
2000	210.790	234.720	252.100	231.897

	MES.GM	MES.GH	HES.GL	HES.GM
1980	133.043	133.043	133.043	133.043
1985	164.996	168.554	167.693	175.079
1990	187.300	193.721	195.237	210.739
1995	222.314	234.464	235.344	262.421
2000	260.497	281.314	273.307	312.477

	HES.GH
1980	133.043
1985	179.347
1990	221.319
1995	281.899
2000	342.815

SCENARIO NAMES:

LES.GL - Low Economic/Low Government
LES.GM - Low Economic/Moderate Government
LES.GH - Low Economic/High Government
MES.GL - Moderate Economic/Low Government
MES.GM - Moderate Economic/Moderate Government
MES.GH - Moderate Economic/High Government
HES.GL - High Economic/Low Government
HES.GM - High Economic/Moderate Government
HES.GH - High Economic/High Government

Note: Values in 1980 adjusted to be the same in all cases; adjusts for minor differences in exogenous series.

the number of households increased by 158 percent over the projection period.

In all three scenarios, over 80 percent of the expansion of households results from the increase in the population. In scenario LL, 82 percent of the household expansion results from population growth, 85 percent in scenario MM, and 84 percent in scenario HH. These differences reflect the different household age structures which result from rapid growth. The average number of people per household drops from 3.2 in 1980 to 2.7 in LL, 2.7 in MM, and 2.6 in HH. This approximate 20 percent drop in the average people per household is consistent with the projected decline in the national level of number of persons per household (Bureau of the Census, 1979).

REGIONAL PROJECTIONS

Anchorage Region

This section describes the projection of employment, population, and households for the Anchorage region. These projections are for the period 1980 to 2010; growth beyond 2000 is assumed to follow the state patterns for each of the major variables. The Anchorage region includes the Anchorage, Matanuska-Susitna, Kenai, and Seward Census Divisions. Three state scenarios were chosen for the regional economic and end-use projections. These scenarios are the high economic-moderate government, moderate economic-moderate government, and low economic-moderate government scenarios; these scenarios were chosen since they reflect the most likely range of future growth. Table C.13 shows the growth in Anchorage.

TABLE C.13. ANCHORAGE ECONOMIC GROWTH, 1980-2000

	Low Scenario[1]			Moderate Scenario[2]			High Scenario[3]		
	Employment	Population	Households[4]	Employment	Population	Households[4]	Employment	Population	Households[4]
1980[5]	102,529	219,303	68,224	102,529	219,303	68,224	102,529	219,303	68,224
1985	111,118	248,850	85,177	119,352	260,034	85,805	132,186	275,848	89,515
1990	116,939	265,539	94,528	128,267	282,766	97,827	148,498	314,247	108,048
1995	134,425	293,381	108,377	151,735	322,582	116,718	185,601	375,483	136,364
2000	157,268	329,865	127,099	173,021	361,239	137,172	211,011	427,146	163,560
2005	165,290	346,691	133,582	191,029	398,837	151,449	248,203	502,433	192,388
2010	173,722	364,376	140,396	210,912	440,348	167,212	291,950	590,989	226,278

[1]Growth beyond 2000 at 1 percent per year.

[2]Growth beyond 2000 at 2 percent per year.

[3]Growth beyond 2000 at 3.3 percent per year.

[4]Households exclude 3,212 on-base housing not included in energy projections.

[5]1980 has been adjusted to be consistent among scenarios.

The Anchorage region is of central importance to the Alaska economy. Because it contains Anchorage--the state's administrative, distribution, and finance center--much of the growth in the state will be reflected in this region. In the past, many of the events which have influenced state growth have occurred in the region. Projected future growth will continue to follow these patterns; however, the projected future contains relatively more activity occurring out of this region than in the past.

The low scenario reflects limited growth in the state and Anchorage region. Anchorage is assumed to grow at an annual average rate of 1.8 percent per year over the projection period (2.2 percent per year between 1980 and 2000). This is approximately the rate of growth in the state economy and reflects the fact that the growth of basic sector activity which is assumed promotes the existing distribution of activity. Population growth follows the pattern of employment. Population grows slightly less rapidly than employment; population grows at an annual average rate of 1.7 percent per year between 1980 and 2010 (2.1 percent per year between 1980 and 2000). Finally, household growth is determined by the growth in population and the changing pattern of household composition assumed at the state level. The number of households in the Anchorage region is projected to increase by 106 percent over the projection period; as at the state level, over 83 percent of this growth results from population growth.

The moderate scenario illustrates the effect of the increased basic sector activity outside of the Anchorage region; Anchorage growth, as measured by employment and population, is slightly slower than the state growth. Employment in this scenario grows at an annual average rate of 2.43 percent (2.7 percent for the 1980-2000 period). Population grows at an annual average rate of 2.35 percent (2.5 percent for the 1980-2000 period). As at the state level, population grows less rapidly than employment as a result of increased labor force participation. The number of households in this scenario is 19 percent more than in the low scenario. Households increase by 145 percent between 1980 and 2010; 84 percent of this growth results from the increase in population.

The growth of basic sector activity outside of Anchorage has a more profound effect on the growth of Anchorage relative to state growth. Employment in the Anchorage region grows at an annual average rate of 3.6 percent between 1980 and 2010 (3.7 percent between 1980 and 2000), which is .1 of a percent slower than state growth of 3.7 percent. Population in this scenario increases to 377,000 by 2010 and averages a 3.4 percent rate of growth over the projection period (3.4 percent between 1980 and 2000). As in the other scenarios, the change in the number of households is a result of changes in the population and in household size. Households increase by 221 percent in this scenario; 84 percent of this growth is a result of population growth.

Fairbanks Region

Table C.14 presents the projections for the Fairbanks region for the low economic-moderate government, moderate economic-moderate government, and high economic-moderate government scenarios. The Fairbanks

TABLE C.14. FAIRBANKS ECONOMIC GROWTH, 1980-2000

	Low Scenario[1]			Moderate Scenario[2]			High Scenario[3]		
	Employment	Population	Households[4]	Employment	Population	Households[4]	Employment	Population	Households[4]
1980[5]	29,641	59,268	17,114	29,641	59,268	17,114	29,641	59,268	17,114
1985	36,508	70,276	21,152	38,813	73,072	22,118	43,223	78,354	24,121
1990	37,270	74,187	23,530	40,485	78,911	25,330	47,638	88,555	28,711
1995	41,729	81,966	27,433	46,840	89,398	30,414	57,492	104,871	36,287
2000	48,326	92,159	32,712	53,068	100,111	35,843	65,852	118,836	43,716
2005	50,791	96,861	34,381	58,591	110,531	39,574	77,459	139,782	51,422
2010	53,382	101,802	36,134	64,690	122,035	43,692	91,111	164,419	60,836

[1] Growth beyond 2000 at 1 percent per year.

[2] Growth beyond 2000 at 2 percent per year.

[3] Growth beyond 2000 at 3.3 percent per year.

[4] Households exclude 3,062 on-base households not included in energy projections. Energy projections assume only 91 percent of households are served by electricity in 1980 (based on 1978 end-use inventory). This rate grows to 95 percent by 2010.

[5] 1980 has been adjusted to be consistent among scenarios.

region contains the Fairbanks and Southeast Fairbanks Census Divisions. The projection period is between 1980 and 2010; employment, population, and households are assumed to grow at state rates after 2000.

Fairbanks is a regional center for the Interior and Arctic regions of Alaska. Its past growth has been connected with resource development in the region; most recently, Fairbanks has acted as a center for development of Prudhoe Bay and the trans-Alaska pipeline. Since it is a regional center, Fairbanks' future growth will be affected by growth of state government as well as resource development in the region.

The growth in the Fairbanks region is only slightly faster than for the state; both major resource development and growth of state government affect the growth of the region. In the low scenario, employment grows at a rate of 1.9 percent per year between 1980 and 2010 (2.5 percent between 1980 and 2000). Population in this scenario reaches almost 102,000 by 2010; the growth is at an annual average rate of 1.8 percent per year between 1980 and 2010 (2.2 percent between 1980 and 2000). As at the state level, the increased labor force participation accounts for a slower rate of population growth. The number of households almost doubles, growing by 94 percent over the period. Eighty-eight percent of this growth results form population growth.

In the moderate scenario, the Fairbanks region grows at approximately the same rate as the state; resource development is spread more evenly in this scenario, with fisheries and OCS development occurring out of the

Fairbanks region. Employment grows at an average annual rate of 2.6 percent per year between 1980 and 2010 (3.0 percent between 1980 and 2000). Population in 2010 is 20 percent greater than in the low scenario; growth during the projection period is faster, averaging 2.4 percent per year (2.7 percent between 1980 and 2000). The number of households in the Fairbanks region increases by 132 percent in the moderate scenario; 88 percent of this change is a result of population growth.

The high scenario has major developments--petrochemicals and agriculture--occurring in the region. Because of this, growth (particularly in the 1980-2000 period) is faster than for the state. Employment in this scenario grows at an annual rate of 3.8 percent (4.1 percent for the 1980-2000 period). Population follows the typical pattern, growing slightly less rapidly than employment. The growth rate of population averages 3.5 percent per year between 1980 and 2010 (3.5 percent between 1980 and 2000). Households follow the same pattern; the number of households more than doubles, with the majority of the growth resulting from population growth.

Valdez Region

The Valdez Region consists of the Valdez-Chitina-Whittier Census Division. This region has experienced major growth recently as a result of the construction of the trans-Alaska pipeline and tanker port in Valdez. Future growth of this region may result from expansion of industrial activity due to the location of the pipeline terminus. Table C.15 shows the projected growth in Valdez.

TABLE C.15. VALDEZ ECONOMIC GROWTH, 1980-2000

	Low Scenario[1]			Moderate Scenario[2]			High Scenario[3]		
	Employment	Population	Households[4]	Employment	Population	Households[4]	Employment	Population	Households[4]
1980[5]	2,146	5,821	1,878	2,146	5,821	1,878	2,146	5,821	1,878
1985	2,967	6,739	2,255	3,782	8,063	2,698	7,464	9,660	3,182
1990	3,328	7,163	2,491	4,241	8,768	3,059	7,323	11,080	3,830
1995	3,532	7,914	2,853	4,713	10,003	3,628	7,358	12,467	4,522
2000	4,033	8,898	3,354	5,237	11,201	4,197	7,717	13,296	5,060
2005	4,239	9,352	3,525	5,782	12,367	4,634	9,077	15,640	5,952
2010	4,455	9,829	3,705	6,384	13,654	5,116	10,677	18,396	7,001

[1] Growth beyond 2000 at 1 percent per year.

[2] Growth beyond 2000 at 2 percent per year.

[3] Growth beyond 2000 at 3.3 percent per year.

[4] Energy projections assume only 71 percent of households are served by electricity in 1980 (based on 1978 end-use inventory). This rate is assumed to grow to 75 percent by 2010.

[5] 1980 has been adjusted to be consistent among scenarios.

[6] Because of the rapid growth assumed in the Valdez economy in this scenario (between 1980 and 1985, employment more than triples), we assume that not all of the new employees bring families but that they live in an enclave-type area and commute to a shift-work situation from other regions. We assume that in 1985, this amounts to close to 40 percent of total employment, but this drops to 20 percent by the end of the period.

Valdez is projected to grow rapidly in all scenarios. The rapid rate of growth results from the location of major projects in Valdez and the small population and employment base at the beginning of the period. In the low scenario, employment is projected to increase by 2,310 by 2010, at an annual rate of growth of 2.5 percent per year (3.2 percent per year between 1980 and 2000). Population increases at a slower rate of 1.7 percent per year (2.1 percent per year between 1980 and 2000). Households follow the pattern of population, increasing by 97 percent over the projection period.

In the moderate scenario, the construction of a fuels refinery in Valdez results in a greater divergence from the state growth. Employment increases at an average rate of 3.7 percent per year, tripling during the period. Population increases at a slower rate of 2.9 percent per year (2.7 percent per year between 1980 and 2000). Finally, households follow the pattern of population and increase by 172 percent over the period.

In the high scenario, a major petrochemical facility is developed in Valdez. This results in major growth in the region; employment almost triples between 1980 and 1985. It is assumed that, because of this major growth, not all employees bring families to Valdez but commute, on some shift basis, from other regions. We assume that 40 percent of the employees commute in 1985; this proportion is assumed to decrease to 20 percent by 2000 and remain at this level for the rest of the period.

Employment in the high scenario increases by almost 300 percent between 1980 and 2010; this is an annual rate of 5.5 percent per year (6.6 percent per year between 1980 and 2000). Population, because of our assumption, increases much less rapidly, increasing at an annual average rate of 3.9 percent over the period (4.2 percent between 1980 and 2000). Households follow the pattern of population, increasing by 273 percent over the period; 85 percent of this is due to poulation.

HOUSING STOCK PROJECTIONS

The growth in population and households determines the growth of the housing stock in the three regions. Tables C.16 through C.18 illustrate the projected growth in housing stock in each region. The growth in the housing stock parallels the growth in the number of households. Housing stock does not grow as rapidly as the number of households because each region begins the projection period with excess housing.

In Anchorage and Fairbanks, minimal change in the housing distribution is projected. In Anchorage, single-family units go from 52 percent to approximately 51 percent of the housing stock in all scenarios. In Fairbanks, the reduction in the proportion of single-family housing is somewhat greater, falling from 52 percent to 49 percent in each scenario. The other important distributional shift involves a shift in the type of multifamily housing from duplex to other multifamily units.

TABLE C.16. ANCHORAGE HOUSING STOCK[1]
1980-2010

Low Scenario

	1980	1990	2000	2010
Single Family	37,422	50,130	65,506	72,346
Multifamily	19,061	25,409	36,430	40,239
Mobile Home	9,239	11,725	16,032	17,666
Duplex	5,871	6,226	8,958	9,955
Total	71,593	93,490	126,927	140,206

Moderate Scenario

	1980	1990	2000	2010
Single Family	37,422	53,309	71,837	87,555
Multifamily	19,061	27,530	40,772	49,689
Mobile Home	9,239	12,561	17,890	21,760
Duplex	5,871	6,770	10,060	12,337
Total	71,593	100,170	140,559	171,341

High Scenario

	1980	1990	2000	2010
Single Family	37,422	57,894	85,160	117,802
Multifamily	19,061	31,090	49,132	67,945
Mobile Home	9,239	13,982	21,331	29,450
Duplex	5,871	7,101	11,996	16,696
Total	71,593	110,667	167,619	231,893

[1]Housing served, only off-base housing. The distribution in 2000 is assumed to remain constant after 2000.

TABLE C.17. FAIRBANKS HOUSING STOCK[1]
1980-2010

Low Scenario

	1980	1990	2000	2010
Single Family	9,009	11,462	15,446	17,321
Multifamily	4,792	6,550	10,005	11,230
Mobile Home	2,252	2,964	4,178	4,682
Duplex	1,272	1,278	1,772	1,971
Total	17,325	22,254	31,401	35,204

Moderate Scenario

	1980	1990	2000	2010
Single Family	9,009	12,244	17,026	21,048
Multifamily	4,792	7,245	10,162	13,592
Mobile Home	2,252	3,192	4,545	5,624
Duplex	1,272	1,279	1,906	2,343
Total	17,325	23,960	34,439	42,607

High Scenario

	1980	1990	2000	2010
Single Family	9,009	13,529	20,436	28,873
Multifamily	4,792	8,519	13,586	19,209
Mobile Home	2,252	3,617	5,543	7,826
Duplex	1,272	1,505	2,410	3,379
Total	17,325	27,170	41,975	59,287

[1] Housing served, an increasing proportion of offbase households. The distribution in 2000 is assumed to remain constant after 2000.

TABLE C.18. VALDEZ HOUSING STOCK[1]
1980-2010

Low Scenario

	1980	1990	2000	2010
Single Family	472	706	1,184	1,334
Multifamily	189	306	543	610
Mobile Home	642	629	606	681
Duplex	192	197	189	213
Total	1,495	1,838	2,522	2,838

Moderate Scenario

	1980	1990	2000	2010
Single Family	472	951	1,572	1,950
Multifamily	189	412	725	902
Mobile Home	642	684	649	808
Duplex	192	220	212	263
Total	1,495	2,267	3,158	3,923

High Scenario

	1980	1990	2000	2010
Single Family	472	1,231	1,902	2,684
Multifamily	189	533	892	1,256
Mobile Home	642	792	763	1,074
Duplex	192	259	250	354
Total	1,495	2,815	3,807	5,368

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[1] Housing served, an increasing proportion of total households. The distribution of housing stock is assumed to change in a straight-line manner from the 1978 distribution to that projected for 2000. Distribution in 2000 is assumed to remain constant beyond 2000.

In Valdez, the change in housing stock distribution is somewhat more pronounced. It was assumed that housing preferences, which were projected to be much different than the beginning 1978 housing stock, would only slowly change the distribution as removal and growth of the population increased the demand for housing of different types. Because of this assumption, the proportion of housing which is single-family increases from 32 percent in 1980 to 47 percent in 2010. In all scenarios, the proportion of housing stock which is mobile homes decreases; this reflects a stabilizing of the population over time.

APPENDIX D. COMPONENTS OF THE END USE MODEL

D.1. HOUSEHOLDS AND HOUSING STOCK

The basic consuming unit for residential electricity consumption is the off-military-base household. Much of the data available to analyze energy consumption, however, is more closely associated with the number of housing units, which will generally be larger than the number of households for a number of reasons.

Tables D.1 and D.2 present information on housing units for the years 1960 and 1970 and indicate the different types of housing. Using the 1970 census definition as a guide, all housing units can be divided into year-round and seasonal units. The latter are not designed for year-round habitation. Of the year-round units, only a portion are occupied; and of those not occupied, only a portion are vacant in the sense of being for sale or rent. Second homes are not identified but are a component of both the seasonal category and the year-round category.

For energy consumption purposes, there are three important housing stock measures:

1. Occupied housing units. Each household will occupy a housing unit, and this forms the basis for estimating the appliance electricity demand in the residential sector.

TABLE D.1. HOUSING UNIT ANALYSIS: 1960

Census Division	All Housing Units	Year-Round Housing Units[a]	Occupied Housing Units	Vacant Year-Round Housing Units Not for Sale or Rent[b]	Population Per Occupied Housing Unit	Median Rooms
GREATER ANCHORAGE AREA						
Anchorage	23,972	23,564	21,853	788	3.4	3.9
Matanuska-Susitna	2,593	2,346	1,501	775	3.4	3.4
Kenai-Cook Inlet	2,504	2,339	1,686	551	3.4	3.4
Seward	1,494	1,294	966	146	3.0	3.2
GREATER FAIRBANKS AREA						
Fairbanks	12,598	11,928	11,056	550	3.3	3.6
GLENNALLEN-VALDEZ AREA						
Valdez-Chitina-Whittier	1,241	1,049	785	153	3.1	3.1
WESTERN REGION U.S.	--	--	--	--	3.2	-

[a] Constructed variable equal to occupied housing units plus vacant year-round housing units.

[b] Constructed variable equal to year-round housing units minus occupied housing units minus vacant year-round housing units for sale or rent. This category thus includes 1) rented and sold awaiting occupancy, 2) held for occasional use, 3) held for other reasons, and 4) dilapidated.

Notes: Second homes may be classified as either seasonal or year-round housing units.
Southeast Fairbanks was not a separate census division in 1960.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Tables 28, 29.

TABLE D.2. HOUSING UNIT ANALYSIS: 1970

Census Division	All Housing Units	Year-Round Housing Units	Occupied Housing Units	Vacant Year-Round Housing Units Not for Sale or Rent	Population Per Occupied Housing Unit	Median Rooms	Occupied Units Which Own Second Home
GREATER ANCHORAGE AREA							
Anchorage	37,650	37,617	34,988	975	3.4	4.5	3,492
Matanuska-Susitna	4,214	3,355	1,826	1,073	3.4	4.0	177
Kenai-Cook Inlet	4,877	4,650	3,889	470	3.5	4.0	442
Seward	1,106	956	605	239	3.1	3.9	157
GREATER FAIRBANKS AREA							
Fairbanks/ S.E. Fairbanks	13,895	13,729	12,644	596	3.4	4.3	986
GLENNALLEN-VALDEZ AREA							
Valdez-Chitina-Whittier	1,447	1,405	947	411	3.2	2.9	257
WESTERN REGION U.S.	12,031,802	11,938,658	11,171,550	302,970	3.0	4.7	-

SOURCES: 1970 Census of Housing, Detailed Housing Characteristics: Alaska. Tables 60, 63, 66.
1970 Census of Housing, Detailed Housing Characteristics: United States Summary. Tables 1, 3.

2. <u>Occupied plus vacant (but available for rent or purchase) housing units</u>. Housing units which are occupied plus vacant units form the basis for space heating requirements because houses which are vacant, but available, must be heated in winter (although to a lower temperature) to prevent damage.

3. <u>Second homes</u>. Vacation homes and homes used seasonally will have different energy use characteristics than first homes.

Before estimating the number of households and the housing stock for 1978, those individuals housed in group quarters must be identified and subtracted from total population since their consumption of electricity is not reflected in the utility residential load. Table D.3 shows that in 1970 the population in group quarters was large in both Anchorage and Fairbanks. Although a large proportion of this population is military and the military population has declined since 1970, we assume the same number of individuals in group quarters in 1978 as in 1970. That is, the decline has affected military personnel not in group quarters.

Table D.4 presents two estimates of railbelt households in 1978 and compares them with year-end electric utility residential customers. At least four factors contribute to the discrepancies between the household and utility customer figures:

TABLE D.3. 1970 POPULATION LIVING IN GROUP QUARTERS

	Population	Population in Housing Units	Population in Group Quarters
GREATER ANCHORAGE AREA			
Anchorage	124,542	118,809	5,733
Matanuska-Susitna	6,552	6,208	344
Kenai-Cook Inlet	14,250	13,719	531
Seward	2,021	1,870	151
GREATER FAIRBANKS AREA			
Fairbanks	50,262	42,682	7,580
GLENNALLEN-VALDEZ AREA			
Valdez-Chitina-Whittier	3,116	3,023	93

Note: Group quarters are primarily institutions, boarding houses, military barracks, college dormitories, hospitals, religious centers, and ships.

SOURCE: 1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 60.

TABLE D.4. 1978 HOUSEHOLD ESTIMATES

(thousand)

	Population (1,000): Department of Commerce[a]	Population (1,000): Department of Labor[b]	Population in Housing Units (1,000)		Population per Occupied Housing Unit[c]	1978 Households		Electric Utility Residential and Rural Customers[d]	Ratio of Households to Customers	
Greater Anchorage Area	215.7	226.3	209.0	219.6	- -	61.6	64.7	77,000	.80	.84
Anchorage	179.0	185.5	173.3	179.8	3.4	51.0	52.9	57,916	.88	.91
Kenai-Cook Inlet	19.6	22.3	19.1	21.8	3.4	5.6	6.4	7,904	.71	.81
Matanuska-Susitna	14.2	15.4	13.9	15.1	3.4	4.1	4.4	10,152	.40	.43
Seward	2.9	3.1	2.7	2.9	3.0	.9	1.0	1,027	.90	1.00
Greater Fairbanks Area	59.4	60.8	51.8	53.2	3.3	15.7	16.1	17,524	.90	.92
Fairbanks	54.1	55.5	-	-	-			-		
Southeast Fairbanks	5.3	5.3	-	-	-			-		
Glennallen-Valdez Area										
Valdez-Chitina-Whittier	5.9	5.0	5.8	4.9	3.1	1.9	1.6	1,539	1.27	1.07

SOURCES:
(a) State of Alaska Department of Commerce and Economic Development, Division of Economic Enterprise, "Numbers: Basic Economic Statistics of Alaska Census Division," 1979.

(b) State of Alaska, Department of Labor.

(c) 1970 Census of Housing, Detailed Housing Characteristics: Alaska.

(d) Federal Energy Regulatory Commission, Utility Power Systems Statements.

1. The household calculations and population estimates may be incorrect.
2. Some residential electricity hookups are for second and vacation homes.
3. Some residential electricity hookups are for units which are vacant since a minimal amount of electricity is necessary even in an unoccupied housing unit for such things as the heat distribution pump.
4. Some households may not have access to the electric utility.

Table D.5 (compared to Table D.4) shows that in all areas of the railbelt the ratio of residential customers-to-households has apparently increased since 1970 unless the population and household size estimates for 1978 are very low.

TABLE D.5. 1970 UTILITY HOOKUP RATES

	A 1970 Occupied Housing Units	B 1970 Residential & Rural Utility Customers	B/A
Greater Anchorage Area	41,233	41,151	1.00
Greater Fairbanks Area	12,612	10,756	.85
Glennallen-Valdez	1,017	561	.55

Part of the differences among the census divisions in the ratios of households to utility customers arises from the fact that the utility boundaries do not correspond to the census division boundaries used in developing Table D.4. Specifically, Chugach Electric serves portions of Anchorage, Kenai-Cook Inlet, Seward, and Valdez-Chitina-Whittier. Matanuska Electric serves a portion of Anchorage. A portion of Golden Valley Electric Association customers reside in the Yukon-Koyukuk Census Division.

The only identifiable household concentrations not having access to utility service from the seven major railbelt utilities appear to be portions of Valdez-Chitina-Whittier (Chistochina, Mentasta Lake, Tatitlek), portions of Kenai-Cook Inlet (Tyonek, Seldovia), and portions of Southeast Fairbanks (Tok).

Vacancy rates for housing are not collected in a complete and accurate manner. The rental housing vacancy rate for Anchorage in 1978 was estimated at 14 percent.[1] As of June 1979, the unsold inventory of new houses was approximately 2 percent of the stock.[2] It is not possible from this information to develop an overall vacancy rate, but realtors generally agreed that the rate was higher in 1978 than in a normal market. A recent housing study by the Fairbanks North Star Borough estimated a vacancy rate of 14 percent overall.[3] Vacancy rates for other areas are unknown but assumed to be lower than for Anchorage and Fairbanks.

The number of second homes within the railbelt served by electric utilities is not known but is assumed to be concentrated in the Matanuska-Susitna Census Division. In the 1970 census, 3,492 households in the Anchorage Census Division indicated they owned second homes.[4] Some are located in the Matanuska-Susitna Census Division, and some of these would have appeared in the census as year-round housing units although there is no accurate information on actual numbers.

We assume 2,000 second homes among the Greater Anchorage Area utility customers.[5] Using this figure and the information from Table D.4 results in an estimate of the overall Greater Anchorage Area vacancy rate of between 14 and 18 percent, which would be about twice the normal rate. This may be somewhat high based upon the rate reported for Fairbanks.

We have no vacancy information for Glennallen-Valdez. If we assume 25 percent of the population is not serviced by Copper Valley Electric Association, the vacancy rates derived using Table D.4 data range from zero to 20 percent, which probably brackets the actual value.

The estimate of the number of households could be obtained either by estimating population and dividing by average household size or by using utility hookup numbers and adjusting for vacancies. Neither method is foolproof; but the latter involves only one estimate, while the former requires two. We choose the latter and assume a 13 percent vacancy rate. The resulting household estimates are shown in Table D.6.

TABLE D.6. HOUSING UNIT AND HOUSEHOLD ESTIMATES

	First Housing Units	Vacancy Rate (percent)	Households
Greater Anchorage	75,000	13	65,250
Greater Fairbanks	17,524	13	15,245
Glennallen-Valdez	1,539	13	1,339

The housing stock may alternatively be calculated directly by a count or estimate, independent of the number of electric hookups. This method provides a check on the utility hookup method of housing stock estimation as well as providing information on the geographic distribution of the stock (within the Greater Anchorage Area) and an estimate of the distribution of the stock by type. Table D.7 tabulates the housing stock analyses which have been done for the railbelt communities.

From these analyses, it is relatively easy to construct an estimate of the 1978 housing stock for the Anchorage Census Division of 57,896, which is included in the table. Estimates for other Census Divisions must be developed more indirectly. Table D.8 shows the result of applying the 1978-to-1970 population ratios to the 1970 year-round housing unit stock in each census division. These housing stock estimates can be adjusted to arrive at final estimates.

TABLE D.7. HISTORICAL RAILBELT HOUSING STOCK DISTRIBUTION BY TYPE

	Single Family	Duplex	Multi-Family	Mobile Home	Other	Total
GREATER ANCHORAGE AREA						
Anchorage Census Division						
1950[a]	3,325	964	1,128	202	0	5,619
1960[b]	13,435	1,427	7,625	1,485	0	23,972
1970[c]	15,572	3,813	13,368	4,864	0	37,617
1978[d] (off base)	28,530	4,581	18,196	6,589	-	57,896
Anchorage Bowl						
1975[e] (off base)	23,227	5,324	14,754	6,246	0	49,551
1975[e] (on base)	34	0	4,122	0	0	4,156
1975[e] (total)	23,261	5,324	18,876	6,246	0	53,707
1979[f]	26,300	- 24,203 -		6,960	0	57,463
Eagle River 1979[f]	-	-	-	-	0	3,524
Girdwood 1978[g]	-	-	-	-	-	198
Kenai-Cook Inlet Census Division						
1960[b]	2,117	19	182	186	0	2,504
1970[c]	2,627	108	594	1,321	0	4,650
Seldovia 1970[h]	102	- 29 -		22	0	153
1976[j]	153	- 20 -		41	15	229
Soldotna 1970[h]	159	- 95 -		143	0	397
1976[j]	311	- 110 -		180	0	601
Homer 1970[h]	310	- 39 -		18	0	367
1976[j]	251	- 31 -		134	16	432
Kenai 1970[h]	574	- 371 -		231	0	1,176
1976[j]	684	- 350 -		274	0	1,308

Table D.7. (continued)

	Single Family	Duplex	Multi-Family	Mobile Home	Other	Total
Seward Census Division						
1960[b]	1,307	86	77	24	0	1,494
1970[c]	789	19	138	10	0	956
Seward 1976[j]	497	–	212 –	36	36	781
Matanuska-Susitna Census Division						
1960[b]	2,336	20	149	88	0	2,593
1970[c]	2,947	41	159	208	0	3,355
1978[k]	–	–	310	–	–	7,616
GREATER FAIRBANKS AREA						
Fairbanks-Southeast Fairbanks Census Division						
1950[a] (urban)	1,295	166	352	2	0	1,815
1960[b]	6,527	671	4,547	853	0	12,598
1970[c]	5,335	1,068	6,072	1,254	0	13,729
Fairbanks Census Division						
1970[c]	4,775	1,017	5,603	1,129	0	12,524
Southeast Fairbanks Census Division						
1970[c]	560	51	469	125	0	1,205
Fairbanks North Star Borough (off base)						
1970[l]	–	–	–	–	–	9,884
1975[m]	–	–	–	–	–	11,324
1976[n]	–	–	–	–	–	15,200
1976[o]	–	–	–	–	–	16,894
1978[o]	8,787	1,232	5,616	2,306	0	17,941
1979[o]	–	–	–	–	–	17,684
Fairbanks North Star Borough (off base)						
1976[p]	49%	8%	25%	17%	1%	
1978[q]	52%	–	30% –	12%	6%	

Table D.7. (continued)

	Single Family	Duplex	Multi-Family	Mobile Home	Other	Total
GLENNALLEN-VALDEZ AREA						
Valdez-Chitina-Whittier Census Division						
1960[b]	803	31	392	15	0	1,241
1970[c]	881	34	278	212	0	1,405
Valdez 1970[h]	105	– 95 –		98	0	298
1978[r]	222	143	135	518	12	1,030
1978[s]	314	– 171 –		521	16	1,022
Glennallen 1970[h]	58	– 25 –		26	0	109

SOURCES: (a) U.S. Department of Commerce Census of Housing 1950: Alaska, General Characteristics, Table 14. These are all dwelling units.

(b) U.S. Department of Commerce Census of Housing 1960: Alaska, Table 28. These are all housing units.

(c) U.S. Department of Commerce Census of Housing 1970: Alaska, Table 62. These are all year-round housing units.

(d) Estimated by author by netting out 1978 housing units authorized for Anchorage Municipality from 1979 total and adding Eagle River and Girdwood (latter assumed all single-family units).

(e) Anchorage Urban Observatory, University of Alaska, 1975 Housing Survey, Appendix I, p. 2.

(f) Municipality of Anchorage, Planning Department.

(g) Municipality of Anchorage, Planning Department. These are full-time residences only. Total residences were calculated at 729.

(h) State of Alaska Department of Community and Regional Affairs, Division of Community Planning, Selected 1970 Census Data for Alaska Communities, 1974.

(j) Kenai Peninsula Borough, Profile of 5 Kenai Peninsula Towns, 1977, Table 130. These are year-round dwelling units (vacant and occupied units designed for year-round living). This includes housing within the city limits of these towns only and estimates 250 units outside Homer.

Table D.7. (continued)

(k) Matanuska-Susitna Borough Planning Department.

(l) 1970 Census of Housing as reported in Fairbanks North Star Borough, FMATS Housing Study, draft, 1980.

(m) E. Allen Robinson. "Situation Report: Fairbanks, Alaska," HUD Anchorage 1975, as reported in Fairbanks North Star Borough, FMATS Housing Study, draft, 1980.

(n) Jack Kruse, "Fairbanks Community Survey," Institute of Social and Economic Research, University of Alaska, Fairbanks, 1976, as reported in Fairbanks North Star Borough, FMATS Housing Study, draft, 1980.

(o) William Rose, Fairbanks North Star Borough Planning Department, as reported in Fairbanks North Star Borough, FMATS Housing Study, draft, 1980.

(p) Jack Kruse, "Research Notes: Fairbanks Community Survey," Institute of Social and Economic Research, 1976, p. 2.1.

(q) Jack Kruse, "Fairbanks Petrochemical Study," Institute of Social and Economic Research, University of Alaska, Fairbanks, 1978, as reported in Fairbanks North Star Borough, FMATS Housing Study, draft, 1980.

(r) Michael Baring-Gould et al. Valdez City Census, 1978. University of Alaska, Anchorage, Table 13.

(s) Northrim Associates, Inc., CCC/HOK from the Environmental Impact Statement, Alaska Petrochemical Company Refining and Petrochemical Facility, Valdez, Appendix, Vol. II, p. 93. This is total housing net of hotel-motel units and campers.

TABLE D.8. 1978 YEAR-ROUND HOUSING STOCK ESTIMATE BASED ON POPULATION RATIOS

Census Division	1970 Year-Round Housing Units	1978/1970[a] Population	1978 Year-Round Housing Unit Estimate
Anchorage			
Kenai-Cook Inlet	4,650	1.56	7,277
Matanuska-Susitna	3,555	2.35	8,356
Seward	956	1.53	1,463
Fairbanks/Southeast Fairbanks	13,729	1.25	17,207
Valdez-Chitina-Whittier	1,405	1.61	2,268

[a]Based on Alaska Department of Labor estimates for 1978.

In Seward, 40 percent of year-round housing units were unoccupied in 1970 and 35 percent in 1960.[6] If we assume that 25 percent were unoccupied and did not require space heating in 1978, this results in an estimate of about 1,100 "first" year-round housing units (year-round housing units, as defined by the census, which are actually utilized on a year-round basis).

Kenai-Cook Inlet had a 16 percent vacancy rate in 1970, down from 33 percent in 1960. The growth in the number of units in the major communities of the census division between 1970 and 1978 was much slower than would be indicated by the 1978 estimate of Table D.8.[7] Thus, growth was more rapid outside these cities and may or may not have been accounted for by second homes. We assume 500 second homes and thus arrive at an estimate of the first home housing stock of 6,777.

In the Matanuska-Susitna Borough, 44 percent of year-round housing units were unoccupied at the time of the 1970 census and 42 percent in 1960. If we assume that this rate has fallen since 1970 (Matanuska Electric Association had 678 seasonal rate customers in 1978, but this is not equivalent to second homes) to about 35 percent, it would be consistent with a 15 percent vacancy rate and 1,500 second homes. The Borough counted 7,616 dwelling units in 1978 but did not distinguish vacation homes. Netting out second homes would produce a first housing unit estimate of about 6,100 units.

These census division estimates can be aggregated to arrive at an overall first housing unit estimate for the Greater Anchorage Area of 71,873, shown in Table D.9. This is somewhat lower than the estimate derived by counting the number of electric utility accounts but is more reasonable as a basis for calculating electricity consumption on an end use basis. (For example, there are some residences in Anchorage with two electric meters, each of which were counted as a customer during 1978.)[8]

For the Greater Fairbanks area, the Fairbanks North Star Borough housing surveys closely correspond to the utility hookup data; however, researchers admit that deficiencies exist in at least some of the surveys, which could lead to an overcount.[9] These house counts, however, would not include utility customers located outside the Borough in the Southeast Fairbanks and Yukon-Koyukuk Census Divisions. We assume that these effects, as well as the presence of some vacant, non-market housing in the North Star Borough and second homes outside the Borough, cancel one another out so that the utility hookup figure becomes our housing stock estimate for the Greater Fairbanks Area.

In the Valdez-Chitina-Whittier Census Division, the vacancy rate was 33 percent in 1970, up from 25 percent in 1960. A large portion of this increase could be the decline in population of Whittier. Without additional information on the housing stock in the utility service area in the census division, we must use the electric utility residential hookup estimate of about 1,500.

TABLE D.9. FIRST HOME HOUSING STOCK ESTIMATES FOR 1978 USED IN END USE CALCULATIONS

Greater Anchorage Area	71,873
Anchorage	57,896
Kenai-Cook Inlet	6,777
Matanuska-Susitna	6,100
Seward	1,100
Greater Fairbanks Area	
Fairbanks/Southeast Fairbanks	17,500
Glennallen-Valdez	
Valdez-Chitina-Whittier	1,500

The first housing unit housing stock is divided into four housing types which have very different space heating characteristics--single-family detached, duplex, multifamily, and mobile home. Information on the distribution of the housing stock by type comes primarily from the housing stock surveys shown in Table D.7.

For Matanuska-Susitna, the planning department has estimated multi-family units and mobile homes. We allocate the remaining units between single-family and duplex units on the basis of the Anchorage proportions.

In Kenai-Cook Inlet, the proportion of single-family units in the larger communities was representative of the census division as a whole. Thus, the 1976 proportion of 54 percent found in these larger communities is used for the 1978 estimate. For mobile homes, this was not the case as the proportion in the whole census division in 1970 was 28 percent, while it was only 20 percent in the larger communities. In these larger communities, it grew to 24 percent by 1976, so we assume the same type of growth for the census division as a whole but that some of the relative growth in the utilization of mobile homes is in areas inaccessible to the railbelt utilities. Thirty percent becomes our estimate. The most recent estimate of the distribution between duplex and multifamily units is the 1970 census. From the total data, a pattern toward single-family living is evident, so we assume that a majority of the growth since 1970 is in duplexes and that multifamily units are 600.

For Seward, we assume the same distribution for the utility service area as indicated in the 1976 survey and that multifamily and duplex units are equal in number.

For Fairbanks single-family units, we utilize information collected in the 1978 survey for the Borough and assume the same distributions for housing units outside the Borough. For trailers, we assume a downward trend in the percentage since 1976 and assume that the "other" category from the 1978 survey is not relevant for our purposes. Thus, the 13 percent figure from the Borough count is taken. We further assume 21 percent of duplex and multifamily units are duplexes, which is an average of the various surveys.

For Glennallen-Valdez, the data indicates a much higher proportion of mobile homes in Valdez than in Glennallen. We use the 1978 Valdez City Census for Valdez and apply the 1970 Glennallen distribution to the remainder of the service area. The results of this analysis are shown in Table D.10.

D.2. RESIDENTIAL ELECTRIC SPACE HEATING

Data on the proportion of housing units heating with electricity and average consumption levels for various housing types in different locations is fragmentary. None of the electric utilities compile this information at present; and although some had special all-electric rates in the past, utility records of those customers have not been retained.

The space heating distribution is currently relatively stable except in the outlying areas of the Greater Anchorage Area and in Fairbanks. In the former, use of electricity for space heating is growing relative to the primary alternative (fuel oil) because of the rising price of fuel oil and the relatively stable price of natural gas-generated electricity. In Fairbanks, there is a shift away from electric space heat toward fuel oil as the price of oil increases since incremental electricity is produced by fuel oil. These shifts make it more difficult to estimate the actual space heating mode split in these areas.

Census data on fuels used for space heating presented in Table D.11 encompass the whole railbelt but are not current because of the rapid

TABLE D.10. 1978 FIRST HOME HOUSING STOCK DISTRIBUTION BY HOUSING TYPE

	Single Family	Duplex	Multi-Family	Mobile Home	Total
GREATER ANCHORAGE AREA	37,357	5,930	19,254	9,332	71,873
Anchorage	28,530	4,581	18,196	6,589	57,896
Kenai-Cook Inlet	3,660	484	600	2,033	6,777
Matanuska-Susitna	4,463	717	310	610	6,100
Seward	704	148	148	100	1,100
GREATER FAIRBANKS AREA					
Fairbanks/Southeast Fairbanks	9,100	1,285	4,840	2,275	17,500
GLENNALLEN-VALDEZ AREA					
Valdez-Chitina-Whittier	472	197	189	642	1,500

TABLE D.11. PERCENT DISTRIBUTION OF SPACE HEATING FUELS IN THE RESIDENTIAL SECTOR

Census Division	Utility Gas	Oil	Electric	Coal	Wood	Propane	Other
GREATER ANCHORAGE AREA							
Anchorage							
1950	0	92	0	7	1	0	0
1960	0	82	0	15	0	0	3
1970	53	34	6	1	0	2	4
Matanuska-Susitna							
1960	0	47	0	24	28	0	1
1970	0	62	1	14	17	6	0
Kenai-Cook Inlet							
1960	0	69	0	8	23	0	0
1970	31	52	4	3	5	3	2
Seward							
1960	0	88	0	0	12	0	0
1970	0	92	4	0	4	0	0

SOURCES: 1950 Census of Housing, General Housing Characteristics: Alaska. Table 17.
1960 Census of Housing, General Housing Characteristics: Alaska. Tables 29, 30.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 63.

Table D.11. (continued)

Census Division	Utility Gas	Oil	Electric	Coal	Wood	Propane	Other
GREATER FAIRBANKS AREA							
Fairbanks and Southeast Fairbanks							
1950	0	30	0	54	16	0	0
1960	0	47	0	49	3	1	0
1970	3	61	7	20	2	1	6
GLENNALLEN-VALDEZ AREA							
Valdez-Chitina-Whittier							
1960	0	57	0	0	17	0	26
1970	0	72	0	0	21	7	0

growth in the housing stock since 1970. Fuel oil is the predominant fuel except in those areas of Anchorage and the Kenai-Cook Inlet Census Division where natural gas is now available. Coal was historically very important in Fairbanks, but it was surpassed by fuel oil in the 1960s. The census data does indicate a significant proportion of the occupied housing stock utilizing coal, wood, propane, and other fuels, even in 1970.

Information on four electric utilities is available from a Federal Power Commission (now Federal Energy Regulatory Commission) report. This information is shown in Table D.12. Utility personnel are unable to determine the source of this information but feel it is reasonable. This data shows that all electric customer growth in Anchorage in the early 1970s was more rapid than total customer growth. No such trend is apparent for Fairbanks.

Additional published data on the residential space heating mode split in the railbelt is shown in Table D.13. This data tends to confirm information gathered informally in conversations with utility and real estate personnel as well as analyses of utility monthly load curves. [Matanuska Electric Association (MEA) and Homer Electric Association (HEA) analyzed monthly bills in an attempt to identify the number and average consumption levels for their electric space heating customers. The HEA analysis requires further work. The MEA analysis yielded an estimate of 2,685 space heating customers in 1978 and 18,172 kWh annual consumption for space heating per customer in 1979.]

TABLE D.12. ALL-ELECTRIC HOMES INFORMATION

	Customers			Average Annual Consumption (kWh)			
	Total	All-Electric	Non-All-Electric	Total	All-Electric	Non-All-Electric	Heating Only For All-Electric Customers
Chugach Electric							
1963	13,170	120	13,050	6,137	37,882	5,845	
1970	24,682	1,280	23,402	8,057	38,500	6,392	29,600
1971	25,761	1,475	24,286	9,194	38,700	7,402	29,100
1972	28,687	1,756	26,931	9,386	39,000	7,455	29,600
1973	29,077	2,010	27,067	9,887	39,050	7,721	29,750
1974	31,779	2,605	29,174	9,621	39,100	6,989	29,900
Anchorage Municipal Light and Power							
1963	6,592	NA	NA	4,681	NA	NA	NA
1970	8,477	381	8,096	6,431	18,045	5,884	NA
1971	9,295	700	8,595	6,782	18,127	5,858	NA
1972	10,130	700	9,430	7,080	18,127	6,260	NA
1973	10,523	928	9,595	7,855	17,985	6,875	NA
1974	11,268	1,123	10,145	7,982	17,355	6,944	NA
Golden Valley Electric Association							
1963	NA	NA	NA	NA	NA	NA	NA
1970	6,624	802	5,822	10,133	42,516	5,672	NA
1971	6,741	850	5,891	12,158	43,000	7,708	NA
1972	6,947	850	6,097	13,920	43,000	9,866	NA
1973	7,382	1,448	5,934	14,479	40,000	8,251	NA
1974	8,643	900	7,743	14,795	43,000	16,015	NA
Fairbanks Municipal Utility System							
1963	4,120	0	4,120	3,013	--	3,013	NA
1970	4,532	NA	NA	5,167	NA	NA	NA
1971	4,443	NA	NA	5,504	NA	NA	NA
1972	4,540	19	4,521	5,341	46,316	5,169	NA
1973	4,443	19	4,424	5,841	46,316	5,667	NA
1974	NA	NA	NA	NA	NA	NA	NA

SOURCE: Compiled from Federal Power Commission, All Electric Homes, annual.

TABLE D.13. RAILBELT RESIDENTIAL SPACE HEAT MODE SPLIT INFORMATION

(percent)

	gas	oil	electric	wood	other-unknown
Seward 1977[a]	-	96	-	1	3
Kenai-Cook Inlet 1977					
Seldovia[a]	-	88.2	3.9	3.9	4
Soldotna[a]					
City	70.4	25	2.8	.9	.9
Total	57.7	35.8	4.4	1.5	.7
Kenai	76.2	13.2	9.3	.7	.7
Total of Three Cities	66	25	7	1	1
Anchorage 1975					
Anchorage Bowl[b]					
house	68	17	11.5	.5	3
house new since 1970	77.5	6	16	0	0
trailer	48.5	36.5	7.5	1	6.5
trailer new since 1970	33.5	55.5	0	11	0
apartment	52	8.5	31	0	8.5
Fairbanks 1979[c]	0	70	11	12	7

SOURCES: (a) Kenai Peninsula Borough, Profile of 5 Kenai Peninsula Towns, 1977, Table 72.

(b) Anchorage Urban Observatory, Anchorage Housing Survey, 1975, unpublished data.

(c) Fairbanks North Star Borough, Community Information Center, Community Information Quarterly, Spring 1980, Vol. III., No. 1, p. 81.

Additional information for drawing inferences about the number of electric space heating customers and their annual average consumption rates can be obtained from several sources. These include the following:

1. natural gas consumption data,
2. "typical" home space heating analysis, and
3. average annual and monthly residential consumption per customer information of electric utilities.

In addition, information on housing unit sizes, in terms of average square feet, and the relative sizes and heating efficiencies of different-sized units can be helpful.

Using data obtained from Alaska Gas and Service Company, an analysis of natural gas consumption for space heating was done. This analysis indicates that for residential gas utility customers (assumed to be single-family, mobile home, and duplex units and all space heated with gas) average annual consumption for space heating (that portion of the load which varies over the course of the year with heating degree days) is about 84 percent of total consumption or 187 mcf/customer/year for the 1970s and 175 mcf/customer for 1978. Details of this analysis are shown in Table D.14.

The analysis further reveals no trend in consumption per customer in the 1970s, which might be the result of either larger homes or better insulation. Personnel at Alaska Gas and Service Company using national data estimate the space heat load at 75 percent of the total. Recognizing the imprecision of both the regression model and the national

TABLE D.14.
DETERMINATION OF AVERAGE NATURAL GAS CONSUMPTION
IN THE RESIDENTIAL SECTOR

A. Alaska Gas and Service Company Residential Consumption Data

	Consumption (mcf)	Customers	Average Consumption (mcf)				Heating Degree Days (annual)
			Eagle River	Soldotna/ Kenai	Anchorage	Total	
1970	2,615,042	12,097	-	-	-	216.2	10,137
1971	3,406,227	15,233	-	-	-	223.8	11,879
1972	3,817,869	16,231	-	-	-	235.2	12,016
1973	4,162,662	17,983	-	-	-	231.5	11,665
1974	4,312,701	20,135	-	-	-	214.2	10,683
1975	5,402,111	22,779	257	237	236	237.2	11,308
1976	5,765,871	25,659	225	225	225	224.7	10,361
1977	5,848,812	27,901	262	243	206	209.6	9,394
1978	6,367,015	30,629	199	196	209	207.9	9,131
1979	6,730,022	33,229	-	-	-	202.5	-
Average 1970-1978						222.3	10,730
Normalized by Heating Degree Days						226	10,911

SOURCE: Annual financial report to APUC and internal company records.

TABLE D.14. (continued)
DETERMINATION OF AVERAGE NATURAL GAS CONSUMPTION
IN THE RESIDENTIAL SECTOR

B. Monthly Natural Gas Sales Data

Month	Year	Sales/Customer (mcf) Residential	Commercial	Industrial	Heating Degree Days (Anchorage) Current	Lagged 1 Month
Dec	1974	26	100	NA	1,425	1,263
Jan	1975	37	140	872	1,643	1,425
July	1975	8	31	345	192	354
Aug	1975	7	29	360	252	192
Dec	1975	30	109	640	1,654	1,517
Jan	1976	36	136	889	1,485	1,654
July	1976	7	29	307	184	332
Aug	1976	7	25	310	262	184
Dec	1976	25	92	706	1,294	1,028
Jan	1977	40	142	606	1,017	1,294
July	1977	7	26	306	75	208
Aug	1977	6	26	337	144	75
Dec	1977	32	117	836	1,659	1,486
Jan	1978	31	118	813	1,349	1,659
July	1978	9	31	290	186	308
Aug	1978	7	23	281	160	186
Dec	1978	25	90	708	1,344	1,153
Jan	1979	28	101	788	1,321	1,344
July	1979	7	24	285	NA	265
Aug	1979	6	19	179	NA	

SOURCE: Alaska Gas and Service Company records.

TABLE D.14. (continued)
DETERMINATION OF AVERAGE NATURAL GAS CONSUMPTION
IN THE RESIDENTIAL SECTOR

C. Regression Results

Equation: monthly consumption = a + b * degree days

a is interpreted as monthly, nonclimate related gas consumption in mcf or simply nonspace heat related consumption

Dependent Variable	a Value	R^2	Standard Error of Equation	Independent Variable
monthly residential consumption	2.86	.93	3.60	heating degree days (HDD) lagged
monthly residential consumption	2.87	.88	4.49	2 month average HDD
monthly residential consumption	4.65	.86	5.06	HDD
monthly commercial consumption	10.81	.93	12.58	HDD lagged
monthly commercial consumption	10.93	.89	16.18	2 month average HDD
monthly commercial consumption	17.70	.86	18.15	HDD
monthly industrial consumption	239.69	.91	74.09	HDD lagged
monthly industrial consumption	242.94	.93	63.36	2 month average HDD
monthly industrial consumption	257.23	.92	68.49	HDD

data, we average the estimates to obtain 80 percent as the space heat load of residential natural gas sales.

Table D.15 shows the total number of residential natural gas space heat customers, including both gas utilities in the Greater Anchorage Area. Average annual consumption in the residential sector of the Kenai system was 90 percent of the Anchorage system in 1978.

TABLE D.15. 1978 RESIDENTIAL NATURAL GAS CUSTOMERS

Anchorage	27,664
Kenai	910
Soldotna/North Kenai	1,103
Eagle River	1,856
Total	31,533

SOURCE: Alaska Public Utilities Commission records.

The University of Alaska Fairbanks, Cooperative Extension Service, has developed a model which is capable of analyzing the fuel requirements necessary to heat a typical house with design specifications chosen and input by the model user. This model has calculated the annual fuel requirements shown on Table D.16.

TABLE D.16.
"TYPICAL" HOUSE SPACE HEATING FUEL REQUIREMENTS

	Anchorage	Fairbanks
Single Family House		
1. 2300 square feet (2 floors with daylight basement)		
natural gas (mcf)	200	-
electricity (kWh)	40,917	52,392
fuel oil (gallons)	1,492	1,910
2. 768 square feet (closed crawl space)		
electricity (kWh)	-	29,042
fuel oil (gallons)	-	1,059
3. 768 square feet (heated crawl space)		
electricity (kWh)	-	26,620
fuel oil (gallons)	-	970
Mobile Home		
1. 768 square feet (closed crawl space)		
electricity (kWh)	-	34,873
fuel oil (gallons)	-	1,272
2. 768 square feet (heated crawl space)		
electricity (kWh)	-	32,761
fuel oil (gallons)	-	1,194

SOURCE: Axel Carlson, Extension Engineer, Cooperative Extension Service, University of Alaska, Fairbanks, as reported in Fairbanks North Star Borough, Community Information Center, Special Report #2, 1978, and Special Report #4, 1976.

Recent trends in average annual residential consumption per customer are depicted in Figure D.1. The rapid growth for Golden Valley Electric Association (GVEA), Matanuska Electric Association (MEA), and Homer Electric Association (HEA) is primarily due to space heating load.

Table D.17 shows electric utility monthly residential loads per customer in 1979 for several utilities. The winter-to-summer month ratios provide some indication of the space heating load. Copper Valley Electric Association (CVEA), with no significant space heating load, has a winter-to-summer ratio of 1.48. The other utilities with space heating load have higher winter peaks. Unfortunately, this information is not precise enough to allow one to draw inferences about the amount of load devoted to space heat for the various utilities. An attempt was made to calculate the space heat load for the average space heat customer; but the results, shown in the final row, are implausible.

Information on the average size of units in the housing stock is available for Fairbanks and is shown in Table D.18 along with national averages.

Anchorage retailers indicate that trailer dimensions have been increasing over time, although it is difficult to use sizes of trailers sold to estimate size of trailers in place. This is because people tend to add to trailers in place. Newer trailers are 924 square feet (14x66), while those sold in the early 1970s are 732 square feet (12x61).

Figure D.1.

Residential Electricity Consumption Per Customer

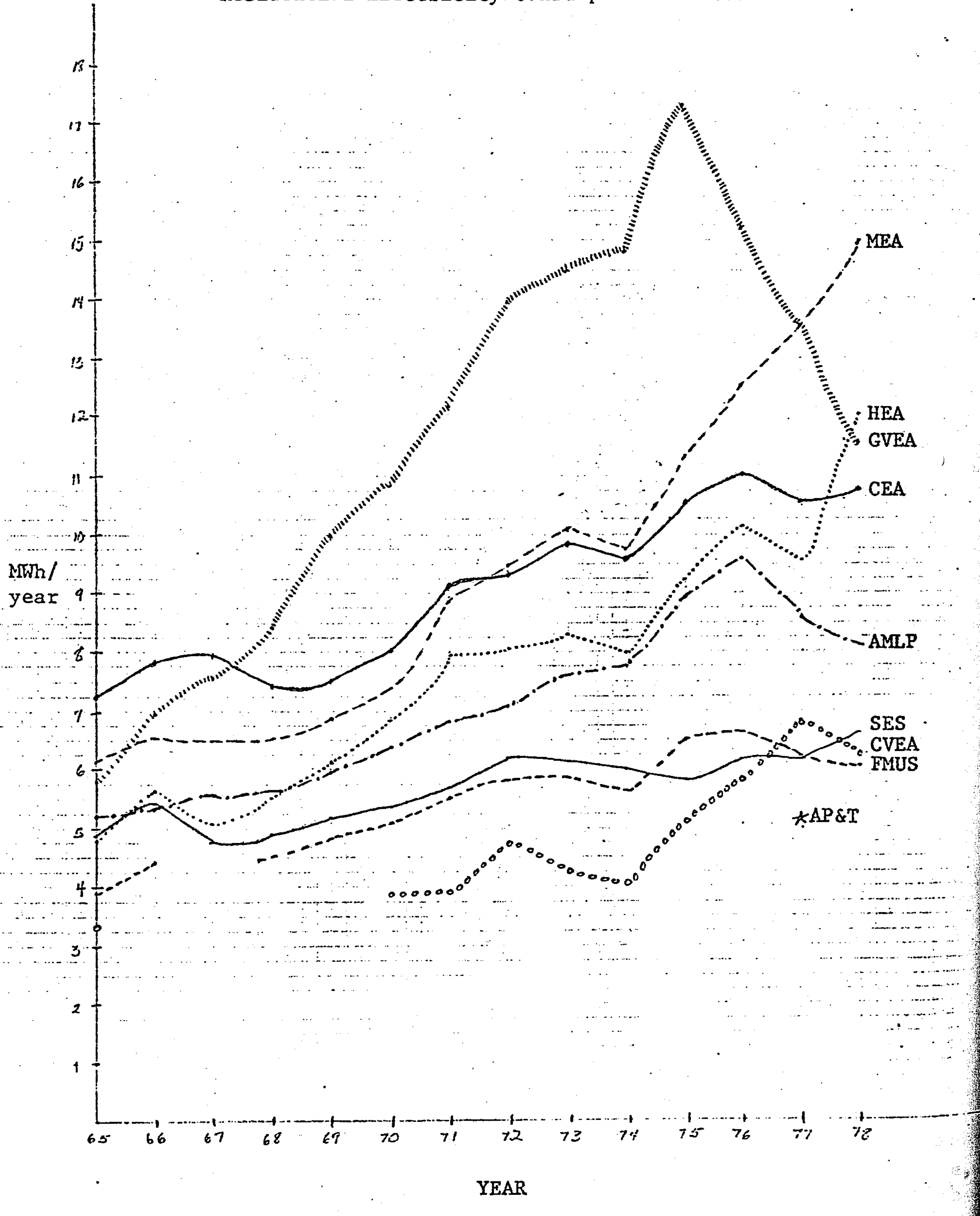

TABLE D.17.

MONTHLY RESIDENTIAL ELECTRIC UTILITY LOAD FOR 1979

	CVEA	CEA	AMLP	HEA	MEA	GVEA
January	620	1,179	1,131	1,418	2,017	1,308
February	646	1,324	762	1,501	1,936	1,495
March	562	1,127	1,062	1,407	1,691	969
April	525	856	783	1,183	1,396	803
May	466	779	678	1,004	1,079	637
June	432	741	568	909	903	613
July	371	726	563	740	850	562
August	426	583	482	737	771	592
September	432	779	611	720	834	671
October	434	783	410	849	962	743
November	571	953	666	1,002	1,245	887
December	549	1,279	917	1,216	1,590	1,258
Monthly Average	491	871	716	1,054	1,270	877
Winter-Summer Ratio[a]	1.48	1.84	1.74	1.73	2.20	2.30
Total	5,892	10,452	8,592	12,648	15,240	10,524
Nonspace Heat Load[b]	5,892	9,828	7,726	11,429	12,090	8,464
Total Minus Nonspace Heat	0	624	866	1,219	3,150	2,060
Percent Space Heat Customers[c]	0	.14	15	30	33	6
Space Heat Average	-	4,457	5,907	4,063	9,545	34,333

SOURCES: Utility Monthly Reports to Rural Electrification Association and internal utility records.

(a) (December + January + February)/(June + July + August)

(b) Based upon the CVEA ratio of total annual sales to sales in the summer months of June, July, and August (4.79).

(c) Author estimate.

TABLE D.18. AVERAGE SQUARE FEET FOR VARIOUS HOUSING TYPES FAIRBANKS AND NATIONAL DATA

	Fairbanks[a]	National[b]
Single-Family	1,384	1,570
Duplex	796	1,370
Apartment	847	900
Mobile Home	919	720
Total	1,116	

[a]Fairbanks North Star Borough, Community Information Center, "1978 Fairbanks Energy Inventory," Special Report No. 4, July 1979, p. 40.

[b]U.S. Department of Energy, Office of Buildings and Community Systems, Comprehensive Community Energy Planning: A Workbook, Vol. 1.

New homes constructed in the Anchorage area tend to be in the range of 1,600 square feet on average according to real estate personnel. This includes a mixture of one-story ranch homes, split levels, and other types. The average house also seems to be getting larger. This is consistent with the hypothesis that the Alaskan housing stock is being upgraded toward the national average. In 1977, the average size of new, single-family homes built in the United States was 1,720 square feet.[10] Evidence that the average size of the Alaskan housing unit was smaller than the national average in 1970 can be inferred from earlier data from the 1970 census shown in Table D.2 on the median number of rooms and population per housing unit for Alaska. In all railbelt census divisions, median number of rooms was lower and population per occupied housing unit was higher than the average for the western region of the United States.

Real estate and electric utility personnel indicate that housing units are smaller in the outlying areas of the railbelt such as Seward, Homer, and Valdez.

Finally, Table D.19 shows national average estimates of average size and thermal requirements for various types of structures. This table demonstrates the apparent variation in thermal requirements of different types of buildings. Also, the very high average electrical requirements calculated by the author for Anchorage, based upon the thermal requirements data, bring into question the use of nationally determined formulas and ratios for the Alaskan railbelt.

TABLE D.19. NATIONAL AVERAGES: RESIDENTIAL SPACE HEATING

Type of Structure	Average Size (square foot)	Thermal Requirement (btu/sq.ft./HDD	Anchorage[a] Electrical Requirement (kWh)
Single Family Detached	1,570	11.3	56,716
Single Family Attached	1,370	6.2	27,154
Multifamily High Rise	900	4.5	12,947
Multifamily Low Rise	900	5.0	14,386
Mobile Home	720	15.0	34,526

[a]Calculated on the assumption of 10,911 heating degree days.

SOURCE: "Comprehensive Community Energy Planning: A Workbook," prepared for the Office of Buildings and Community Systems, U.S. Department of Energy, Volume 1, pp. 4-7.

To begin the actual determination of residential electric space heating, based upon all this fragmentary information, it is possible to first net out natural gas users in Anchorage and Kenai-Cook Inlet among single-family, duplex, and mobile home residents. We assume all residential gas customers use gas for space heating. We can thus calculate the non-natural gas customers according to Table D.20. In order to divide total gas customers among structural types, we note that trailers are somewhat less likely to be heated by gas according to the 1975 Anchorage survey and use this information for both census divisions.

In 1970, fuels other than natural gas, electricity, and fuel oil accounted for 7 percent of space heating units in Anchorage and 13 percent in Kenai-Cook Inlet. If we assume no additions to the number of such units and no conversions, these percentages fall to about 3 and 8 percent, respectively, by 1978. It seems reasonable to assume that units burning these fuels would not be multifamily but might otherwise be randomly distributed among different types of structures. Netting these units out leaves only electric and fuel oil-heated units.

Information on electricity and fuel oil for Anchorage consists of the census, the 1975 Survey, and all-electric homes data; and these sources are not consistent. According to the census, 6 percent of residences were electrically space heated in 1970; while only 4 percent were all-electric homes in the Anchorage utility service areas. Growth in the proportions of all-electric homes was rapid in the early 1970s, based on new all-electric homes as a proportion of all new homes (about

TABLE D.20. NON-NATURAL GAS CUSTOMER CALCULATION

	Total Units	Natural Gas Customers	Non-Natural Gas Customers
Anchorage	39,700	29,520	10,180
Single Family	28,530	22,437	6,093
Duplex	4,581	3,603	978
Mobile Home	6,589	3,480	3,109
Kenai-Cook Inlet	6,177	2,013	4,164
Single Family	3,660	1,363	2,297
Duplex	484	180	304
Mobile Home	2,033	470	1,563

SOURCE: See text.

17 percent). If that growth held through the mid-1970s, then using the all-electric homes information as a base, about 5,800 units would be all-electric presently, or about 10 percent of the total.

Discussions with realtors indicate a significant proportion of multifamily units built in the middle 1970s were electrically heated. The number of building permits issued for multifamily units between 1974 and 1977 was 6,855 (including duplexes[11] until 1977) or about 44 percent of total permits. If their electric space heat installation proportion was double that of the historical trend, then another approximately 1,000 multifamily units were built that were electric. Apart from these multifamily units (including condominiums), electric space heating is allocated based upon total units of each type (not heated by propane, wood, or coal) after an upward adjustment of the total by 3 percent to account for the discrepancy between the census and the Federal Power Commission's estimates of all-electric homes and the growth in housing in areas not served by gas.

In Kenai-Cook Inlet, the census indicates 4 percent electric space heat in 1970; while the proportion from the 1977 Survey for the three cities of Kenai, Soldotna, and Seldovia is 7 percent. Average residential consumption data for Homer Electric Association (HEA) is indicative of a substantial growth in space heating load in the last few years. In 1977, a mail survey of their service area indicated a 33 percent electric space heat proportion for 7,171 active accounts.[12] Based upon consumption data, the 7 percent figure is obviously low, which is logical because Kenai and Soldotna have access to natural gas; while Homer itself does not. We scale down to 30 percent the HEA figure on the assumption that it might be somewhat of an over-estimate for 1977 for first homes but that the electric heat load trend was upward throughout 1977 and 1978. The load is distributed among all structures proportionately after netting out propane, wood, coal, and other fuels.

For Matanuska-Susitna and Seward, natural gas is not an available option. Seward Electric Association estimated 2 percent all-electric homes, and the census reported 4 percent.[13] We compromise on 3 percent and allocate them all to single-family and mobile home units. For Matanuska-Susitna, the census reports 1 percent electrically heated homes, but much of the growth in the housing stock since then has been electrically heated units. If all housing added since 1970 was electrically space heated, the proportion could be over 50 percent even without retrofitting electric systems. A portion of the Matanuska Electric Association (MEA) service area is in Eagle River where natural gas is available. Of total MEA residential customers in 1978, about 3,500 were located in the Anchorage Census Division and 1,856 of these were gas customers. Thus, when MEA calculates 2,685 to be the number of all-electric customers on their system (26 percent), this converts to about 40 percent in the Matanuska-Susitna Borough proper. On the basis of the criterion used by MEA to identify electric space heat customers (2,500 kWh or more on the December bill), they may have underestimated their electric space heating load. With this in mind, as well as a comparison of the average residential bill with HEA which is estimated at

30 percent electric, we raise our estimate of electric space heating to 50 percent. To distribute this among types of units, we assume that use of coal, wood, and propane has fallen from 37 to 15 percent of the total and is not utilized in multifamily units at all. Thus, the allocation is net of this amount.

For Fairbanks, we have information from the census and from the all-electric home data, both of which indicate about 7 percent electric mode split in 1970 and the latter which indicates that the proportion remains constant during the early 1970s. A recent mailback survey reported 11 percent late in 1979.[14] The Fairbanks utilities say that growth was rapid in the mid-1970s but that now, because of the high price of peak electric power, they are discouraging the use of electricity for space heating. In April 1975, Golden Valley Electric Association (GVEA) put a prohibition on further electric space heat installations. In addition, they are assisting people to get off electric space heat and, as a consequence, the average residential consumption fell from a peak of 17,332 kWh in 1975 to 10,524 kWh in 1979. (Their average bill in 1970 was 10,785 kWh.)

On this basis, an electric space heat load of about 800 units (the 1970 number) would be reasonable for 1979 and a slightly higher number for 1978. GVEA estimates that they currently have about 750 electric space heat customers, which would be about 6 percent. We extrapolate back to 1978 and estimate 1,000 electric space heat units in that year which would be 8 percent of the total stock served by both utilities.

To allocate the electric heat among units, we estimate 20 percent of the housing stock is now heated by coal, wood, propane, steam, and other but that those fuels are not used in multifamily units. The electric space heat is evenly distributed among all types of units net of these fuels. The resulting electric space heat mode splits are shown in Table D.21.

Average consumption data is available for past years from the Federal Power Commission All-Electric Homes reports, from engineering analyses, and from inferences drawn from natural gas consumption. Since this last source contains the most recent information and is from a known source, it forms the basis for determining average consumption which will vary according to:

1. location (heating degree days),
2. type of structure, and
3. size of structure (square feet of floor space).

The age of the structure and the habits of the occupants are important sources of variation which cannot be formally addressed at present. In addition, the heating load can vary considerably from year-to-year because of variation in weather conditions.

Using the average annual heat load of 162 mcf calculated for Anchorage Natural Gas customers in 1978, we convert to kWh of electricity on the assumption of 65 percent efficiency for gas space heating and 95 percent for electricity resulting in an electric equivalent of approximately 32,400 kWh. This is the average among three types of

TABLE D.21. 1978 ELECTRICAL SPACE HEATING PERCENTAGES

	Single Family	Duplex	Multi-Family	Mobile Home	Total
Greater Anchorage Area	18.8	18.4	19.9	18.4	19.0
Anchorage	12.9	12.9	18.9	11.9	14.8
Kenai-Cook Inlet	30.0	30.0	32.7	29.4	30.0
Matanuska-Susitna	49.5	49.5	58.7	49.5	50.0
Seward	4.0	0	0	5.0	3.0
Greater Fairbanks Area					
Fairbanks	7.3	7.2	10.0	7.3	8.0
Glennallen-Valdez Area					
Valdez-Chitina-Whittier	2	0	0	0	0

structures of different characteristics and sizes. There are estimated to be 23,800 single-family units, 3,783 duplexes, and 3,950 mobile homes using natural gas, for a total of 31,533 units.

Using this information as well as average structure size and space heating efficiency estimates, the average electric heating load for Anchorage by type of structure can be calculated. This calculation is shown in Table D.22.

Floor space is the average of the values for Fairbanks and the national average. Heating efficiency factors for duplexes are based on the idea that the heating requirement is a function of wall and roof surface area, which increases less than proportionally as floor space increases. Specifically, two duplex units with 1,085 square feet each have a floor area of 2,170 which is 1.47 the area of the average single-family unit. The duplex wall and ceiling area, however, is about 1.38 times the single-family unit, indicating that heating requirements per square foot of floor space will be less. The ratio of outside wall-to-floor space for the duplex is about 1.85 and for the smaller single-family house, 2.05. On this basis, one can calculate that the duplex is about 10 percent more efficient to heat on a square foot basis.

Studies in Fairbanks indicate that a mobile home requires 20 percent more energy to heat per square foot than a single-family unit of the same size. Using this assumption and the fact that the average mobile home has a surface area-to-floor space ratio of about 2.35 (which would mean

TABLE D.22. CALCULATION OF ANCHORAGE ELECTRIC SPACE HEAT LOAD BY TYPE OF UNIT

Type of Unit	Number of Units	Average Floor Space (square foot)	Total Floor Space	Average Heat Requirement Per Square Foot Relative to Total	Average Space Heat Load/Square Foot (kWh)	Average Space Heat Load (kWh)
Single-Family	23,800	1,480	35,224,000	1.0	23.53	34,823
Duplex	3,783	1,085	4,104,555	.9	21.18	22,976
Mobile Home	3,950	820	3,239,000	1.38	32.47	26,626
Total	31,533	1,350	42,567,555	1.02	24	32,400

it consumes about 15 percent more energy per square foot of floor space than the average single-family home), the average heat requirement factor for mobile homes relative to single-family units thus becomes 1.38.

The requirement for a multifamily unit is calculated similarly to that of a duplex assuming an average unit size of 900 square feet and that the average multifamily structure is 8 units. The ratio of surface area to floor space is calculated as 1.48. Compared to the single-family ratio of 2.05, the heating requirement on a square foot basis would only be 72 percent as large. Since the floor space of the multifamily unit is 61 percent that of the single-family unit, the overall energy requirement is calculated at 44 percent of the single-family unit.

Adjustments for other parts of the railbelt are made on the basis of average size of units and average heating degree days. The former is directly available only for Fairbanks, but a general idea of average size of unit is available from information on median rooms from the census. Outlying parts of the Greater Anchorage Area have somewhat smaller units, and Glennallen-Valdez has considerably smaller units than Anchorage.

We assume per-unit heating requirements outside Anchorage are 20 percent less for Kenai-Cook Inlet and Seward and 15 percent less for Matanuska-Susitna than in Anchorage on the basis of smaller average unit size. For Fairbanks, we assume the average size of units is 92 percent of Anchorage, based on actual survey data for Fairbanks on single-family, duplex, and mobile home units.

No difference in heat requirements, based upon variation in heating degree days within the Greater Anchorage Area, is assumed. The ratio of heating degree days in Fairbanks-to-Anchorage for the average of the 1977 and 1978 seasons was 1.43. This information, in addition to average unit size information, results in an estimate of Fairbanks unit requirements at 132 percent of those in Anchorage.

For Glennallen-Valdez, we assume the average unit is 75 percent of the size of an Anchorage unit and average the heating degree days in the different parts of the census division to obtain a ratio to Anchorage of 122 percent. Combining these yields an estimate for Glennallen-Valdez which is about 91 percent that of Anchorage. The results of these calculations are presented in Table D.23.

For projection purposes, it is necessary to adjust the figures on average annual electric space heating requirements to account for the fact that 1978 was a warmer-than-normal year. Adjustment factors, based on the ratio of normal to 1978 heating degree days, are used in the projections and presented in Table D.24.

TABLE D.23.
1978 AVERAGE ANNUAL ELECTRIC SPACE HEATING REQUIREMENT
(kWh)

	Single Family	Duplex	Multifamily	Mobile Home
GREATER ANCHORAGE AREA				
Anchorage	34,800	23,000	15,300	26,600
Kenai-Cook Inlet	27,800	18,400	12,200	21,300
Matanuska-Susitna	29,600	19,600	13,000	22,600
Seward	27,800	18,400	12,200	21,300
GREATER FAIRBANKS AREA				
Fairbanks/Southeast Fairbanks	45,900	30,400	20,200	35,100
GLENNALLEN-VALDEZ AREA				
Valdez-Chitina-Whittier	31,700	20,900	13,900	24,200

TABLE D.24. HEATING DEGREE DAY COMPARISONS

	Average of 1977-78 and 1978-79	Normal	Ratio of Normal to Recent
Anchorage	9,548	10,911	1.14
Fairbanks	13,719	14,344	1.05
Glennallen-Valdez	11,621	12,241	1.05

D.3. MAJOR APPLIANCE SATURATION RATES

Present appliance saturation rates (Table D.25) must be based upon past Alaskan trends in saturation rates, trends in other states, and national trends in the percentage of wired homes which have at least one of a particular appliance. This is because current data on saturation rates is not available. Because future saturation rate projections utilize the same methodology used to develop the present estimates, they are also discussed in this section.

D.3.A. Ranges

The saturation rate is essentially 100 percent for ranges; it is not assumed to change in the future.

D.3.B. Refrigerators

The penetration rate (number of households with at least one unit/ number of households) for refrigerators is assumed to be approximately 100 percent. The saturation rate may exceed 100 percent, however,

TABLE D.25.
1978 CALCULATED APPLIANCE SATURATION RATES

Appliance	Census Division					
	Anchorage	Matanuska-Susitna	Kenai-Cook Inlet	Seward	Fairbanks	Glennallen-Valdez
Hot Water	100	91	94	93	97	91
Clothes Dryers	71	65	76	73	66	48
Freezers	42	62	56	66	42	43
Clothes Washers	76	82	85	83	74	65
Television Sets	156	108	104	147	149	80
Dishwashers	50	35	31	45	36	11
Ranges	100	100	100	100	100	100
Refrigerators	100	100	100	100	100	100
Room Air Conditioners	0	0	0	3	1	0

because of multiple ownership. The California Energy Commission, for example, estimates a saturation rate of between 113 and 116 percent.[15] It can safely be assumed that the colder climate of Alaska reduces the incidence of second refrigerators below that of California, but a saturation rate in excess of 100 is still a possibility. Since no information is currently available on this possibility, however, it is assumed that the saturation rate remains at 100 percent.

D.3.C. Air Conditioners

The incidence of room air conditioners is rare in Alaska. The 1970 saturation rates are assumed to continue in all future years (Table D.26).

D.3.D. Dishwashers

The saturation of dishwashers should be related to the rate of growth of the housing stock since a large proportion of new housing is built with dishwashers. It should also be related to the incidence of households with two wage earners because it is a labor-saving device. On this basis, we assume that the growth in the dishwasher saturation rate since 1970 is slightly in excess of the national average. In 1970, the various Alaskan census divisions were close to or slightly lower than the national average and the Western Region U.S. saturation rates.

Nationally, dishwasher saturation rates have grown at 6 percent annually since 1970, as calculated from data in Table D.27. For Alaska, we assume 7 percent for Anchorage, Fairbanks, and Seward and 8 percent

TABLE D.26. APPLIANCE SATURATION RATES[a]

	Hot Water	Range	Clothes Dryer	Freezer	Clothes Washer	Dish Washer	Television	Room Air Conditioning
GREATER ANCHORAGE AREA								
Anchorage								
1960	95	99	28	29	62	NA	99	1
1970	99	100	59	39	63	29	121	0
Matanuska-Susitna								
1960	64	100	15	43	65	NA	61	0
1970	82	99	47	67	68	19	84	0
Kenai-Cook Inlet								
1960	53	100	18	35	60	NA	43	0
1970	88	98	55	61	70	17	81	0
Seward								
1960	79	93	12	33	72	NA	6	0
1970	87	100	53	71	83	26	114	3
GREATER FAIRBANKS AREA								
Fairbanks								
1960	88	94	21	21	58	NA	88	1
1970	94	100	48	39	61	21	116	1
GLENNALLEN-VALDEZ AREA								
Valdez-Chitina-Whittier								
1960	66	97	6	19	39	NA	26	0
1970	57	98	35	40	54	6	40	0
WESTERN REGION U.S.								
1960	--	--	--	--	--	NA	--	--
1970	99	100	45	28	70	27	122	15

[a]Calculated as the number of appliances divided by occupied housing units. A response of two or more television sets or room air conditioners is counted as two sets.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Tables 29, 30.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Tables 62, 63.
1970 Census of Housing, Detailed Housing Characteristics: United States Summary Tables 23, 24.

TABLE D.27. PERCENTAGE OF ELECTRICALLY WIRED HOMES WITH SELECTED APPLIANCES

	1960	1965	1970	1973	1974	1975	1976	1977
Room Air Conditioners	15.1	24.2	40.6	48.9	51.6	52.8	54.4	55.3
Dishwashers	7.1	13.5	26.5	34.3	36.6	38.3	39.6	40.9
Clothes Dryers (include gas)	19.6	26.4	44.6	53.9	56.5	57.7	58.6	59.3
Freezers	23.4	27.2	31.2	37.9	41.7	43.5	44.4	44.8
Televisions (color)	-	9.5	42.5	67.1	71.5	74.4	77.7	81.3
Televisions (black & white)	89.4	97.1	98.7	99.9	99.9	99.9	99.9	99.9
Clothes Washers	68.3	57.4	62.1	67.8	68.4	69.9	72.5	73.3
Refrigerators	98.2	99.5	99.8	99.9	99.9	99.9	99.8	99.9

SOURCE: U.S. Department of Commerce, Statistical Abstract, annual.

for the other smaller census divisions with lower 1970 saturations. Subsequent to 1980, the saturation rate (S_t) is determined by the following equation:

$$S_t = S_{t-1} + (1-S_{t-1}) * .02$$

The parameter .02 is based upon a rough estimate of the long-run national trend.

D.3.E. Clothes Washers

With respect to clothes washers in 1970, most Alaskan railbelt census divisions had saturation rates relatively close to the national and Western Region U.S. rates. Thus, the same growth rate observed nationally between 1970 and 1977 is applied to Alaskan census divisions to generate 1978 saturation rates. This procedure is modified only in the case of Seward, where it would result in a saturation rate in excess of 100 percent. The saturation rate for Seward is arbitrarily maintained at its 1970 level of 83 percent.

Subsequent to 1978, the increase in saturation rates is assumed to moderate as a practical upper limit on clothes washer saturation would be less than 100 percent. This is based upon the assumption that most apartment units will have washer and dryer units for tenants but at less than a one-to-one ratio. Consequently, the growth of clothes washer saturations are based upon the following equation:

$$S_t = S_{t-1} + (1-S_{t-1}) * .01$$

D.3.F. Clothes Dryers

The 1970 Alaskan saturation rates for clothes dryers are close to the national average except for Anchorage, where it is considerably higher. Thus, all census division saturation rates except Anchorage are assumed to grow at the national average rate between 1970 and 1978. Anchorage already had reached the average national saturation rate for 1978 of 59 percent in 1970. Also, Anchorage figures reflect a higher-than-average ratio between clothes dryers and clothes washers. We base the Anchorage clothes dryer estimate on the clothes washer estimate and on this 1970 ratio.

Subsequent to 1978, it is assumed that the ratio between clothes dryers and washers will remain constant so that clothes dryer saturations grow at the same rate as clothes washer saturations.

D.3.G. Freezers

Alaskan freezer saturation rates were consistently and considerably above the national and Western Region rates for 1970. In addition, the rural census divisions had considerably higher saturations than the urban areas, suggesting that the high saturation might be partially attributable to the unavailability of adequate grocery facilities. It seems reasonable to assume that this will continue to be an important factor in determining future freezer saturation rates and, in addition, that the strong hunting and fishing interests of the typical Alaskan will contribute to high freezer saturation rates.

Nationally, the freezer saturation rate has grown about 5 percent annually since 1970, compared to 3 percent annually in the previous decade. These growth rates applied to 1970 Alaskan saturation rates would give unreasonably high values for 1978 and subsequent saturation levels.

We assume that for the Anchorage, Fairbanks, and Valdez-Chitina-Whittier Census Divisions, the annual saturation rate growth rates are one percent. For the other census divisions with unusually high 1970 saturation rates, we assume that they decline by one percent annually to reflect growth in those areas close to adequate grocery facilities.

Subsequent to 1978, those census divisions which have increasing saturation rates continue to grow, based on the following equation:

$$S_t = S_{t-1} + (1-S_{t-1}) * .01$$

while those census divisions with declining saturation rates are assumed to maintain constant saturation rates in future years.

D.3.H. Water Heaters

Alaskan 1970 water heater saturation rates show surprising variation among census divisions. Here national data cannot serve as a guide because the national average is virtually 100 percent. This was the case in Alaska only for Anchorage. One possible explanation for the relatively low saturation rates might be the fact that a percentage of the population in 1970 lived outside utility service areas and also areas where petroleum products were readily available. This proportion of the population has been greatly reduced since 1970 as population growth has centered in the urban areas.

One pattern that does emerge from examination of the historical Alaskan saturation data is that between 1960 and 1970, the saturation rates grew rapidly toward 100 percent (except in the inexplicable case of Valdez-Chitina-Whittier). On this basis, it is reasonable to assume a continuation of those growth trends in the 1970s. We assume that between 1970 and 1978 nonsaturation (1-S) is reduced by 50 percent in each instance, except for Valdez-Chitina-Whittier which is arbitrarily set equal to Matanuska-Susitna. Subsequent saturation rate growth results in 100 percent saturation by 1990.

D.3.I. Television Sets

The differences in television saturation rates between Alaska census divisions and the nation likely reflect the possibility of the household's receiving a television signal. Thus, Anchorage has a pattern close to the national growth, while the saturation of television sets in Seward grew dramatically between 1960 and 1970.

Nationally, growth in saturation in the 1970s has been the result of increased ownership of color television sets, which nearly doubled between 1970 and 1977. We assume the same growth rates in the 1970s for Alaskan census divisions, except for Valdez-Chitina-Whittier which is assumed to follow the pattern of Kenai-Cook Inlet with an approximate ten-year lag.

Future growth of television saturations will be modest if recent national trends can be used to gauge future trends. Alaskan growth will continue to lead national trends, but Alaskan saturations will not reach national levels. We assume a growth in saturation as follows:

$$S_t = S_{t-1} + (2-S_{t-1}) * .02$$

D.4. MAJOR APPLIANCE FUEL TYPE MODE SPLIT

Four appliances--water heaters, ranges, clothes dryers, and refrigerators--may normally be designed to operate on fuels other than electricity. The appliance mode split, defined as the proportion of appliances using a particular energy fuel, is determined by current relative prices of fuels and appliances and consumer tastes, as well as the past values for these variables. That is, the current mode split will partially be a reflection of past patterns of relative prices which are no longer relevant for the purchase of new appliances so that the mode split observed at any point in time may not be an equilibrium split.

Because mode split is determined by these factors, national information is not particularly applicable to Alaskan conditions. In order to calculate mode split, we thus rely on Alaskan information. Because information on consumption of other fuels in these appliances is relevant to the determination of what percentage of the appliance utilizes electricity, it is utilized wherever appropriate. (It is basically used to provide a check on the mode split by insuring that some alternative fuel has not been allocated an unrealistically large or small percentage of total appliances of a particular type.)

Information to develop the mode split estimates shown in Table D.28 comes primarily from the census of housing (Table D.29) and conversations with utility, home construction, and real estate personnel.

D.4.A. Within the Natural Gas Service Area

The starting point of the analysis is to net out, where applicable, natural gas utility sales. No natural gas refrigerator sales have been identified, except for campers and recreational vehicles; so water heaters, ranges, and clothes dryers are the appliances which may be gas fired. From the 1970 census and more recent national data, one can calculate ratios between gas space heating customers and gas water heating and cooking customers. These ratios are shown in Table D.30.

They indicate that the choice of gas water heat is closely associated with the gas space heat decision but that such may not be the case for cooking fuel. In particular, Anchorage is far below the national average for gas ranges among natural gas customers.

TABLE D.28. 1978 ELECTRICAL APPLIANCE MODE SPLITS

	CENSUS DIVISION						
	Anchorage	Matanuska-Susitna	Kenai-Cook Inlet	Seward	Greater Anchorage Area	Fairbanks	Glennallen
Water Heater	33	43	41	35	34	43	40
Range	66	75	35	53	64	81	40
Clothes Dryer	91	96	78	70	90	98	75
Refrigerator	100	100	100	100	100	100	100

TABLE D.29. WATER HEAT MODE SPLIT INFORMATION

	PROPORTION OF APPLIANCES USING VARIOUS FUELS[a]						
	Utility Gas	Oil	Electric	Coal	Wood	Propane	Other
GREATER ANCHORAGE AREA							
Anchorage							
1960	0	41	39	15	0	4	1
1970	45	13	35	1	0	4	2
Matanuska-Susitna							
1960	0	19	50	20	7	4	0
1970	0	28	38	11	12	11	0
Kenai-Cook Inlet							
1960	0	60	21	7	0	12	0
1970	34	17	37	2	0	9	1
Seward							
1960	33	57	0	0	5	5	0
1970	0	60	35	0	0	5	0

[a]Proportions sum to 100.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Tables 29, 30.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 63.

TABLE D.29. (continued)

WATER HEAT MODE SPLIT INFORMATION

	PROPORTION OF APPLIANCES USING VARIOUS FUELS[a]						
	Utility Gas	Oil	Electric	Coal	Wood	Propane	Other
GREATER FAIRBANKS AREA							
Fairbanks and Southeast Fairbanks							
1960	0	23	19	48	0	9	1
1970	3	33	37	15	0	8	4
GLENNALLEN-VALDEZ AREA							
Valdez-Chitina-Whittier							
1960	0	56	4	0	0	0	40
1970	0	41	36	0	0	23	0

[a]Proportions sum to 100.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Tables 29, 30.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 63.

TABLE D.29. (continued)

COOKING APPLIANCE MODE SPLIT INFORMATION

	PROPORTION OF APPLIANCES USING VARIOUS FUELS[a]						
	Utility Gas	Oil	Electric	Coal	Wood	Propane	Other
GREATER ANCHORAGE AREA							
Anchorage							
1960	2	8	64	0	0	26	0
1970	20	1	65	0	0	14	0
Matanuska-Susitna							
1960	6	7	38	1	15	33	0
1970	0	1	44	0	16	38	1
Kenai-Cook Inlet							
1960	21	17	23	8	0	31	0
1970	30	4	24	1	1	40	0
Seward							
1960	0	29	35	0	4	32	0
1970	4	15	47	0	0	34	0

[a]Proportions sum to 100.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Tables 29, 30.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 63.

TABLE D.29. (continued)

COOKING APPLIANCE MODE SPLIT INFORMATION

	PROPORTION OF APPLIANCES USING VARIOUS FUELS[a]						
	Utility Gas	Oil	Electric	Coal	Wood	Propane	Other
GREATER FAIRBANKS AREA							
Fairbanks and Southeast Fairbanks							
1960	3	2	62	2	2	29	0
1970	4	1	76	0	1	18	0
GLENNALLEN-VALDEZ AREA							
Valdez-Chitina-Whittier							
1960	3	19	29	0	14	35	0
1970	6	6	18	0	5	65	0

[a]Proportions sum to 100.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Tables 29, 30.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 63.

TABLE D.29. (continued)

CLOTHES DRYING APPLIANCE MODE SPLIT INFORMATION

	PROPORTION OF APPLIANCES USING VARIOUS FUELS[a]		
	Utility Gas	Oil	Electric
GREATER ANCHORAGE AREA			
Anchorage			
1960	1	0	99
1970	9	0	91
Matanuska-Susitna			
1960	0	0	100
1970	7	0	93
Kenai			
1960	15	0	85
1970	22	0	78
Seward			
1960	18	0	82
1970	30	0	70

[a]Proportions sum to 100.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Tables 29, 30.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 63.

TABLE D.29. (continued)

CLOTHES DRYING APPLIANCE MODE SPLIT INFORMATION

	PROPORTION OF APPLIANCES USING VARIOUS FUELS[a]		
	Utility Gas	Oil	Electric
GREATER FAIRBANKS AREA			
Fairbanks and Southeast Fairbanks			
1960	1	0	99
1970	2	0	98
GLENNALLEN-VALDEZ AREA			
Valdez-Chitina-Whittier			
1960	100	0	0
1970	50	0	50

[a]Proportions sum to 100.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Tables 29, 30.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 63.

TABLE D.30. PROPORTION OF GAS SPACE HEATING CUSTOMERS WITH OTHER GAS APPLIANCES

	Water Heater	Range
Anchorage 1970	.84	.38
Kenai-Cook Inlet 1970	.96	.94
United States 1970	1.00	.89
United States 1975	--	.79

SOURCES: 1970 Census of Housing, Detailed Housing Characteristics: Alaska.

American Gas Association, Gas Facts, annual.

We assume that since 1970 the ratios of gas water heating to gas space heating have approached 100 percent and the gas range ratio has increased in Anchorage and remained constant in Kenai-Cook Inlet. Growth in the housing stock in each census division has been about 50 percent since 1970 so that the differences between the national and local ratios could have declined by 30-to-50 percent. We assume 50 percent for water heaters to arrive at 92 percent for Anchorage and 98 percent for Kenai-Cook Inlet. Noting the declining ratio in gas ranges nationally, we estimate 50 percent for Anchorage and 90 percent for Kenai-Cook Inlet.

This yields the mode split estimates for gas water heaters and ranges for 1978, shown in Table D.31.

TABLE D.31. 1978 GAS APPLIANCE MODE SPLIT ESTIMATES

	Gas Space Heat	Gas Hot Water	Gas Range
Anchorage	.69	.63	.35
Kenai-Cook Inlet	.33	.32	.30

Comparing these estimates to the 1970 census information on mode split indicates that the gas mode split has grown in Anchorage and has remained constant in Kenai-Cook Inlet. This is consistent with the observation that growth in Kenai-Cook Inlet has been balanced between areas accessible to gas and those not accessible to gas.

To determine the electric mode split for these regions and appliances, use is made of an incremental mode split calculation using the 1960 and 1970 censuses. These incremental mode splits are calculated as the increments to the number of a particular appliance between 1960 and 1970 divided by the increment to total housing units over the same period (see Table D.32). Applying these incremental mode splits for electric water heating and cooking to the increase in housing units between 1970 and 1978 (about 50 percent) results in average mode splits which are reasonable when considered in relation to the natural gas mode splits, except for ranges in Kenai-Cook Inlet. These values are, therefore,

TABLE D.32. INCREMENTAL MODE SPLIT CALCULATIONS BASED UPON HOUSING CENSUS DATA

	Built-In Electric Units	Electric Space Heating Fuel	Electric Water Heating Fuel	Electric Cooking Fuel	Electric Clothes Dryer
GREATER ANCHORAGE AREA					
Anchorage	.1403	.1695	.2962	.6706	.9841
Matanuska-Susitna	.0525	.0676	.2770	.7669	1.8919
Kenai-Cook Inlet	.0815	.0638	.4989	.2378	.6410
Seward	0.0	-0.0486	.1991	.1644	- .2431
GREATER FAIRBANKS AREA					
Fairbanks/Southeast Fairbanks	.8320	.5553	1.6292	2.0463	2.3406
GLENNALLEN-VALDEZ AREA					
Valdez-Chitina-Whittier	.0427	0.0	.7974	-0.1897	.7672

SOURCES: Census of Housing: 1970 Detailed Housing Characteristics Final Report HC(1)-B3, Alaska.

U.S. Census of Housing: 1960 Vol. 1, States and Small Areas Final Report HC(1)-3, Alaska.

used as the estimates, except that the Kenai-Cook Inlet range estimate is increased based on Homer Electric Association survey data. For gas clothes dryers, the 1970 mode split is used for 1978.

D.4.B. Outside the Natural Gas Service Area

For Matanuska-Susitna, the information from the census is difficult to interpret because, between 1960 and 1970, electric water heaters declined as a percentage, while those of wood and propane increased. Wood and propane also gained as cooking fuels, but electricity also increased at the expense of oil. One explanation of this phenomenon would be that the population increase was in relatively inaccessible areas and, thus, the same pattern of growth might not be expected to have occurred in the more recent decade.

If we can assume that 90 percent of the appliances used by new residents since 1970 are oil or electric, then the proportions accounted for by coal, wood, propane, and other fall to about 18 percent for water heat and 30 percent for cooking and 4 percent for clothes drying. This is based upon the observation that the number of residences has essentially doubled since 1970. In addition, changeovers of existing appliances toward electricity and oil probably occurred, thus further decreasing the proportions of the other fuels. If this was about 25 percent, then the remaining percentages would be 14 percent for water heat and 23 percent for cooking, with clothes drying assumed unchanged.

In the absence of better information, we assume an equal mode split between oil and electricity for water heat and a continuation of the 1970 census ratio for cooking.

In Seward, electric appliances made impressive gains over propane and oil in the 1960s as a proportion of the totals in spite of declines in the total housing stock. At the same time, oil maintained its share of the water heat market. In the absence of other information, we assume a continuation of the same mode splits for water heat and clothes drying. For cooking, we assume 75 percent of new households choose electricity, which brings the electric mode split up to 53 percent.

Fairbanks electricity consumption for water heat increased in the 1970s, as did fuel oil consumption, both at the expense of coal which was rapidly phased out. We assume that no new housing since 1970 uses coal and that half the existing coal units have been converted. This leaves coal with about 4 percent mode split in 1978 since the housing units in Fairbanks have nearly doubled in the 1970s. We assume that the other fuels, except oil and electricity, maintain their 1960 mode splits and that oil and electricity maintain their 1970 ratio, which gives a 43 percent split for electricity.

Electricity is preferred for cooking by the majority of Fairbanks households. If 85 percent of new households since 1970 chose it, then the electric cooking mode split would be about 81 percent. We assume the clothes drying mode split is unchanged from 1970.

In the Glennallen-Valdez area, electric water heaters become much more popular in the 1960s. On the other hand, the electric mode split for cooking fell. In the absence of other information, we assume the mode splits for the Glennallen-Valdez area move toward those of similar parts of the railbelt, as reflected in the 1970 census.

D.5. ELECTRICAL APPLIANCE AVERAGE ANNUAL CONSUMPTION

A reliable library of information on average electricity consumption by various appliances is just now beginning to emerge based upon manufacturer estimates, modeling efforts, and actual surveys which monitor consumer behavior. Some of the more widely circulated estimates appear as Table D.33. These estimates are all national averages.

Examination of the various estimates reveals several important facts. First, only one--the Midwest Research Institute--is based upon actual metering of appliances; and it shows a considerable variance from other sources for the use of several appliances. Their results for ranges, dishwashers, and water heaters are below the others and for refrigerators, considerably above. This suggests actual use patterns may be considerably different from those assumed by manufacturers and other researchers.

Second, the consumption of electricity by appliances depends upon the features of the appliance. In particular, larger refrigerators and

TABLE D.33. AVERAGE ANNUAL ENERGY CONSUMPTION ESTIMATE FOR MAJOR APPLIANCES: VARIOUS SOURCES

(kWh/year)

	1976-1977 Midwest Research Institute[a]	Edison Electric Institute[b]	1968 Stanford Research Institute[c]	1970 Arthur D. Little[d]	1973 Merchandising Week[e]	1976 California Energy Commission[f]	1978 California Energy Commission[g]
Water Heater	4,046	4,811	4,490	5,626	4,515	3,025	4,876
Cooking	-	-	1,180	1,143	-	1,200	-
Range	782	700	-	-	2,071	-	778
Auto. Clothes Washer	88	103	98	88	90	70	76
including hot water	-	2,500	-	-	-	1,115	-
Clothes Dryer	1,032	993	990	937	993	950	1,212
Refrigerator (12 cu.ft.)	1,665	-	1,270	1,084	1,228	1,235	1,515
frostless (12 cu.ft.)	-	728	-	-	-	-	-
Refrig/Freezer (12 cu.ft.)	-	1,217	-	-	-	-	-
frostless (12 cu.ft.)	-	1,500	-	-	-	-	-
frostless (17.5 cu.ft.)	-	2,250	-	-	-	-	-
Freezer	1,342	-	-	1,348	1,480	-	1,294
regular (16 cu.ft.)	-	1,190	-	-	-	-	-
frostless (16.5 cu.ft.)	-	1,820	-	-	-	-	-
Dishwasher	149	363	360	352	363	230	305
including hot water	-	2,100	-	-	-	925	-
Television - Black & White							
tube	-	350	360	-	-	-	-
solid state	-	120	-	-	-	-	-
general	-	-	-	-	362	140	129
Television - Color							
tube	-	660	490	-	-	-	-
solid state	-	440	-	-	-	-	-
general	-	-	-	-	502	420	300
Television - General	-	-	-	439	-	-	-
Air Conditioner	978	860	-	-	1,389	-	-

SOURCES FOR TABLE D.33.

(a) Midwest Research Institute, Patterns of Energy Use by Electrical Appliances, EPRI EA 682, January 1979, p. 5-3.

(b) Edison Electric Institute.

(c) Office of Science and Technology Executive Office of the President, Patterns of Energy Consumption in the United States.

(d) Federal Energy Administration, Project Independence Blueprint Final Task Force Report, Residential and Commercial Energy Use Patterns 1970-1990. Under the Direction of Council on Environmental Quality, November 1974, Volume I, p. 98. (Presented in btu's and converted by author.)

(e) Merchandizing Week as reported in Patterns of Energy Use by Electrical Appliances, EPRI EA 682, p. 5-23.

(f) California Energy Commission, "Appendix A: Analysis of Residential Energy Uses," 300-76-034, 1976.

(g) California Energy Commission, "California Energy Demand 1978-2000: A Preliminary Assessment," August 1979, Table D.5. These figures are for new appliances purchased in 1978.

freezers, as well as frost-free features, add considerably to annual energy requirements. In contrast, solid state televisions use considerably less electricity than tube models.

Third, the consumption of hot water, and thus of electricity by a water heater, is related to the ownership and utilization of dishwashers and clothes washers.

Because of these complications, it is not a straightforward matter to apply national averages to Alaska. Furthermore, average annual consumption of electricity in various appliances will vary as a function of the following:

1. geographic location
2. size of household
3. income of household
4. age of appliance stock.

Geographic location is obviously a factor in room air conditioning consumption and appears also to be an important facet in refrigerator and freezer consumption, although the information is preliminary.[16] It is reasonable to assume that refrigerators need not work as hard in colder climates and will not be opened and closed as often. Water heating requirements may vary based upon the average annual inlet temperature of the cold water being heated.

It is also reasonable to expect that use of electric ranges, clothes washers and dryers, water heaters, and perhaps dishwashers would be related to household size. There is some statistical information and research to support this hypothesis.[17] The relationship appears most important for clothes washers where consumption might be estimated as a simple multiple of household size; while for the others, there is a significant "base load" independent of household size.

Common sense and economic theory suggest that households with higher incomes will prefer appliances with features which may (frost-free and large refrigerators) or may not (solid state television sets) be more energy using than the average. This idea is related to the age of the appliance stock which is a reflection of past purchase decisions based upon past income levels. As incomes grow over time, the existing stock of appliances will not accurately reflect present income levels of households but rate back present and past levels.

There is no direct information available on Alaskan-specific electricity consumption in various large appliances or how that consumption may differ from national norms. On the basis of climate, one might assume higher-than-average use for water heaters and ranges and lower-than-average use for air conditioners and refrigerators. On the basis of a slightly smaller average household size in Alaska, use of clothes washers and dryers, water heaters, and dishwashers might be less than the average. On the basis of income and the appliance stock, Alaska could be less than or greater than the national average. Contributing to a lower average for Alaska would be the fact that, historically, Alaskan personal income per capita has been less than the national average. The higher-than-average per capita income in recent years in combination with rapid growth in the appliance stock could more than offset this, however.

Since there is no clear direction to adjust the national data, the choice becomes essentially that of choosing among the various national series available. The choice makes significant difference only in the cases of water heaters, ranges, refrigerators, and dishwashers and clothes washers.

We use the California Energy Commission's estimates of water heat consumption because they separate out consumption related to clothes and dish washing machines. The latter, we attribute directly to those appliances based upon the probability of an owner of an electric washer also owning an electric water heater. This could be an underestimate because of not counting hot water consumption for dish washing by those households without dishwashers. To adjust for this and the added heating load caused by a colder-than-average water inlet temperature, we adjust the base figure upward by 15 percent.

We define the appliance entitled "range" broadly to encompass all heating for cooking purposes, including electric skillets, etc. This probably accounts for the discrepancies among the national estimates.

Variation among estimates for refrigerator consumption is considerable and is a function of the average size and type of refrigerator assumed for the stock. The Midwest Research Institute estimate may be high because the sample chosen for metering was 97 percent single-family homes and duplexes.[18] The other estimates fall within a much narrower band.

Variation in freezer use is again a function of the stock although the various sources are in general agreement as to the average stock characteristics and electricity consumption. Anchorage merchants indicate most of their sales are in the manual defrost category, so we choose a lower-range estimate.

Clothes dryer consumption may be nearer the high range of estimates in Alaska because of the cold climate. Air conditioner consumption will be considerably below the national average, and television consumption is a broad average of all estimates. The values used in the model are summarized in Table D.34.

TABLE D.34. MODEL VALUES FOR MAJOR APPLIANCE AVERAGE CONSUMPTION FOR 1978

	Average kWh/Year
Water Heater	3,475
Range	1,200
Clothes Dryer	1,000
Clothes Washer	70
Clothes Washer Hot Water	1,050
Refrigerator	1,250
Freezer	1,350
Dishwasher	230
Dishwasher Hot Water	700
Television	400
Air Conditioner	400

D.6. SMALL ELECTRIC APPLIANCE USE

The average annual electricity requirements of several common, smaller electrical appliances are listed in Table D.35. Individually, the electricity used in each is not a large amount; but in the aggregate, it can be substantial for a household. Netting out the calculated quantities of electricity consumed in the residential sector for large appliances and space heating results in the amounts attributable to small appliances in 1978 as shown in Table D.36.

TABLE D.35. AVERAGE ANNUAL CONSUMPTION OF VARIOUS SMALL APPLIANCES

(kWh)

Trash Compactor	50
Iron	144
Electric Blanket	147
Humidifier	163
Hair Dryer	14
Clock	17
Sewing Machine	11
Vacuum Cleaner	46
Hi-fi (tube)	120
Hi-fi (solid state)	30
Radio (tube)	100
Radio (solid state)	10
Headbolt Heater	480
Garbage Disposal	36
Lighting	720

SOURCE: Edison Electric Institute, Canadian Wind Energy Program Papers by the National Research Council of Canada, and Alaska Village Electrical Cooperative "Light Lines," May 1978.

TABLE D.36. 1978 RESIDENTIAL ELECTRICITY CONSUMPTION ATTRIBUTABLE TO SMALL APPLIANCES

	kWh/Customer
Greater Anchorage Area	2,010
Greater Fairbanks Area	2,466
Glennallen-Valdez Area	2,333

It is not possible at present to identify the specific small appliance mix in each region or to account for the interregional differences in small appliance consumption. We assume the Alaskan lighting load is considerably greater than the national average and arbitrarily set it at 1,000 kWh annually. The remainder is attributed to all other small appliances.

D.7. COMMERCIAL-INDUSTRIAL REQUIREMENTS

Commercial and industrial electricity requirements supplied by utilities are combined because of the small industrial base in the railbelt. Table D.37 presents the distribution of employment by category and indicates the relatively small size of manufacturing employment in the railbelt economy. Table D.38 further shows that the total number of manufacturing establishments is small (244), that they average 16 employees, and that a large number are food and kindred products (at least 47) or

TABLE D.37. 1978 WAGE AND SALARY EMPLOYMENT

	Government Civ.	Government Mil.*	Trade	Services	Finance-Ins.-R.E.	Trans.-Comm.-Utilities	Manuf.	Const.	Mining	Misc.	Total
GREATER ANCHORAGE AREA											
Anchorage	21,161	11,098	16,865	15,526	5,081	7,924	1,683	6,431	1,874	459	88,040
Kenai-Cook Inlet	1,414	0	1,190	853	197	574	989	485	805	58	6,565
Matanuska-Susitna	1,220	7	639	363	124	307	**	235	**	**	3,090
Seward	313	101	**	164	16	**	**	12	**	**	1,327
GREATER FAIRBANKS AREA											
Fairbanks	7,218	5,399	4,072	3,939	1,004	2,765	564	1,960	54	86	27,061
Southeast Fairbanks	570	845	**	157	**	24	**	**	0	**	1,719
GLENNALLEN-VALDEZ AREA											
Valdez-Chitina-Whittier	838	0	259	409	56	362	**	89	**	**	2,043

*Active duty

**Information withheld under regulations protecting confidentiality of data for individual firms.

SOURCE: State of Alaska Department of Commerce and Economic Development, Division of Economic Enterprise, "Numbers: Basic Economic Statistics of Alaska Census Divisions," 1979.

TABLE D.38. RAILBELT MANUFACTURING ACTIVITY

	Number of Reporting Units in 1979						
	Anchorage	Kenai-Cook Inlet	Matanuska-Susitna	Seward	Fairbanks	Southeast Fairbanks	Valdez-Chitina-Whittier
Food and Kindred	23	20	-	-	4	-	-
Textile Mills	2	0	-	-	0	-	-
Apparel and Other Textiles	6	1	-	-	2	-	-
Lumber and Wood	10	4	-	-	4	-	-
Furniture and Fixtures	1	0	-	-	2	-	-
Paper	1	0	-	-	0	-	-
Printing and Publishing	33	4	-	-	7	-	-
Chemicals	1	1	-	-	0	-	-
Petroleum and Coal	2	2	-	-	1	-	-
Rubber and Misc. Plastics	4	0	-	-	1	-	-
Leather and Products	0	0	-	-	0	-	-
Stone, Clay, Glass	8	5	-	-	3	-	-
Fabricated Metal	8	0	-	-	3	-	-
Nonelectrical Machinery	10	3	-	-	3	-	-
Electrical Equipment	1	0	-	-	1	-	-
Transportation Equipment	4	5	-	-	0	-	-
Instruments	1	0	-	-	0	-	-
Miscellaneous	18	1	-	-	3	-	-
Total Reporting Units	133	46	14	11	34	2	4
Average Second Quarter 1979 Employment	1,709	1,155	35	*	682	*	15

*Information withheld under regulation protecting confidentiality of data.

SOURCE: State of Alaska Department of Labor, Statistical Quarterly, Second Quarter 1979.

printing and publishing (at least 44). Petroleum processing and seafood processing are the most visible components of the manufacturing sector in terms of employees.

Electricity and other energy end use in the commercial sector is most conveniently tabulated on the basis of the energy requirement per square foot of floor space. An accurate measure of this quantity--and its disaggregation into types of commercial floor space--is not available for any portion of the railbelt at the present time.[19] The only fragment of information available is an unpublished study conducted by the Municipality of Anchorage Planning Department which classified all nonresidential floor space by use.[20] An attempt was made, shown as Table D.39, to modify and update the survey results to make them compatible with the purposes of this study. The result is an estimate of 37 million square feet of floor space in Anchorage in 1978. This figure is about 35 percent higher than would be calculated using Anchorage employment and national square feet per employee ratios. The difference may be attributable to a high vacancy rate in Anchorage office and retail space, a large proportion of newer construction, or the mix of employment within industries. This result is also considerably higher than a recent informal realtor survey.[21]

Estimates of floor space in other regions of the railbelt can be based either on national ratios of floor space per employee or on the estimate developed for Anchorage.[22] The Anchorage ratio is preferred because it is based, however roughly, on Alaskan data.

TABLE D.39.
CALCULATION OF ANCHORAGE
COMMERCIAL-INDUSTRIAL FLOOR SPACE

		10^3 ft.^{2}
AMATS Survey (Anchorage Bowl, 1975)		42,067
Minus Non-energy Using (parking lots, cemetaries, etc.)		18,918
Energy Using Floor Space		23,149
20 Percent Adjustment for Underreporting		4,630
		27,779
Sectors not Included in Survey:		
1. Girdwood/Indian[a]		53
2. Eagle River/Chugiak[b]		300
3. Hotels/Motels[c]		1,000
4. Assorted Cultural Buildings[d]		500
		29,632
Retail Trade	6,148	
Warehousing	3,722	
Education	3,528	
Wholesale Trade	3,131	
Transport-Communication-Public Utilities	2,663	
Government	1,405	
Manufacturing	706	
Other	7,331	
Growth Between 1975-1978[e] (approximately 25 percent)		7,400
1978 Estimated Commercial-Industrial Floor Space[f]		37,000
General	25,120	
Education	5,000	
Warehousing	4,520	
Hotels	1,500	
Manufacturing	860	

See following page for table notes.

TABLE D.39. (continued)

(a) Twenty-five businesses in 1975 according to telephone book. Assume 2,500 square feet/business.

(b) Based on the ratio of the housing stock in 1978 between Eagle River/Chugiak and Anchorage.

(c) Assumes 2,000 rooms at 500 square feet/room. Based on Oak Ridge National Laboratory, "Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use," Oak Ridge, Tennessee, p. 40.

(d) Forty-six establishments identified in 1975 telephone book. Average size assumed to be 10,000 square feet.

(e) This is based upon two indicators. The first is the growth in employment between 1974-75 and 1978. Civilian employment was as follows: 1974 - 58,700, 1975 - 69,650, and 1978 - 76,900. Employment growth was 31 percent in the period 1974 to 1978 and 10 percent in the period 1975 to 1978. (State of Alaska, Department of Labor, Alaska Labor Force Estimates by Industry and Area, various issues.) The second is the growth in the appraised value of buildings over the period 1975 to 1978. After adjusting for inflation, the increase was 48 percent. Based on the assumption that the rapid employment increase in 1975 resulted in undersupply of floor space in that year, we assume a 25 percent growth in floor space between the summer of 1975 and 1978.

(f) Independent estimates of floor space in 1978 in the educational category and the hotel/motel category were available from the Anchorage School District and Anchorage Chamber of Commerce, respectively. The remaining growth was allocated proportionately among the other categories.

On this basis, 1978 commercial-industrial floor space estimates for the railbelt have been developed and are presented in Table D.40, using the Anchorage estimate of 480 square feet per employee.

TABLE D.40. 1978 COMMERCIAL-INDUSTRIAL FLOOR SPACE ESTIMATES

	Million Square Feet
GREATER ANCHORAGE AREA	42.3
Anchorage	37.0
Kenai-Cook Inlet	3.2
Matanuska-Susitna	1.5
Seward	.6
GREATER FAIRBANKS AREA	10.8
Fairbanks	10.4
Southeast Fairbanks	.4
GLENNALLEN-VALDEZ AREA	
Valdez-Chitina-Whittier	1.0

Because different types of commercial establishments have different energy use characteristics, it is useful to categorize the commercial-industrial floor space by type of use. Unfortunately, it is not possible to do this accurately with the data that is presently available beyond the general categorization of the preceding Table D.39.

Several studies at the national level and for other regions have broken the commercial sector into separated categories and have estimated the annual energy requirements for each on a square foot basis or a per-employee basis. Table D.41 reveals that no consistent pattern has emerged

TABLE D.41.

CATEGORIZATION OF THE COMMERCIAL SECTOR
VARIOUS END-USE ANALYSES

CEC[a]	FEA (1974)[b]	FEA (1977)[c]	PEW[d]	NYS[e]	PRNL[f]	NEPOL[g]
Offices	Offices	Retail	Offices	State Bldgs.	Retail-Whlse.	Forestry-Fishing-Construction
Restaurants	Retail	- food	Dispersed Retail	Health Care	Educational	Transportation & Public Utilities
Retail	Schools	- restaurants	CBD Retail	Education	Public Admin.	Wholesale Trade
Groceries	Hospitals	- office	Other	Local Gov't.	Finance & Office	Retail Trade
Warehouse	Other	- other		Office	Health	Finance-Insurance-Real Estate
Elementary & Secondary Schools		Wholesale			Hotel	Services & Gov't.
Health		- warehouse			Warehouse	
Hotel		- non-ref.			Religious	
Misc.		Finance-Insurance-Real Estate			Garage	
State Offices		- office			Other	
		- lodging				
		- laundry				
		- recreation				
		- automotive				
		- outdoor activities				

SOURCE: (a) California Energy Commission, "California Energy Demand 1978-2000: A Preliminary Assessment," 1979.

(b) Federal Energy Administration, "Residential and Commercial Energy Use Patterns, 1970-1990," 1974.

(c) Federal Energy Administration, National, Energy Information Center, "Energy Consumption in Commercial Industries by Census Division - 1974," March 1977.

(d) T. Owen Carroll et al. "The Planners Energy Workbook," Brookhaven National Laboratory and State University of New York Land Use and Energy Utilization Project.

TABLE D.41. (continued)

(e) New York State Energy Office, "Development of a Commercial Sector Energy Use Model for New York State," 1979.

(f) Jerry R. Jackson and William S. Johnson, "Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use," Oak Ridge National Labs., 1978.

(g) NEPOL Load Forecasting Task Force and Battelle Columbus, "Report on Model for Long-Range Forecasting of Electric Energy and Demand to the New England Power Pool," 1977.

in terms of the categorical breakdown utilized by different researchers either because of data restrictions, different objectives, or different perceptions and data availability concerning end-use patterns in different sectors. Most researchers separate office, retail, warehousing, educational, and health-related buildings as having obviously different energy end-use characteristics.

The most useful national source of information on energy consumption in the commercial sector for this study proved to be an analysis done by the Oak Ridge National Laboratory. Based upon their analysis of end use, Table D.42 was constructed, and it shows, for various components of the commercial sector, both proportion of energy consumed in various uses and the space heating load relative to office space.

For Alaska, there is scattered information available on energy and electricity use on a square foot basis, essentially all of it from public buildings in Anchorage and Fairbanks. This information can be summarized as follows:

1. Based upon an inventory of 4.3 million square feet of space used by the Anchorage School District for the fiscal year 1978-1979, average electricity consumption (none for space heat) was 11.9 kWh/square foot/year. In addition, based upon 4 million square feet, the average natural gas consumption for space heat and related uses during the same period was .143 mcf/square foot/year.

TABLE D.42.

ENERGY USE IN THE COMMERCIAL SECTOR
NATIONAL PATTERN

Commercial Sector	Percent of Fuel Used For Various Activities[a]				Space Heating Requirement per Square Foot Relative to Office Space
	Space Heat	Water Heat	Lighting	Other	
Office	78	4	15	4	1
Retail-Wholesale	80	0	13	7	1.02
Garage & Service Station	83	0	14	3	.45
Warehouse	84	1	12	3	.45
Education	80	5	12	3	.84
Hospital	72	11	10	7	1.58
Religious	87	1	10	2	.67
Hotel	90	5	4	1	1.58
Other	76	3	18	3	.88
				nationally weighted average	1.01

[a]Does not include fuel used for air conditioning.

SOURCE: Jerry R. Jackson and William S. Johnson, "Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use," Oak Ridge National Laboratory, 1978.

2. Anchorage commercial real estate experts use 2-4¢/square foot/month as a rule of thumb for electricity costs in the commercial sector. This converts to between 8 and 16 kWh/square foot/year if electricity averages 3¢ kWh. Gas consumption for space heating is also estimated to cost between .8 and 1.2¢/square foot/month which converts to between .062 and .093 mcf/square foot/year at a gas price of about $1.56 mcf.

3. Consumption of electricity on the Anchorage Community College campus in 1975 averaged 20.8 kWh/square foot/year; and for Kenai and Matanuska-Susitna, it averaged 17.63 kWh/square foot/year.[23]

4. Commercial consumption of electricity in 1975 in the Fairbanks Area averaged 12.3 kWh/square foot/year for 552 thousand square feet of space surveyed. In addition, the 1.6 million square feet of space occupied by the University of Alaska averaged 17.4 kWh/square foot/year.[24] Variation in use among consumers was dramatic, ranging from about 4 kWh to 50 kWh.

5. A 1978 inventory of Fairbanks schools indicates electricity consumption of 12.4 kWh/square foot/year based on 1.2 million square feet. In addition, space heating plus water heating requirements for the schools averaged 136 btu/square foot/year x 10^3 broken down by fuel type as follows: oil - 103 thousand btu, coal - 185 thousand btu, steam - 70 thousand btu.[25]

6. Another Fairbanks survey of public buildings done in 1978 indicates that the space heating requirement in two electrically heated buildings in Fairbanks is 302 thousand btu/square foot/year (88 kWh); and for four buildings heated by fuel oil, the average is 52 thousand.[26]

7. A sample of electricity and natural gas consumption of buildings used by the Anchorage Borough indicates an average consumption of electricity of 21.8 kWh/square foot/year. The figure calculated for gas seemed unreasonably high and so is not reported.

8. The Anchorage International Airport reports electricity use at 51.8 kWh/square foot/year.

No information is available on the incidence of the use of electricity as a fuel for space heating in the commercial-industrial sector, although it is generally agreed that it is not significant. Gas supplies the majority of the load in the Anchorage area, supplemented by fuel oil; and fuel oil, coal, and steam supply the Fairbanks market. Fuel oil and propane serve Glennallen-Valdez.

On the basis of this small amount of data, it is not possible to develop a plausible end use model of the commercial sector.

It is, however, possible to substantiate the assertion that there is little electric space heating in the commercial sector in the Anchorage region and to develop a rough suggestion of electricity end use in the commercial sector. First, we calculate the use of natural gas in the commercial-industrial category. The total of such consumption in 1978 was 6,917,786 mcf, including apartments which are defined in this study to be in the residential sector. Netting out this component of natural gas demand[27] leaves 5,848,922 mcf. Using the school system average consumption figures as a rule of thumb, this amount of consumption could provide space heat to 40.9 million square feet of space, or over 100 percent of the calculated space in the gas service area. Adjusting the school district figure upward by the ratio of general office-to-education building heat requirements taken from the Oak Ridge National Laboratory Report (1.5) yields 27.3 million square feet gas heated. (Natural gas use for process heat and air conditioning is very limited in the Anchorage market.) Thus, at most, somewhat between zero and one-third of commercial space heating requirements in the Anchorage area and within the gas utility service district could have electric space heat.

Second, we confirm the predominance of gas for space heating by allocating nonspace heat electricity consumption. Again using the Oak Ridge National Laboratory (ORNL) information on proportions of fuel used in various activities within a type of commercial building, we calculate the lighting and miscellaneous electricity requirement in various categories of buildings relative to education. We then apply those ratios to the observed electricity consumption figures for electricity in Alaskan educational buildings. This results in Alaskan estimates of nonspace heating and cooling electricity consumption, which are shown in Table D.43.

TABLE D.43. ESTIMATES OF COMMERCIAL ELECTRICITY CONSUMPTION

Sector	Electricity Requirement Relative to[a] Education	Calculated Electricity in kWh Requirement/ft.^{2}/year[b]
Education	1	13
General	1.5	19.5
Warehouse	.53	7
Hotel	.63	8
Manufacturing[c]	1.5	19.5

[a]Based on Jerry Jackson and William Johnson, "Commercial Energy Use: A Disaggregation by Fuel, Building Type and End Use," Oak Ridge National Laboratory, 1978.

[b]Based on 13 kWh/ft.^{2}/year assumed for the education sector (a rough-weighted average of the available information).

[c]Assumed to have the same requirement as general commercial space.

Using this data and the previously calculated information on square footage, it is possible to estimate total electricity use for nonspace heating in the commercial sector and compare it to the actual commercial sales. This is done in Table D.44, which also includes comparable calculations for other portions of the railbelt. By netting this use out of total sales, the amount remaining must be allocated to either space heating, water heating, air conditioning, or process electricity.

The 165,128 MWh calculated for Anchorage could, at 36 kWh annually per square foot for space heat (based again on the Anchorage School District data converted from gas to electricity and adjusted to cover general commercial space using the ORNL data) heat about 4.6 million square feet of Greater Anchorage Area commercial space (about 11 percent). The comparable figures for Fairbanks and Glennallen would be about 12 and 23, respectively, if the electric heating requirement for Anchorage is converted on the basis of heating degree days in these other locations.

The electric space heating load is lower than indicated by this procedure. There are some industrial and miscellaneous users of electricity which consume much larger than average amounts of energy. The Anchorage International Airport, the petroleum-related facilities on the Kenai Peninsula, and the pipeline pump stations in Valdez are examples.

TABLE D.44. CALCULATING THE POSSIBLE USE OF ELECTRICITY FOR SPACE HEATING IN THE COMMERCIAL-INDUSTRIAL-GOVERNMENT SECTOR

Area	Type of Building	Floor Space (10^3 ft.^{2})	Unit Electricity Consumption (non-space heat) kWh/ft.^{2}/year	Total Electricity Consumption (mWh)	Actual 1978 Utility Sales (mWh)	Space Heat or Process Electricity[a] (mWh)
GREATER ANCHORAGE AREA		-	-	721,620	886,748	165,128
Anchorage				618,270	677,021	58,751
	education	5,000	13	65,000		
	general	25,120	19.5	489,840		
	hotel	1,500	7	10,500		
	warehouse	4,520	8	36,160		
	manufacturing	860	19.5	16,770		
Kenai-Cook Inlet						
	general	3,200	19.5	62,400	129,483	67,083
Matanuska-Susitna						
	general	1,500	19.5	29,250	67,835	38,585
Seward						
	general	600	19.5	11,700	12,409	709
GREATER FAIRBANKS AREA						
Fairbanks and Southeast Fairbanks						
	general	10,800	19.5	210,600	271,726	61,126
GLENNALLEN-VALDEZ AREA						
Valdez-Chitina-Whittier						
	general	1,000	19.5	19,500	28,604	9,104

[a]Difference between total utility sales and calculated non-space heat sales.

ENDNOTES: APPENDIX D

1. Anchorage Real Estate Research Report Vol. III, Fall 1979, p. 44. Anchorage Real Estate Research Committee.

2. Ibid., p. 55.

3. FMATS Study of Housing (draft), p. 16.

4. 1970 U.S. Census of Housing, Detailed Housing Characteristics: Alaska, Table 63.

5. In 1970, there were 2,757 year-round housing units unoccupied but not for sale or rent. Not all of these are vacation homes. In 1978, the Municipality estimated 729 residences in Girdwood, of which 198 were full time.

6. Calculated from census data.

7. In 1970, Homer, Kenai, Seldovia, and Soldotna had 2,093 year-round housing units according to the census; and in 1978, 2,570 according to the Kenai Peninsula Borough, Profile of 5 Kenai Peninsula Towns. Applying this growth rate to the whole census division would yield only 5,710 units in 1978.

8. Discussions with AMLP personnel.

9. Fairbanks North Star Borough, FMATS Housing Study (draft), 1980, p. 14.

10. U.S. Department of Commerce, Bureau of the Census, Privately Owned One-Family Homes Completed, 1977, Table 15.

11. Anchorage Real Estate Research Report, Ibid, p. 12.

12. Homer Electric Association, Power Requirements Study 1978, p. C.4.

13. CH_2M Hill, "Feasibility Assessment for Hydroelectric Development at Grant and Crescent Lakes," for Seward Electric Association 1979, p. 10.

14. Fairbanks North Star Borough, "Community Information Quarterly," Spring 1980, p. 81. This survey may have substantial bias, but its direction is uncertain.

15. California Energy Commission, "Appendix A: Analysis of Residential Energy Uses," 1976, Table A.7.2.

16. Midwest Research Institute, "Patterns of Energy Use by Electrical Appliances," DPRI EA-682 project 576, January 1979, p. 5-3.

17. Midwest Research Institute, Ibid., pp. 5-12; and California Energy Commission, Ibid.

18. Midwest Research Institute, Ibid., p. 3-2.

19. A partial tabulation is available for Fairbanks through the Municipality Planning Office in conjunction with the Fairbanks Metropolitan Area Transportation System (FMATS) Studies.

20. Anchorage Metropolitan Area Transportation System (AMATS) Studies.

21. Alaska Center for Real Estate Education and Research and University of Alaska, Anchorage, Department of Real Estate.

22. National estimates are available in Ide Associates Inc., "Estimating Land and Floor Area Implicit in Employment Projections," prepared for U.S. Department of Transportation, Bureau of Public Roads, 1970.

23. Based on studies conducted by Mark Fryer and Associates.

24. Ibid.

25. Ibid.

26. Fairbanks North Star Borough, Community Information Center, "Special Report #4," July 1979, p. 84.

27. Assume 90 percent of non-electrically heated units are gas (14,064). Converting the average heat load to gas yields about 76 mcf per unit or 1,068,864 mcf total apartment gas for space heating demand.

APPENDIX E. ELECTRIC UTILITY SALES PROJECTION METHODOLOGY

E.1. Residential Nonspace Heating Electricity Requirements

The following appliances are identified in this model:

1. water heater
2. range (cooking)
3. clothes dryer
4. refrigerator
5. freezer
6. dishwasher
7. clothes washer
8. television
9. air conditioner
10. small appliances

Time is measured in five-year increments beginning in 1980, and there are three separate regions: Greater Anchorage, Greater Fairbanks, and Glennallen-Valdez.

The electricity requirement for appliance type j at time t for region r (the r notation is dropped in all that follows) ($REQ_{j,t,r}$) is the product of five components. It begins with the number of households (HH_t) multiplied by the appliance saturation rate ($S_{j,t}$). This yields the total number of appliances of type j ($A_{j,t}$). The portion of those appliances which use electricity is determined by the fuel mode split for electricity ($FMS_{j,e,t}$). The result is the number of electric appliances which is multiplied by average annual consumption ($KWH_{j,t}$) to yield preliminary total consumption. This is finally adjusted by an average household size adjustment ($AHS_{j,t}$) to yield total consumption. The equation is as follows:

$$REQ_{j,t} = HH_t * S_{j,t} * FMS_{j,e,t} * KWH_{j,t} * AHS_{j,t} \tag{E.1}$$

Total electricity requirement is the sum over all appliances j.

$$REQ_t = \sum_j REQ_{j,t} \tag{E.2}$$

The number of households (HH_t) is determined by the demographic model. The saturation rates ($S_{j,t}$) are exogenously entered. The average household size adjustment ($AHS_{j,t}$) applies to the following appliances only: clothes washer, water heater, clothes dryer. For these appliances, the adjustment is the ratio of average household size at t to average household size in the base year, 1980. For other appliances, it is one.

The fuel mode split ($FMS_{j,e,t}$) is the proportion of appliances of type j which use electricity.

$$FMS_{j,e,t} = \frac{A_{j,e,t}}{A_{j,t}} \tag{E.3}$$

The number of appliances of type j in period t which use electricity is a function of the previous stock of such appliances ($A_{j,e,t-1}$), the proportion of those appliances which are scrapped ($d_{j,e,t-1}$), and the number of new appliances of type j purchased at time t which utilize electricity ($NA_{j,e,t}$).

At this point, it is useful to distinguish different appliance "vintages," that is to identify the time period during which an appliance was manufactured (and sold). This is important because appliances of different vintages may have inherently different energy-use characteristics. This identification is accomplished by defining the appliance stock at any time t in terms of the initial stock and additions to the stock during each subsequent time period. Each vintage of appliances (m) may have a different scrapping rate ($d^{m}_{j,e,t}$) between time m and time t because of different characteristics. The scrapping rate of the initial stock ($d^{1980}_{j,e,t}$) will differ from that of subsequent vintages because the initial stock is composed of appliances of different ages and, thus, vintages.

For the existing appliance stock, the scrapping rate is also a function of the past growth rate of the stock. Specifically, if g_k is the historical growth rate of the stock and ex_{jk} is the average lifetime, then the scrapping rate in any year y can be approximated by:

$$\frac{g_j}{(1+g_j)^{ex_j - 1}} * (1+g_j)^{y-1980} \qquad \text{(E.4)}$$

This equation captures the phenomenon that the observed annual scrapping rate for a growing appliance stock will be less than (1/average lifetime) and that for a declining appliance stock the scrapping rate will be greater than (1/average lifetime).[a]

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[a] In practice, it was not possible to utilize this function. The scrapping rates for the existing appliance stock were based upon a calculation using the scrapping rate for new appliances extrapolated backwards and weighted by the post-1970 growth rate of the stock.

The stock of electrical appliances of type j at time t ($A_{j,e,t}$) is thus as follows:

$$A_{j,e,t} = A_{j,e,1980} * (1-d^{1980}_{j,e,t}) + NA_{j,e,1985} * (1-d^{1985}_{j,e,t})$$

$$+ \ . \ . \ . + NA_{j,e,t-5} * (1-d^{t-5}_{j,e,t}) + NA_{j,e,t} \tag{E.5}$$

The number of additions to the appliance stock j at time t using electricity is the product of the total number of new appliances at time j ($NA_{j,t}$) and the incremental (or marginal) electrical mode split ($msi_{j,e,t}$). This equation is simply,

$$NA_{j,e,t} = NA_{j,t} * msi_{j,e,t} \tag{E.6}$$

The number of new appliances of type j at time t is the difference between the stock demanded at time t, represented by the number of households multiplied by the saturation rate, and the supply of those appliances which is the stock from the previous period net of scrapping. Thus, it is necessary to consider appliances using all types of fuels in calculating new appliance type j requirements at t. This demand can also be stated in terms of the initial appliance stock and all subsequent additions to the stock as follows:

$$NA_{j,t} = A_{j,t} - \sum_k A_{j,k,1980} * (1-d^{1980}_{j,k,t})$$

$$- \sum_k NA_{j,k,1985} * (1-d^{1985}_{j,k,t}) - \ldots$$

$$- \sum_k NA_{j,k,t-5} * (1-d^{t-5}_{j,k,t}) \qquad (E.7)$$

The average annual electricity requirement in kilowatt hours of appliance type j at time t ($KWH_{j,t}$) is a function of the age distribution of the appliance stock and the electricity requirement for each vintage. Four factors are involved in the determination of the electricity requirement for each vintage. First, there is an average electricity requirement for the existing appliance stock ($kwh_{j,1980}$). Second, there is an average electricity requirement for new additions to the stock in year t ($kwh_{j,t}$). Third, the average size of additions to the appliance stock j may change. This is accounted for by a growth rate on average appliance size subsequent to 1985 ($1+kwhg_j$). Finally, mandatory improvements in appliance efficiency may reduce average electricity requirements for new vintages of appliances. These Federal conservation targets ($cs_{j,t}$) are implemented beginning in the interval 1980 to 1985. The average consumption of appliance j at time t can thus be expressed as the following:

$$KWH_{j,t} = kwh_{j,1980} * [A_{j,e,1980} * (1-d^{1980}_{j,e,t})]/A_{j,e,t} +$$

$$(1+kwhg_j)^{o} * (1-cs_{j,1985}) * kwh_{j,1985} *$$

$$[NA_{j,e,1985} * (1-d^{1985}_{j,e,t})]/A_{j,e,t} + \ldots$$

$$(1+kwhg_j)^{t-1985} * (1-cs_{j,t}) * kwh_{j,1985} *$$

$$[NA_{j,e,t}]/A_{j,e,t} \qquad \text{(E.8)}$$

A major portion of electricity use in dish and clothes washer operation is for water heating. We account for this by separately calculating this component of electricity use in these appliances. The estimate of the use of electricity for water heating for these appliances is the product of the water heater saturation rate, the electric mode split, and the washer saturation rate.

Small appliances are not differentiated. Thus, their electricity requirement is simply the product of the number of households, the initial consumption level (KWH_{1980}), and a growth factor [nkwh * (t-1980)].

$$REQ_{j,t} = HH_t * KWH_{j,t} * [nkwh * (t-1980)] \qquad \text{(E.9)}$$

Electric light consumption is assumed to be a simple multiple of the current consumption level per household and the number of households.

E.2. Residential Space Heating Electricity Requirements

Total residential space heating electricity requirements in region r (not indicated in the algebraic notation for ease of exposition) at time t ($SHREQ_{e,t}$) is composed of the requirements calculated separately for four different types of structures. These are the following:

1. single family
2. duplex
3. multifamily
4. mobile home

The electricity requirement for each type of structure j ($SHREQ_{j,e,t}$) is based upon the required heat load measured in btu's ($TOTBTU_{j,e,t}$), the conversion efficiency of electric devices for producing space heat ($EFF_{j,e,t}$), and the conversion constant between btu and kWh. Algebraically, it is

$$SHREQ_{j,e,t} = TOTBTU_{j,e,t}/EFF_{j,e,t}/CONV_{e} \qquad (E.10)$$

In the present use of the model, the conversion efficiency is assumed constant throughout (no utilization of heat pumps), so the energy requirement can be calculated as kWh throughout.

The space heating requirement for structure type j can be further defined as the product of the number of housing units of type j (HT_{j}), the proportion utilizing electric space heat ($FMS_{j,e,t}$), the average level of consumption ($KWH_{j,t}$), and the utilization rate ($UT_{j,e,t}$).

$$SHREQ_{j,e,t} = HT_{j,t} * FMS_{j,e,t} * KWH_{j,t} * UT_{j,e,t} \tag{E.11}$$

The number of units of housing type j in year t will be a proportion ($HMS_{j,t}$) of the first home housing stock in year t (FHU_t).

$$HT_{j,t} = FHU_t * HMS_{j,t} \tag{E.12}$$

The proportion of housing units of type j at year t using electric space heat will be simply

$$FMS_{j,e,t} = HT_{j,e,t}/HT_{j,t} \tag{E.13}$$

The number of housing units of type j using electric space heat at time t will be a function of the initial stock of such installations ($HT_{j,e,1980}$) plus additions to the stock over time ($NHT_{j,e,t}$) and net of scrapping from the stock over time ($d^m_{j,e,t}$). The rate of scrapping is vintage specific for the reasons mentioned in the appliance stock discussion. Thus, the electric space heat units for structure type j at time t can be written as follows:

$$HT_{j,e,t} = HT_{j,e,1980} * (1-d^{1980}_{j,e,t}) + NHT_{j,e,1985} * (1-d^{1985}_{j,e,t})$$

$$+ \ . \ . \ . + NHT_{j,e,t-5} * (1-d^{t-5}_{j,e,t}) + NHT_{j,e,t} \tag{E.14}$$

New electric heating units for structures of type j at time t are determined by the electric incremental mode split ($msi_{j,e,t}$) applied to all purchasers of space heating appliances for housing units of type j at time t ($NHT_{j,t}$),

$$NHT_{j,e,t} = NHT_{j,t} * msi_{j,e,t} \tag{E.15}$$

New space heating requirements for structures of type j at time t are determined by the difference between the total number of housing units type j required at time t ($HT_{j,t}$) and the existing stock with space heating appliances. We assume the scrapping rate for the housing stock is zero but that there is a scrapping rate for space heating appliances using different fuel types k. Thus, new space heating appliance demand in housing units type j at time t is as follows:

$$NHT_{j,t} = HT_{j,t} - \sum_k HT_{j,k,1980} * (1-d^{1980}_{j,k,t}) - \sum_k NHT_{j,k,1985} * (1-d^{1985}_{j,k,t})$$

$$- \ . \ . \ . - \sum_k NHT_{j,k,t-5} * (1-d^{t-5}_{j,k,t}) \tag{E.16}$$

Finally, the electricity requirement per unit ($KWH_{j,t}$) will be the weighted average of the per unit requirement of space heating appliances of all different vintages of the stock. The average per unit electricity requirement for any vintage will be the product of the base year requirement ($kwh_{j,1985}$), the growth rate in basic unit consumption ($kwhg_j$), the mandated energy savings for the unit ($1-cs_{j,t}$), and the energy savings as a result of system retrofitting $(1-ret^{m}_{j,e,t})$ in the interval between m and t. As with appliances, a difference between average existing and new unit energy consumption is recognized so that there is a separate and different unit consumption parameter for the existing stock $(kwh_{j,1980})$. The average consumption calculation is thus as follows:

$$KWH_{j,t} = (1-ret^{1980}_{j,e,t}) * kwh_{j,1980} * [HT_{j,e,1980} * (1-d^{1980}_{j,e,t})]/HT_{j,e,t} + (1-ret^{1985}_{j,e,t}) * (1-cs_{j,1985}) * kwh_{j,1985} * (1+kwhg_{j})^{o} * [NHT_{j,e,1985} * (1-d^{1985}_{j,e,t})]/HT_{j,e,t} + \ldots + (1-cs_{j,t}) * kwh_{j,1985} * (1+kwhg_{j})^{t-1985} * NHT_{j,e,t}/HT_{j,e,t} \tag{E.17}$$

E.3. Commercial-Industrial Electricity Requirements

Commercial-industrial-government electricity requirements are aggregated into a single category because of data limitations. Total requirements at time t in region r (dropped from equation for ease of exposition) for these combined sectors ($CIREQ_t$) is the product of nonagricultural wage and salary employment (EM_t) and average consumption per employee ($CIKWH_t$).

$$CIREQ_t = EM_t * CIKWH_t \tag{E.18}$$

Average consumption per employee varies as a function of time and the implementation of conservation standards. Specifically, new or incremental electricity users ($EM_t - EM_{t-5}$), who represent new commercial-industrial-government floor space, will have different electricity requirements than existing customers. Thus, existing customers at the beginning of the projection will have an average consumption rate (kwh_{1980}) different from incremental customers added in subsequent five-year intervals. A different consumption rate is assigned to incremental customers (kwh_{1985}) and this consumption rate grows over time linearly at a fixed amount (nkwh). Efficiency standards at time t ($1-cs_t$) are effective on increments to electricity requirements but not to the total.

The general equation for the commercial-industrial-government load can then be written as follows:

$$CIREQ_t = EM_{1980} * kwh_{1980} + (EM_{1985} - EM_{1980}) * kwh_{1985}$$

$$* (1-cs_{1985}) + (EM_{1990} - EM_{1985}) * [kwh_{1985} + nkwh]$$

$$* (1-cs_{1990}) + . . . + (EM_t - EM_{t-5})$$

$$* [kwh_{1985} + nkwh * (\frac{t-1985}{5})] * (1-cs_t) \qquad (E.19)$$

E.4. Miscellaneous Electric Utility Sales

Miscellaneous sales consist of two very small components of total sales: street lighting and recreational homes.

Street lighting sales ($SLREQ_t$) is a fixed percentage (sl) of the total of residential and commercial-industrial-government sales.

$$SLREQ_t = sl * [REQ_t + SHREQ_t + CIREQ_t] \qquad (E.20)$$

Similarly, recreational home consumption ($RECREQ_t$) is calculated as a fixed level of consumption (kwh) multiplied by a fixed proportion of households (rec).

$$RECREQ_t = HH_t * rec * kwh \qquad (E.21)$$

APPENDIX F. ELECTRIC UTILITY SALES PROJECTION MODEL PARAMETERS

F.1. Projection Model Parameters for Base Case

F.1.A. RESIDENTIAL NON-SPACE HEATING ELECTRICITY REQUIREMENTS

Parameters used in this model are presented in Tables F.1 and F.2.

F.1.A.1. Conservation

The Energy Policy and Conservation Act of 1975 and the National Energy Conservation Policy Act of 1978 direct the Federal Energy Administration (Department of Energy) to promulgate energy efficiency targets for electrical appliances sold beginning in 1980.

The targets are based upon an aggregate 20 percent increase in the efficiency of energy use for 13 appliances using 1972 as a base year. The targets for the various appliances differ because each is determined on the basis of economic and technical feasibility.

For example, the efficiency improving changes in refrigerator design include improved compressor motor efficiency, improved insulation, improvement of door seals, provision of an on/off switch for anti-sweat heaters and elimination of the condensor fan motor. These changes were estimated to increase the retail price of the refrigerator by half the cost of electricity saved in the first year of operation.[1]

The efficiency targets are presented in Table F.3.

F.1. MODEL PARAMETERS: RESIDENTIAL NON-SPACE HEAT APPLIANCES

Parameter		Region		
		Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Saturation Rates ($S_{j,t}$)				
S_{WH}	1980	.99	.97	.91
	1985	1.00	.99	.94
	1990+	1.00	1.00	1.00
S_C	1980+	1.00	1.00	1.00
S_{CD}	1980	.71	.67	.49
	1985	.72	.69	.52
	1990	.73	.71	.54
	1995	.74	.72	.56
	2000	.75	.73	.58
	2005	.76	.74	.60
	2010	.77	.75	.62
S_R	1980+	1.00	1.00	1.00
S_F	1980	.46	.45	.46
	1985	.48	.48	.49
	1990	.51	.51	.52
	1995	.52	.53	.54
	2000	.55	.55	.56
	2005	.57	.57	.58
	2010	.58	.59	.60
S_{DW}	1980	.49	.38	.15
	1985	.54	.44	.24
	1990	.59	.50	.32
	1995	.63	.55	.39
	2000	.67	.60	.45
	2005	.71	.64	.51
	2010	.74	.68	.56

KEY:
- WH Water Heater
- C Cooking
- CD Clothes Dryer
- R Refrigerator
- F Freezer
- DW Dishwasher
- DWW Dishwasher Water
- CW Clothes Washer
- CWW Clothes Washer Water
- TV Television
- AC Air Conditioner

F.1. (Continued)

Parameter		Region		
		Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Saturation Rates ($S_{j,t}$)				
S_{CW}	1980	.77	.75	.66
	1985	.78	.76	.68
	1990	.79	.77	.70
	1995	.80	.78	.72
	2000	.81	.79	.73
	2005	.82	.80	.74
	2010	.83	.81	.75
S_{TV}	1980	1.50	1.51	.85
	1985	1.55	1.56	1.00
	1990	1.60	1.60	1.10
	1995	1.64	1.64	1.19
	2000	1.68	1.68	1.27
	2005	1.71	1.71	1.34
	2010	1.74	1.74	1.41
S_{AC}	1980+	0	.01	0
Incremental Electrical Appliance Mode Split ($msi_{j,e,t}$)				
msi_{WH}	1980+	.35	.5	.4
msi_{C}	1980+	.66	.85	.4
msi_{CD}	1980+	.90	.98	.75
msi (other)	1980+	1.0	1.0	1.0

F.1. (Continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Annual Appliance Consumption in 1980 ($kwh_{j,1980}$)			
WH		3,475	
C		1,200	
CD		1,000	
R		1,250	
F		1,350	
DW		230	
DWW		700	
CW		70	
CWW		1,050	
TV		400	
AC		400	
Average Annual New Appliance Consumption ($kwh_{j,1985}$)			
WH		3,650	
C		1,250	
CD		1,000	
R		1,560	
F		1,550	
DW		230	
DWW		740	
CW		70	
CWW		1,050	
TV		400	
AC		400	

F.1. (Continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Conservation Target for New Appliances ($cs_{j,1985}$)			
WH		.14	
C		.03	
CD		.06	
R		.29	
F		.21	
DW		.18	
CW		.29	
TV		.32	
AC		.21	
Growth in Appliance Size ($kwhg_j$)			
WH		.005	
C		0	
CD		0	
R		.01	
F		.01	
DW		.005	
CW		0	
TV		0	
AC		0	

F.1. (Continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Lifetime of Appliance (ex_j)			
WH		10	
C		10	
CD		15	
R		15	
F		20	
DW		10	
CW		10	
TV		10	
AC		10	
		10	
Historical Electric Appliance Stock Growth Rates (g_j)			
WH	.05	.03	.15
C	.05	.03	.10
CD	.06	.04	.14
R	.05	.03	.10
F	.05	.03	.11
DW	.09	.04	.25
CW	.06	.04	.12
TV	.07	.04	.20
AC	0	.03	0

TABLE F.2. MODEL PARAMETERS: SMALL RESIDENTIAL APPLIANCES

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Annual Consumption Level (KWh 1980)			
electric lights	1,000	1,000	1,000
assorted appliances	1,010	1,466	1,333
Annual Increment to Small Appliance Consumption (nKWh)	50	70	70

TABLE F.3. FEDERALLY-MANDATED ELECTRICAL APPLIANCE EFFICIENCY

Electrical Appliance	Percent Reduction in Energy Consumption of New Appliance Using 1972 as a Base
1. Refrigerator	32
2. Freezer	23
3. Dishwasher	20
4. Clothes Dryer	7
5. Water Heater	15
6. Air Conditioner	23
7. Television (black & white)	65
8. Television (color)	35
9. Range	3
10. Clothes Washer	32

SOURCE: Federal Energy Administration, Energy Conservation Program for Appliances. Federal Register, Vol. 42, No. 136.

Independent studies of the potential for conservation of electricity in appliance design conclude that much greater savings in energy is possible at modest cost. For example, a Danish study in 1979 concluded that a 64 percent savings in electricity consumption could be obtained from refrigerator design changes with a payback time of five years. The design included increased insulation thickness, elimination of automatic defroster, and increased condenser efficiency.[2] More radical design changes could further reduce the electricity consumption of refrigerators and other appliances.

This study assumes that the Federal guidelines will be implemented during the period 1981 to 1985.[3] The target efficiencies are reduced by 10 percent to take account of the fact that the base consumption levels from which the targets are calculated are those of 1972; and in the interim between 1972 and the present, some efficiency improvements have already appeared in new appliances. For example, the primary design improvement for television sets is a conversion to solid-state circuitry. This is already happening and, consequently, the application of the target value to the 1980 stock would overestimate the actual energy savings.[4]

The rationale for assuming implementation of the Federal guidelines but no additional changes in appliance efficiency is based on the idea that these are improvements which will, in fact, occur, while further improvements will require addition-specific programs at the

Federal or state level. Should they occur, they can be subsequently introduced into the model.

F.1.A.2. Appliance Lifetime

Appliance lifetime estimates are available from the Home Appliance Manufacturers Association. Relevant appliance lifetimes are presented in Table F.4.

TABLE F.4. APPLIANCE LIFETIMES

Appliance	Lifetime in Years
Freezer	20
Refrigerator	15
Electric Clothes Dryer	14
Electric Range	12
Television (color)	12
Dishwasher	11
Clothes Washer	11
Television (black & white)	11
Room Air Conditioner	10
Electric Water Heater	10

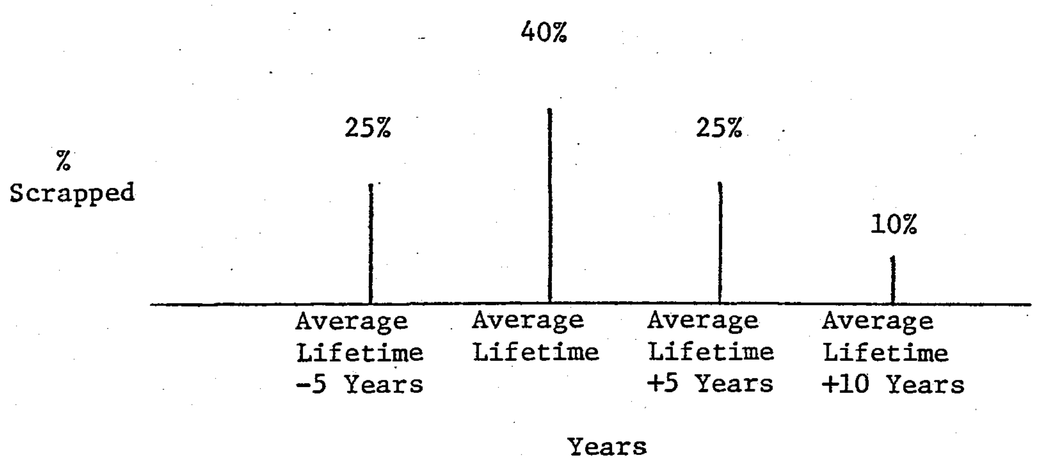
SOURCE: Richard B. Comerford, "PSE&G Method of Forecasting Residential Kilowatthour Consumption," and George L. Fitzpatrick, "Peak Load Forecasting Methodology," in How Electric Utilities Forecast: ERPI Symposium Proceedings, March 1979.

Other estimates of appliance lifetimes indicate some variation from these figures, although it is not substantial.[5]

In this analysis, since appliances of different vintages have different energy-use characteristics, it is important to identify not only the average lifetime but also the probability distribution of lifetimes for specific appliances. One recent study which has investigated the durability probability distribution for air conditioners concluded that it is a Weibull distribution which has a mean of approximately ten years with 50 percent of the population wearing out in the interval between 4.5 years and 13.75 years.[6]

We assume the same probability distributions for the durability of other electrical appliances and use a simplified distribution to distribute appliance disposals around the mean lifetime. Since the model calculates appliance stocks on a five-year interval, appliance disposals are assumed to occur in the five-year interval preceeding and the ten-year interval succeeding the average lifetime which is adjusted to be a multiple of five years. The typical distribution is shown in Figure F.1.

FIGURE F.1. PROBABILITY DISTRIBUTION FOR TYPICAL APPLIANCE DURABILITY



F.1.A.3. Appliance Capacity Growth Rates

The capacity of the existing appliance stock and consequently the average consumption level for those appliances is discussed in Appendix D, Section 5.

The capacity of many major appliances has grown over the years. This contributes to higher electricity consumption. For example, it has been estimated that the capacity in cubic feet of the average refrigerator sold in the United States has increased from 8.5 in 1950 to 12.0 in 1960 and to 14.0 in 1970.[7]

Analysis of past Alaskan electricity consumption patterns indicates that this phenomenon is occurring here and presumably will continue to occur in the future.[8]

This growth is a function of both increasing incomes and technological change. The latter factor is obvious in the example of refrigerators because in 1950 there were no refrigerators sold with a capacity of 15 cubic feet, while by 1970 the average was that size.[9]

The following appliances are assumed to maintain a constant capacity over time in terms of energy consumption:

1. Range
2. Clothes washer
3. Clothes dryer
4. Television sets
5. Room air conditioners

There is no direct information available on changes in the average capacity of appliances in use in Alaska, and the information available nationally is not necessarily applicable to Alaska because of differences in existing stock as well as preferences. Some general assumptions may be made, however, for those appliances which may be subject to capacity change.

Dishwashers may include two features which affect electricity consumption for each load. These are the "pots and pans" feature which adds about 1 kWh per load and a "no-heat dry" feature which reduces consumption by about .4 kWh per load.[10] There is no current information on the utilization of these features, although the Department of Energy appliance efficiency guidelines include the "no-heat dry" feature as one of the components of their efficiency target. It is assumed here that the "pots and pans" feature becomes more commonplace over time on new dishwashers but is used relatively infrequently so that the average capacity growth rate is .5 percent annually for new dishwasher purchases. The average new dishwasher is assumed to use 1.05 times the electricity of the existing stock based roughly on this growth rate and our estimate of average appliance life.

Refrigerator volumes have been increasing over time as indicated above, and with increasing volumes has come increasing energy consumption. The inclusion of a freezer and a "no-frost" feature also add to average consumption rates. Elimination of these features is not suggested in the Department of Energy appliance efficiency standard targets.

Nationally, the percentage of refrigerator sales by type for selected years is as follows:

TABLE F.5. DISTRIBUTION OF DOMESTIC REFRIGERATOR SALES FOR SELECTED YEARS[11]
(percentage)

	Single-Door Manual	Two-Door Freezer Partial	Two-Door Freezer Non-Frost	Side-By-Side
1950	100	0	0	0
1963	39	28	33	0
1966	23	20	50	7
1973	13	18	49	20

Using annual refrigerator sales volumes, the growth rate in the size of the average volume of refrigerators sold was 3.6 percent in the 1950s, 2.3 percent in the 1960s, and 1 percent in the early 1970s.[12]

From this information, it is apparent that the trend nationally is for some moderation in the growth rate of refrigerator volumes with a simultaneous shift toward refrigerators with more energy-using features. Alaska is assumed to be experiencing the same trends with a resultant increase in the energy requirements of new refrigerators.

The California Energy Commission's end-use model assumes that the average electricity consumption of new refrigerators is 1,609 kWh annually in 1974; while for the existing stock, it is 1,235 kWh annually, a ratio of 130 percent. It also presents information indicating that the growth rate in annual energy consumption of new refrigerators was 3.7 percent between 1960 and 1974 and 2.2 percent between 1970 and 1974.[13]

On this basis and the assumption that the average age of the appliance stock is less in Alaska than nationally, it is assumed that new refrigerators operate at 1.25 times the consumption rate of the existing stock and that the growth rate in consumption of the new stock is 1 percent annually.

Freezers vary in size, shape, and whether they have a "no-frost" feature. The "no-frost" feature adds about 50 percent to average electricity consumption.[14] As with refrigerators, elimination of this optional feature is not a stated component of the appliance efficiency standards targets of the Department of Energy. There is no historical series nationally on the proportion of sales of freezers which are of the "no-frost" type and no data in Alaska on the characteristics of the existing stock.

Because of this lack of data, the most reasonable assumption would be to assume the same growth characteristics for freezers as for refrigerators; that is, the new freezers will be more likely to have a larger capacity and the "frost-free" feature than the existing stock. However, it is assumed that the standard deviation around the mean of the size distribution of existing freezers is smaller than for refrigerators so that the ratio of the average consumption of the new-to-existing stock will be smaller than in the case of refrigerators. It is assumed to be 1.15.

Water heater size has increased over time, as indicated by manufacturer shipments of domestic gas water heaters,[15] which grew in capacity by about 1 percent annually during the mid-1970s. Since energy requirements will not grow as fast as volume and because average per capita residential hot water consumption is relatively constant except for use in dishwashers and clothes dryers, continued growth in water heater energy use should be small. However, because the existing stock may continue to be replaced by larger units, a small positive growth rate is assumed for energy use of additions to the stock. The average consumption of new units is assumed to be 1.05 times the existing stock based upon this assumption and on estimate of the age of the existing stock.

Small appliances. Electricity consumption from the use of small appliances will increase as additional appliances are purchased by the average household. Individually, such appliances do not constitute a large proportion of total demand, but the combined consumption of electricity through such appliances could continue to increase as new appliances, some not even now on the market, become available and are purchased.

It is difficult to specify a growth rate for electricity consumption through these appliances because there is no information available on existing saturation rates and use patterns in Alaska and because of the following considerations:

1. Use of electricity in some new appliances may substitute for electricity use in existing appliances. For example, increased use of microwave ovens may partially reduce electricity use for conventional ranges.
2. Use patterns for smaller appliances may change significantly in the future. For example, a more dispersed population would result in greater use of electricity in water pumps to bring well water to the surface.
3. It is not possible to anticipate all future uses of electricity in the home. Humidifiers, large-screen televisions, and trash compactors are examples of recent additions to small appliances in use in the residential sector.

An annual increase of 5 percent of the 1978 consumption level for small appliances is assumed for future growth. The base figure used in this calculation varies between the regions because of different climate, preferences, and other unidentified factors. These differences are assumed to persist.

The average household use of electricity for lighting is assumed to remain constant over time.

F.1.A.4. Appliance Saturation Rates

Deviation of appliance saturation rates is discussed in Appendix D, Section 3.

F.1.A.5. Incremental Mode Split

To calculate incremental mode splits for water heaters, ranges, and clothes dryers, we rely upon the same sources of information used in the development of the 1978 end use inventory. We begin by comparing the average mode split reported in the 1970 Census (Table D.29) to the incremental mode split calculated for the period 1960 to 1970 (Table D.32). When the average and incremental mode splits thus calculated are approximately equal, the market for the appliance is in equilibrium with respect to the fuel types used. Unfortunately, it was not generally the case that such an equilibrium could be identified.

Table F.6 shows the incremental mode splits used in the model. They remain constant throughout the projection period on the assumptions that the relative prices and availabilities of the various fuels will not change and that preferences for various fuels does not change.

The Anchorage splits have been relatively constant historically with only electric water heaters losing ground to gas. The census-calculated incremental mode splits are utilized.

The census-reported information for the Matanuska-Susitna Borough is not useful because of the rapid subsequent growth there which has relied heavily on electricity. We calculate the water heater and range incremental mode splits on the assumption that the price advantage enjoyed by electricity over fuel oil will persist and the majority of purchasers will choose electricity. Electric ranges will be slightly

TABLE F.6.
INCREMENTAL ELECTRICAL APPLIANCE MODE SPLIT

	Water Heater	Range	Clothes Dryer	Refrigerator
Anchorage	.30[a]	.67[a]	.98[a]	1.00
Matanuska-Susitna	.75[d]	.80[d]	.96[e]	1.00
Kenai-Cook Inlet	.50[a]	.40[b]	.90[c]	1.00
Seward	.35[e]	.75[f]	.70[e]	1.00
Fairbanks	.50[g]	.85[g]	.98[g]	1.00
Glennallen-Valdez	.40[h]	.40[h]	.50[e]	1.00

[a] Census calculated incremental mode split.

[b] HEA survey estimate.

[c] Assumes a shift away from gas toward the pattern observed for Anchorage.

[d] Based on price advantage of electricity.

[e] 1970 Census.

[f] Assumes shift toward electricity.

[g] Based on growth since 1970.

[h] Based on shift toward electric range preference.

more preferred than electric water heaters. The electric clothes dryer mode split is taken from the 1970 Census.

In Kenai-Cook Inlet, we utilize the incremental mode split calculated from the census for water heaters reflecting a shift in preference toward electricity. The electric range split is taken from an end use survey conducted by Homer Electric Association in 1977 because the census figures appeared low based upon the general pattern of growth since 1970. The clothes dryer mode split presumes a shift away from natural gas toward electricity in a reflection of Anchorage preferences.

For Seward, the 1970 Census data was used to calculate water heater and clothes dryer mode splits while a shift toward a preference for electricity for cooking was assumed on the basis of cleanliness and convenience.

For Fairbanks, the 1970 water heater electric mode split was 37 percent and the end use inventory calculated a 43 percent split in 1978. The incremental split over the interval would thus be about 50 percent. We assume this for future projections, although the recent electricity price increases might result in a shift in preference back to fuel oil in the future. Electricity is preferred for cooking in Fairbanks based upon the census-calculated incremental mode split which shows a substantial electric range retrofit between 1960 and 1970. We assume a continuation of the trend toward electric ranges with an 85 percent incremental mode split. For clothes dryers, we use the 1970 Census information.

The Glennallen-Valdez census data is out-dated because of the rapid post-1970 growth, but subsequent information is not currently available. We assume a shift toward electrical appliances occurs in reflection of trends observed elsewhere in the railbelt. The clothes drying mode split is based on the 1970 Census.

F.1.A.6. Household Size Adjustment Factor

Clothes washers, clothes dryers, and water heaters are used more intensively by larger households. A study conducted by the Midwest Research Institute calculated average annual electricity requirements for these appliances as a linear function of household size using metered appliances.[16] These equations are converted to use in this model by:

1. annualizing them (they are based on daily consumption);
2. normalizing them by a 1980 average household size of three persons; and
3. calculating a ratio by which to adjust calculated consumption to account for changing household size.

The adjustment factor is a function of the ratio of average household size in year t to 1980 (AHH_t) and is formed from the equations of Table F.7.

F.1.B. RESIDENTIAL SPACE HEATING ELECTRICITY REQUIREMENTS

Parameters used in the residential space heating model are presented in Table F.8.

TABLE F.7. EQUATIONS TO DETERMINE HOUSEHOLD SIZE ELECTRICITY CONSUMPTION ADJUSTMENTS

Appliance	Equation
Clothes washer	1 * AHH
Clothes washer water	.25 + .75 * AHH
Clothes dryer	.25 + .75 * AHH
Water heater	.51 + .49 * AHH

F.8. MODEL PARAMETERS: RESIDENTIAL SPACE HEATING

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Annual Unit Consumption (Existing Units) ($kwh_{j,1980}$)			
SF	36,500	48,200	33,300
DP	24,200	31,900	21,900
MF	17,100	21,200	14,600
MH	27,300	36,900	25,400
Average Annual Unit Consumption (New Units) ($kwh_{j,1985}$)			
SF	40,100	53,000	36,600
DP	26,600	35,100	24,100
MF	18,800	23,300	16,100
MH	30,000	40,600	27,900
Growth in Unit Size ($kwhg_j$)			
SF		.01	
DP		.01	
MF		.01	
MH		.01	
Average Unit lifetime (ex_j)			
SF		20	
DP		20	
MF		20	
MH		20	

KEY:
- SF Single Family
- DP Duplex
- MF Multifamily
- MH Mobile Home

F.8. (Continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Incremental Electrical Appliance Mode Split ($msi_{j,e,t}$)			
$msi_{SF,1980+}$	.19	.01	.02
$msi_{DP,1980+}$	.19	0	0
$msi_{MF,1980+}$	.19	0	0
$msi_{MH,1980+}$	.19	.01	0
Conservation Target for New Appliances ($cs_{j,1985}$)			
SF		.05	
DP		.05	
MF		.05	
MH		0	
Utilization Rates ($UT_{j,e,t}$)			
$UT_{SF,1980+}$		1	
$UT_{DP,1980+}$		1	
$UT_{MF,1980+}$		1	
$UT_{MH,1980+}$		1	

F.8. (Continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Retrofitting Coefficients			
$(ret^{m}_{j,e,t})$			
$ret^{1980}_{SF,1985}$	.02	.04	.03
$ret^{1980}_{DP,1985}$	0	0	0
$ret^{1980}_{MF,1985}$	0	0	0
$ret^{1980}_{MH,1985}$	0	0	0

F.1.B.1. Conservation

Conservation enters into the determination of the residential space heating load through assumptions about retrofitting of existing units with energy saving improvements and the application of efficiency standards to new housing units.

Retrofitting existing structures to reduce the required heat load will be a function of the quality of the housing stock, the expected length of housing unit ownership, the amount of information available to individuals interested in retrofitting, and the cost of fuel saved compared to the investment in supplies and labor required to do the retrofit.

Several federal and some current state programs are designed to stimulate retrofitting in the residential sector. Among the important federal programs are a tax credit of 15 percent of the first $2,000 expended for conservation measures, a home improvement loan program for energy conservation measures, and a weatherization grant program for low income families.[17]

The most important state program is a 10 percent residential fuel conservation tax credit for capital improvements to reduce the heat load of residential buildings. Several studies have attempted to assess the impact of retrofitting on energy requirements for space heating. In 1974 a study by Arthur D. Little estimated that nationally-applied retrofitting measures based upon current reasonable technology and cost could reduce the electric space heating load by 26 percent, 20 percent, and 17 percent for single family, multi-family, and mobile home type units, respectively.[18] A 1977 study estimated at 20 percent savings in energy consumption from retrofitting 20 million single family units between 1977 and 1990.[19]

Unfortunately, these estimates are not based upon actual observed human behavior but, rather, are based upon simple engineering models. A study reported by the California Energy Commission indicates that the actual response to retrofit conservation programs and actual energy savings may be only about 50 percent of what engineering models would suggest.[20]

The only information currently available concerning retrofitting of the housing stock is available from state tax returns for 1977 and 1978. The number of returns, percentage claiming credits, average credit claimed, and implied value of capital investment in retrofitting equipment are shown in Table F.9.

Since this data is not regionally divided and specific fuel used is not specified, it is not possible to accurately estimate the impact of this program on electric space heat consumption.

If we assume an even distribution statewide, an even distribution among all types of fuels, and a 5-year payback for investments (with no discounting), then in 1978 about $975 thousand was spent for railbelt

TABLE F.9. STATE OF ALASKA RESIDENTIAL FUEL CONSERVATION CREDITS

	1977	1978
tax returns	195,394	183,725
percent claiming credit	5.6%	8.1%
number claiming credit	10,942	14,882
average credit	$74.10	$57.61
implied capital investment (@ 15% credit)	$741	$576
implied total capital investment	$8,108,070	$8,571,873

Source: Alaska Department of Revenue, "Fuel, Conservation, and Industrial Credits Relative to the Individual Income Tax," 1980.

electric space heat unit retrofits. This saved $195,000 in electric bills. If the average cost of electricty was 5¢, then about 3,900 MWh of electricty were conserved by the retrofit program, or less than 1 percent of residential electric space heat requirements. This is obviously only on order of magnitude estimate, but it suggests that the impact of the existing state retrofit program on aggregate consumption of electricity is probably modest. The impact could quite possibly be much smaller with a longer payback period or if a smaller percentage of credits were taken by electric space heaters than assumed.

A further problem with using national estimates of the potential savings from retrofitting is that the thermal integrity of the typical Alaskan house may be much better than the national average. It is clearly a younger than average stock, so few homes would be without insulation as in the lower 48. The harsh winters would suggest more concern during construction for thermal integrity, but this may not have been the case in fact.

On the basis of this spotty information, it is not possible to assume a substantial impact on electric space heating of the existing federal and state retrofitting programs. Obviously, some of the impact has already occurred, and to project an estimate of the full impact of these programs into the future would involve some double counting of conservation.

We assume that retrofitting is confined to single family residences and occurs on the existing housing stock during the period 1980 to 1985. It is twice as important in Fairbanks as in Anchorage because the higher price of electricity in Fairbanks creates an extra incentive there. The impact on Glennallen-Valdez falls midway between the 4 percent saving for Fairbanks and 2 percent saving for Anchorage.

The application of mandatory construction or performance standards to new housing in order to improve their thermal integrity has been under consideration for several years by the federal government. The sets of standards which may be implemented are either the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 90-75 standards or standards developed by the U.S. Department of Housing and Urban Development (HUD). These standards now are supposed to become effective in 1980.

National studies have estimated the impact of these mandatory standards on energy consumption. The Arthur D. Little study estimated potential savings of 35 percent, 45 percent, and 40 percent in mobile homes, single family units, and multi-family units, respectively. A 1977 study estimated savings of 11 percent for single family units and 46 percent for multi-family units under the ASHRAE 90-75 standards and 20 percent and 51 percent savings under the HUD standards.[22] Substantial savings are thus apparently possible, but there are no precise estimates of what the savings would be from standards.

An attempt has been made to estimate the impact of the two aforementioned standards on Alaskan energy consumption, but the conclusions of the study were qualitative rather than quantitative and suggested only that substantial savings would be possible.[23]

We assume that a program of mandatory standards is implemented in 1981 which has the effect of reducing the heat load in new construction (except for mobile homes) by 5 percent independent of other factors. This percentage takes into account the assumption that Alaskan housing is already more thermally efficient than the national average, the fact that actual savings observed will be less than savings in theory, and the idea that it will take some time to actually implement the program. No conservation is assumed for mobile home units.

F.1.B.2. Heating Appliance Lifetimes

For ease of calculation, the demolition rate for the existing housing stock is set at zero. This is not significantly different from actual ratios as indicated from building permit information. The assumption also applies to the heat distribution system for the home. The heat generating system (boiler, furnace, etc.) is assumed to have an average lifetime of 20 years, independent of type or fuel used. This is based on Home Appliance Manufacturers Association data, and, as with other appliances, the actual time of scrapping of an appliance is determined by a probability distribution centered at the average lifetime.

F.1.B.3. Average Housing Unit Size and Consumption

The average housing unit size was estimated in Appendix D, Section 2, and electricity consumption for space heating was assumed to be a function of the average unit square feet of floor space. (An adjustment factor was calculated to account for the fact that 1978 was a warmer than normal winter. See Table D.24.)

We assume that the average electricity requirement for new units constructed after 1980 (independent of conservation) is 10 percent greater than existing units because new construction is assumed to consist of larger units on average than the existing stock of housing units.

Two sources of information confirm the observation of an increasing average size of the housing stock. In Table F.10, the average consumption of natural gas per heating degree day is presented for recent years.

The consumption growth in the 1970s of between 2 and 3 percent annually can be attributed to growth in the average size of the housing stock (or to deterioration in the thermal integrity of the housing stock). Second, as noted in Appendix D, Section 2, the average size of new single family units nationally is larger than the average for the existing stock by about 10 percent (1720/1570).

We assume new housing of all types constructed after 1980 will be on average 10 percent larger than the existing stock based upon this national ratio.

TABLE F.10. RESIDENTIAL CONSUMER NATURAL GAS CONSUMPTION FOR SPACE HEATING PER HEATING DEGREE DAY

Year	Average Annual Consumption for Space Heating (mcf)	Heating Degree Days	Consumption/ Heating Degree Day
1970	172	10,137	.0170
1971	180	11,879	.0152
1972	191	12,016	.0159
1973	188	11,665	.0161
1974	170	10,683	.0159
1975	193	11,308	.0171
1976	181	10,361	.0175
1977	166	9,394	.0177
1978	164	9,131	.0180
1979	159	9,430	.0169

Source: Alaska Gas and Service Company annual financial reports and internal company records.

In subsequent years, new additions to the housing stock are larger by 1 percent annually. This is a balance of several factors which can be identified but not quantified. Increasing disposable incomes will increase the demand for larger housing units, but the increasing cost of housing will partially offset this. The role of the federal and state governments in stimulating home ownership through various programs could increase the size of new additions to the housing stock or reduce it, depending on the particulars of the program. The declining average household size in future years should reduce the demand for larger units somewhat. The Alaskan climate which requires that people spend a large proportion of their time indoors during the winter months suggests a strong preference for larger housing units.

The Arthur D. Little study of 1975 assumed that these various factors would cancel one another out so that the size of new housing was projected to remain constant in future years and that only replacement of demolitions would increase the average size of the stock by 4 percent between 1975 and 1990. We assume the disposable income effect, the climate-related preference, and the presence of state intervention into the housing market predominate and result in an increasing size for increments to the housing stock.

F.1.B.4. Incremental Mode Split*

We assume that the Greater Anchorage Area space heat mode split is in equilibrium. Thus, the incremental mode split will be equal to

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*See also Section F.2 for a discussion of the space heating mode choice decision.

the average mode split for electricity. The Greater Anchorage Area average of 19 percent electric residential space heating is assumed for all housing types. This is a slight decline from the existing multi-family stock of 19.9 percent (see Table D.21) but a slight increase for the other type of units. This assumption presumes no shift in the geographic distribtuion of new housing units either toward or away from areas where natural gas is available or the extension of natural gas service into new areas. Growth in the mid-1970s in these outlying areas has been relatively rapid, but it is not clear whether this is a temporary phenomenon or represents the emergence of a long-term trend. Growth has decelerated in the last year, but that could be a reflection of the general softening of the Alaskan economy.

In Fairbanks, Golden Valley Electric Association (GVEA) has put a ban on new electric space heat hookups. This is assumed to be permanent in the absence of new generating facilities powered by fuels other then fuel oil because of the high incremental cost of power from this source. Nevertheless, we assume that 1 percent of new and replacement single family and mobile home units are heated by electricity. This represents a gradual decline in the electric space heat load occurring over a period of about 20 years as existing units wear out and are replaced. GVEA in their own load growth estimates assumes that all of their residential space heat customers will be shifted off of electricity by 1982.

There is very little electricity used for space heating in the Glennallen-Valdez service area because of its relative price. We assume the same incremental mode split for electric space heating as the present average.

F.1.B.5. Utilization Rates

We assume utilization rates are unchanged from current levels. That is, people do not manually set back their thermostats at night, etc.

F.1.C. COMMERCIAL-INDUSTRIAL-GOVERNMENT ELECTRICITY REQUIREMENTS

Model parameters for the component are shown in Table F.11.

F.1.C.1. Conservation

Conservation measures in the industrial sector consist of efficiency standards for new appliances, construction or performance standards for new construction, and retrofitting of existing structures to increase the thermal efficiency and reduce the electricity load in the various building systems such as the heating, ventilating, and air conditioning systems (HVAC). Because detailed end use information is not currently available, it is not possible to identify in detail the impact on electricity consumption of specific conservation measures. Because federal conservation programs are and will be in effect, however, it is necessary to try to quantify their impact.

The major conservation programs of the federal government specifically targeted to the commercial, industrial, and government sectors

TABLE F.11. MODEL PARAMETERS:
COMMERCIAL-INDUSTRIAL-GOVERNMENT SALES

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez
Average Consumption Rate for Existing Stock (KWh_{1980})	10.675	10.983	9.178
Average Consumption Rate for Increments to Stock (KWh_{1985})	15.156	18.537	12.979
Subsequent Increases to Incremental Consumption Rate (nKWh)	3.020	3.707	2.596
Design and Performance Efficiency Targets (CS_t)			
1985	0	0	0
1990	.05	.05	.05
1995+	.1	.1	.1

include grants to schools and hospitals for improving energy efficiency, a local public building energy audit program, conservation requirements for federal buildings, energy efficiency labeling of industrial equipment, stimulation of cogeneration, business energy tax credits, and performance standards for new commercial buildings similar to the residential sector.[24]

National studies have attempted to measure the potential impact of these federal programs. A 1979 analysis of the National Energy Plan estimated the growth rate of energy use in the commercial sector could be reduced from 4 to 3.2 percent annually as a result of implementation of the plan.[25]

The Arthur D. Little study previously mentioned estimated potential energy conservation factors for several types of commercial buildings. These factors, shown in Table F.12, are the proportion of energy savings possible using "practical methods and existing materials in addition to allowing for some technological improvements in selected HVAC and electrical components between now and 1990."[26]

These calculations are based upon a technical analysis of possibilities, but the study also includes a discussion of the institutional setting within which energy conservation in the commercial sector would be addressed and provides some insight into the problems which implementation of energy conservation would entail. Specifically, the relative complexity of the typical commercial structure makes it

TABLE F.12. ENERGY CONSERVATION FACTORS FOR COMMERCIAL BUILDINGS (1970 = 1.0)

	Existing Buildings	New Construction
Office Buildings		
Lighting	.80	.50
Auxilliary equipment	.95	.90
Space heating	.78	.60
Cooling	.82	.53
Hot water heating	.95	.90
Retail Establishments		
Lighting	.70	.50
Auxilliary equipment	.95	.90
Space heating	.76	.50
Cooling	.77	.54
Hot water heating	.95	.90
Schools, Educational		
Lighting	.80	.50
Auxilliary equipment	.95	.90
Space heating	.79	.50
Cooling	.81	.59
Hot water heating	.95	.90

Source: Arthur D. Little, "Residential and Commercial Energy Use Patterns: 1970 to 1990," for Federal Energy Administration, 1974, p. 156.

difficult to calculate actual energy consumption of the various systems in the building and to determine potential savings from design changes. (For example, the lighting system waste heat provides some space heat.) In addition, the design of a building normally involves the attempt to meet a large number of objectives, only one of which would be energy efficiency. The implementation of this objective requires the close interaction of client, architect, and engineers designing the various building systems. It is clear from the discussion in the Arthur D. Little report that energy conservation was not a major concern in building design and maintenance in the early 1970s. This was reflected in the fact that architects consulted were sensitive to conservation issues but lacked "the detailed knowledge to apply conservation measures with any degree of sophistication."[27]

The heterogeneity of this component of electricity consumption is a further problem, making it difficult to analyze electricity use and potential savings. Finally, consumption is dramatically effected by building use patterns. The same building, from a design standpoint, can have energy and electricity consumption differences of over 100 percent, depending upon the patterns of use of the building.[28]

We assume that the majority of electricity used in the commercial-industrial-government sector is for lighting, in conjunction with space conditioning systems, and for auxilliary electrical equipment. The new construction conservation potential in these areas is significant, but we assume that the impact of currently-planned federal programs, including design or performace standards, will be more modest and will take considerable time in implementation due to institutional constraints to development of the standards and immediate implementation when they become available. We assume a 5 percent reduction in electricity requirements for new construction during the period 1985 to 1990 (independent of other growth factors), increased to 10 percent in the following decade. This suggests a higher conservation potential in this sector than the residential space heat sector but a longer time for implementation.

At the same time, because of the absence, particularly in the Greater Anchorage Area, of a strong price incentive, retrofitting measures in the commercial sector are assumed to have no impact on electricity consumption. (See next section concerning assumptions regarding growth of consumption by existing customers.) In other words, the new construction standards program is the measure which results in conservation in this sector.

F.1.C.2. Commercial-Industrial-Government Utility Sales Per Customer

Historical annual utility sales per customer data for the major railbelt regions and the U.S. as a whole are compared in Table F.13. The average Alaskan customer consumes about 70 percent more electricity in a year than those in the U.S. as a whole, and over the long run, the growth rate in average sales has been realtively equal for Alaska and the U.S. In the period of the 1970s, the Alaskan growth rates have been more rapid, but this has been offset by apparently slower growth rates in the late 1960s.

TABLE F.13
COMMERCIAL/INDUSTRIAL UTILITY SALES PER CUSTOMER

(MWh)

	Greater Anchorage Area	Greater Fairbanks Area	U.S.A.[a]
1950	-	-	9.3
1955	-	-	12.7
1960	-	-	17.0
1965	47.2	41.2	27.4
1966	52.0	40.5	-
1967	55.2	-	-
1968	57.7	53.0	-
1969	61.7	57.8	-
1970	62.7	62.8	40.0
1971	69.1	69.0	41.9
1972	73.7	67.9	44.5
1973	80.6	73.4	47.6
1974	79.8	72.1	46.6
1975	85.1	90.0	49.0
1976	87.6	86.6	50.7
1977	85.8	84.8	52.9
1978	86.5	85.0	-

[a] Edison Electric Institute, Statistical Year Book, annual.

It would be premature to identify the period of the mid-1970s as a per customer peak for commercial sales in Alaska, but there is a noticeable deceleration of growth rates in more recent years. This could partially be the result of more rapid than normal growth during the Alyeska oil pipeline boom years or a succession of abnormally warm winters (in Anchorage) in the late 1970s or both. These are temporary phenomena which should not form the basis for analysis of underlying trends.

Examination of the year-to-year growth rates of commercial sales nationally reveals a very rapid growth rate in consumption historically and also the possibility of a new long-term trend after the watershed years of 1973-1974 (the time of the great recession and oil embargo). The average annual growth rate in the 1970s before the embargo was 6 percent, while afterwards it was 4.3 percent. Again, it is premature to emphatically call this a shift in long-term trend, but it is suggestive of that.

In order to facilitate analysis of various conservation programs and trends in new commercial structures, we calculate sales estimates for the existing stock of commercial-industrial-government buildings and for increments to the stock. For ease of calculation, we assume a zero rate of demolition of the stock. For the existing stock, the average consumption rates in 1978 are utilized in the projections. This assumes, therefore, that all growth in consumption is the result of additional hookups at higher consumption rates and that commercial-industrial-government consumption is not sensitive to heating degree days. (1978 was a warmer than normal year.)

The annual consumption per hookup for incremental customers is assumed to grow at a rate consistent with the period between 1973 and 1978. Specifically, the following equation was solved in Greater Anchorage and Greater Fairbanks to obtain the average sales per customer of customers added to the systems after 1973.

$$\text{average sales per customer for customers added after 1973} = \frac{\text{total 1978 sales} - \text{total 1973 sales}}{\text{customers added after 1973}}$$

This value was then compared to the 1973 average to arrive at an estimate of the growth in average sales to incremental customers. These results are summarized in Table F.14.

TABLE F.14. CALCULATIONS OF ELECTRICITY SALES TO INCREMENTAL COMMERCIAL-INDUSTRIAL-GOVERNMENT CUSTOMERS

	Average Sales 1973 (MWh)	Average Incremental Sales (1973-1978) (MWh)	Ratio
Greater Anchorage	80.557	97.903	1.22
Greater Fairbanks	73.429	114.806	1.56

Thus, assuming that existing customer sales remained constant, new customers between 1973 and 1978 on average purchased 22 percent more electricity in Anchorage and 56 percent more electricity in Fairbanks.

Based upon the longer trend for the two areas from TAble F.13 and the slower growth for Fairbanks in the early 1970s, we assume the same growth characteristics for the two regions and also for Glennallen-Valdez. Specifically, Table F.15 shows the steps in calculating average and incremental rates of consumption. Consumption figures have been converted to a per employee basis (discussed in the next section). 1978 actual average consumption figues are converted to 1980 estimates on the basis of growth rates calculated from recent trends on average sales growth rates. This is multiplied by the ratio of incremental to average sales to obtain a base for calculating incremental consumption rates for the period 1981 to 1985. These rates are 25 percent above the 1980 base incremental rates. In subsequent five-year periods, the same amount is added to incremental sales per employee.

F.1.C.3. Commercial-Industrial-Government Hookups

The number of electric utility hookups is related to employment. Table F.16 indicates the stability of that relationship historically except during the pipeline years of 1975 through 1977.

Because of this stability between the level of employment and the number of hookups, it is possible to utilize sales per employee as the forecasting variable in this section of the model and link it directly to the employment forecast generated by the economic model.

TABLE F.15. COMMERCIAL-INDUSTRIAL-GOVERNMENT CONSUMPTION PER EMPLOYEE DATA

	1978 average sales /employee (MWh)	1978-1980 growth in sales/empl.[c] (%)	1980 average sales /employee (MWh)	Rate of 1973-1978 incremental to 1978 av. sales	Av. sales/ employee for 1981-1985 incremental customers (MWh)	Succeeding 5 yr. increments to sales to incremental customers (MWh)
Greater Anchorage	10.071	6%	10.675	1.13	15.156	3.020
Greater Fairbanks	10.768	2%	10.983	1.35	18.537	3.707
Glennallen-Valdez	10.085[a]	-9%	9.178	1.13[b]	12.979	2.596

[a] 8,000 MWh of pipeline pump station sales netted out.

[b] Assume the same relationship as Anchorage.

[c] Based on recent trends in average sales growth.

TABLE F.16. RATIO OF NON-AGRICULTURAL WAGE AND EMPLOYMENT (NET OF MILITARY) TO COMMERCIAL-INDUSTRIAL-GOVERNMENT HOOKUPS

	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez
1965	8.55	8.73	5.37
1966	8.63	8.02	-
1967	8.79	-	-
1968	8.34	8.43	-
1969	8.50	8.80	-
1970	7.79	7.61	3.58
1971	8.37	7.59	4.37
1972	8.46	7.78	-
1973	8.54	7.54	2.66
1974	9.12	8.81	4.32
1975	10.12	13.14	11.18
1976	9.45	12.15	17.69
1977	8.94	9.06	8.55
1978	8.59	7.90	4.12
Average	8.72	8.89	6.87
Average net of 1975-1977	8.52	8.12	4.07

F.1.D. MISCELLANEOUS ELECTRICITY REQUIREMENTS

This very small category consists of street light and second home sales. Street light sales are assumed to be 1 percent of the sum of all other components of sales.

The electricity requirements for second homes is difficult to identify for several reasons. First, as discussed in Appendix D, Section 1, it is difficult to identify from the existing housing stock studies just what is a second home or a vacation home. Specifically, what the census defines as a year-round housing unit may actually be a second or vacation home. It is possible from the census to determine the number of households within a census division which own a second home, but not its location. Most utilities do not have separate rate schedules for second homes, and if they did, the utility definition would not necessarily be the appropriate one since it might cover seasonal units rather than units used year-round but infrequently. It is also difficult to estimate average electricity requirements for second homes because of this lack of data.

We make the following very rough estimates to calculate second home electric utility sales:

1. 25 percent of households have second homes, based on census information;
2. 50 percent of the second homes are located within the railbelt;

3. 50 percent of the second homes in the railbelt are serviced by electric utilities.

The average annual consumption per second home is 500 KWh, based upon conversations with utility personnel.

F.2. Assumptions for the Price Induced Shift Toward Electricity Consumption Case

F.2.A. FACTORS INVOLVED IN APPLIANCE CHOICE FOR SPACE HEATING

The most important variable in a model of appliance choice for space heating or any other function is the system cost, including both the initial purchase price and lifetime fuel costs for system operation. Other characteristics are important and will affect the choice but will not be explicitly considered here. Some of these other considerations are as follows:

Heating System

1. Heat distribution within the building
2. Amount of space occupied by the heating system
3. Multiple controls capability
4. Integration with other appliances (hot water, humidifier, air conditioner)
5. Comfort factor (annoyance of hot air, for example)
6. Reliability
7. Compatability with auxilliary heating systems

Fuel

8. Fuel availability
9. Maintenance cost
10. Safety of fuel
11. Cleanliness
12. Convenience

Because of these considerations, not all households will make the same appliance type and fuel choice even when faced with identical prices.

In considering the least-cost space heating system, it is necessary to recognize that for the new residence there are at least two decisions after having decided in favor of a centralized heating system. The first is the type of heat distribution system and the second is the type of fuel to produce the heat. The choice of distribution system--hydronic (hot water or steam), hot air, electric resistance, etc.--affects not only the initial cost but also the cost of a subsequent retrofit to an alternative system. Having once chosen a heating distribution system, the fuel to provide the heat is determined, basically on the basis of price.[29]

For a given set of desired heating characteristics, the distribution system and fuel type chosen will, in theory, be that which minimizes the present value of total future system costs. In practice, several factors tend to distort the decision in favor of the system with the least initial cost or the least cost over a shorter period than the system lifetime.

1. Homebuilders who build for others are concerned with minimizing construction costs and will opt for the system with the least initial cost if a related higher total operating cost is not reflected in a reduced market price for the house.

2. The same analysis applies for landlords to the extent that they are able to pass system operating costs on to tenants.

3. For individuals who own their homes for only a short time before moving, the lifetime operating costs of the heating equipment in those homes is less important than initial system cost.[30]

4. Lack of information about the least-cost system may prevent people from switching to it.

5. Individuals may not act consistently with the actual opportunity cost of money. In other words, a system choice with a high initial cost may have a rate of return in terms of money saved (compared to the next best alternative which has a lower initial cost but a higher operating cost) which exceeds the return the purchaser could receive investing the same amount of money alternatively. Yet, for some reason, the consumer chooses the system with the lower initial cost but higher lifetime cost. In other words, the observed discount rate used by the consumer exceeds his opportunity cost.[31]

6. Promotional activities of utilities.

In general, electric baseboard heating is the cheapest system to install followed by hydronic and then warm air systems. Both hydronic and warm air systems require a flue and a distribution system. The initial cost of oil relative to natural gas depends upon the cost of connecting the residence to the gas main compared to the cost of oil storage tanks and the somewhat higher cost of an oil burner. This may vary with location.

Based on this discussion, it can be seen that the proportion of a particular type of heating system in place at any time may exceed what would appear to be economically justified based upon total system lifetime cost.

Table F.17 shows the prices of various fuels which equalize the operating cost of space heating. For example, if electricity is 3¢/kWh, then heating with fuel oil will be less expensive if it is available for under $.84/gallon.

Table F.18 shows the actual relative prices presently encountered in various parts of the railbelt. It is clear that natural gas is the cheapest fuel wherever it is available. Outside of the gas utility service area in the Anchorage region, the prices of fuel oil and electricity are comparable after adjusting for the higher conversion efficiency of electricity. This is because electricity is produced using cheap natural gas.

In the Fairbanks area, fuel oil and electricity are comparable for one utility, while the price of electricity from the other exceeds that of fuel oil. This situation results from the fact that the lower cost electricity is produced by coal, while the higher cost electricity is generated by a combination of fuel oil and coal.

In Glennallen-Valdez, fuel oil is clearly cheaper than electricity.

This pattern is confirmed by looking at historical data on relative fuel prices. In Anchorage, natural gas and electricity prices are largely determined by the long-term purchase contracts for Cook Inlet gas. The pricing clauses in these contracts have resulted in fairly stable prices during the 1970s. In contrast, fuel oil prices have risen with rising crude oil prices.

TABLE F.17.
EQUIVALENT DELIVERED PRICE FOR SPACE HEATING
USING VARIOUS FUELS

$\$/10^6$ btu	Electricity ¢/kWh	Fuel Oil $/gallon	Crude Oil $/barrel	Natural Gas $/mcf
1	.5	.14	5.88	1.53
2	1	.28	11.77	3.06
3	1.5	.42	17.64	4.59
4	2	.56	23.54	6.12
5	2.5	.70	29.40	7.65
6	3	.84	35.28	9.18
7	3.5	.98	41.16	10.71
8	4	1.12	47.07	12.24
9	4.5	1.26	52.92	13.77
10	5	1.40	58.80	15.30
11	5.5	1.54	64.68	16.83
12	6	1.68	70.56	18.36
13	6.5	1.82	76.44	19.89
14	7	1.96	82.32	21.42
15	7.5	2.10	88.20	22.95

Notes: 1) Furnace conversion efficiencies:
- electric .95
- gas and oil .65

2) BTU content of fuels:
- 1 kWh = 3,413 btu
- 1 gallon fuel oil = 138,000 btu
- 1 mcf gas = 1,005,000 btu
- 1 barrel crude oil = 5,800,000 btu

3) No refinery margin netted out of crude oil price

TABLE F.18.
PRICES OF ALTERNATIVE FUELS FOR RESIDENTIAL SPACE HEATING

	Natural Gas[a]		Fuel Oil[b]		Electricity[c]	
	$/mcf	$10^6 btu	$/gallon	$10^6 btu	¢/kWh	$10^6 btu
GREATER ANCHORAGE AREA						
Anchorage						
1980	-		.98	7.10	-	
1979	-		-		2.98/[d] 2.49/ 4.52	8.73/[d] 7.30/ 13.25
1978	1.89	1.88	-		-	
Kenai-Cook Inlet						
1980	-		.94	6.80	-	
1979	-		-		3.52/[f] 3.75/ 4.23	10.32/ 10.99/ 12.40
1978	2.01[e]	2.00	-		-	
Matanuska-Susitna						
1980	unavailable		1.07	7.75	-	-
1979	unavailable		-		4.52	13.25
GREATER FAIRBANKS AREA						
Fairbanks						
1980	unavailable		.84	6.09	-	-
1979	unavailable		-		3.50/[g] 7.97	10.26/ 23.37
GLENNALLEN-VALDEZ AREA						
1980	unavailable		.98	7.10	-	-
1979	unavailable		-		12.1/[h] 13.82	35.47/ 40.52

See following page for table notes and sources.

Table F.18 (Continued)

Table Notes:
(a) 10 mcf monthly bill
(b) 500 gallons delivered
(c) 1,500 kWh monthly bill
(d) CEA/AMLP/MEA
(e) ANG
(f) HEA/SES/HEA (Kenai)
(g) FMUS/GVEA
(h) CVEA (Valdez)/CVEA (Glennallen)

SOURCES: Electricity: State of Alaska, Division of Energy and Power Development, "1980 Alaska Power Development Plan."

Gas: Alaska Public Utilities Commission, Annual Report, 1978.

Fuel Oil: Survey by authors and Fairbanks North Star Borough, Community Information Quarterly, Vol. III, No. 1, Spring 1980.

In Fairbanks, fuel oil and electricity generated by fuel oil have been most susceptible to price increases in the 1970s. The price of electricity generated by coal has been less susceptible to increases in the 1970s.

In Glennallen-Valdez, electricity is produced by fuel oil and, thus, the two prices move together.

This review suggests that a substantial change in the existing fuel mode split for space heating would require a large change in the relative price of electricity. Specifically, for electricity to become the least expensive space heating fuel, the following price changes would be necessary;

> Anchorage - the relative price of natural gas would need to increase at least 3 times;
>
> Fairbanks - the relative price of fuel oil would need to increase at least two and one-half times; and
>
> Glennallen-Valdez - the relative price of fuel oil would need to increase at least three and one-half times.

On the other hand, it is possible that a large increase in the price of <u>all</u> fuel will result in a shift away from the "conventional" fuels—oil, gas, and electricity—toward more conservation or auxilliary systems such as efficient fireplaces and wood stoves. This phenomenon may be beginning to occur in the outlying parts of the Greater Anchorage area and in Fairbanks.

This introduces the second group selecting a space heating fuel--the retrofit market. This consists of households whose existing system has worn out as well as those whose systems are still functioning but because of changed operating costs decide that a system replacement is cost effective.

Fuel retrofits are relatively common when the switch is between oil and gas in hot air or hydronic systems. For example, a large portion of the Anchorage residential market has been retrofit from oil to gas. This required only switching the burner and connecting the unit to the gas main. Switches to an electric resistance furnace could similarly be relatively inexpensively accomplished.

System retrofits in which one type of heating system is replaced with another are far less common, and the feasibility of such a switch will depend upon the construction of the building.

For example, in a house built on a concrete slab, it would be virtually impossible to retrofit a hydronic or hot air system because there would be nowhere for the placement of the pipes or ductwork. In replacing an electric resistance system with a hydronic or hot air system, it is necessary both to locate a place for the furnace and to install a flue. Generally, the cheapest system retrofit is to electric resistance heating since the installation of the required wiring is less complicated than that of pipes or ductwork.

Table F.19 summarizes the conversion costs (prices as of the early 1970s, although the relative costs are unchanged) of various fuel and system retrofits. The table confirms the discussion that retrofits to electric baseboard are relatively inexpensive, but retrofits from electricity to oil or gas conventional systems are relatively expensive. Basically, it is easier to switch into the electric mode than out of it.

Obviously, for the household contemplating a retrofit, the cost of the switch plus the present discounted cost of the fuel in the new system is the relevant variable against which the cost of using the current system must be compared. The higher the cost of retrofit, the higher the relative price of the existing fuel used for space heating can become and still be less costly than switching.

Table F.20 shows what the actual railbelt heating systems have been historically. The pattern has been one of shifting from heaters to central space heating systems over time (which consume more energy). Hydronic systems were more common in Anchorage, Fairbanks, and Glennallen-Valdez in 1970, while hot air systems were more common elsewhere. This suggests that shifts to electric heat could involve either resistance systems or electric furnaces using the existing heat distribution systems (or possibly heat pumps).

There is a historical example of a retrofitting phenomenon in the railbelt. In the early 1960s, natural gas from the Cook Inlet fields became available to the Kenai Peninsula and Anchorage. The natural gas

TABLE F.19.

CONVERSION COSTS OF RESIDENTIAL HEATING SYSTEMS

(dollars)

	To	Gas		Electricity		Oil	
Fuel System	From	Warm Air	Hot Water	Baseboard	Warm Air	Warm Air	Hot Water
Gas	Warm Air	X	3,300	1,500	1,500	650	3,400
	Hot Water	2,600	X	1,500	3,100	2,700	650
Electricity	Baseboard	2,600	3,300	X	2,700	2,700	3,400
	Warm Air	1,000	3,300	1,100	X	1,100	3,400
Oil	Warm Air	400	3,300	1,500	1,500	X	3,400
	Hot Water	2,600	400	1,500	3,100	2,700	X

SOURCE: Arthur D. Little, "Project Independence: Residential and Commercial Energy Use Patterns 1970-1990," for Federal Energy Administration, 1974, p. 175.

TABLE F.20.
HOME HEATING EQUIPMENT

	PROPORTION OF TOTAL					
	Steam or Hot Water	Warm Air Furnaces	Built-in Electric Units	Floor, Wall, or Pipeless Furnaces	Heaters, Fireplaces	None
GREATER ANCHORAGE AREA						
Anchorage						
1960	46	20	0	8	26	0
1970	56	26	5	3	9	0
Matanuska-Susitna						
1960	12	13	0	7	67	1
1970	16	30	1	1	53	0
Kenai-Cook Inlet						
1960	9	14	0	2	72	4
1970	25	32	4	5	33	1
Seward						
1960	18	12	0	14	56	1
1970	27	28	0	0	44	1
GREATER FAIRBANKS AREA						
Fairbanks						
1960	50	25	0	3	22	1
1970	59	22	7	1	11	0
GLENNALLEN-VALDEZ AREA						
Valdez-Chitina-Whittier						
1960	34	11	0	3	51	1
1970	28	20	1	1	50	1
WESTERN REGION U.S.						
1970	5	40	9	22	22	2

Note: Based on all year-round housing units.

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska. Table 29.
1970 Census of Housing, Detailed Housing Characteristics: Alaska. Table 62.
1970 Census of Housing, Detailed Housing Characteristics: United States Summary.

was cheaper than fuel oil; but in response to competition, the fuel oil distributors lowered their price. This, in combination with the fact that residents of short tenure would not recover their capital costs of conversion from an oil to gas boiler in spite of the relatively low cost, kept the rate of conversions low. The limiting factor does not appear to have been the speed at which gas mains could be laid to the various neighborhoods.[32]

Over a period of 15-to-20 years, as indicated by Table F.21, there was a substantial shift toward natural gas space heating as a result of both new units choosing gas and retrofitting of gas burners where fuel oil had previously been used. The retrofitting of gas burners continues today but is asymptotically approaching zero. Unfortunately, because of a lack of intercensal housing stock data for the 1960s for Anchorage, it is neither possible to trace the exact time pattern of the retrofitting of gas burners nor possible to correlate the rate of retrofitting with the relative prices of fuels or other variables in an attempt to develop a model for predicting possible future responses to relative fuel price changes.

F.2.B. ASSUMPTIONS FOR A HIGH ELECTRIC SPACE HEAT SCENARIO

Given the present structure of relative fuel prices in the railbelt, the electric portion of the residential space heating load should remain relatively constant over time. This is predicated on the following assumptions:

TABLE F.21.
GROWTH OF USE OF NATURAL GAS FOR
ANCHORAGE RESIDENTIAL SPACE HEATING

Year	Dwelling Units (not including multifamily)	Residential Gas Customers	Percentage of Residences Using Gas
1960	16,313	0	0
1965	19,876	5,922	30
1970	24,216	12,097	50
1975	33,894	22,779	67
1978	39,702	30,629	77

SOURCES: 1960 Census of Housing, General Housing Characteristics: Alaska.

1970 Census of Housing, Detailed Housing Characteristics: Alaska.

Anchorage Urban Observatory, University of Alaska. 1975 Housing Study.

Alaska Gas and Service Company Annual Reports.

1. Retrofitting of fuel oil for electric space heating in Fairbanks will continue, but more slowly than in the years since 1975 when a ban on new residential electric space heating was imposed by Golden Valley Electric Association (GVEA). This is because of the high cost of conversion from resistance electric heating to a fuel oil boiler. Some switching will be partial conversions not to an alternative central heating system but rather to room-by-room heating units.

2. Retrofitting of natural gas for electric space heating in Anchorage will continue but also at a slow pace because not only is the conversion cost high but also because a large portion of the electric space heating load is in multifamily units where conversion may be relatively more expensive and the incentive to the owner less if the tenant absorbs the cost of the fuel. The conversion of such units to condominiums might speed the conversion process but not guarantee it.

3. The existing natural gas utility service areas do not expand significantly and thus capture a larger market share from the electric utilities. Such expansion might occur north into the Matanuska Valley, south into the Homer area, or into thinly populated portions of the Anchorage Borough such as the Hillside area and Girdwood. Such expansions would be a question of regulatory policy and the economics of laying new gas mains. This relates to the fourth assumption.

4. The distribution of the population within the regions of the railbelt (particularly Anchorage) does not change significantly. If all future population increase associated with economic growth in the Municipality of Anchorage settled in the Matanuska Valley, then the use of electric space heating would expand relatively rapidly. However, this growth, particularly if it were accompanied by an increase in the density of settlement, would be a stimulus to the extension of gas service into the Matanuska Valley, thus reducing the electric space heating proportion in favor of gas.

5. New natural gas utilities do not make natural gas an available alternative in either the Fairbanks or Glennallen-Valdez areas.

6. Presently available fuels, particularly natural gas, will continue to be available for residential space heating purposes.

The amount of recoverable reserves of natural gas remaining in Cook Inlet is the subject of some controversy. This is understandable since exploration is still proceeding and new reserves may be discovered. The total is obviously finite, but the proportion of existing reserves annually utilized for Anchorage space heating is relatively small. In 1979, for example, of 266 million mcf utilized, only 14 million was marketed to consumers for space heating and other uses.[33] Thus, to the extent space heating is a priority use of natural gas, relatively modest reserves and reserve additions would be sufficient to satisfy even a rapidly growing market. To a certain extent, the space heating priority is automatically built into the gas distribution structure. Gas sales from the gas utility to the electric utilities are under interruptible contract so that if supply constraints develop, the shortfall will occur in the availability of gas for electricity generation (at least in the short run).[34]

A reliable published estimate of currently proven recoverable reserves of natural gas in Cook Inlet does not exist. Recent past estimates are as follows:

1. 7.044 trillion cubic feet as of January 1, 1977.[35]
2. 6.413 trillion cubic feet as of January 1, 1977.[36]

Estimates of undedicated reserves are as follows:

1. 3.919 trillion cubic feet as of January 1, 1977.[37]

2. 4.236 trillion cubic feet as of January 1, 1978, from the currently producing fields.[38]

3. 5.422 trillion cubic feet as of January 1, 1978.[39]

Estimates of potential additional resources are from 6 to 29 trillion cubic feet.[40]

On the basis of existing reserves, the supply of gas in Cook Inlet is sufficient to meet demand growth through 2000 if a large proposed LNG export facility were not built. If it is built to preliminary design capacity and consumes 3.2 trillion cubic feet of gas over a twenty-year lifetime, then the existing supply will not be able to meet all expected demands.[41]

If the availability of alternative fuels (including natural gas, fuel oil, but also wood) is reduced or if the relative prices of alternative fuels rise and thus make electric space heating more economically attractive, then the proportion of space heating needs met electrically might increase.

It is clearly impossible to identify all of the conditions under which such a change might actually take place. Thus, it is also impossible to quantify the impacts on electricity use of all possible scenarios of changing relative electricity prices.

The factors determining relative prices could be divided into four categories as follows: Alaskan market conditions (supply and demand), national and international market conditions, national energy regulations and policies, and Alaskan energy policies. Both Federal and state policies will undoubtedly alter the relative prices and availabilities of fuels which would result from normal market forces over the next thirty years.

The state is in a central position in terms of being able to affect fuel prices and availabilities because of both its substantial surplus revenue position and its ownership of significant energy resources. The state government could, in the short run, easily subsidize the total energy requirements of the entire population out of excess revenues. It can provide fuel resources such as coal, oil, and natural gas to local markets at below market prices. Whether it will choose to do these things is a political question.

Federal regulations and policies may act to make particular fuels more expensive or unavailable for specific uses. Environmental regulations on coal are one example of the former, while possible prohibition on the use of gas in the generation of electricity is another.

Absent such government induced changes in energy fuel markets, the long-run trend in prices will likely be towards comparability and equality with world oil prices. In particular, it is plausible to assume that fuel oil prices and domestic oil prices will gradually approach the level of world oil prices as decontrol of prices is phased in. Prices of other fuels can thus be examined in relation to the fuel oil price. Examining region-by-region, the following price scenario is reasonable:

Anchorage. Natural gas prices will rise relative to fuel oil as existing contracts expire and as pricing provisions of existing contracts are activated which require that all purchasers pay the same price as the highest priced purchaser from a field.[42] The effect of these trends will be to raise the delivered price to the consumer of both natural gas and electricity since electricity is gas generated. Because of different contracts, the exact relative effects cannot be estimated accurately. The advent of the Pacific LNG facility has been estimated to have a larger price impact on electricity users rather than gas users, but overall price increases are not so easily estimated.[43] In any event, as long as gas is used to generate electricity and current space heating practices are maintained, gas will be the less expensive space heating fuel. It is possible, but not likely, that gas prices will reach parity with fuel oil. Working against such parity is the cost of transportation of gas to its alternative market on the West Coast. Working toward price parity is the fact that the market for gas on the West Coast may value the gas at its peak rather than baseload value. In this case, gas in Anchorage would lose its attractive price relative to fuel oil, but not electricity.

In order for electricity to be the cheapest fuel of the three, it must be produced by a means other than natural gas or fuel oil such as coal or hydropower. Electricity thus generated has the potential for being least cost, although it is by no means assured.

Fairbanks. As fuel oil prices rise, electricity prices will also increase because the present generating mode in Fairbanks utilizes fuel oil for incremental electricity generation. To the extent that electricity consumption also grows, the cost of electricity will continue to exceed the fuel oil cost for space heating purposes. This link will be broken, and the cost of electricity made independent of the fuel oil price if an alternative fuel such as coal or hydropower is used to generate electricity. In such a case, electricity may become a less costly fuel for space heating than fuel oil.

Glennallen-Valdez. The cost of electricity is presently tied to that of fuel oil because fuel oil is used to generate electricity. In the future, this will no longer be the case since a hydroelectric facility is currently under construction in the area. In the short run, the integration of the electricity from hydropower is not anticipated to reduce the price of electricity. If the price is stabilized at its current level, the price of fuel oil would have to increase by three times before electricity would be priced equivalent to fuel oil for space heating. This would occur in twenty years at a 6 percent rate of fuel price increase, or ten years at a 13 percent rate of fuel price increase.

Under these assumptions, a significant shift toward use of electricity could occur under the following conditions:

Anchorage. Decreased availability and/or increased price of gas result in the addition of coal and/or hydroelectric baseload electric generating facilities by 1990. The electricity price does not fall relative to that of gas until 2000, however, because:

1. The initial cost of those capital-intensive facilities is large.

2. The main source of electricity will continue to be gas-fired turbines which, since the gas will have become expensive, will keep the average price of electricity high.

Fairbanks. Increased demand or very rapid increase in the price of fuel oil makes a coal plant attractive. If it is in place by 1990, it could immediately "back out" high priced oil, but the electricity price would not immediately fall relative to that of alternatives because:

1. The initial cost of the capital-intensive coal plant will be large.

2. The cost of the fuel oil-fired generation facilities will still be a part of the price of electricity.

Glennallen-Valdez. By 1990, the fuel oil price may have increased sufficiently to make electricity from hydropower relatively attractive. For this to happen, any additional generating capacity requirements must also be met by low cost modes of generation.

This study cannot predict these outcomes since they are obviously dependent upon not only the level of demand but also upon costs of supply, taking into account not only the cost of additions to systems but the impact on system cost of those additions.

We can, however, analyze the case presented above where electricity becomes relatively inexpensive as a fuel. Based upon the foregoing, we assume a shift towards electricity for space heating beginning in the period 1995-2000 for Anchorage and Fairbanks and 1990-1995 for Glennallen-Valdez.

The price advantage for electricity is assumed to be real and lasting but not of a substantial magnitude. Thus, the shift to electric space heating follows the pattern observed in Fairbanks in the early 1970s, rather than the pattern in Anchorage in the 1960s during the shift to natural gas. That is, new installations are predominantly electric, but existing units are not retrofitted to electric space heat. This is primarily because of the cost of retrofitting to electric space heat (compared to switching from an oil to a gas burner, for example) combined with the relatively short average tenure by an owner in a home.

In addition, electric appliances became more attractive relative to natural gas and fuel oil. The electric incremental mode splits for water heaters, ranges, and clothes dryers increase at the same time that the shift to electric space heating occurs. The commercial-industrial-government sector projections are similar to those of the base case.

The parameter changes for this case are summarized in Table F.22.

TABLE F.22. PARAMETER VALUES: THE PRICE INDUCED SHIFT TOWARD ELECTRICITY CONSUMPTION IN THE RESIDENTIAL SECTOR CASE

Parameter	Region		
	Greater Anchorage	Greater Fairbanks	Glennallen-Valdez
SPACE HEAT			
incremental mode split ($msi_{j,t}$)			
SF			
1985	.19	.01	.02
1990	.19	.01	.02
1995	.19	.01	.9
2000+	.9	.9	.9
DP			
1985	.19	0	0
1990	.19	0	0
1995	.19	0	.9
2000+	.9	.9	.9
MF			
1985	.19	0	0
1990	.19	0	0
1995	.19	0	.9
2000+	.9	.9	.9
MH			
1985	.19	.01	0
1990	.19	.01	0
1995	.19	.01	.9
2000+	.9	.9	.9
APPLIANCES			
incremental mode split ($msi_{j,e,t}$)			
WH			
1985	.35	.5	.4
1990	.35	.5	.4
1995	.35	.5	.9
2000+	.9	.9	.9
C			
1985	.66	.85	.4
1990	.66	.85	.4
1995	.66	.85	.9
2000+	.9	.85	.9

SF = single family
DP = duplex
MF = multifamily
MH = mobile home
WH = water heating
C = cooking

ENDNOTES: APPENDIX F

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2. Jorgen S. Norgard, "Improved Efficiency in Domestic Electricity Use," Energy Policy, March 1979, pp. 43-56.

3. Battelle Columbus and Nepool Load Forecasting Task Force, "Report on Model for Long-Range Forecasting of Electric Energy and Demand to the New England Power Pool," June 30, 1977, p. 624.

4. California Energy Commission, "Appendix A: Analysis of Residential Energy Uses," Section A9.

5. Eric Hirst, William Lin, and Jane Cope, "A Residential Energy-Use Model Sensitive to Demographic Economic and Technological Factors," Quarterly Review of Economics and Business, Vol. 17, No. 2, p. 13.

6. Jerry A. Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy Using Durables," Bell Journal of Economics, Vol. 10, No. 1, p. 45.

7. Data from California Energy Commission, "Appendix A: Analysis of Residential Energy Uses," Appendix 7, Table A7.6.

8. Present average electricity consumption figures applied to 1960 saturation rate data results in a substantial overestimate of actual electricity consumption for that year.

9. California Energy Commission, Ibid.

10. California Energy Commission, Ibid., Section 12.

11. California Energy Commission, Ibid., Section 7, Table A7.5.

12. Compiled from California Energy Commission, Ibid., Section 7, Table A7.6.

13. California Energy Commission, Ibid., Section 7, Table A7.10.

14. California Energy Commission, Ibid., Section 10, Table A10.2.

15. American Gas Association, Gas Facts, annual.

16. Midwest Research Institute, Patterns of Energy Use by Electrical Appliance, for Electric Power Research Institute, EPRIEA 682, 1979, p. 512.

17. U.S. Department of Energy, Office of Public Affairs, "The Natural Energy Act," 1978.

18. Arthur D. Little, "Project Independence Residential and Commercial Energy Use Patterns 1970-1990," for Federal Energy Administration, 1974, p. 21-23.

19. Hirst and Carney, Ibid., p. 217.

20. California Energy Commission, Ibid., Section A3.

21. Arthur D. Little, Ibid.

22. Hirst and Carney, Ibid.

23. Larry Breeding. "Phase III Evaluation: ASHRAE 90-75 Energy Conservation in New Building Design, HUD Minimum Property Standards," for State of Alaska, Energy Conservation Program, 1976.

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25. Eric Hirst and Bruce Hannon, "Effects of Energy Conservation in Residential and Commercial Buildings," Science, Vol. 205, August 17, 1979, p. 656-661.

26. Arthur D. Little, Ibid., p. 157.

27. Ibid., p. 137.

28. Ibid., p. 139 and conversations with local engineers.

29. Charles Rivers Associates, "Analysis of Household Appliance Choice," report for Electric Power Research Institute, 1979, Chapter 2.

30. In Alaska, this is definitely a factor. A 1976 survey in Fairbanks found the median length of residence in owner-occupied housing to be three years. John Kruse, Fairbanks Community Survey, Institute of Social and Economic Research, 1977, p. 5. A 1975 Survey of Anchorage found that 61 percent of households had lived at their present address less than three years. Diddy Hitchens et al, "Anchorage Municipal Housing Study," Anchorage Urban Observatory, 1976.

31. A recent study estimated the discount rate used by consumers in making appliance choice decisions to be 25 percent, which is considerably above the opportunity cost of capital for many consumers. This suggests a bias in favor of systems with the least initial cost. Jerry Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy Using Durables," The Bell Journal of Economics, Vol. 10, No. 1, p. 33.

32. Based on conversations with Harold Schmidt of Anchorage Natural Gas Company.

33. Scott Goldsmith and Kristina O'Connor, "Alaska Historic and Projected Oil and Gas Consumption," prepared for the Alaska Royalty Oil and Gas Development Advisory Board and the Alaska State Legislature, 1980, p. 5.

34. Harold Schmidt, Ibid.

35. Stanford Research Institute, "Natural Gas Demand and Supply to the Year 2000 in the Cook Inlet Basin of Southcentral Alaska," for Pacific Alaska LNG Company, 1977, p. 37.

36. Alaska Department of Natural Resources estimate noted in Scott Goldsmith and Tom Lane, "Oil and Gas Consumption in Alaska 1976-2000," for the Alaska Royalty Oil and Gas Development Advisory Board and the Alaska State Legislature, p. III.5.

37. W. H. Swift et al, "Alaskan North Slope Royalty Natural Gas: An Analysis of Needs and Opportunities for In-State Use," for State of Alaska, Division of Energy and Power Development, p. V.5.

38. Scott Goldsmith and Tom Lane, Ibid., p. III.7.

39. Ibid., p. IV.5.

40. Stanford Research Institute, Ibid., p. 36.

41. Scott Goldsmith and Tom Lane, Ibid., p. IV.5.

42. For a recent analysis of this, see Jack Kreinheder, State of Alaska, House Research Agency Report - Request No. 30, February 1980.

43. Ibid.

APPENDIX G: PROJECTING MILITARY AND SELF-SUPPLIED INDUSTRIAL ELECTRICITY NET GENERATION

G.1. Military Requirements

Six major military installations, all of which produce and consume their own electricity, are located within the railbelt region of Alaska. The level of activity at these bases is a function of national defense policy and, as such, it is difficult to project. Historically, there has been considerable variation in the number of personnel stationed at these facilities with peaks occurring during World War II and the Korean War. Table G.1 shows the variation in the level of military personnel for the whole state over the historical period. (Currently, about 80 percent of statewide military personnel are located in the railbelt.) The general trend since the late 1950s has clearly been for a gradual decline, but this may not be a reasonable guide to future personnel levels.

We have not attempted to correlate military electricity consumption with the level of personnel or other factors for a number of reasons. A complete historical data series on military consumption would be difficult to obtain. A large and varying proportion of personnel live off base, and, consequently, their residential consumption is satisfied by utility-supplied power. Finally, the difficulty in projecting military personnel nullifies the value of utilizing a functional relationship between personnel and electricity consumption.

TABLE G.1. AVERAGE ANNUAL MILITARY PERSONNEL IN ALASKA (thousand)

1940	1	1960	33
1941	8	1961	33
1942	60	1962	33
1943	152	1963	34
1944	104	1964	35
1945	60	1965	33
1946	19	1966	33
1947	25	1967	34
1948	27	1968	33
1949	30	1969	32
1950	26	1970	31
1951	38	1971	30
1952	50	1972	31
1953	50	1973	27
1954	49	1974	26
1955	50	1975	25
1956	45	1976	24
1957	48	1977	25
1958	35	1978	23
1959	34	1979	23

Source: 1940-1959 - George Rogers, The Future of Alaska: The Economic Consequences of Statehood, Resources for the Future, 1962, p. 95.

1960-1965 - George Rogers, "Alaska Regional Population and Employment," ISER, 1967, p. 42.

1960-1969 - MAP model data.

1970-1979 - Alaska Department of Labor, "Alaska Population Overview, December 1979, p. 50.

The Air Force conservation goal is to reduce their total energy requirements by 20 percent by 1985, according to the Alaskan Air Command. The Army may have a similar conservation goal. It is not clear what impact this policy will have on electricity consumption.

Because of these difficulties which make detailed projections of military electricity requirements questionable, we assume the current level of net generation in all future years. Current requirements are shown in Table G.2.

G.2. Self-Supplied Industrial Requirements

The largest industrial users of self-generated electricity in the railbelt are, with one exception, in the category of petroleum production, processing, and transportation. The University of Alaska, Fairbanks campus, is the only large public, non-utility generator of electricity.

Table G.3 shows that most of the self-supplied electricity is centered in the Greater Anchorage Area. Offshore and onshore drilling and producing petroleum rigs contribute a major portion of the total load, along with the pipelines and other facilities for transporting and transshiping the petroleum. The major industrial facilities at North Kenai, consisting of two refineries, an LNG plant, and a fertilizer plant, complete the list of major consumers.

In Valdez, the oil pipeline Pump Station 12 and the facilities at the pipeline terminal are the major consumers.

TABLE G.2. RAILBELT MILITARY ELECTRICITY NET GENERATION
(FY 1979)
(10^3 MWh)

Greater Anchorage	
Fort Richardson Army Base	56.7
Elemdorf Air Force Base	98.8
Total	155.5
Greater Fairbanks	
Fort Greely Army Base	14.4
Fort Wainwright Army Base	36.8
Eilson Air Force Base	47.0
Clear Air Force Base	80.0
Total	178.2
Total Railbelt	333.7

Source: Military and Alaska Power Authority records.

TABLE G.3. RAILBELT SELF-SUPPLIED INDUSTRIAL NET GENERATION (10^3 MWh)

Area	1977	1978	1979
North Kenai	69.5	94.6	94.6
Valdez	39.4	54.8	54.8
Cook Inlet	208.9	226.7	226.7
Interior Alaska	25.7	37.9	37.9
Total	343.5	414.0	414.0

Source: Alaska Power Authority worksheets.

In Fairbanks, the University and pipeline Pump Stations 8 and 9 are the major consumers.

In some cases, an industrial facility will both generate its own electricity and purchase power from the local utility. For example, Alyeska Pump Station 12 uses electricity provided by Copper Valley Electric Association for all its needs except the pumps themselves, which are powered by self-supplied generation. In other instances, the facility may purchase power but maintain its own backup generation capability.

The difficulties in attempting to project self-supplied industrial electricity are that additions over time have been "lumpy" (large but infrequent) and that there is not always a clear criterion to determine whether a particular consumer will choose to provide his electricity from self generation rather than from utility purchased power. In some instances, such as the case of offshore drilling and production platforms, self-supplied electricity is the only practical method of obtaining power. In other cases, however, the industrial facility faces a choice, and the decision will depend upon the cost of self-generated electricity vs. the price of purchased electricity. Each instance will be different depending upon, among other things, the type of load, the capacity and load characteristics of the utility, and the resources available to the facility for generating electricity compared to those which the utility has available.

The utilities are presently supplying a portion of the large industrial consumer load, even though in total the load is relatively small. This is the case in Fairbanks for the refinery and a portion of oil pipeline requirements, in Valdez for a portion of oil pipeline requirements, and in the Greater Anchorage Area for the refineries and the LNG plant as well as some petroleum production and transportation facilities. Thus, a portion of increments to industrial requirements is already included in the utility load projections. Self-supplied industrial requirements should be limited to new industrial uses that would not normally be picked up by the utilities given the same general market conditions in the future as in the past.

Having thus narrowed the definition of self-supplied industrial requirements, it is still possible to identify two types of industrial facilities. The first is any facility which chooses to locate in the railbelt independent of the price of electricity, while the second is any facility which chooses to locate in the railbelt because of price of electricity or the availability of electricity. We address ourselves to and consider only the first type of facility because the determination of whether such "electricity intensive" industries will locate in Alaska in the future is a function of, among other things, future electricity price, which is beyond the scope of the present study.

Table G.4 presents the self-supplied electricity requirements for those facilities identified in the economic scenarios. Three have relatively small requirements which we assume to be incorporated in

TABLE G.4. PROJECTED ADDITIONS TO RAILBELT SELF-SUPPLIED INDUSTRIAL ELECTRICITY REQUIREMENTS (10^3 MWh annual)

Facility	Economic Scenario					
	Minimum		Likely		Maximum	
	Consumption (10^3 MWh)	Start Date	Consumption (10^3 MWh)	Start Date	Consumption (10^3 MWh)	Start Date
Pacific Alaska LNG[a]	0	-	127	1985	127	1985
Alpetco Refinery[b]	0	-	30	1985	306	1985
Cook Inlet Oil Development[c]	0	-	0	-	46	1990
Fairbanks Petro-chemicals[d]	0	-	0	-	88	1990
Northwest Alaska Gas Pipeline	Incorporated in utility sales forecast.					
State Capital Move	Incorporated in utility sales forecast.					
Beluga Coal Development	Incorporated in utility sales forecast.					

[a]Homer Electric Association, Power Requirements Study, 1977.

[b]Calculated from Alpetco Refinery Environmental Impact Statement, Volume II, p. 343 and 413. Assuming 51.5 MW operating at 80 percent capacity, 85 percent of the year for high case. Authors' estimate of basic refinery requirement for medium case.

[c]Assumes a 20 percent increase from present requirements.

[d]With a capacity for processing 200 million cubic feet/day of royalty gas and if 8 percent of input is used for processing and if 25 percent of processing is steam and electricity, 4.0×10^9 btu daily would be used. (Based upon same proportions as the Alpetco refinery.) This can be converted to electricity by assuming a 25 percent conversion efficiency and 80 percent load factor.

the utility projections. Of the other facilities, they all could have their electricity requirements met by utilities if it were available, except perhaps in the case of additional oil development in the Cook Inlet. Their requirements are large enough, however, that they should be treated, for projection purpose, as additions to, rather than components of, the utility electricity requirement.

APPENDIX H

HISTORICAL ELECTRICITY SALES AND ECONOMIC DATA

TABLE H.1.

RAILBELT TOTAL ELECTRICITY SALES TO FINAL CONSUMERS

(GWh)

GREATER ANCHORAGE AREA

	Chugach Electric Association	Anchorage Municipal Light & Power	Matanuska Electric Association	Homer Electric Association	Seward Electric System	Total
1965	165	133	34	31	6	369
1966	190	143	36	39	7	415
1967	207	159	39	49	7	461
1968	235	170	39	67	8	519
1969	262	190	44	82	9	587
1970	309	222	50	93	10	684
1971	368	254	61	103	11	797
1972	435	288	72	99	13	906
1973	485	326	81	105	14	1,010
1974	517	350	92	112	14	1,086
1975	596	405	118	133	17	1,270
1976	668	468	147	161	18	1,463
1977	727	492	172	194	17	1,603
1978	781	498	223	224*	20	1,747
1979[p]	803	523	232	247	-	

[p]Preliminary, based on data from various sources.

*Approximate

TABLE H.1. (continued)

RAILBELT TOTAL ELECTRICITY SALES TO FINAL CONSUMERS (Continued)

(GWh)

	GREATER FAIRBANKS AREA				GLENNALLEN-VALDEZ AREA	RAILBELT TOTAL
	Golden Valley Electric Association	Fairbanks Municipal Utilities System	Alaska Power and Telephone Tok	Total	Copper Valley Electric Association	
1965	50	47	1	98	6	473
1966	59	49	**	108	**	523
1967	66	**	**	66	**	527
1968	84	58	**	141	**	661
1969	104	66	**	170	**	758
1970	136	75	2	213	9	907
1971	175	76	**	251	10	1,059
1972	190	70	2	262	6***	1,174
1973	206	81	3	290	11	1,311
1974	231	88	3	322	14	1,422
1975	300	110	3	413	24	1,707
1976	306	114	3	423	33	1,920
1977	324	118	5	447	42	2,092
1978	310	116	5	432	38	2,217
1979[p]	302	-	-		37	

[p] Preliminary, based on data from various sources.

** Not available   *** Valdez only

TABLE H.2. HISTORICAL RESIDENTIAL UTILITY SALES

GREATER ANCHORAGE AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Chugach Electric Association (CEA)

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	111,587	15,446	7,224
1966	128,484	16,487	7,793
1967	134,985	17,037	7,923
1968	148,591	19,893	7,470
1969	166,146	22,036	7,540
1970	198,856	24,682	8,057
1971	236,857	25,761	9,194
1972	269,252	28,687	9,386
1973	287,484	29,077	9,887
1974	305,739	31,779	9,621
1975	359,922	34,031	10,576
1976	397,846	35,960	11,064
1977	432,070	41,025	10,532
1978	472,040	43,542	10,841
1979[p]	477,189	42,761	11,161

[p]Preliminary, based on data from various sources.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Anchorage Municipal Light and Power (AMLP)

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	34,656	6,664	5,201
1966	35,056	6,516	5,380
1967	38,426	6,894	5,574
1968	42,825	7,544	5,677
1969	47,781	8,043	5,941
1970	54,518	8,477	6,431
1971	63,038	9,295	6,782
1972	72,993	10,130	7,206
1973	82,663	10,838	7,627
1974	89,946	11,674	7,705
1975	105,214	11,803	8,914
1976	119,475	12,353	9,672
1977	117,986	13,605	8,672
1978	115,638	14,374	8,045
1979[p]	116,211	13,517	8,597

[p]Preliminary, based on data from various sources.

NOTE: Year-end customer data overstated in 1977 and 1978 due to a computer error within Municipality of Anchorage.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Matanuska Electric Association (MEA)[a]

	Energy Delivered To Final Customers[b] (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	16,628	2,688	6,186
1966	18,012	2,707	6,554
1967	19,623	3,022	6,493
1968	20,760	3,174	6,541
1969	24,861	3,611	6,885
1970	29,416	3,975	7,400
1971	37,791	4,281	8,828
1972	44,147	4,669	9,455
1973	51,026	5,045	10,114
1974	59,764	6,153	9,713
1975	77,592	6,834	11,354
1976	96,280	7,681	12,535
1977	112,662	8,321	13,539
1978	152,133	10,152	14,986
1979[p]	157,889	10,362	15,237

[a]Palmer and Talkeetna stations.

[b]Farm (including irrigation) and nonfarm residential.

[p]Preliminary, based on data from various sources.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Homer Electric Association (HEA)[a]

	Energy Delivered To Final Customers[b] (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	7,526	1,569	4,797
1966	9,809	1,753	5,596
1967	12,402	2,441	5,081
1968	17,673	3,182	5,554
1969	20,200	3,296	6,129
1970	22,768	3,312	6,874
1971	27,267	3,431	7,947
1972	28,299	3,491	8,106
1973	30,849	3,708	8,320
1974	33,752	4,215	8,008
1975	44,008	4,773	9,220
1976	55,859	5,508	10,141
1977	70,742	7,346	9,630
1978	94,846	7,904	12,000
1979[p]	108,973	8,764	12,434

[a]Homer and Kenai stations.

[b]Farm and nonfarm residential customers.

[p]Preliminary, based on data from various sources.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Seward Electric System (SES)

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	3,169	649	4,883
1966	3,073	656	5,439
1967	2,987	634	4,711
1968	3,179	650	4,891
1969	3,481	667	5,219
1970	3,771	705	5,349
1971	4,101	718	5,712
1972	4,535	730	6,212
1973	4,711	765	6,158
1974	4,664	785	5,941
1975	5,120	885	5,785
1976	5,632	911	6,182
1977	6,020	978	6,155
1978	6,807	1,027	6,628
1979	*	*	*

*Not available

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Total Anchorage Area System

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	173,566	27,016	6,425
1966	194,434	28,028	6,937
1967	208,423	30,028	6,941
1968	233,028	34,443	6,766
1969	262,469	37,653	6,971
1970	309,329	41,151	7,517
1971	369,054	43,486	8,487
1972	419,226	47,707	8,788
1973	456,733	49,433	9,239
1974	493,865	54 606	9,044
1975	591,856	58,326	10,147
1976	675,092	62,413	10,817
1977	739,480	71,275	10,375
1978	841,464	76,999	10,928

GREATER FAIRBANKS AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Golden Valley Electric Association (GVEA)

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	23,142	4,036	5,734
1966	29,184	4,213	6,927
1967	33,444	4,402	7,597
1968	41,917	4,957	8,456
1969	54,569	5,459	9,996
1970	67,123	6,224	10,785
1971	81,960	6,741	12,158
1972	96,702	6,947	13,920
1973	106,882	7,382	14,479
1974	127,873	8,643	14,795
1975	160,199	9,243	17,332
1976	162,369	10,680	15,203
1977	168,275	12,443	13,524
1978	150,804	13,030	11,574
1979[p]	142,960	13,711	10,427

[p]Preliminary, based on data from various sources.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER FAIRBANKS AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Fairbanks Municipal Utility System (FMUS)

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	16,172	4,147	3,900
1966	17,485	3,957	4,419
1967	*	*	*
1968	19,461	4,387	4,436
1969	22,327	4,564	4,892
1970	23,419	4,532	5,167
1971	24,456	4,443	5,504
1972	24,248	4,540	5,341
1973	25,952	4,443	5,841
1974	25,909	4,618	5,610
1975	30,181	4,634	6,513
1976	31,302	4,739	6,605
1977	29,497	4,754	6,205
1978	27,109	4,494	6,032
1979	*	*	*

*Not available

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER FAIRBANKS AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Alaska Power and Telephone, Tok

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	142	*	*
1966	*	*	*
1967	*	*	*
1968	*	*	*
1969	*	*	*
1970	279	*	*
1971	*	*	*
1972	396	*	*
1973	411	*	*
1974	470	*	*
1975	603	*	*
1976	730	*	*
1977	795	155	5,129
1978	870	*	*
1979	*	*	*

*Not available

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER FAIRBANKS AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Total Fairbanks Area System[a]

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	39,314	8,183	4,804
1966	46,669	8,170	5,712
1967	*	*	*
1968	61,378	9,344	6,569
1969	76,896	10,023	7,672
1970	90,542	10,756	8,418
1971	106,416	11,184	9,515
1972	120,950	11,487	10,529
1973	132,834	11,825	11,233
1974	153,782	13,261	11,600
1975	190,380	13,877	13,719
1976	193,671	15,419	12,561
1977	197,772	17,197	11,500
1978	177,913	17,524	10,153

[a] Net of Tok

* Not available

GLENNALLEN-VALDEZ AREA
RESIDENTIAL ELECTRICITY CONSUMPTION

Copper Valley Electric Association (CVEA)[a]

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	1,445	432	3,345
1966	*	*	*
1967	*	*	*
1968	*	*	*
1969	*	*	*
1970	2,133	561	3,802
1971	2,611**	676**	3,862
1972	1,528	324	4,716
1973	2,887	680	4,246
1974	3,751	935	4,012
1975	7,656	1,487	5,149
1976	10,234	1,758	5,821
1977	10,895	1,601	6,805
1978	9,545	1,539	6,202
1979[p]	9,354	1,588	5,890

[a]Glennallen and Valdez stations.

[p]Preliminary, based on data from various sources.

*Not available **Valdez only

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

TABLE H.3. HISTORICAL COMMERCIAL-INDUSTRIAL-GOVERNMENT CONSUMPTION DATA

GREATER ANCHORAGE AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Chugach Electric Association (CEA)

	Energy Delivered To Final Customers[a] (MWh)	Year-End Customers[b]	Consumption/Customer[c] (kWh)
1965	52,920	964	51,605
1966	60,601	1,047	53,626
1967	71,561	1,135	57,532
1968	84,513	1,381	55,652
1969	94,565	1,678	51,544
1970	108,298	2,040	53,087
1971	128,675	2,126	60,525
1972	163,566	2,449	66,789
1973	194,973	2,579	75,600
1974	208,855	2,835	73,670
1975	231,377	3,036	76,211
1976	264,731	3,494	75,767
1977	289,394	4,208	68,772
1978	303,263	4,331	70,021
1979[p]	320,365	4,414	72,579

[a] Commercial and other (public authorities).

[b] Other only since 1970.

[c] Other only since 1970.

[p] Preliminary, based on data from various sources.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Anchorage Municipal Light and Power (AMLP)

	Energy Delivered To Final Customers[a] (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	92,889	2,071	44,852
1966	104,663	2,058	50,857
1967	116,157	2,060	56,387
1968	121,490	2,107	57,660
1969	135,306	2,115	63,974
1970	159,538	2,159	73,894
1971	181,374	2,226	81,480
1972	205,288	2,315	88,677
1973	233,312	2,350	99,282
1974	250,409	2,417	103,603
1975	289,296	2,464	117,409
1976	339,550	2,675	126,935
1977	365,510	2,800	130,539
1978	372,511	2,885	129,120
1979[p]	396,811	2,933	135,292

[a]Commercial and industrial.

[p]Preliminary, based on data from various sources.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Matanuska Electric Association (MEA)[a]

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	16,441	412	39,905
1966	17,187	425	40,440
1967	18,172	490	37,086
1968	17,471	500	34,942
1969	18,148	511	35,515
1970	19,311	594	32,510
1971	22,239	599	37,127
1972	26,264	675	38,910
1973	28,252	739	38,230
1974	30,630	800	38,288
1975	38,756	980	39,547
1976	48,296	1,128	42,816
1977	57,263	1,265	45,267
1978	66,699	1,307	51,032
1979[p]	71,255	1,315	54,186

[a]Palmer and Talkeetna stations.

[p]Preliminary, based on data from various sources.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Homer Electric Association (HEA)[a]

	Energy Delivered To Final Customers[b] (MWh)	Year-End Customers[c]	Consumption/Customer[d] (kWh)
1965	23,419	416	44,647
1966	28,707	493	48,032
1967	30,705	561	52,989
1968	49,421	687	63,086
1969	63,155	705	72,852
1970	69,887	813	85,962
1971	75,955	861	88,217
1972	70,382	797	88,308
1973	74,194	831	89,283
1974	78,517	981	80,038
1975	88,714	1,066	83,221
1976	105,239	1,232	85,421
1977	122,512	1,355	90,415
1978	129,493	1,422*	91,064
1979[p]	137,727	**	**

[a]Homer and Kenai stations.

[b]Commercial, industrial, and public buildings.

[c]Public buildings only since 1970.

[d]Public buildings only since 1970.

[p]Preliminary, based on data from various sources.

*Yearly average **Not available

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Seward Electric System (SES)

	Energy Delivered To Final Customers[a] (MWh)	Year-End Customers[b]	Consumption/Customer[c] (kWh)
1965	2,989	131	15,349
1966	4,109	124	17,702
1967	4,267	117	14,197
1968	4,367	129	14,969
1969	4,814	116	18,552
1970	5,695	178	31,994
1971	6,513	194	33,572
1972	7,680	184	41,739
1973	8,436	194	43,485
1974	8,640	199	43,417
1975	11,174	204	54,775
1976	12,080	260	46,462
1977	10,842	232	46,733
1978	12,409	274	45,288
1979	*	*	*

[a] Commercial, industrial, and public authorities.

[b] Public authorities only since 1970.

[c] Public authorities only since 1970.

* Not available

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER ANCHORAGE AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Total Anchorage Area System

	Energy Delivered To Final Customers (MWh)	Year-End Customers[a]	Consumption/Customer[a] (kWh)
1965	188,658	3,994	47,235
1966	215,267	4,147	51,909
1967	240,862	4,363	55,206
1968	277,262	4,804	57,715
1969	315,988	5,125	61,656
1970	362,729	5,784	62,713
1971	414,756	6,006	69,057
1972	473,180	6,420	73,704
1973	539,167	6,693	80,557
1974	577,051	7,232	79,791
1975	659,317	7,750	85,073
1976	769,896	8,789	87,598
1977	845,521	9,860	85,753
1978	884,375	10,219	86,542

[a]Number of customers are slightly underreported and average consumption calculations are slightly overestimated prior to 1970 due to incomplete information prior to 1970 on the following customer categories: Chugach "other," Homer public buildings, and Seward public authorities.

GREATER FAIRBANKS AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Golden Valley Electric Association (GVEA)

	Energy Delivered To Final Customers (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	25,850	523	49,426
1966	28,982	591	49,039
1967	30,830	576	53,524
1968	41,585	634	65,915
1969	49,284	703	70,105
1970	69,064	844	81,829
1971	84,295	914	92,226
1972	92,758	916	101,264
1973	98,744	973	101,484
1974	102,342	1,132	90,408
1975	133,972	1,209	110,812
1976	138,735	1,365	101,637
1977	155,426	1,649	94,255
1978	157,202	1,675	93,852
1979[p]	155,436	*	*

[p] Preliminary, based on data from various sources.

*Not available

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER FAIRBANKS AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Fairbanks Municipal Utility System (FMUS)

	Energy Delivered To Final Customers[a] (MWh)	Year-End Customers[b]	Consumption/Customer[c] (kWh)
1965	29,348	795	27,810
1966	30,394	876	25,862
1967	*	*	*
1968	36,321	835	33,101
1969	41,928	876	36,397
1970	49,496	1,044	47,410
1971	48,761**	1,015**	48,040
1972	43,115**	1,086**	39,701
1973	52,079	1,081	48,177
1974	59,273	1,110	53,399
1975	76,787	1,133	67,773
1976	80,440	1,165	69,047
1977	85,037	1,185	71,761
1978	85,466	1,179	72,490
1979	*	*	*

[a]Commercial and other (public) categories.

[b]Other only since 1970.

[c]Other only since 1970.

*Not available. **Based on author's estimate of street lighting requirements due to aberration in reporting method for these years.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER FAIRBANKS AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Alaska Power and Telephone, Tok

	Energy Delivered To Final Customers[a] (MWh)	Year-End Customers	Consumption/Customer (kWh)
1965	1,343	*	*
1966	*	*	*
1967	*	*	*
1968	*	*	*
1969	*	*	*
1970	1,537	*	*
1971	*	*	*
1972	1,949	*	*
1973	2,663	*	*
1974	2,526	*	*
1975	2,652	*	*
1976	2,730	*	*
1977	4,089	75	54,520
1978	4,514	*	*
1979	*	*	*

[a] Commercial, industrial, and other categories.

* Not available

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GREATER FAIRBANKS AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Total Fairbanks Area System[a]

	Energy Delivered To Final Customers (MWh)	Year-End Customers[b]	Consumption/Customer[b] (kWh)
1965	55,198	1,318	41,880
1966	59,376	1,467	40,474
1967	*	*	*
1968	77,906	1,469	53,033
1969	91,212	1,579	57,766
1970	118,560	1,888	62,797
1971	133,056	1,929	68,977
1972	135,873	2,002	67,869
1973	150,823	2,054	73,429
1974	161,615	2,242	72,085
1975	210,759	2,342	89,991
1976	219,175	2,530	86,630
1977	240,463	2,834	84,849
1978	242,668	2,854	85,027

[a]Net of Tok and University of Alaska.

[b]Number of customers are slightly underreported, and average consumption calculations are slightly overestimated prior to 1970 due to incomplete information prior to 1970 on the following customer categories--FMUS other (public).

*Not available

GREATER FAIRBANKS AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

University of Alaska

	Energy Delivered To Final Consumers (MWh)
1965	*
1966	*
1967	*
1968	*
1969	*
1970	21,768
1971	*
1972	29,567
1973	31,913
1974	27,646
1975	28,259
1976	27,195
1977	25,644
1978	*
1979	*

*Not available

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

GLENNALLEN-VALDEZ AREA
COMMERCIAL-INDUSTRIAL-GOVERNMENT
ELECTRICITY CONSUMPTION

Copper Valley Electric Association (CVEA)[a]

	Energy Delivered To Final Customers[b] (MWh)	Year-End Customers[c]	Consumption/Customer[c] (kWh)
1965	4,188	141	29,702
1966	*	*	*
1967	*	*	*
1968	*	*	*
1969	*	*	*
1970	7,235	240	30,146
1971	7,657	249	30,751
1972	3,842**	122**	31,492
1973	8,130	371	21,914
1974	10,193	354	28,794
1975	16,062	426	37,704
1976	22,465	455	49,374
1977	31,307	491	63,762
1978	28,604	495	57,786
1979[p]	26,917	492	54,709

[a]Glennallen and Valdez stations.

[b]Commercial, industrial, and other (public buildings).

[c]Public building customers only since 1970.

[p]Preliminary, based on data from various sources.

*Not available **Valdez only

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

TABLE H.4.
MISCELLANEOUS ELECTRICITY CONSUMPTION

(Primarily Street Lighting)

(MWh)

	GREATER ANCHORAGE AREA	GREATER FAIRBANKS AREA	GLENNALLEN-VALDEZ AREA
1965	6,907	2,429	0
1966	5,439	2,585	*
1967	6,322	1,560[a]	*
1968	8,875	2,207	*
1969	10,257	2,216	*
1970	11,845	2,289	115
1971	13,682	11,197	136
1972	14,086	2,984	134
1973	15,940	3,361	151
1974	16,609	3,354	97
1975	18,619	8,945	130
1976	18,542	7,193	152
1977	17,707	3,467	171
1978	21,362	5,864	182

[a] Golden Valley Electric Association only.

* Not available.

SOURCE: Federal Energy Regulatory Commission, Power System Statement.

TABLE H.5. HISTORICAL RAILBELT EMPLOYMENT

GREATER ANCHORAGE AREA
NONAGRICULTURAL WAGE AND SALARY EMPLOYMENT[a]

(thousand)

	Census Division				
Year	Anchorage	Kenai-Cook Inlet	Matanuska-Susitna	Seward	Total
1965	30,704	1,756	1,085	621	34,166
1966	31,519	2,465	1,139	645	35,768
1967	32,958	3,678	1,075	638	38,349
1968	34,021	4,470	988	602	40,081
1969	37,789	4,144	1,002	626	43,561
1970	39,667	3,546	1,142	689	45,044
1971	44,616	3,454	1,415	774	50,259
1972	48,252	3,818	1,447	809	54,326
1973	50,630	4,049	1,610	862	57,151
1974	58,716	4,487	1,786	934	65,923
1975	69,561	5,595	2,149	1,152	78,457
1976	73,019	6,473	2,398	1,137	83,027
1977	76,997	7,340	2,653	1,155	88,145
1978	76,942	6,565	3,083	1,226	87,816

[a] Does not include active-duty military or self-employed.

SOURCES: 1975 through 1978: Alaska Department of Commerce and Economic Development, Division of Economic Enterprise, "Numbers: Basic Economic Statistics of Alaska Census Divisions," November 1979.

1965 through 1974: Alaska Department of Labor.

GREATER FAIRBANKS AREA
NONAGRICULTURAL WAGE AND SALARY EMPLOYMENT[a]

(thousand)

	Census Division		
Year	Fairbanks	Southeast Fairbanks	Total
1965	-	-	11,511
1966	-	-	11,767
1967	-	-	11,929
1968	-	-	12,383
1969	-	-	13,901
1970	-	-	14,377
1971	-	-	14,648
1972	-	-	15,583
1973	-	-	15,480
1974	-	-	19,749
1975	28,740	2,044	30,784
1976	28,118	2,615	30,733
1977	24,868	819	25,687
1978	21,662	874	22,536

[a]Does not include active-duty military or self-employed.

SOURCES: 1975 through 1978: Alaska Department of Commerce and Economic Development, Division of Economic Enterprise, "Numbers: Basic Economic Statistics of Alaska Census Divisions," November 1979.

1965 through 1974: Alaska Department of Labor.

GLENNALLEN-VALDEZ AREA
NONAGRICULTURAL WAGE AND SALARY EMPLOYMENT[a]

(thousand)

Year	Valdez-Chitina-Whittier
1965	757
1966	826
1967	773
1968	667
1969	786
1970	859
1971	1,087
1972	906
1973	988
1974	1,529
1975	4,763
1976	8,049
1977	4,199
1978	2,043

[a]Does not include active-duty military or self-employed.

SOURCES: 1975 through 1978: Alaska Department of Commerce and Economic Development, Division of Economic Enterprise, "Numbers: Basic Economic Statistics of Alaska Census Divisions," November 1979.

1965 through 1974: Alaska Department of Labor.

TABLE H.6. HISTORICAL RAILBELT HEATING DEGREE DAYS

GREATER ANCHORAGE AREA
HEATING DEGREE DAYS

(Annual)

Season	Anchorage	Homer	Talkeetna
1960-61	10,261	10,026	11,160
1961-62	11,524	10,696	12,621
1962-63	10,406	9,966	11,304
1963-64	10,781	10,108	11,845
1964-65	11,064	10,577	11,991
1965-66	11,174	10,840	12,499
1966-67	11,384	10,278	11,947
1967-68	9,997	9,793	11,364
1968-69	10,779	10,410	11,851
1969-70	9,351	9,446	10,631
1970-71	11,670	11,340	13,280
1971-72	12,077	11,471	13,406
1972-73	11,555	-	12,203
1973-74	11,223	10,807	12,235
1974-75	10,868	10,389	12,081
1975-76	11,115	10,694	12,340
1976-77	9,050	8,901	10,268
1977-78	9,701	9,668	10,984
1978-79	9,395	-	-
Normal	10,911	10,364	11,708

SOURCE: "Local Climatological Data," National Oceanic and Atmospheric Administration, Environmental Data and Information Service, National Climatic Center, Asheville, N.C.

GREATER FAIRBANKS AREA
HEATING DEGREE DAYS

(Annual)

Season	Fairbanks
1960-61	14,009
1961-62	14,786
1962-63	13,692
1963-64	14,912
1964-65	15,009
1965-66	15,688
1966-67	14,544
1967-68	13,671
1968-69	14,664
1969-70	12,939
1970-71	15,215
1971-72	15,141
1972-73	13,547
1973-74	14,391
1974-75	13,808
1975-76	14,683
1976-77	12,674
1977-78	13,635
1978-79	13,802
Normal	14,344

SOURCE: "Local Climatological Data," National Oceanic and Atmospheric Administration, Environmental Data and Information Service, National Climatic Center, Asheville, N.C.

GLENNALLEN-VALDEZ AREA
HEATING DEGREE DAYS

(Annual)

Season	Gulkana	Valdez
1960-61	13,707	-
1961-62	14,551	-
1962-63	13,227	-
1963-64	14,183	-
1964-65	14,062	-
1965-66	15,054	-
1966-67	14,527	-
1967-68	13,290	-
1968-69	14,594	-
1969-70	12,975	-
1970-71	15,002	-
1971-72	15,810	-
1972-73	14,266	-
1973-74	-	10,682
1974-75	13,768	9,911
1975-76	14,061	10,255
1976-77	-	9,130
1977-78	13,966	9,422
Normal	13,937	10,545

SOURCE: "Local Climatological Data," National Oceanic and Atmospheric Administration, Environmental Data and Information Service, National Climatic Center, Asheville, N.C.

TABLE H.7.
SEASONAL VARIATION IN ELECTRICAL ENERGY GENERATION

	Summer July-August Sales		Winter December-January Sales	
	Percent of Annual	Percent of Monthly Average	Percent of Annual	Percent of Monthly Average
SOUTHCENTRAL				
1964	13.1	78.6	21.1	126.6
1965	13.6	81.6	20.9	125.4
1966	14.2	85.2	21.0	126.0
1967	13.5	81.0	21.1	126.6
1968	13.1	78.6	22.0	132.0
1969	13.5	81.0	21.0	126.0
1970	13.4	80.4	22.1	132.6
1971	12.8	76.8	21.3	127.8
1972	12.5	75.0	21.9	131.4
1973	12.9	77.4	20.8	124.8
1974	13.2	79.2	20.8	124.8
1975	13.0	78.0	21.7	130.2
1976	13.0	78.0	20.2	121.2
1977	12.8	76.8	21.7	130.2
1978	13.6	81.6		
INTERIOR				
1964	14.4	86.4	21.2	127.2
1965	12.5	75.0	21.4	128.4
1966	13.0	78.0	22.3	133.8
1967	14.9	89.4	21.4	128.4
1968	14.6	87.6	22.5	135.0
1969	12.0	72.0	22.9	137.4
1970	11.7	70.2	25.1	150.6
1971	11.1	66.6	22.9	137.4
1972	11.4	68.4	23.6	141.6
1973	11.5	69.0	22.2	133.2
1974	11.2	67.2	23.7	142.2
1975	10.8	64.8	24.0	144.0
1976	11.9	71.4	21.8	130.8
1977	12.6	75.6	23.3	139.8
1978	12.9	77.4		

SOURCE: Compiled from data supplied by the Alaska Power Administration.

APPENDIX I. A REVIEW AND COMPARISON OF RAILBELT ELECTRIC POWER REQUIREMENT PROJECTIONS

I.1. Susitna River Basin: A Report on the Potential Development of Water Resources in the Susitna River Basin of Alaska by U.S. Department of Interior, sponsored and prepared by the Bureau of Reclamation, Alaska District Office, 1952.

This report did not present a detailed analysis of the electric load beyond the accompanying Figure I.1 which depicts a 30-year forecast. Residential space heating was assumed to be 50 percent electric by 1970, resulting in an average residential use of 10,000 KWh annually and total consumption of 635,000 MWh. The market area (equivalent to the present study minus the Glennallen-Valdez area) was projected to have a population of 260,000 in 1970. Farm requirements were projected at 66,000 MWh based on 3,800 to 4,000 farms by 1970. Commercial and municipal requirements were projected at 256,000 MWh for the same year. Projected large industrial electricity users included an electrified railroad, minerals, petroleum, synthetic fuels from coal, and local industries together consuming 1,732,000 MWh in 1970.

I.2. Devils Canyon Project: Alaska, Feasibility Report by U.S. Department of Interior, Bureau of Reclamation, Alaska District, 1960.

Gross generation requirements in this study are projected for 22 years for utilities, large industry, and military as shown in Figure I.2 and Table I.1. Simple growth rates ranging from 10 to 12 percent annually were

FIGURE I.1.

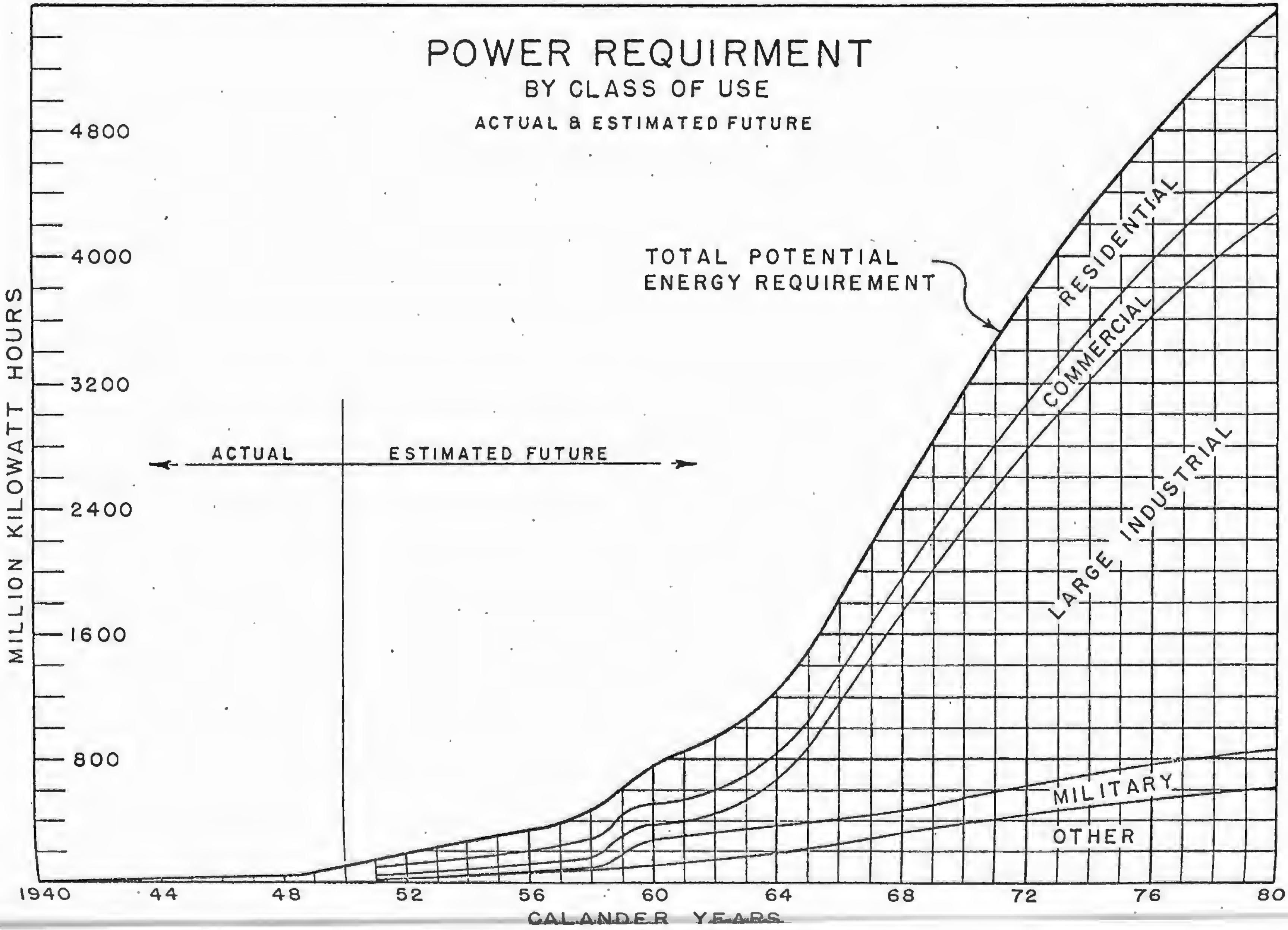

POWER REQUIRMENT
BY CLASS OF USE
ACTUAL & ESTIMATED FUTURE
TOTAL POTENTIAL
ENERGY REQUIREMENT
RESIDENTIAL
COMMERCIAL
LARGE INDUSTRIAL
MILITARY
OTHER
ACTUAL
ESTIMATED FUTURE
MILLION KILOWATT HOURS
4800
4000
3200
2400
1600
800
1940
44
48
52
56
60
64
68
72
76
80
CALANDER YEARS

FIGURE I.2.

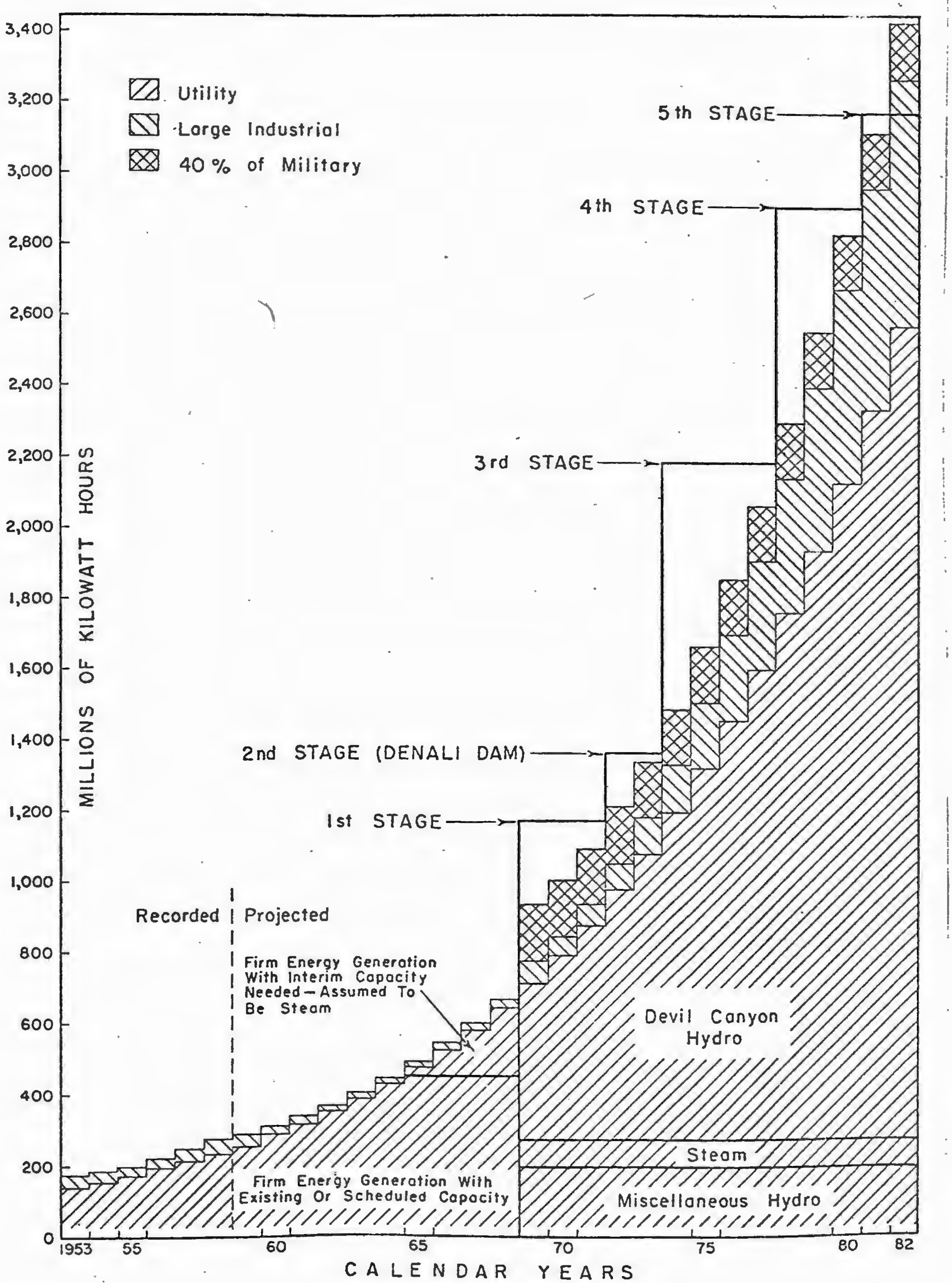

MILLIONS OF KILOWATT HOURS
3,400
3,200
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Utility
Large Industrial
40 % of Military
5th STAGE
4th STAGE
3rd STAGE
2nd STAGE (DENALI DAM)
1st STAGE
Recorded
Projected
Firm Energy Generation With Interim Capacity Needed — Assumed To Be Steam
Devil Canyon Hydro
Steam
Firm Energy Generation With Existing Or Scheduled Capacity
Miscellaneous Hydro
1953
55
60
65
70
75
80
82
CALENDAR YEARS

TABLE I.1.

Projection of Total Energy Load

Devil Canyon Power Market Area

Unit: Million kilowatt-hours

Calendar Year	Nonmilitary loads: Utility	Nonmilitary loads: Large industrial	Nonmilitary loads: Total	Nonmilitary loads: Supplied by utility	Nonmilitary loads: Supplied by project	Military load supplied by project	Total load supplied by project
1960	287	22	309	309	-	-	-
1961	317	22	339	339	-	-	-
1962	351	19	370	370	-	-	-
1963	388	16	404	404	-	-	-
1964	429	14	443	443	-	-	-
1965	474	19	493	493	-	-	-
1966	524	21	545	545	-	-	-
1967	580	22	602	602	-	-	-
1968	641	25	666	666	-	-	-
1969	711	42	773	270	503	158	661
1970	789	51	840	270	570	158	728
1971	876	60	936	270	666	158	824
1972	972	75	1,047	270	777	158	935
1973	1,077	99	1,176	270	906	158	1,064
1974	1,191	137	1,328	270	1,058	158	1,216
1975	1,315	184	1,499	270	1,229	158	1,387
1976	1,449	242	1,691	270	1,421	158	1,579
1977	1,594	305	1,899	270	1,629	158	1,787
1978	1,753	384	2,137	270	1,867	158	2,025
1979	1,928	463	2,391	270	2,121	158	2,279
1980	2,121	542	2,663	270	2,393	158	2,551
1981	2,333	616	2,949	270	2,679	158	2,837
1982	2,566	695	3,261	519	2,742	158	2,900

TABLE I.2.

Projection of Alaska's Electric Power Requirements, Electric Utility Systems, and Nonutility Installations

Region and type of load	Load center number (fig. 4)	1965		1975		1985	
		Energy mwh.	Peak demand (mw.)	Energy mwh.	Peak demand (mw.)	Energy mwh.	Peak demand (mw.)
Northwest		52, 927	12. 09	72, 690	16. 52	110, 680	25. 19
Utility	1, 2, 3	8, 219	1. 86	18, 100	4. 12	44, 790	10. 24
Do	[1]	468	. 18	700	. 30	1, 100	. 35
Nonutility	[1]	44, 240	10. 05	53, 890	12. 10	64, 790	14. 60
Southwest		154, 293	35. 11	189, 800	43. 15	237, 990	51. 06
Utility	4, 5, 6	7, 038	1. 55	12, 800	2. 85	24, 790	5. 51
Do	[1]	1, 255	. 26	2, 000	. 40	3, 200	. 55
Nonutility	[1]	146, 000	33. 30	175, 000	39. 90	210, 000	45. 00
Southcentral		643, 473	144. 07	1, 484, 240	324. 48	3, 647, 890	784. 94
Anchorage-Kenai	9 to 13	563, 749	126. 51	1, 364, 720	297. 79	3, 442, 090	739. 49
Utility		406, 604	92. 66	1, 137, 840	249. 79	3, 201, 190	689. 49
Nonutility (military)		157, 145	33. 85	226, 880	48. 00	240, 900	50. 00
Other areas	7, 8, 14, 15	56, 030	11. 76	88, 620	19. 29	165, 000	35. 85
Utility		22, 917	5. 06	50, 660	11. 09	118, 690	25. 95
Nonutility		33, 113	6. 70	37, 960	8. 20	46, 310	9. 90
Utility	[1]	7, 494	2. 10	11, 600	3. 00	18, 900	4. 60
Nonutility	[1]	16, 200	3. 70	19, 300	4. 40	21, 900	5. 00
Interior		368, 860	81. 89	654, 130	144. 71	1, 145, 680	256. 29
Fairbanks	16	239, 669	52. 23	500, 110	109. 26	967, 980	215. 89
Utility		106, 867	25. 16	275, 850	64. 26	721, 350	164. 69
Nonutility (military)		132, 802	27. 07	224, 260	45. 00	246, 630	51. 20
Utility	[1]	2, 191	. 55	4, 020	. 95	6, 700	1. 40
Nonutility	[1]	127, 000	29. 11	150, 000	34. 50	171, 000	39. 00
Southeast		419, 942	69. 84	609, 050	111. 04	959, 730	183. 24
Utility	17 to 24	155, 023	33. 76	323, 370	70. 79	668, 630	141. 94
Nonutility (industrial)	20 and 23	246, 621	31. 60	263, 000	35. 00	263, 000	35. 00
Utility	[1]	2, 298	. 78	3, 680	. 85	6, 100	1. 30
Nonutility	[1]	16, 000	3. 70	19, 000	4. 40	22, 000	5. 00
Total utility requirement		720, 374	163. 92	1, 840, 620	408. 40	4, 815, 440	1, 046. 02
Total nonutility requirement		919, 121	179. 08	1, 169, 290	231. 50	1, 286, 530	254. 70
Total Alaska		1, 639, 495	343. 00	3, 009, 910	639. 90	6, 101, 970	1, 300. 72

[1] Scattered nonload center loads.

NOTE.—1965 utility actual, nonutility partly estimated; 1975 and 1985 estimated.

assumed for the utility load. Large industrial requirements were generally unspecified but were projected to total 695,000 MWh by 1982. Military requirements were assumed to remain constant at a level of 360,000 MWh annually.

I.3. Alaska Power Survey, Federal Power Commission, 1969.

Utility and non-utility power requirements were projected to 1985 for all regions of the state. As shown in Table I.2, the sum of the Southcentral and Interior requirements (excluding Glennallen-Valdez and large industrial but including military) were projected to be 4,410,000 MWh in 1985. This projection of growth was predicted upon a population estimate of 410,000 in 1975 and 550,000 by 1985.

I.4. 1974 Alaska Power Survey, U.S. Department of Interior, Alaska Power Administration, 1974; 1976 Alaska Power Survey, Federal Power Commission, 1976; and Devils Canyon Status Report, U.S. Department of Interior, Alaska Power Administration.

The load estimates of these reports are identical and thus discussed simultaneously. Tables I.3 and I.4 present the utility and total load projections by region through 2000, and Figure I.3 graphically depicts the statewide load growth projected. The Southcentral and Yukon regions generally conform to the railbelt as presently defined except that the Alaska Power Administration includes Kodiak as part of the Southcentral region. As shown in the tables and figure, this was the

TABLE I.3.

Regional Utility Load Estimates, 1972-2000

Region	Actual Requirements 1972		Estimated Future Requirements 1980		1990		2000	
	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH
			Higher Rate of Growth					
Southcentral	224	1,037	680	2,990	1,640	7,190	3,590	15,740
Yukon (Interior)	69	307	200	870	460	2,020	970	4,230
Total	293	1,344	880	3,860	2,100	9,210	4,560	19,970
			Likely Mid Range of Growth					
Southcentral			610	2,670	1,220	5,350	2,220	9,710
Yukon (Interior)			180	780	340	1,500	600	2,610
Total			790	3,450	1,560	6,850	2,820	12,320
			Lower Rate of Growth					
Southcentral			530	2,340	980	4,290	1,470	6,430
Yukon (Interior)			160	680	270	1,200	390	1,730
Total			690	3,020	1,250	5,490	1,860	8,160

Note: Estimated future peak demand based on 50 percent annual load factor.
Source: Alaska Power Survey, Technical Advisory Committee on Economic Analysis and Load Projection.

TABLE I.4.

Regional Total Load Estimate, 1972-2000

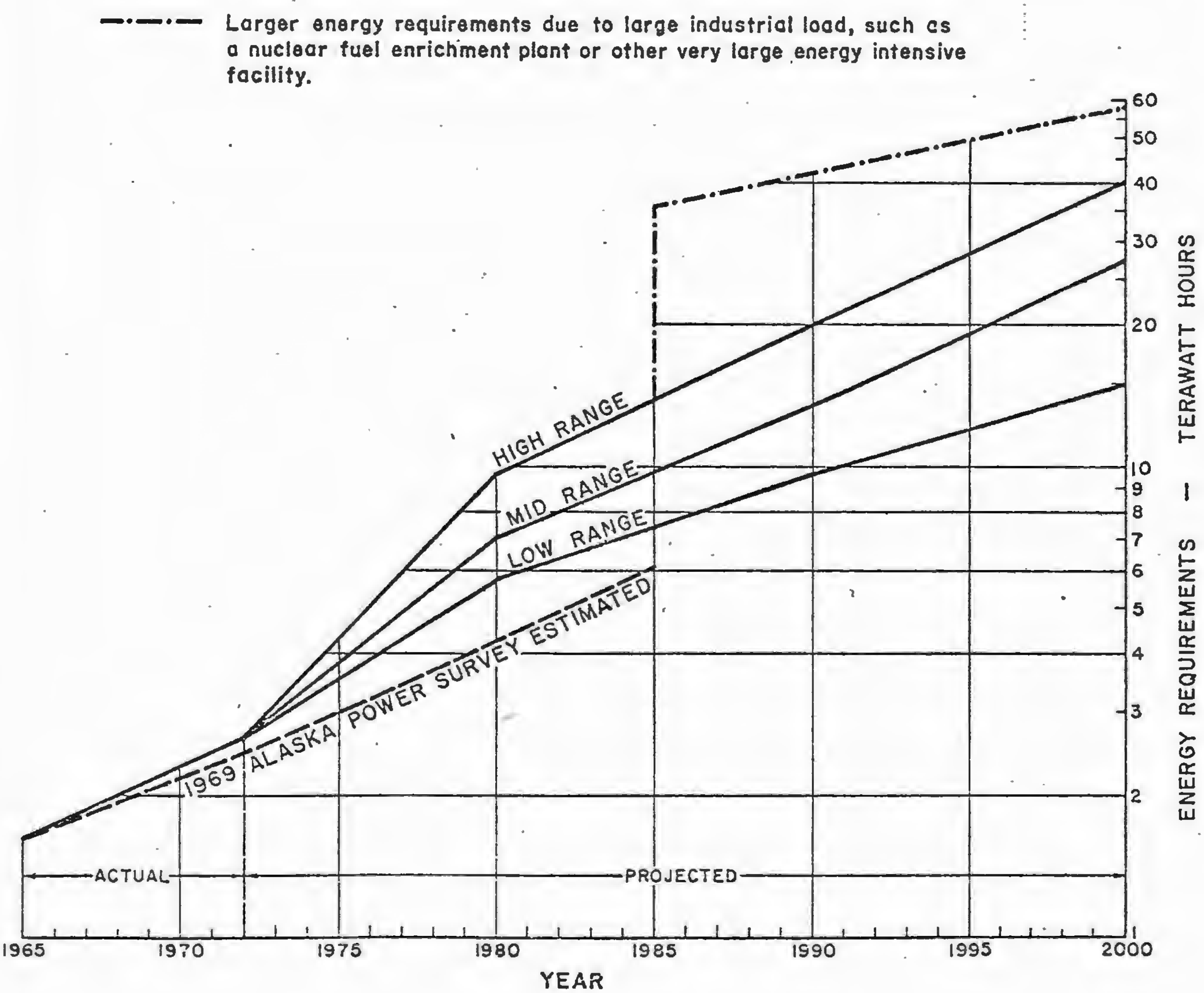
	Actual Requirements 1972		Estimated Future Requirements 1980		1990		2000	
Region	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH
			Higher Rate of Growth					
Southcentral	317	1,465	990	5,020	5,020	30,760	7,190	40,810
Yukon (Interior)	115	542	330	1,610	760	3,980	1,390	7,000
Total	432	2,007	1,320	6,630	5,780	34,740	8,580	47,810
			Likely Mid Range of Growth					
Southcentral			790	3,790	1,530	7,400	3,040	15,300
Yukon (Interior			280	1,310	470	2,270	910	4,610
Total			1,070	5,100	2,000	9,670	3,950	19,910
			Lower Rate of Growth					
Southcentral			650	3,040	1,160	5,430	1,790	8,510
Yukon (Interior)			250	1,140	370	1,760	530	2,540
Total			900	4,180	1,530	7,190	2,320	11,050

Note: Assume 80 percent annual load factor for industrial requirements; 50 percent for utility requirements. Higher estimate includes nuclear enrichment facility in 1980's with requirements of 2.5 million kilowatts.

Source: Alaska Power Survey, Technical Advisory Committee on Economic Analysis and Load Projection.

FIGURE I.3.

ALASKA TOTAL ENERGY REQUIREMENTS
(1965 - 2000)



Source: Alaska Power Survey, Technical Advisory Committee on Economic Analysis and Load Projection.

first study which attempted to delineate a range of forecasts. The 1980 "likely midrange rate of growth" forecast is somewhat high.

The projection for utility load utilized the 1980 load projections of the actual utilities. These are shown, for railbelt utilities, in Table I.5. The high and low estimates for 1980 were 20 percent above and below, respectively, those aggregated estimates. For the subsequent decades, growth rates were assumed in each case based upon unidentified population projections. The growth rates declined over time, reflecting the assumtion of increasing appliance saturation, efficiency, and utilization of conservation measures. In the "likely midrange" case, the growth rates were assumed to be 7 and 6 percent, respectively, for the 1980s and 1990s.

Military requirements were assumed to grow at 1.7 percent annually.

The industrial load growth estimate was based upon a State of Alaska Department of Commerce and Economic Development study of possible industrial projects. This estimate is shown in Table I.6. The assumptions behind these estimates are:

1. a high probability of major new petroleum, natural gas, coal, and other new mineral production and processing;

2. significant further developments in timber processing; and

3. good possibilities that Alaska energy and other resources will attract energy intensive industries.

The estimates vary basically in the speed with which developments occur except that the high case includes a nuclear enrichment facility

TABLE I.5.

Utility Load Estimate Extended to 1990

Location and Utility Symbol	Generation 1972 Peak Demand 1000 KW	Generation 1972 Annual Generation Million KWH	Projected Requirements 1980 Peak Demand 1000 KW	Projected Requirements 1980 Annual Generation Million KWH	Projected Requirements 1990 Peak Demand 1000 KW	Projected Requirements 1990 Annual Generation Million KWH
Southcentral						
City of Anchorage (AML&P) 3/	71.9	310.1	123.0	658.0	314.0	1,680.0
Chugach (CEA) 3/	123.5	600.0	360.0	1,800.0	1,065.0	5,370.0
Include:						
Homer (HEA) 3/	(16.5)	(85.1)	(36.5)	(190.0	(90.0)	(490.0)
Kenai (HEA) 3/	(4.7)	(22.1)	(7.9)	(37.6)	(14.9)	(71.1)
Seldovia-Port Graham (HEA) 3/	(0.8)	(3.4)	(1.6)	(6.8)	(3.5)	(16.1)
Seward (SL&P) 3/	Not Available		(5.2)	(27.9)	(8.0)	(45.0)
Tyonek 3/	Not Available		(2.1)	(8.7)	(3.0)	(12.3)
Palmer-Talkeetna (MEA) 3/	15.9	73.9	54.0	225.0	181.0	850.0
Subtotal, Anchorage-Cook Inlet	211.3	984.0	537.0	2,683.0	1,560.0	7,900.0
Yukon (Interior)						
Fairbanks Area						
City of Fairbanks (FMU) 3/	21.0	90.0	51.8	221.0	161.1	687.3
Golden Valley (GVEA) 3/	45.9	211.0	131.0	610.0	379.0	1,790.0
Subtotal, Fairbanks Area	66.9	301.0	182.8	831.0	540.1	2,477.3

TABLE I.6.

Assumed Regional Industrial Power Requirements, 1972-2000

Region	Actual Requirements 1972		Estimated Future Requirements 1980		1990		2000	
	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH	Peak Demand 1000 KW	Annual Energy Million KWH
			High Rate of Development Assumed					
~~Southeast~~	~~46~~	~~201~~	~~210~~	~~1,470~~	~~430~~	~~3,010~~	~~570~~	~~3,990~~
Southcentral	58	254	260	1,820	3,330	23,340	3,540	24,810
Yukon (Interior)			70	490	240	1,680	350	2,450
			Mid Range of Development Assumed					
~~Southeast~~			~~90~~	~~630~~	~~210~~	~~1,470~~	~~430~~	~~3,010~~
Southcentral			130	910	260	1,820	760	5,330
Yukon (Interior)			40	280	70	490	240	1,680
			Low Development Assumed					
~~Southeast~~			~~50~~	~~350~~	~~90~~	~~630~~	~~210~~	~~1,470~~
Southcentral			70	490	130	910	260	1,820
Yukon (Interior)			30	210	40	280	70	490

in Southcentral with a peak load of 2.5 million kilowatts. All estimates assume that minerals other than petroleum and natural gas could account for the majority of industrial requirements by 2000. The relevant facilites within the railbelt were assumed to be coal mining, the nuclear fuel enrichment plant, metal mining, metal processing plants, and metal dredging operations.

I.5. Reassessment Report on Upper Susitna River Hydroelectric Development for the State of Alaska by Henry J. Kaiser Company, 1974.

This study projects net energy for the Anchorage and Fairbanks areas (but not Glennallen-Valdez) through 1990. The forecast is shown in Table I.7. The forecast used a model which related number of customers in the residential and commercial-industrial sectors to population and employment projections. 1980 energy sales per customer were forecast at 13,000 and 14,000 in Anchorage and Fairbanks in the residential sector and 148,000 and 118,000 in those respective areas for the commercial-industrial sector.

I.6. Southcentral Railbelt Area, Alaska: Interim Feasibility Report: Hydroelectric Power and Related Purposes for the Upper Susitna River Basin, Alaska District Corps of Engineers, Department of the Army, 1975.

The previous Alaska Power Administration report was updated for this study with no significant modifications in methodology but some changes in assumptions which result in a reduction of the projections.

TABLE I.7.

Year	Anchorage-Cook Inlet Net Energy million kwh	Anchorage-Cook Inlet Peak Load thousand kw	Fairbanks Net Energy million kwh	Fairbanks Peak Load thousand kw	Total Net Energy million kwh	Total Peak Load thousand kw
Actual						
1968	559	125	161	43	720	168
1973	1,090	213	318	73	1,408	286
Forecast						
1975	1,400	271	410	87	1,810	358
1980	2,740	513	803	164	3,543	677
1985	5,080	928	1,354	266	6,434	1,194
1990	9,420	1,721	2,281	434	11,701	2,155

In this study, the actual areas that would be served by a railbelt electric faicility were the basis for projections so some small components of the previously defined Southcentral and Yukon regions are not included. Projections are shown in Table I.8 and Figure I.4.

The utility estimates are somewhat lower than earlier projections reflecting this as well as the analysis of two additional years of historical data. Beyond 1980, the growth rates are identical to the previous studies. These are as follows:

	1980-1990	1990-2000
high range	9%	8%
likely midrange	7%	6%
lower range	6%	4%

Military load growth is now projected at 1 percent annually rather than 1.7 percent.

The most significant change in this study from the previous work is a reduction in the projected industrial load which accounts for the majority of the difference between the total load projected in this and the previous study. The 1980 midrange projection has declined from 1,190,000 MWh to 350,000 MWh. The specific industrial developments assumed in the projections are presented and shown here as Table I.9.

TABLE I.8.

Type of Load	Actual Requirements				Estimated Future Requirements			
	1974		1980		1990		2000	
Area	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh
Utilities			High Rate of Growth					
Anchorage	284	1,305	650	2,850	1,570	6,880	3,430	15,020
Fairbanks	83	330	160	700	380	1,660	800	3,500
Total	367	1,635	810	3,550	1,950	8,540	4,230	18,520
			Likely Mid-Range Growth					
Anchorage			590	2,580	1,190	5,210	2,150	9,420
Fairbanks			150	660	290	1,270	510	2,230
Total			740	3,240	1,480	6,480	2,660	11,650
			Lower Rate of Growth					
Anchorage			550	2,410	1,010	4,420	1,500	6,570
Fairbanks			140	610	240	1,050	350	1,530
Total			690	3,020	1,250	5,470	1,850	8,100

TABLE I.8. (cont.)

Type of Load	Actual Requirements				Estimated Future Requirements			
	1974		1980		1990		2000	
Area	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh
National Defense								
Anchorage	33	155	35	170	40	190	45	220
Fairbanks	41	197	45	220	50	240	55	260
Total	74	352	80	390	90	430	100	480
Industrial			High Rate of Development Assumed					
Anchorage	10	45	100	710	2,910	20,390	2,920	20,460
Fairbanks 1/	--	--	--	--	--	--	--	--
			Mid-Range Development Assumed					
Anchorage			50	350	100	710	410	2,870
Fairbanks 1/			--	--	--	--	--	--
			Low Development Assumed					
Anchorage			20	140	50	350	100	710
Fairbanks 1/			--	--	--	--	--	--

TABLE I.8. (concluded)

Type of Load	Actual Requirements				Estimated Future Requirements			
	1974		1980		1990		2000	
Area	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh
Combined Utility, National Defense, and Industrial Power Requirements								
Higher Growth Rate								
Anchorage	327	1,505	785	3,730	4,520	27,460	6,395	35,700
Fairbanks	124	527	205	920	430	1,900	855	3,760
Total	451	2,302	990	4,650	4,950	29,360	7,250	39,460
Likely Mid-Range Growth Rate								
Anchorage			675	3,100	1,330	6,110	2,605	12,510
Fairbanks			195	880	340	1,510	565	2,490
Total			870	3,980	1,670	7,620	3,170	15,000
Lower Growth Rate								
Anchorage			605	2,720	1,100	4,960	1,645	7,500
Fairbanks			185	830	290	1,290	405	1,790
Total			790	3,550	1,390	6,250	2,050	9,290

Total	790	3,550	1,390	6,250	2,050	9,290

FIGURE I.4.

ESTIMATED FUTURE POWER REQUIREMENTS
1974-2000

2. ANNUAL ENERGY REQUIREMENTS

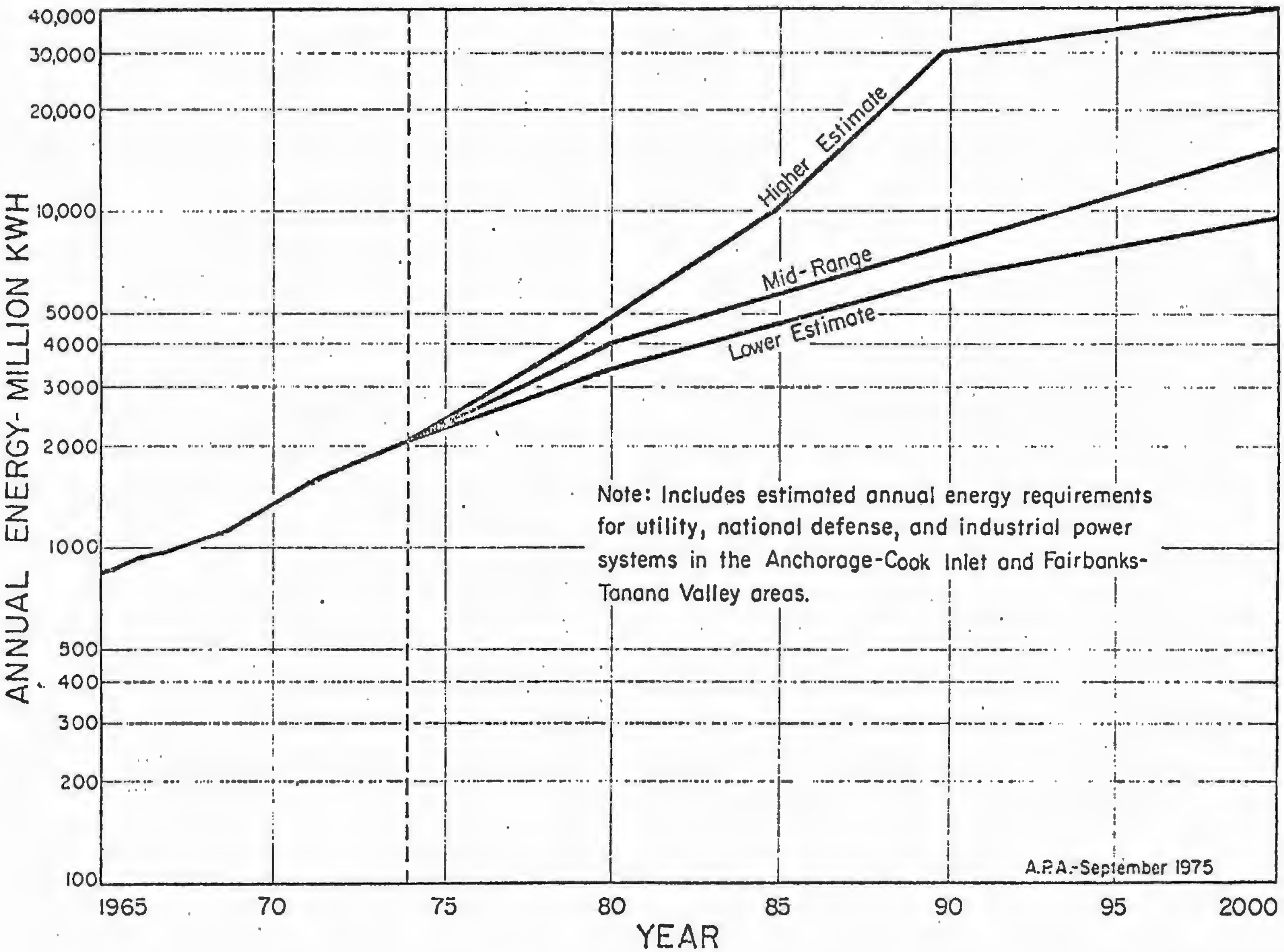


TABLE I.9.

Rate of Development	Industrial Capacity in MW								
	Low Range			Mid Range			High Range		
Year	1980	1990	2000	1980	1990	2000	1980	1990	2000
Anchorage Area: Kenai Peninsula:									
Chemical Plant 1/	11	11	11	12	14	16	13	16	20
LNG Plant 1/	.4	.4	.4	.4	.5	.6	.5	.6	.7
New Plant		10	10	10	10	10	10	10	10
Refinery 1/	2.2	2.2	2.2	2.2	3	4	3	4	5
Timber 1/	2	3	5	3	5	5	5	5	5
Other Vicinities:									
Coal Gasification			10		10	250	10	250	250
Mining and Mineral Processing		5	25	5	25	50	25	50	50
Nuclear Fuel Enrichment								2500	2500
Timber		5	7	5	7	7	7	7	7
New City		17	30	10	30	70	30	70	70
TOTAL (rounded)	20	50	100	50	100	410	100	2910	2920
Fairbanks Area 2/									

Source: 1974 Alaska Power Survey Technical Advisory Committee Report on Economic Analysis and Load Productions, pages 81-89.

1/ Existing Installations

2/ Timber processing and oil refinery loads totaled less than 10 MW.

A population growth rate of 3 percent annually is assumed in the study, resulting in estimates of 410,000 in 1980 and rising to 740,000 in 2000.

I.7. Electric Power in Alaska, 1976-1995 and "Alaska Electric Power Requirements," Alaska Review of Business and Economic Conditions, Institute of Social and Economic Research, University of Alaska, 1976.

This study estimated growth in electricity requirements for the entire state based upon a model of the Alaskan economy and detailed assumptions concerning customer growth and average consumption rates. Projections were made based upon two sets of economic assumptions and four sets of electricity use assumptions. This resulted in a significant range of projections, a reflection of the uncertainty surrounding both the future of economic growth of the state, and electricity use patterns. Table I.10 shows the range of estimates of sales for utilities for the Anchorage, Southcentral, and Fairbanks regions (a larger region than the railbelt).

The economic projections assumed growth rates in population for the state of between 3.8 and 4.8 percent with the growth concentrated in Southcentral Alaska.

TABLE I.10. 1976 ISER ELECTRIC POWER REQUIREMENTS PROJECTIONS

Anchorage, Southcentral, & Fairbanks	Total Energy Sales			Average Annual Growth Rates		
	1974	1985	1995	1975-1980	1975-1985	1975-1995
LOWEST	1,468	3,697	8,092	9.1	8.8	8.5
HIGHEST	1,468	7,787	20,984	17.6	16.4	13.5

Military electricity requirements are assumed to remain constant over time.

Self-generated industrial electricity requirements are not specifically modelled.

I.8. Alaskan Electric Power: An Analysis of Future Requirements and Supply Alternatives for the Railbelt Region, Battelle Pacific Northwest Laboratories for Alaska Division of Energy and Power Development and the Alaska Power Authority, 1978.

This report did not do a load growth analysis but summarized and interpreted several earlier studies, including those of the Institute of Social and Economic Research and the Alaska Power Administration (APA). Individual load growth studies of several railbelt utilities were also utilized in selecting a narrow projection band from the broader band represented by the earlier analyses. The industrial scenarios developed by the APA were somewhat modified as well. The resulting projections for the railbelt are shown in Table I.11 and Figure I.5.

I.9. Upper Susitna River Project Power Market Analyses, U.S. Department of Energy, Alaska Power Administration, 1979; Southcentral Railbelt Area, Alaska, Upper Susitna River Basin, Supplemental Feasibility Report by the Corps of Engineers, 1979; and Phase I Technical Memorandum: Electric Power Needs Assessment, Southcentral Alaska Water Resources Committee, 1979.

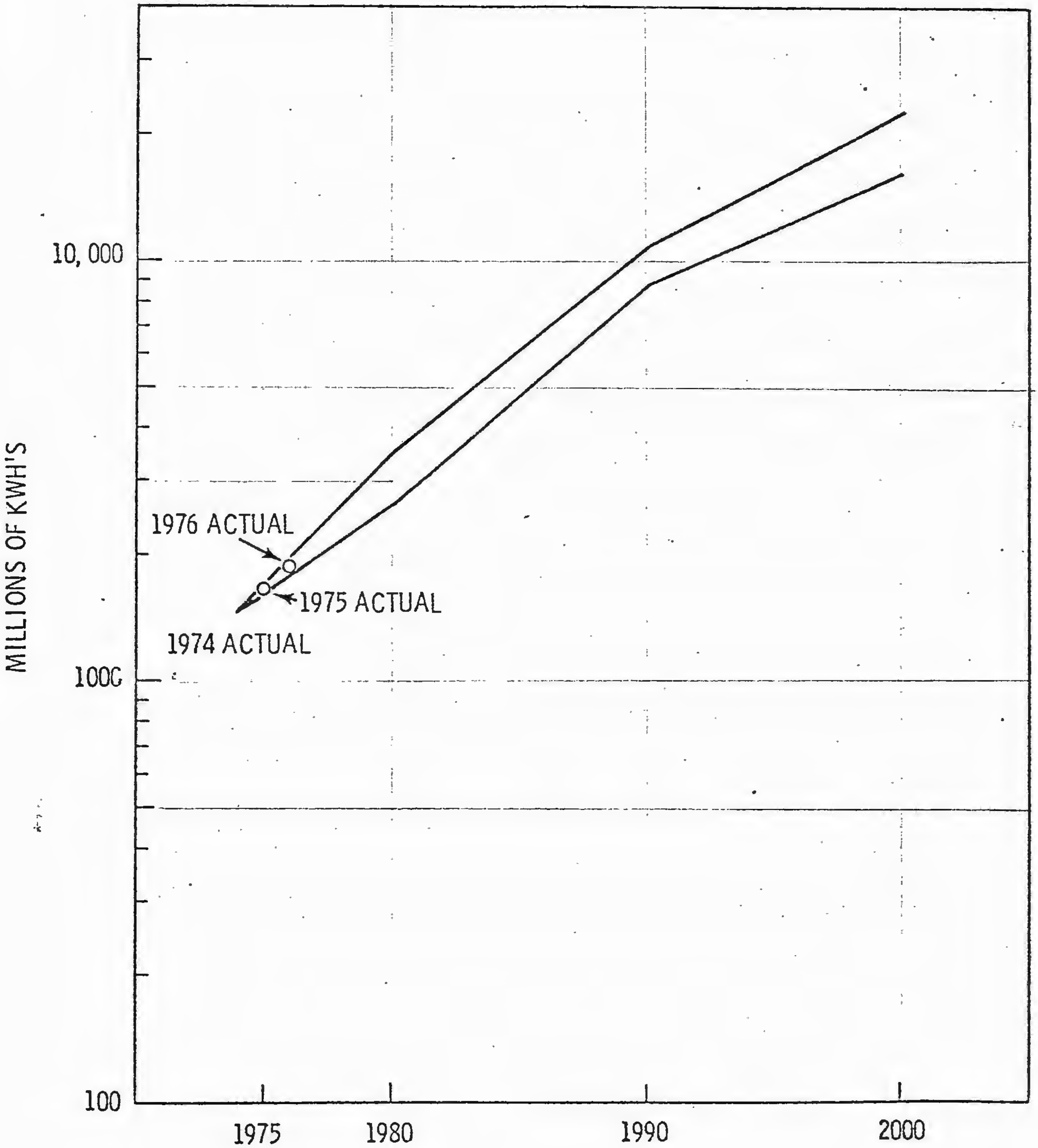
This report is a continuation of the work done by the Alaska Power Administration and again provides load requirements projections for

TABLE I.11.

Range of Railbelt Annual Consumption (Includes use by utility and industrial customers likely to be part of an intertied system. Excludes national defense and non-intertied users.)

Year	Annual Consumption	Compound Annual Growth Rate
1974	1.6 B kWh	
1980	2.6 to 3.4 B kWh	8.4 to 13.4 (1974-1980)
1990	8.5 to 10.8 B kWh	9.6 to 15.3 (1980-1990)
2000	16.0 to 22.5 B kWh	4.0 to 10.2 (1990-2000)

FIGURE I.5.



Most Likely Range of Utility and Industrial Annual Consumption; Intertied Railbelt Area utility, military, and industry electricity users. The overall projections are summarized in Table I.12 and Figure I.6.

Utility requirements are projected on the basis of explicit population estimates (provided by the ISER econometric and demographic model) multiplied by average annual consumption per capita estimates. The estimate of per capita growth in average annual electricity consumption is based upon growth in this indicator for Alaska utilities during the interval of 1973 to 1977. This is presumed to capture the effect of conservation over the period, and, furthermore, the growth rate is assumed to decline over time to reflect additional conservation measures and saturation of appliances, etc. For the three "consumption per capita" scenarios, the following annual growth rates were assumed:

Time Period	Scenario		
	High	Medium	Low
1980-1985	4.5%	3.5%	2.5%
1985-1990	3.5	3.0	2.0
1990-1995	3.0	2.5	1.5
1995-2000	2.5	2.0	1.0
2000-2025	2.0	1.0	0.0

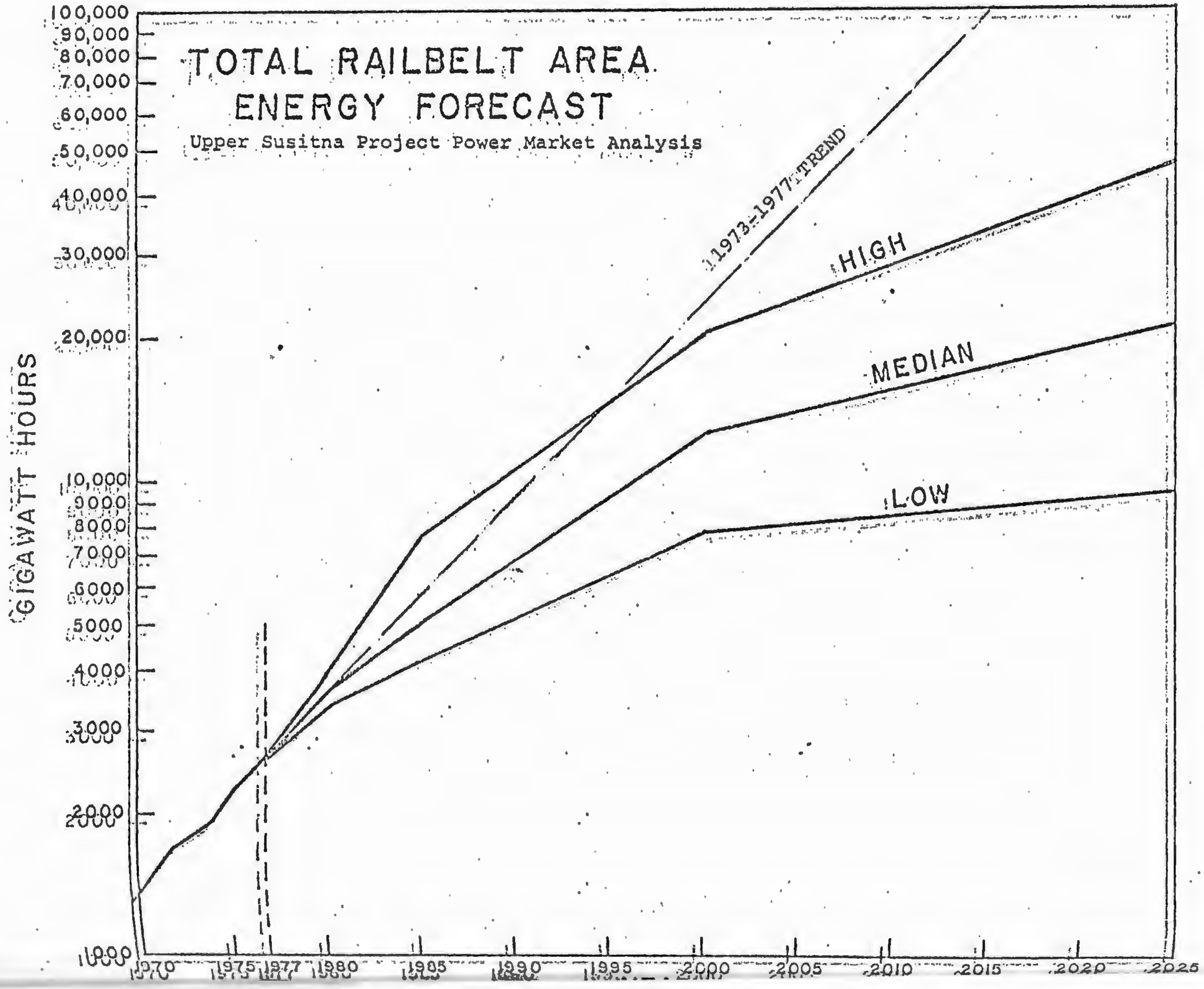
These growth rates were applied beginning in 1980. In the interim, growth rates of net generation were assumed to be 12 percent annually for Anchorage and 10.3 percent for Fairbanks. The high and low estimates

TABLE I.12.

Railbelt Area Energy Forecast
(GWH)

	1977 (Historic)	1980	1990	2000	2025
Utility:					
High		3,410	8,200	16,920	38,020
Mid	2,273	3,155	6,110	10,940	17,770
Low		2,920	4,550	7,070	8,110
National Defense:					
High		348	384	425	544
Mid	338	338	338	338	338
Low		330	299	270	210
Self-Supplied Industry:					
High		170	2,100	3,590	8,490
Mid	70	170	630	1,460	3,470
Low		141	370	550	1,310
Total:					
High		3,928	10,684	20,935	47,054
Mid	2,681	3,663	7,078	12,738	21,578
Low		3,391	5,219	7,890	9,630
Trend @ 1973-77 annual/growth:		(3,215)	(10,270)	(33,000)	(601,000)

FIGURE I.6.


TOTAL RAILBELT AREA
ENERGY FORECAST
Upper Susitna Project Power Market Analysis
GIGAWATT HOURS
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1970
1975
1977
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
1973-1977 TREND
HIGH
MEDIAN
LOW

for 1980 appear to be based on estimates of growth between 1977 and 1980 which are 29 percent higher and 27 percent lower than the mid case respectively.

Two population estimates are utilized. These are presented in Table I.13.

TABLE I.13. POPULATION ESTIMATES (thousands)

Year	Anchorage-Cook Inlet		Fairbanks		Statewide	
	Low	High	Low	High	Low	High
1980	239	270	60	62	500	514
1985	261	320	68	77	563	641
1990	299	407	75	95	618	790
1995	353	499	82	114	680	947
2000	424	651	90	140	743	1,158
2025	491	904	99	179	820	1,485

The result of two population projections and three per capita consumption projections is six scenarios. The high/high and low/low scenarios became the high and low projections, respectively, while the average of the high/low and low/high became the midrange final forecast.

Military requirements were projected to remain constant in the midrange estimate, +1 percent in the high case, and -1 percent in the low case.

The self-supplied industrial load projection is based upon the earlier Battelle report which, in turn, is based upon the earlier APA work. The high range forecast is summarized in Table I.14. The only difference between the cases is that the midrange does not include the aluminum smelter and the low range contains neither the smelter nor the new capital city.

TABLE I.14. SELF-SUPPLIED INDUSTRIES FORECAST
HIGH RANGE

Existing refinery (2.4 MW)
Existing LNG plant (.4 to .6 MW)
Coal gasification (0 to 250 MW)
New city (0 to 30 MW)
New refinery (0 to 15.5 MW)
New LNG plant (0 to 17 MW)

Mining and mineral plants (5 to 50 MW)
Timber (2 to 12 MW)
Existing chemical plant (22 to 26 MW)
Aluminum smelter or other energy
intensive industry (0 to 280 MW)

A comparison of the estimates developed for this report with earlier studies by APA was done and is presented as Table I.15. It indicates a slight downward shift in the projections.

Finally, a compilation and extrapolation of forecasts done by the utilities themselves was compared to the study results. As Table I.16 shows, the aggregated utility forecasts are considerably above those of the study.

TABLE I.15.

COMPARISON OF UTILITY ENERGY ESTIMATES
1976 MARKETABILITY REPORT, UPDATE OF 1976, AND 1978 ANALYSIS

Upper Susitna Project Power Market Analysis

Year	Forecast Range	Anchorage-Cook Inlet 1976 Report	Anchorage-Cook Inlet Update of 1976	Anchorage-Cook Inlet 1978 Forecast	Fairbanks-Tanana Valley 1976 Report	Fairbanks-Tanana Valley Update of 1976	Fairbanks-Tanana Valley 1978 Forecast	Total Railbelt 1976 Report	Total Railbelt Update of 1976	Total Railbelt 1978 Forecast
1974	Historic	1,305 1/		1,189.7 1/	330		353.8	1,635		1,543.5
1975	High	1,489			377			1,866		
	Mid	1,467			371			1,838		
	Low	1,450			367			1,816		
	Historic			1,413.0			450.8			1,863.8
1976	High	1,699			430			2,129		
	Mid	1,649			417			2,066		
	Low	1,611			407			2,018		
	Historic			1,615.3			468.5			2,083.8
1977	High	1,939			490			2,429		
	Mid	1,853			469			2,322		
	Low	1,790			453			2,242		
	Historic		1,790.1	1,790.1		482.9	482.9		2,273.0	2,273.0
1980	High	2,850	2,660	2,720	700	720	690	3,550	3,380	3,410
	Mid	2,580	2,540	2,500	660	690	655	3,240	3,230	3,155
	Low	2,410	2,460	2,300	610	660	620	3,020	3,120	2,920
1990	High	6,880	6,300	6,630	1,660	1,700	1,570	8,540	8,000	8,200
	Mid	5,210	5,000	4,880	1,270	1,360	1,230	6,480	6,360	6,110
	Low	4,420	4,410	3,590	1,050	1,180	960	5,470	5,590	4,550
2000	High	15,020	13,600	13,920	3,500	3,670	3,000	18,520	17,270	16,920
	Mid	9,420	8,950	8,960	2,230	2,440	1,980	11,650	11,390	10,940
	Low	6,570	6,530	5,770	1,530	1,750	1,300	8,100	8,280	7,070

1/ 1974 historic data revised between 1975 and 1978.

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TABLE I.16.

	Utility Forecasts	1978 Susitna Forecasts		
		High	Mid	Low
Energy (GWH)				
1980	3,344	3,410	3,155	2,920
1985	6,277	5,460	4,455	3,630
1990	10,965	8,200	6,110	4,550
1995	17,748	11,600	8,140	5,690
2000	26,550	16,920	10,940	7,070
Peak (MW)				
1980	725	778	720	667
1985	1,377	1,244	1,021	830
1990	2,986	1,873	1,396	1,039
1995	3,835	2,645	1,858	1,298
2000	5,641	3,865	2,497	1,617

Glennallen-Valdez projections were made using the 1976 Copper Valley Electric Association Power Requirements Study as a base. Total energy was projected to be 74,000 MWh in 1980, 134,000 MWh in 1990, and 240,000 MWh in 2000.

I.10. Differences Between Present and Previous Studies

I.10.A. ECONOMIC PROJECTIONS

Differences exist in the economic projections among the various studies because of both different predictions about what large scale projects will be undertaken within the state and when they will occur (the gas pipeline construction is an example) and different assumptions about how the support sector of the economy and the population responds to economic development.

In both these areas, the present study has some benefit of hindsight which earlier studies have not. The 1979 APA study, for example, utilized a 1980 statewide population estimate ranging between 500,000 and 514,000. Present projections place the number closer to 420,000. Part of the error was the result of overly optimistic projections of large project activity which have not yet materialized but which to a large extent the present study expects to occur in the early 1980s. A second component of error was the fact that the entire cyclical pattern of economic behavior in response to the construction of the oil pipeline was not captured in the economic projection technique.

Only the data from the expansion portion of the cycle was internalized into the model but not the contraction portion of the cycle. As a result, the economic model itself contained some upward bias.

I.10.B. ELECTRICITY CONSUMPTION PROJECTIONS

The recent APA study as well as the earlier ISER study developed projections based upon the product of population and consumption per capita. The present study has generally lower growth rate assumptions for per capita consumption based upon explicit estimates of saturation, use patterns, and conservation measures. Another distinguishing characteristic of the present study is that conservation measures reduce consumption growth rates until they have been completely implemented. Subsequently, growth may actually accelerate. The 1979 APA study assumed that the reduction in the rate of growth of electricity consumption after 1973 was the result of the implementation of conservation efforts growing out of the 1973 oil embargo and higher energy prices. This study concludes that the reduction in the growth rate was not conservation-induced because, particularly in Anchorage, there was no, and even today is not, price incentive for the conservation of electricity.

I.10.C. SELF-SUPPLIED INDUSTRIAL PROJECTIONS

Earlier studies done by APA and Battelle all trace their projections of self-supplied industrial electricity consumption to a list of projects compiled in the early 1970s in a State of Alaska Department of Commerce and Economic Development, Division of Economic Enterprise publication entitled "Power Demand Estimates, Summary and Assumptions for the Alaska Situation." Rather than a projection, the report is simply a list of potential projects with their related energy requirements. Such a "list" is not felt to be appropriate as the basis for sound electric power requirements planning.

I.10.D. DEFINITIONS

The present study projects total sales of energy to final consumers. This is a smaller quantity than net energy for system which is the concept used in some earlier studies. The difference is transmission and distribution losses and energy unaccounted for.

APPENDIX J

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