RED: The Railbelt Electricity Demand Model Specification Report

Volume VIII

October 1982

Prepared for the Office of the Governor
State of Alaska
Division of Policy Development and Planning
and the Governor's Policy Review Committee
under Contract 2311204417

Battelle
Pacific Northwest Laboratories

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Richland, Washington 99352

NOTE TO USERS

The Volume VIII documentation report covers the RED model as developed prior to its use in producing the final forecasts for the Railbelt Electric Power Alternatives Study. During the course of making the forecasts included in Volume I of this series of reports, it appeared to the Battelle-Northwest researchers that including both an assumed increase in the saturations of residential electrical appliances and a residential price sensitivity coefficient, as reported in Chapter 5, double-counted the effect of electricity prices on appliance choice. Consequently, appliance saturations were held constant at 1980 levels to do the initial residential forecast prior to price adjustments; this was then modified by the Chapter 5 price adjustment to incorporate the effect of price on appliance ownership and to produce the residential forecast included in Volume I.

Battelle-Northwest advises researchers using the RED model to use the increasing saturations reported in Chapter 5 or the residential price elasticities, but not both.

PREFACE

The State of Alaska commissioned Battelle to investigate potential strategies for future electric power development in Alaska's Railbelt region. The results of the study will be used by the Office of the Governor to formulate recommendations for electric power development in the Railbelt.

The primary objective of the study is to develop and analyze several alternative long-range plans for electric energy development in the Railbelt region (see Volume I). Each plan is based on a general energy development strategy representing one or more policies that Alaska may wish to pursue. The analyses of the plans will produce forecasts of electric energy demand, schedules for developing generation and conservation alternatives, estimates of the cost of power, and discussions of the environmental and socioeconomic characteristics for each plan.

This report (Volume VIII of a series of seventeen reports, listed below), presents the structure of the Railbelt Electricity Demand (RED) model. This model, together with the AREEP model (Volume XI) and an extensive data base, was used to produce electricity demand forecasts (reported in Volume I) for the Railbelt. These demand forecasts provided the electric plans, also presented in Volume I.

RAILBELT ELECTRIC POWER ALTERNATIVES STUDY

Volume I - Railbelt Electric Power Alternatives Study: Evaluation of Railbelt Electric Energy Plans

Volume II - Selection of Electric Energy Generation Alternatives for Consideration in Railbelt Electric Energy Plans

Volume III - Executive Summary - Candidate Electric Energy Technologies for Future Application in the Railbelt Region of Alaska

Volume IV - Candidate Electric Energy Technologies for Future Application in the Railbelt Region of Alaska

Volume V - Preliminary Railbelt Electric Energy Plans

Volume VI - Existing Generating Facilities and Planned Additions for the Railbelt Region of Alaska

Volume VII - Fossil Fuel Availability and Price Forecasts for the Railbelt Region of Alaska

Volume VIII - Railbelt Electricity Demand (RED) Model Specifications

Volume VIII - Appendix - Red Model User's Manual

Volume IX - Alaska Economic Projections for Estimating Electricity Requirements for the Railbelt

Volume X - Community Meeting Public Input for the Railbelt Electric Power Alternatives Study

Volume XI - Over/Under (AREEP Version) Model User's Manual

Volume XII - Coal-Fired Steam-Electric Power Plant Alternatives for the Railbelt Region of Alaska

Volume XIII - Natural Gas-Fired Combined-Cycle Power Plant Alternative for the Railbelt Region of Alaska

Volume XIV - Chakachamna Hydroelectric Alternative for the Railbelt Region of Alaska

Volume XV - Browne Hydroelectric Alternative for the Railbelt Region of Alaska

Volume XVI - Wind Energy Alternative for the Railbelt Region of Alaska

Volume XVII - Coal-Gasification Combined-Cycle Power Plant Alternative for the Railbelt Region of Alaska

SUMMARY

The Alaska Railbelt Electric Power Alternatives Study is an electric power planning study for the State of Alaska, Office of the Governor and the Governor's Policy Review Committee. Begun in October 1980, and extending into April 1982, the study's objectives are to forecast the demand for electric power through the year 2010 for the Railbelt region of Alaska and to estimate the monetary, socioeconomic, and environmental costs of all options (including conservation) that could be used to supply this power.

This document, Volume VIII in the series, describes the Railbelt Electricity Demand model (RED), which is a partial end-use/econometric forecasting model. RED has several unique capabilities: a Monte Carlo simulator for analysis of uncertainty in key parameter values, a fuel price adjustment mechanism that incorporates the impacts of fuel prices on demand, and an explicit consideration of subsidized investments in conservation measures.

Volume VIII Appendix, Red Model User's Manual, describes how the model can be used and provides a description of the computer code derived from this report. The forecasts produced by RED for the study are documented in Volume V, Railbelt Electric Power Alternatives Study: Evaluation of Railbelt Electric Energy Plans.

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FIGURES

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1.0 INTRODUCTION

The Railbelt Electricity Demand (RED) forecasting model documented in this report is a partial end-use/econometric model. Initial estimates of total residential demand are derived by forecasting the number of energy-using devices and aggregating their potential electricity demand into preliminary end-use forecasts. The model then modifies these preliminary forecasts, using econometric fuel price elasticities, to develop final forecasts of total residential energy consumption. The model thus uses both technical knowledge of end uses and econometrics to produce the residential forecast. The industrial (basic) and commercial (government and support) sectors are treated similarly, but since little information is available on end uses in these sectors in Alaska, preliminary demand is estimated on an aggregated basis rather than by detailed end use. Miscellaneous demand is based on the demand of the other three sectors.

Other important features of the model are a mechanism for handling uncertainty in some of the model parameters, a method for explicitly including government programs designed to subsidize conservation and consumer-installed dispersed energy options (i.e. microhydro and small wind energy systems), and the ability to forecast peak electric demand by load center. The model recognizes three load centers: Anchorage and vicinity (including the Matanuska-Susitna Borough and the Kenai Penninsula), Fairbanks and vicinity, and Glennallen-Valdez. It produces annual energy and peak demand forecasts every fifth year from 1980 to 2010.

To produce a forecast, the model user must supply the model with region-specific estimates of total nonmilitary employment and total population for each forecast period. A few statewide variables are also required: forecasts of the age/sex distribution of the state's population, the statewide average annual wage rate, and the Anchorage Consumer Price Index. All of these variables were produced by the University of Alaska Institute of Social and Economic Research MAP econometric model; however, they can be derived from other sources. The user must also supply estimates of prices for gas, oil, and electricity. Finally, the model user may select either ranges or default values for the model's parameters and may run the model in either a certainty-equivalent or uncertain (Monte Carlo) mode. The model then produces the forecasts.

This report consists of 10 sections. In Section 2.0 an overview of the RED model is presented. In Section 3.0 the Uncertainty Module, which provides the model with Monte Carlo simulation capability, is described. In Section 4.0 the Housing Module, which forecasts the stock of residential housing units, is described. These forecasts are used in the electricity demand forecasts of the Residential Consumption Module, discussed in Section 5.0. Forecasts of demand in the business sector are produced by the Business Consumption Module, which is described in Section 6.0. The effects of government market intervention to develop conservation and dispersed generation options are covered by the Conservation Module, Section 7.0. In Section 8.0 miscellaneous electricity demand (street lighting, second homes, etc.) is discussed. The Peak Demand Module, Section 9.0, concerns the relationship between annual electricity consumption and annual peak demand. In Section 10.0 the Rate Model is discussed.

2.0 OVERVIEW

The Railbelt Electricity Demand (RED) Model is a simulation model designed to forecast annual electricity consumption for the residential, commercial-industrial-government, and miscellaneous end-use sectors of Alaska's Railbelt region. The model also takes into account government intervention in the energy markets in Alaska and produces forecasts of system annual peak demand. The forecasts of consumption by sector and system peak demand are produced in five-year steps for three Railbelt load centers:

- Anchorage and vicinity (including Anchorage, Matanuska-Susitna Borough and Kenai Peninsula)
- Fairbanks and vicinity (including the Fairbanks-North Star Borough)
- Glennallen/Valdez (including settlements along the Richardson Highway).

When run in Monte Carlo mode, the model produces a sample probability distribution of forecasts of electricity consumption by end-use sector and peak demand for each load center for each forecast year: 1985, 1990, 1995, 2000, 2005, 2010. This distribution of forecasts can be used for planning electric power generating capacity. The RED model is accordingly designed to be run in tandem with a separate electric capacity planning and dispatching model entitled Alaska Railbelt Electric Energy Planning (AREEP) model. Separate documentation of this model will be available in a report to be issued in September 1982.

Figure 2.1 shows the basic relationships among the seven modules that comprise the RED model. The model begins a simulation with the Uncertainty Module, selecting a trial set of model parameters, which are sent to the other modules. These parameters include price elasticities, appliance saturations, and regional load factors. Exogenous forecasts of population, economic activity, and retail prices for fuel oil, gas, and electricity are used with the trial parameters to produce forecasts of electricity consumption in the Residential Consumption and Business Consumption Modules. These forecasts, along with additional trial parameters, are used in the Conservation Module to model the effects on electricity sales of subsidized conservation and

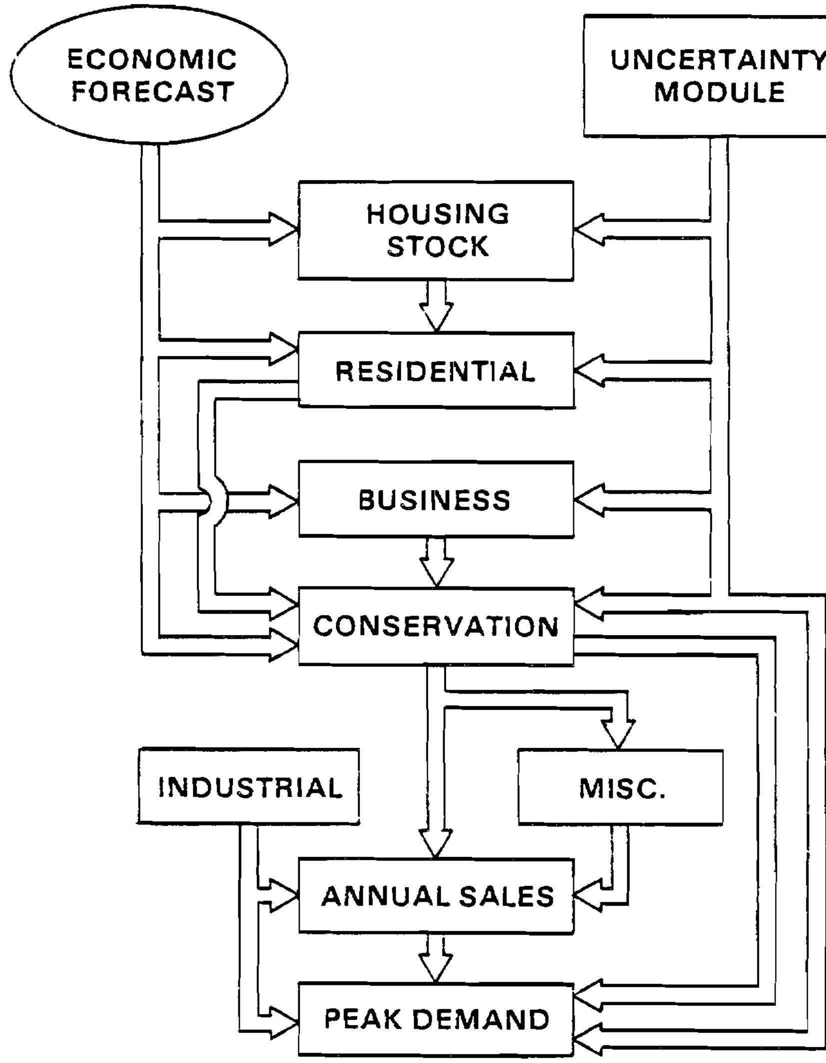

FIGURE 2.1. Information Flows in the RED Model

dispersed generating options such as windmills or microhydro installations. The revised consumption forecasts of residential and business (commercial, small industrial, and government) consumption are used to estimate future miscellaneous consumption and total sales of electricity. Finally, the unrevised and revised consumption forecasts are used along with a trial system load factor forecast to estimate peak demand. The model then returns to start the next Monte Carlo trial. When the model is run in certainty-equivalent mode, a specific "default" set of parameters is used, and only one trial is run.

The RED model produces an output file of trial values for consumption by sector and system peak demand by year and load center. This information can be used by the AREEP model to plan and dispatch electric generating capacity for each load center and year. The AREEP model produces an estimate of the cost of electricity, which is converted to electricity prices used to run the RED model. If the demand level changes by more than 5%, the RED model can be rerun in tandem with AREEP, using new prices until consistency is achieved. Convergence (consistency or near-equality of two successive demand forecasts) is usually achieved in two to three passes.

The remainder of this section presents brief descriptions of each module. Detailed documentation of each of the modules is contained in Sections 3.0 through 9.0 of this report.

UNCERTAINTY MODULE

The purpose of the Uncertainty Module is to randomly select values for individual model parameters that are considered subject to forecasting uncertainty. These parameters include the market saturations for major appliances in the residential sector; the price elasticity and cross-price elasticities of demand for electricity in the residential and business sector; the market penetration of conservation and dispersed generating technologies; the intensity of electricity use per square foot of floor space in the business sector; and the electric system load factors for each load center.

These parameters are generated by a Monte Carlo routine, which uses information on the distribution of each parameter (such as its expected value and range) and the computer's random number generator to produce sets of parameter values. Each set of generated parameters represents a "trial." By running each successive trial set of generated parameters through the rest of the modules, the model builds distributions of annual electricity consumption and peak demand. The end points of the distributions reflect the probable range of annual electric consumption and peak demand, given the level of uncertainty.

The Uncertainty Module need not be run every time RED is run. The parameter file contains "default" values of the parameters that may be used to conserve computation time.

THE HOUSING MODULE

The Housing Module calculates the number of households and the stock of housing by dwelling type in each load center for each forecast year in which the model is run. Using exogenous state-wide forecasts of the number of households, household headship rates by age, the age distribution of Alaska's population, and regional forecasts of total population, the housing stock module first derives a forecast of the number of households in each load center. Next, it estimates the distribution of households by age of head and size of household for each load center. Finally, it forecasts the demand for four types of housing stock: single family, mobile homes, duplexes, and multifamily units.

The supply of housing is calculated in two steps. First, the supply of each type of housing from the previous period is adjusted for demolition and compared to the demand. If demand exceeds supply, construction of additional housing begins immediately. If excess supply of a given type of housing exists, the model examines the vacancy rate in all types of houses. Each type is assumed to have a maximum vacancy rate. If this rate is exceeded, demand is first reallocated from the closest substitute housing type, then from other types. The end result is a forecast of occupied housing stock for each load center for each housing type in each forecast year. This forecast is passed to the Residential Consumption Module.

RESIDENTIAL CONSUMPTION MODULE

The Residential Consumption Module forecasts the annual consumption of electricity in the residential sector for each load center in each forecast year. It does not, in general, take into account explicit government intervention to promote residential electric energy conservation or self-sufficiency. Such intervention is covered in the Conservation Module. The Residential Consumption Module employs an end-use approach that recognizes nine major end uses of electricity, and a "small appliances" category that encompasses a large group of other end uses. For a given forecast of occupied housing, the Residential Consumption Module first adjusts the housing stock to net out housing units not served by an electric utility for each type. It then forecasts the residential appliance stock and the portion using electricity, stratified by the type of dwelling and vintage of the appliance. Appliance efficiency standards and average electric consumption rates are applied to that portion of the stock of each appliance using electricity. The stock of each electric appliance is then multiplied by its corresponding consumption rate to derive a preliminary consumption forecast for the residential sector. Finally, the Residential Consumption Module receives exogenous forecasts of residential fuel oil, natural gas, and electricity prices, along with "trial" values of price elasticities and cross-price elasticities of demand from the Uncertainty Module. It adjusts the preliminary consumption forecast for both short- and long-run price effects on appliance use and fuel switching. The adjusted forecast is passed to the Conservation and Peak Demand Modules.

BUSINESS CONSUMPTION MODULE

The Business Consumption Module forecasts the consumption of electricity by load center in commercial, small industrial, and government uses for each forecast year (1980, 1985, 1990, 1995, 2000, 2005, 2010). Direct promotion of conservation in this sector is covered in the Conservation Module. Because the end uses of electricity in the commercial, small industrial and government sectors are more diverse and less known than in the residential sector, the Business Consumption Module forecasts electrical use on an aggregate basis rather than by end use.

RED uses a proxy (the stock of commercial and industrial floor space) for the stock of capital equipment to forecast the derived demand for electricity. Using exogenous forecasts of regional income, regional population, the rate of inflation, and interest rates, the module forecasts the regional stock of floor space. Next, econometric equations are used to predict the intensity of electricity use for a given level of floor space in the absence of any relative price changes. Finally, a price adjustment similar to that in the Residential Consumption Module is applied to derive a forecast of business electricity consumption (excluding large industrial demand, which must be exogenously determined). The Business Consumption Module forecasts are passed to the Conservation and Peak Demand Modules.

CONSERVATION MODULE

Because of the potential importance of government intervention in the market place to encourage conservation of energy and substitution of other forms of energy for electricity, the RED model includes a module that permits explicit treatment of technologies and programs that are designed to reduce the demand for utility-generated electricity. The module structure is designed to incorporate assumptions on the technical performance, costs, and market penetration of electricity-saving innovations in each end use, load center, and forecast year. The module forecasts the aggregate electricity savings by end use, the costs associated with of these savings, and adjusted consumption in the residential and business sectors.

The Conservation Module requires a set of off-line calculations by a nested computer program called CONSER. These calculations are more complex in the residential than the commercial sector, since more data are available on residential sector conservation options. In the residential sector, the model user supplies information to CONSER on the technical efficiency (electricity savings), electricity price, and costs of installation. Government market intervention in the form of capital subsidies or low-interest loans is incorporated in lowered installed cost to the consumer. CONSER then internally calculates the internal rate of return on the option to the consumer. That rate of return must exceed the passbook savings interest rate if the option is to gain assumed market acceptance. The Conservation Module then calculates the option's payback period for technologies considered "acceptable" by the user, and a payback decision rule links the payback period to a range of market saturations for the technologies. The savings per installation and market saturation of each option are used to calculate residential sector electricity savings and costs. In the business sector, the model user must specify the technical potential for new and retrofit energy-saving technologies. The user must also specify the range of conservation saturation as a percent of total potential conservation. The Conservation Module then calculates total electricity savings due to market intervention in new and retrofit applications and adjusts residential and business consumption for each load center and forecast year.

MISCELLANEOUS CONSUMPTION MODULE

The Miscellaneous Consumption Module forecasts total miscellaneous consumption for second (recreation) homes, vacant houses, and other miscellaneous uses such as street lighting. The module uses the forecast of residential consumption (adjusted for conservation impacts) to predict electricity demand in second homes and vacant housing units. The sum of residential and business consumption is used to forecast street lighting requirements. Finally, all three are summed together to estimate miscellaneous demand.

PEAK DEMAND MODULE

The Peak Demand Module forecasts the annual peak hour demand for electricity. A two-stage approach using load factors is used. The unadjusted residential and business consumption, miscellaneous consumption, and load center load factors generated by the Uncertainty Module are first used to forecast preliminary peak demand. Next, displaced consumption (electricity savings) calculated by the Conservation Module is multiplied by a peak correction factor supplied by the Uncertainty Module to allocate a portion of electricity savings from conservation to peak demand periods. The allocated consumption savings are then multiplied by the load factor to forecast peak demand savings, and the savings are subtracted from peak demand to forecast revised peak demand.

The following sections describe each module of the model in greater detail.

3.0 THE UNCERTAINTY MODULE

RED's Uncertainty Module allows the forecaster to incorporate uncertainty in key parameters of the RED Model forecast. In other words, the impact of uncertain parameter values is reflected in the forecast values.

RED allows generation of key subsets of the full set of parameters. It is not practical to allow all parameters to vary on all runs of the model, as the total number of such parameter values required for a single pass through the model is greater than 1000. For example, if the user wanted to generate 50 values for every uncertain parameter, over 50,000 values would have to be produced. While this is within RED's capabilities, the cost of such an exercise would be very high. Therefore, discretion is encouraged when using this option.

MECHANISM

A Monte Carlo routine uses the host computer's pseudo random number generator to translate user-supplied information on a parameter, such as its expected value, its range, and its subjective probability distribution, into random trial parameter values. By doing repeated simulations of the model, using several such randomly generated values of the parameter, the model will yield electricity consumption forecasts that incorporate each parameter's uncertainty.

INPUTS AND OUTPUTS

The Uncertainty Module requires three basic inputs:

- the number of values to be generated
- a selection of parameters to vary
- the parameter file.

The parameter file contains the default values, ranges, and (if required) the expected value and variance of each parameter. Table 3.1 provides a summary of the inputs and outputs of the module.

TABLE 3.1. Inputs and Outputs of the RED Uncertainty Module

(a) Inputs

Symbol	Variable	Input From
N	Number of Values to be generated	User Interface
(see Table 3.2)	Parameter's Range, Variance, and Expected Values	Parameter File

(b) Outputs

Symbol	Variable	Output To
(See Table 3.2)	Random Parameter Values	Other Modules
N	Number of Times Model is to be Run	Model Control Program

MODULE STRUCTURE

An overview of information flows within the Uncertainty Module is given in Figure 3.1. First, the program asks whether the user would like to generate a parameter. If the answer is no, then the default value (from the parameter file) for each parameter is assigned. If a random parameter value is to be generated, then the user is queried as to which parameters will be allowed to vary.

The next step is to choose the number of values to be generated for each parameter. This is the number of times the remainder of the model will be run, each time with a different generated value for each parameter. Next, an arbitrary seed for the random number generator is entered.

Next, the computer generates a random number for each value to be produced. This is accomplished by calling the computer's "pseudo" random number generator, which generates a random number between 0 and 1. From the parameter file, the information on the range of parameter, or (for parameters with a normal distribution) the range, expected value, and variance are used

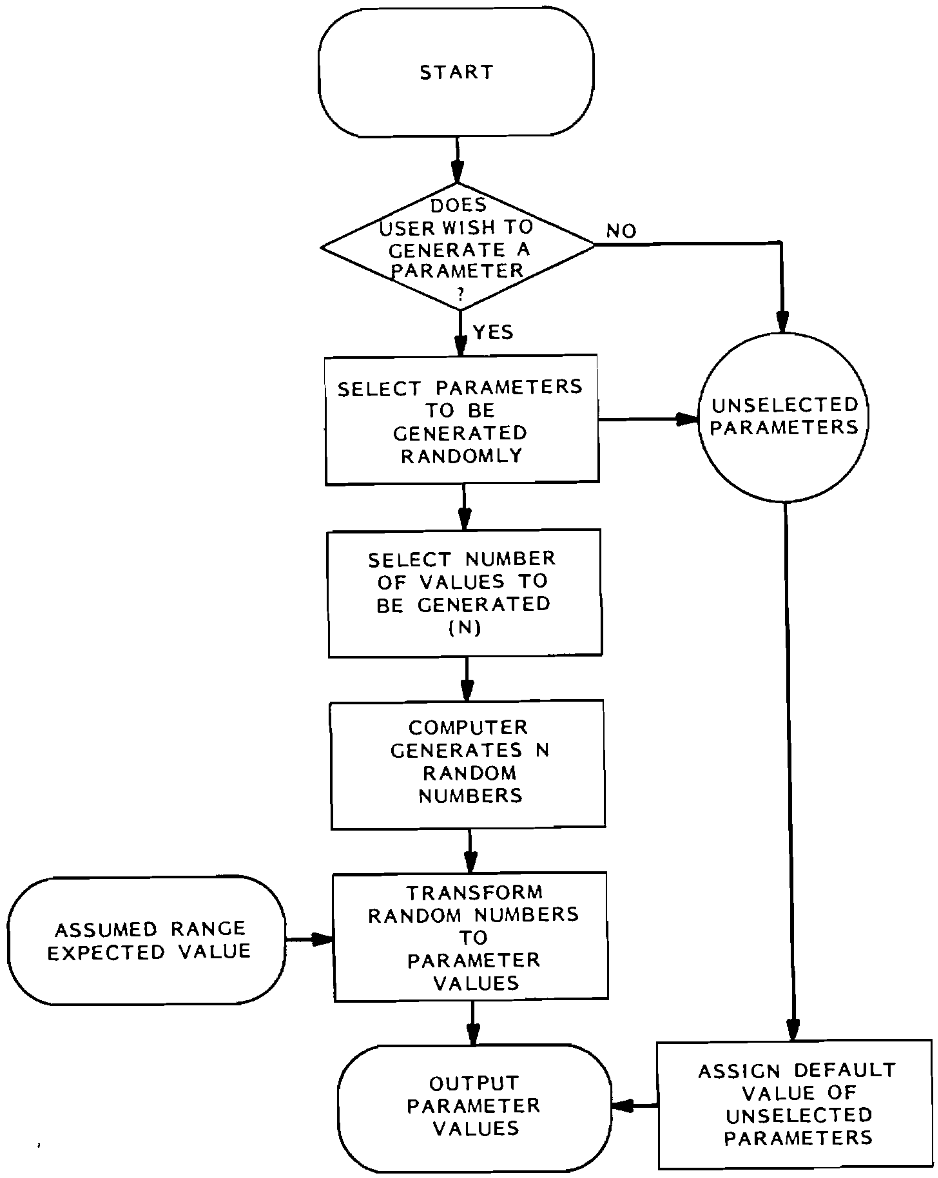

FIGURE 3.1. RED Uncertainty Module

to construct cumulative probability functions for each parameter. The random values for each parameter are then generated by applying the random numbers to these functions.

The Uncertainty Module then passes the generated values for each parameter to the remainder of RED. The mean and variance for each generated parameter are also reported.

PARAMETERS

Table 3.2 provides a list of the parameters that can be generated by the Uncertainty Module.

TABLE 3.2. Parameters Generated by the Uncertainty Module

Symbol	Name	Statistical Distribution
b_{as}; c_{as}; d_{as}	Housing Demand Coefficients	Normal
SAT	Saturation of Residential Appliances	Uniform
	Residential, Industrial, and Combined Support and Government Own-, Oil-Cross and Gas-Cross Price Elasticities	Uniform
BBETA	Floor Space Consumption Parameter	Normal
CONSAT	Saturation of Conservation Technologies	Uniform
LF	Load Factor	Uniform

4.0 THE HOUSING MODULE

The consuming unit in the residential sector is the household, each of which is assumed to occupy one housing unit. The Housing Module provides a forecast of the number of households and the stock of housing by the type of dwelling in each of the Railbelt's load centers. The type of dwelling is a major determinant of energy use in residential space heating. Furthermore, the type of dwelling is correlated with the stock of residential appliances. This module, therefore, provides essential inputs for the Residential Consumption Module.

MECHANISM

The Housing Stock Module uses assumed average household sizes to translate an exogenous forecast of regional population into a forecast of regional households. This forecast is then stratified on the age of the head of household and the number of household members. The housing demand equations then use this distribution of households by size and age of head to predict the initial demand for housing by type of dwelling. The initial demand for each housing type is compared with the remaining stock, and adjustments in housing demand and construction occur until housing market clearance is achieved.

INPUTS AND OUTPUTS

Table 4.1 presents the data used and generated within this module. An exogenous forecast of regional population and the state-wide distribution of households by age of head is needed as input, while the module passes information on the occupied and vacant housing stock to the remainder of RED.

MODULE STRUCTURE

The Housing Module's structure is shown in Figure 4.1. The module begins each simulation with a user-supplied forecast of population for the load center. Assumed household sizes for each load center are divided into the population to obtain a forecast of total households, which is then adjusted

TABLE 4.1. Inputs and Outputs of the RED Housing Module

(a) Inputs

Symbol	Variable	Variable Input From
POP	Population Forecast	Population Scenario File
HH_{Ata}	State Households by Age Group	Forecast File
b, c, d	Housing Demand Coefficients	Uncertainty Module

(b) Outputs

Symbol	Variable	Variable Output From
HD_{TY}	Occupied Housing Stock by Type	Residential Module
VH	Vacant Housing	Miscellaneous Module

for military demand, next stratified by age and size of household, and then used to generate an estimate of demand for each type of housing (TY). Demand is compared to the initial stock, resulting in new construction or reallocation of demand as appropriate. The end result is a set of estimates of occupied and unoccupied housing units by type. Finally, the housing stock is reinitialized for the next forecast period.

The first step in the Housing Module is to find the number of households in a given Railbelt load center, dividing the exogenous forecast of regional population by the region's predicted average household size:

$$THH_{it} = \left(\frac{POP_{it}}{AHS_{it}}\right) - BHH_{it} \tag{4.1}$$

where

THH = total number of households

POP = population (exogenous)

AHS = average household size (parameter)

BHH = military households residing on base (exogenous)

i = region subscript

t = forecast period subscript.

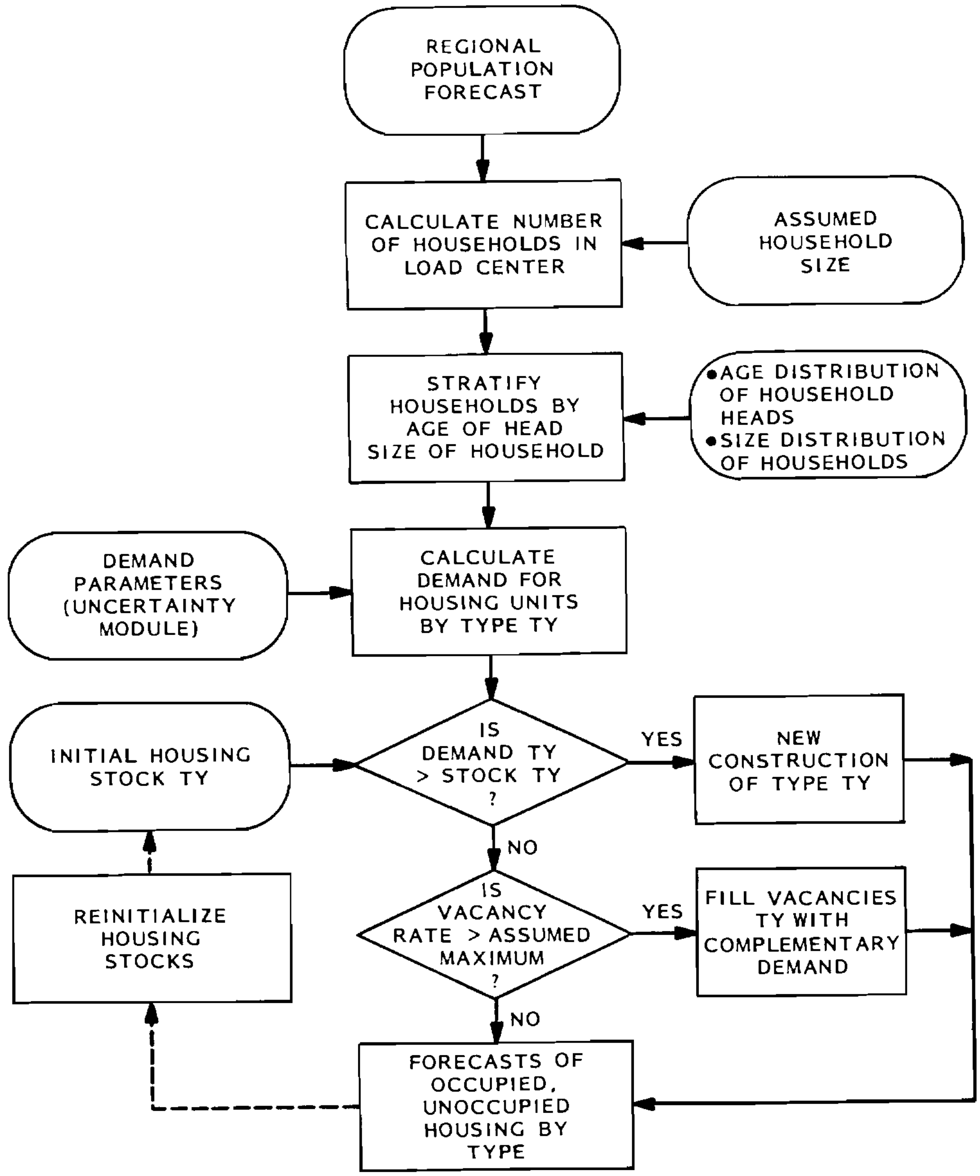

FIGURE 4.1. RED Housing Module

On-base military households are subtracted out because they do not significantly affect off-base housing and, since the military supplies electricity to them, on-base households have no impact on the residential demand for utility-supplied electricity.

Once the total number of households in the region has been obtained, they are stratified by the size of the household and the age of the household head. To obtain the distribution of households by size of household, the total number of households is multiplied by the probabilities of four size categories derived from information provided in a residential survey conducted in the Railbelt by Battelle-Northwest in March and April, 1981. To estimate the distribution of households by the age of head, the 1970 Census ratio between the regional and state relative frequencies of age of head is assumed to remain constant. The user supplies forecasts of the statewide age distribution of heads of households. In the Railbelt Alternatives study, this forecast was produced by the MAP model. Using the state relative frequency distribution, therefore, and applying the constant ratios of regional to statewide frequencies, the model obtains forecasts of the regional distribution of households by age of head.

The joint distribution by size of household and age of head is obtained by multiplying the two distributions:

$$HH_{itas} = THH_{it} \times \frac{HH_{Ata}}{THH_{Ata}} \times P_{its} \times R_{ia} \qquad (4.2)$$

where

HH = number of households in an age/size class

A = subscript denoting aggregate state variable

P = regional household size probability (parameter)

R = ratio of the regional to state relative frequency of age of household head (parameter)

a = age of head subscript

s = household size subscript.

The demand for a particular type of housing - single family, multi-family, mobile home, or duplex - is hypothesized to be a function of the size of the household and the age of the head (which serves as a proxy for household wealth). Equations projecting demand for three of the types of housing (single family, multi-family, mobile homes) were estimated by the

Institute of Social and Economic Research (ISER) from Anchorage data collected by the University of Alaska's Urban Observatory (Goldsmith and Huskey 1980b). The remaining category (duplex) is filled with the leftover households.

The demand for a particular type of housing is given by the following equations:

$$HD_{SFit} = THH_{it} \times b_0 + b_{a1} \times S_{1it} + b_{a2} \times S_{2it} + b_{a4} \times S_{4it} + b_{a2s} \times A_{2it} + b_{3s} \times A_{3it} + b_{4s} \times A_{4it} \quad (4.3)$$

$$HD_{MFit} = THH_{it} \times c_0 + c_{a1} \times S_{1it} + c_{a2} \times S_{2it} + c_{a4} \times S_{4it} + c_{2s} \times A_{2it} + c_{3s} \times A_{3it} + c_{4s} \times A_{4it} \quad (4.4)$$

$$HD_{MHit} = THH_{it} \times d_0 + d_{a1} \times S_{1it} + d_{a2} \times S_{2it} + d_{a4} \times S_{4it} + d_{2s} \times A_{2it} + d_{3s} \times A_{3it} + d_{as} \times A_{4it} \quad (4.5)$$

$$HD_{DPit} = THH_{it} - HD_{SFit} - HD_{MFit} - HD_{MHit} \quad (4.6)$$

where

HD = housing demand

SF = index for single family

$S_{sit} = \sum_{a=1}^{4} HH_{itas}$; $s = 1,2,4$

$A_{ait} = \sum_{s=1}^{4} HH_{itas}$; $a = 2,3,4$

MF = index for multifamily

MH = index for mobile home

DP = index for duplex

a = index denoting the age of household head

a = 1	< 25
a = 2	25-29
a = 3	30-54
a = 4	55+

s = index denoting the size of household

s = 1	≤ 2
s = 2	3
s = 3	4-5
s = 4	6+

b, c, and d are parameters from the Uncertainty Module.

The model then adjusts the housing stock and housing demand so that the housing market is cleared. Initially, the housing stock is calculated as the previous period's stock net of demolition:

$$HS_{TYit} = HS_{TYi(t-1)} \times (1 - r_t) \tag{4.7}$$

where

HS = housing stock

TY = index denoting the type of housing (SF, MF, MH, and DP)

r = period specific removal rate (parameter).

Net demand for each type of dwelling is defined as the demand minus the housing stock:

$$ND_{TYit} = HD_{TYit} - HS_{TYit} \tag{4.8}$$

where

ND = net demand.

If net demand for all types of housing is positive, then new construction immediately occurs in sufficient quantity to meet the net demand plus an equilibrium amount of vacancies required to ensure normal functioning of the housing market:

$$NC_{TYit} = ND_{TYit} + V_{TY} \times (HS_{TYit} + ND_{TYit}) \quad (4.9)$$

where

NC = new construction

V = normal vacancy rate (parameter).

The equilibrium vacant housing stock is the "normal" vacancy rate times the stock of housing.

If the net demand for a particular type of housing is negative, however, then the vacancy rate for that type of housing has to be calculated:

$$AV_{TYit} = 1 - \frac{HD_{TYit}}{HS_{TYit}} \quad (4.10)$$

where

AV = actual vacancy rate.

If the actual vacancy rate is greater than its assumed maximum, then the excess supply of that particular type of housing is assumed to drive down the price of that type of dwelling. Individuals residing in other dwellings could be induced to move to reduce mortgage or rent payments. An adjustment to the distribution of housing demands, therefore, is appropriate.

Substitution occurs, if possible, within groups of housing that are close substitutes (single-family and mobile homes; duplexes and multifamily). If not enough excess demand exists from the close substitutes to fill the depressed market, then substitution occurs from all types. The procedure is as follows:

1. The number of excess vacancies within a type is calculated by subtracting the housing demand from one minus the maximum vacancy rate, times the stock.
2. The number of substitute units available to fill the excess supply is given by subtracting one minus the normal vacancy rate, times the close substitute stock from the close substitute demand.

3. The minimum of 1 or 2 is subtracted from the complementary housing demand and added to the depressed demand.

4. If excess supply persists (the actual vacancy rate is above its assumed maximum), then the above procedure is repeated, only the number of housing units available is now calculated using maximum vacancy rates and all types of housing where the actual vacancy rate is less than their assumed maximum. The available units are then allocated based on normalization weights of the number available by type.

The final outputs of this module are occupied housing by type (HD_{TYit}) and unoccupied housing:

$$VH_{it} = \sum_{TY} \left(HS_{TYit} - HD_{TYit} \right) \tag{4.11}$$

where

VH = total vacant dwelling units.

PARAMETERS

Table 4.2 presents the average household size parameters for the forecast periods by load center. The values for 1980 were derived from 1980 Census of Population (Bureau of Census 1980c). Average household size has declined significantly in the past ten years. Continuity in this trend is anticipated, but the rate of reduction is believed to be more moderate than in the past. The future values of household size in the three Railbelt load centers, therefore, were reduced from the 1980 levels to converge on the predicted statewide household size in the year 2010 (which is 2.443).

The number of on-base military households, presented in Table 4.3, is assumed to remain constant over the forecast periods. The level of military activity in Alaska has stabilized, and little indicates that a major shift will occur in the future.

TABLE 4.2. Average Household Size in Railbelt Load Centers, 1980-2010

Year	Anchorage	Fairbanks	Glennallen-Valdez
1980[a]	2.834	2.812	2.843
1985[a]	2.769	2.751	2.776
1990[a]	2.704	2.689	2.710
1995[a]	2.638	2.628	2.643
2000[a]	2.573	2.566	2.576
2005[a]	2.508	2.505	2.510
2010[a]	2.443	2.443	2.443

(a) Based on assumption that average household size linearly falls to the predicted statewide household size in 2010.

TABLE 4.3. Number of Military Households Assumed to Reside on Base in Railbelt Load Centers

Anchorage	Fairbanks	Glennallen-Valdez
3,212	3,062	0

Source: Supplied by the Institute of Social and Economic Research, University of Alaska.

Tables 4.4 and 4.5 present the parameters used to derive the joint distribution of households by size and age of head. The baseline figures for the probability of size parameters were derived from the Battelle-Northwest end-use survey. Those parameters were adjusted to linearly approach the 1977 Western Regional average household size of 2.6 (Bureau of Census 1977) by the year 1992, then continue to change at the same rate for the remainder of the period. The ratio of regional to statewide frequency of age of head was derived by ISER. These ratios are assumed to remain constant.

The housing demand parameters were estimated by ISER using a linear probability model.[a] The expected values in Table 4.6 are the estimated

TABLE 4.4. Probability of Size of Household in Railbelt Load Centers

Year	Size	Anchorage	Fairbanks	Glennallen-Valdez
1980[a]	<2	0.476	0.455	0.426
	3	0.190	0.210	0.190
	4-5	0.291	0.287	0.341
	6+	0.042	0.048	0.043
1985[b]	<2	0.515	0.515	0.463
	3	0.182	0.152	0.185
	4-5	0.262	0.262	0.309
	6+	0.041	0.041	0.042
1990[b]	<2	0.553	0.553	0.501
	3	0.174	0.174	0.180
	4-5	0.233	0.233	0.277
	6+	0.040	0.040	0.042
1995[b]	<2	0.591	0.591	0.538
	3	0.165	0.165	0.176
	4-5	0.205	0.205	0.245
	6+	0.039	0.039	0.041
2000[b]	<2	0.629	0.629	0.575
	3	0.157	0.157	0.171
	4-5	0.176	0.176	0.213
	6+	0.039	0.039	0.040
2005[b]	<2	0.667	0.667	0.612
	3	0.149	0.149	0.166
	4-5	0.147	0.147	0.182
	6+	0.038	0.038	0.040
2010[b]	<2	0.705	0.705	0.650
	3	0.140	0.140	0.161
	4-5	0.118	0.118	0.150
	6+	0.037	0.037	0.039

(a) Source: Battelle-Northwest End-Use Survey.
(b) The distribution is assumed to linearly approach the 1977 Western Regional Distribution by 1992 (Bureau of Census 1977).

TABLE 4.5. Regional Frequency of Age of Household Head Divided by the State-Wide Frequency

Age of Head	Anchorage	Fairbanks	Glennallen-Valdez
< 25	1.07	1.45	0.56
25-30	1.02	1.12	0.76
31-54	1.02	0.97	1.02
55+	0.80	0.69	1.49

Source: Supplied by the Institute of Social and Economic Research, University of Alaska.

coefficients reported by ISER. The ranges were calculated as the width of the 95% confidence intervals, whereas the variance was backed out of the reported F statistics.

Table 4.7 presents the assumed normal and maximum vacancy rates by type of house. ISER (Goldsmith and Huskey 1980b) derived the normal vacancy rates by taking the ten-year U.S. averages of vacancy rates for owner and renter units. Single-family and mobile homes have the owner rate; multifamily homes have the renter rate; and duplexes are the average of owner and renter rates. For the maximum vacancy rates, Anchorage multifamily rates were available. The relationship between the normal rates for multifamily and all other types was used to derive the maximum rates.

Housing demolition rates (Table 4.8) are a function of the age of the housing stock and the demand for housing. ISER found that approximately one percent of the housing stock was removed between 1975 and 1980 in Anchorage and Fairbanks (Goldsmith and Huskey 1980b). As the existing stock ages, the removal rate is assumed to grow towards the U.S. average, which has been estimated to be between 2 and 4% per forecast period (5 years).

The housing stock figures displayed in Table 4.9 are those derived by ISER for their end-use model. The numbers have been adjusted to reflect the total stock, not only stock served by an electric utility.

TABLE 4.6. Housing Demand Equations: Parameters' Expected Value, Range, and Variance

Parameter	Expected Value	Range	Variance
b_o	0.461	---	--
b_{a1}	-0.303	0.142	0.001
b_{a2}	-0.175	0.152	0.001
b_{a4}	0.080	0.230	0.003
b_{2s}	0.182	0.205	0.003
b_{3s}	0.317	0.182	0.002
b_{4s}	0.380	0.226	0.003
c_o	0.383	--	--
c_{a1}	0.225	0.124	0.001
c_{a2}	0.086	0.133	0.001
c_{a4}	-0.090	0.202	0.003
c_{2s}	-0.203	0.180	0.002
c_{3s}	-0.280	0.159	0.002
c_{4s}	-0.352	0.198	0.003
d_o	0.097	--	--
d_{a1}	0.068	0.101	0.001
d_{a2}	0.039	0.109	0.001
d_{a4}	0.014	0.159	0.002
d_{2s}	0.008	0.152	0.001
d_{3s}	-0.020	0.130	0.001
d_{4s}	-0.016	0.162	0.002

Source: Goldsmith and Huskey 1980b, Table B.6.

TABLE 4.7. Assumed Normal and Maximum Vacancy Rates by Type of House (Percent)

Type	Normal Rate[a]	Maximum Rate[b]
Single Family	1.1	3.3
Mobile Home	1.1	3.3
Duplex	3.3	10.0
Multifamily	5.4	16.0

(a) Imputed by ISER from Bureau of the Census (1980a).
(b) Imputed by ISER from Anchorage Real Estate Research Committee (1979).

TABLE 4.8. Assumed Five-Year Housing Removal Rates in Railbelt Region, 1980-2010 (Percent of Housing Stock at Beginning of Period Removed During Period)

Years	Removal Rate (percent)
1980-1985	1.25
1985-1990	1.50
1990-1995	1.75
1995-2000	2.00
2000-2005	2.25
2005-2010	2.50

Source: Author Assumption.

TABLE 4.9. Railbelt Housing Stock by Load Center and Housing Type, 1980 (number of units)[(a)]

Type	Anchorage	Fairbanks	Glennallen-Valdez
Single Family	37,422	9,900	665
Mobile Homes	9,239	2,475	904
Duplexes	5,871	1,397	270
Multifamily	19,061	5,265	266
Total	71,593	19,037	2,105

(a) A unit is occupied by one household. Thus, a 4-plex is considered four housing units.

Source: Goldsmith and Huskey 1980b, Table C.16, C.17, C.18. These figures have been adjusted to reflect the total stock, rather than units served by electricity.

5.0 THE RESIDENTIAL CONSUMPTION MODULE

The purpose of the Residential Consumption Module is to provide forecasts of residential consumption of electricity. Consumption of electricity is not the instantaneous demand for electricity; rather, it is the quantity of electricity (kWh) required to meet the customer's needs over a period of time. The forecasts of the needs of the residential sector do not include the impacts of conservation produced by market intervention by government. The potential for and impacts of such conservation activities are handled in the Conservation Module. Furthermore, the module's forecast of residential requirements is the amount of electricity that needs to be delivered to the residential sector - it does not include allowances for line losses.

What this module does do, however, is estimate the amount of electricity residential consumers use, with explicit consideration of the impacts of electricity price changes and fuel switching between electricity, gas, and oil. Impacts of fuel switching to and from other fuels (such as wood) are handled in the Conservation Module.

MECHANISM

The Residential Consumption Module employs an end-use approach. In an end-use analysis, the first step is to identify the major uses of electricity. Future market saturations of the uses are forecasted so that the future stock of electricity-consuming devices is defined. The next step is to estimate the amount of electricity demanded to meet a future demand for the services of the devices. The forecast of average consumption of the appliance stock, therefore, reflects both the trend in the size of the device and its utilization rate. Once the stock of major electricity-consuming devices and their corresponding average annual per unit consumption of electricity are forecast, the future consumption of electricity by device type is obtained by multiplying the number of devices by their predicted annual average consumption of electricity. Using the same procedure for miscellaneous residential uses and summing over all end-uses yields an aggregate forecast of electricity requirements.

One major problem of the end-use approach is that the impacts of changes in fuel prices (both electricity and alternatives) and income on electricity usage are usually treated directly through the forecaster's judgment. The RED Residential Consumption Module addresses this problem differently. By adjusting the aggregate residential consumption figure with price and cross-price elasticities of demand derived econometrically from actual consumption data, RED accounts for price change and fuel-switching impacts in the residential sector.

INPUTS AND OUTPUTS

Table 5.1 presents the inputs and outputs of the module. The number of households by dwelling type is the number of occupied dwelling units by type predicted in the Housing Module. The short-run and long-run price and cross-price elasticities, as well as the appliance saturations, are generated in the Uncertainty Module. The output of the module is preliminary residential sales of electricity.

TABLE 5.1. Inputs and Outputs of the RED Residential Module

(a) Inputs

Symbol	Variable	From
HP_{TY}	Households by Type of Dwelling	Housing Stock Module
E, CE	Price Elasticities	Uncertainty Module
SAT	Appliance Saturations	Uncertainty Module

(b) Outputs

Symbol	Variable	To
RESCON	Residential Electricity Requirements	Miscellaneous, Peak Demand and Conservation Modules

MODULE STRUCTURE

The Residential Consumption Module identifies the following major uses of electricity in the residential sector:

1. Water Heating
2. Cooking
3. Refrigeration
4. Freezing
5. Clothes Washing (and additional water heating)
6. Clothes Drying
7. Dishwashing (and additional water heating)
8. Saunas-Jacuzzis
9. Space Heating

In addition, several additional uses of electricity by households are captured by a small appliance category. Small appliances include televisions, radios, lighting, head-bolt heaters, kitchen appliances, heating pads, etc. The basic premise of this module is that the household is the primary consumer of electricity, not the individual. However, the number of individuals in the household significantly affects the consumption of energy for clothes washing, clothes drying, and water heating. Therefore, there is an adjustment in the model for changes in the average household size to recognize the impact of such changes on the usage of these appliances.

For the nine major uses of electricity, the end-use approach is used (see Figure 5.1). Figure 5.1 shows the calculations that take place in the Residential Consumption Module. Beginning with a regional estimate of occupied housing stock by type, the module uses appliance market saturation parameters to estimate the stock of each of the major appliances recognized by the model. The module then calculates the initial fuel mode split for multifuel appliances, calculates preliminary electric consumption for each appliance type (including small appliances), and then sums these estimates together into a preliminary consumption estimate for the residential sector. Price forecasts for gas, oil, and electricity and "trial"-specific own-price and cross-price elasticities are used to adjust the preliminary forecast.

Results from the Battelle-Northwest (BNW) end-use survey show significant differences in the saturations of these nine end uses by the type of dwelling in which the household resides. The module, therefore, uses the number of

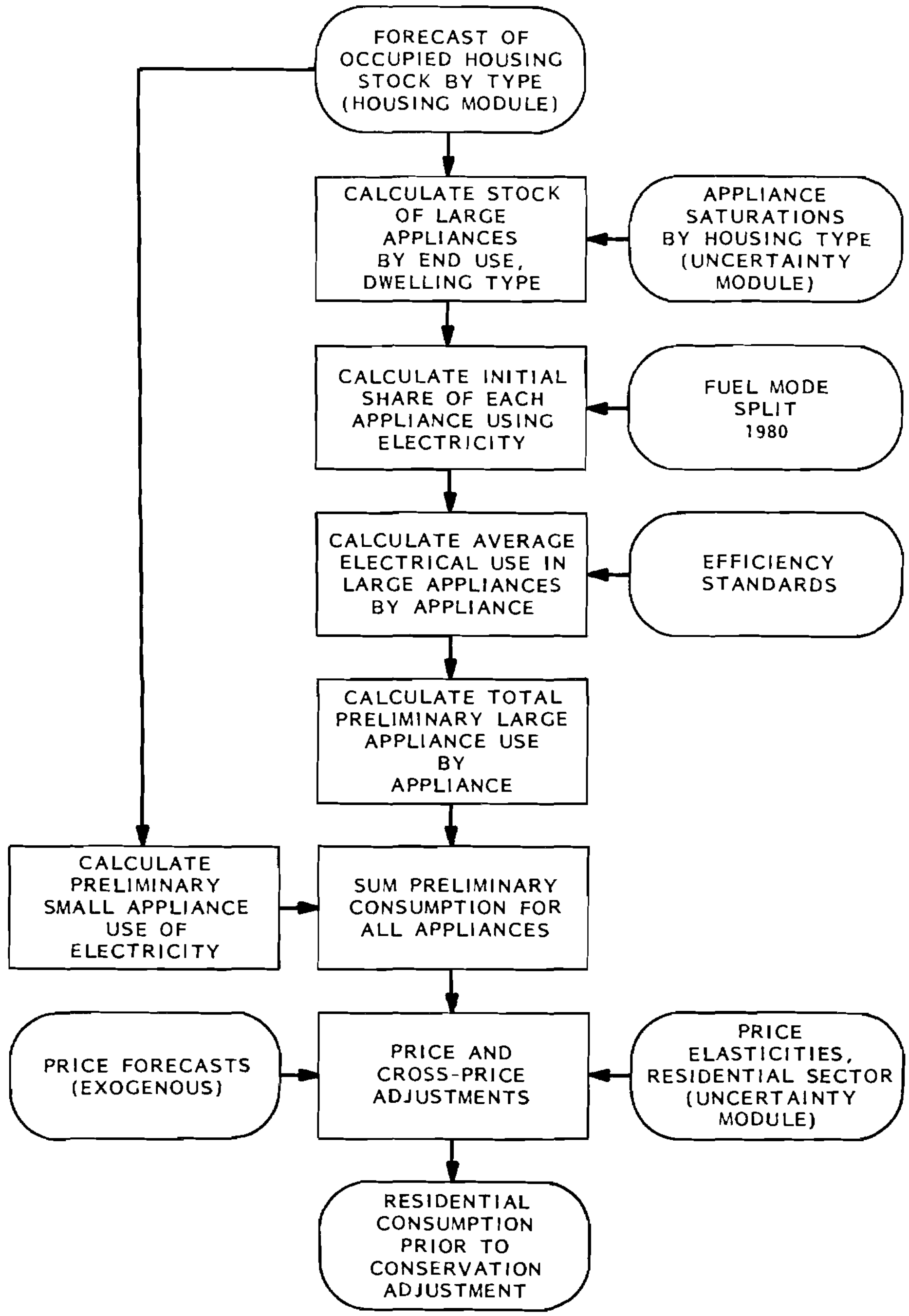

FIGURE 5.1. RED Residential Consumption Module

occupied housing units of each type of dwelling (single family, multifamily, mobile home, and duplex) as predicted by the Housing Module as one of the inputs to estimate the stock of appliances.

The Housing Module, however, merely predicts the number of occupied primary[a] residences by type in a given region, not the number of units served by electric utilities. By multiplying the number of occupied housing units by type by an assumed percentage served, the Residential Consumption Module forecasts the number of primary occupied housing units served:

$$HHS_{TYit} = SE_{it} \times HD_{TYit} \tag{5.1}$$

where

HHS = households served
TY = denotes the type of dwelling
SE = proportion of type served by an electric utility
HD = stock of occupied dwellings from the Housing Module
i = region subscript
t = forecast period (t = 1, 2, 3, ..., 7).

Once the number of electrically-served households by type of dwelling is known, the applicance stock can be estimated. The saturation rate for an appliance is the percentage of households residing in a certain type of dwelling and having the appliance in question. By multiplying the housing-type-specific saturation rate by the number of households residing in that type of housing and then summing across housing types, the model forecasts appliance demand in each future forecast period t:

$$AD_{itk} = \sum_{TY=1}^{4} (SAT_{TYitk} \times HHS_{TYit}) \tag{5.2}$$

(a) Excluding second or recreation homes.

where

AD = appliance demand

SAT = saturation rate (parameter)

k = end-use appliance.

Next, the model calculates the number of additions to the stock in the future. Assuming demand is fully met, the number of new appliances in period t is found by calculating the stock of appliances surviving from all previous periods and subtracting this surviving stock from appliance demand:

$$NA_{itk} = AD_{itk} - \sum_{m=1}^{t-1} NA_{imk} \times (1 - d_{tk}^{m}) - AS_{iok} \times (1 - d_{tk}^{o}) \tag{5.3}$$

where

NA = number of new appliances

AS_{iok} = initial stock of appliances (1980)

d_{tk}^{m} = vintage specific scrap rate in period t; for vintage m (parameter) (m = 1, 2, 3, ..., 7).

Equation 5.3 can be rearranged so that the stock equals the demand:

$$AD_{itk} = AS_{iok} \times (1 - d_{tk}^{o}) + \sum_{m=1}^{t} NA_{imk} \times (1 - d_{tk}^{m}) \tag{5.3'}$$

The future appliance stock, therefore, can be stratified by vintage. Next, the model calculates the initial stock of electricity-consuming appliances by multiplying the number of appliances in each vintage by the percentage using electricity:

$$EAS_{iok} = FMS_{ik} \times AS_{iok} \tag{5.4}$$

$$ENA_{imk} = FMS_{ik} \times NA_{imk} \tag{5.5}$$

$$EAD_{itk} = FMS_{ik} \times AD_{itk} \tag{5.6}$$

where

EAS = initial stock of electric appliances

FMS = fuel mode split

ENA = additions to the electric appliance stock

EAD = total electric appliance stock.

The Residential Consumption Module next calculates the average annual electricity consumption of each major appliance. Different vintages of appliances use different amounts of electricity, so the average consumption must reflect the vintage composition of the stock. Furthermore, industry energy efficiency standards for appliances could change in future years. The future vintage specific consumption rate can be derived by multiplying the current (1980) consumption rate by a growth factor and adjusting for any changes in efficiency standards. By weighting these figures by the proportion of the stock they represent, the average consumption of each appliance type in a forecast year is derived:

$$AC_{itk} = AC_{iok} \times \frac{EAS_{iok} \times \left(1-d^{o}_{tk}\right)}{EAD_{itk}} + \sum_{m=1}^{t} \left(AC_{iok} \times (1+g_k)^{(m-1) \times Z} \times (1-cs_{mk}) \times \frac{ENA_{imk}\ (1-d^{m}_{tk})}{EAD_{itk}} \right) \tag{5.7}$$

where

AC_{itk} = average consumption of appliance k in period t (parameter)

AC_{iok} = average consumption of appliance k in the beginning period (parameter)

Z = length of forecast periods t and m in years (parameter) set equal to 5 for this study.

g = growth rate of appliance k consumption (parameter)

cs = conservation standards target consumption reduction (parameter)

Finally, the preliminary consumption for each major appliance can be calculated by multiplying the stock of each appliance by its calculated average consumption:

$$CONS_{itk} = EAD_{itk} \times AC_{itk} \tag{5.8}$$

where

CONS = preliminary consumption of electricity prior to price adjustments.

The Residential Module makes no distinction among the various types of appliances in the small appliance category. The requirements for these units are simply the product of the number of households in the region, the initial consumption level, and a growth factor in consumption over time:

$$CONS_{itsa} = \sum_{TY} HHS_{TYit} \times \left[AC_{iosa} + (ACG_{itsa} \times t \times Z)\right] \tag{5.9}$$

where

ACG = growth factor in small appliance consumption

sa = index denoting small appliances.

Total preliminary residential consumption is found by summing across end uses:

$$RESPRE_{it} = \sum_{k=1}^{9} CONS_{itk} + CONS_{itsa} \tag{5.10}$$

where

RESPRE = total preliminary residential consumption.

$RESPRE_{it}$ reflects mainly the physical characteristics of the stock of electrical appliances. Consumers, however, can respond dramatically to changes in the prices of electricity and alternative fuels. The own- and cross-price elasticities of demand measure the responsiveness of consumers to price changes. Specifically, the own-price elasticity of demand is the ratio of the percentage of change in the quantity taken of a good to the percentage of change in the price of the good relative to the prices of other goods. If this ratio is less than -1 (for example, -2), then the demand for the good is said to be elastic. In this case, consumers are fairly responsive to price, as they reduce the amount they purchase by more than the relative increase in price (in percentage terms). Similarly, the demand is said to be inelastic if the elasticity is between -1 and zero, in which case the change in quantity is less than the relative change in price (again in percentage terms). In simple terms, the own-price elasticity measures the responsiveness of consumption of a good to changes in the price of the good.

The demand for electricity is also a function of the prices of alternative fuels. The <u>cross</u>-price elasticity of electricity measures the responsiveness of the quantity of electricity taken with respect to change in the price of <u>another</u> fuel. In other words, the cross-price elasticity predicts the percentage change in the quantity of electricity taken for a one-percentage change in the relative price of an alternative fuel.

If the cross-price elasticity is positive, then the fuels are said to be substitutes. As the price of another fuel rises, the quantity taken of electricity rises. For example, natural gas and electricity are substitutes. If the price of gas rises enough relative to the price of electricity, then some natural gas customers will switch to electricity. If the cross-price elasticity is negative, the fuels are complements, and increases in the price of the alternate fuel will cause reductions in the amount of the electricity that is taken.

Distinguishing between short-run and long-run responses to price is possible. In the short run, or the immediate future, consumers cannot alter their usage as much as over longer periods of time, since their stock of appliances is fixed. Over a longer period of time, they can replace elements of their stock with devices that use less electricity, or perhaps use another fuel source. Therefore, making the distinction between the short-run and the long-run elasticities is important.

The elasticities generated in RED are aged over the forecast period from their short-run values to their long-run values, thus explicitly modeling consumers' changing the pattern of use in the short run and fuel switching in the long run. The Uncertainty Module generates both the short-run and long-run values of the elasticities for specific trials. Since RED produces a forecast only every five years in the current study, the transition from the short-run to long-run value is rather abrupt. Specifically, the transition time is assumed to be seven years. If a price change occurs in the first forecast year, in the next forecast period the elasticity is 5/7 of the way from the short-run value.

The actual calculation is as follows:

$$RESCON_{it} = RESPRE_{it} \times OPA_{it} \times CPA_{it} \tag{5.11}$$

$$OPA_{it} = \left(\frac{P_{ite}}{P_{i(t-1)e}}\right)^{E_{SR}} \times \left(\frac{P_{i(t-1)\,e}}{P_{i(t-2)\,e}}\right)^{\left(E_{SR} + \frac{5}{7}\left(E_{LR} + E_{SR}\right)\right)} \times \left(\frac{P_{i(t-2)\,e}}{P_{io\,e}}\right)^{E_{LR}} \tag{5.12}$$

$$CPA_{it} = \left(\frac{P_{itO}}{P_{i(t-1)O}}\right)^{CE_{OSR}} \times \left(\frac{P_{i(t-1)O}}{P_{i(t-2)O}}\right)^{\left(CE_{OSR} + \frac{5}{7}\left(CE_{OLR} - CE_{OSR}\right)\right)} \times \left(\frac{P_{i(t-2)O}}{P_{ioO}}\right)^{CE_{OLR}} \times \left(\frac{P_{itG}}{P_{i(t-1)G}}\right)^{CE_{GSR}} \times \left(\frac{P_{i(t-1)G}}{P_{i(t-2)G}}\right)^{\left(CE_{GSR} + \frac{5}{7}\left(CE_{GLR} - CE_{GSR}\right)\right)} \times \left(\frac{P_{i(t-2)G}}{P_{ioG}}\right)^{CE_{GLR}} \tag{5.13}$$

where

RESCON = consumption of electricity in the residential sector

OPA = own-price adjustment

CPA = cross-price adjustment

P = price

E = own-price elasticity

SR = denotes short-run value

LR = denotes long-run value

CE = cross-price elasticity

O = index denoting oil

G = index denoting gas

e = index denoting electricity.

RESCON is the predicted electricity consumption in the residential sector before adjustments for subsidized conservation. This figure is passed to the Peak Demand and Conservation Modules.

PARAMETERS

The percentage of households served by an electric utility (Table 5.2) is an important parameter. ISER has estimated that only 91% and 71% of the occupied housing in Fairbanks and Glenallen-Valdez were connected to an electric utility (Goldsmith and Huskey 1980b). Due to the high emphasis the state legislature and governor have placed on energy, the extension of electrical service to all who would like service is highly probable. Therefore, electrical services are assumed to be extended to the entire stock of housing in the Fairbanks and Glennallen load centers by 1995.

Appliance Saturations

Because historical growth and comparison with the lower 48 provide weak guidance on both current and future market saturations of major appliances, somewhat arbitrary maximum penetration rates necessarily have been assumed, for which wide bands of uncertainty have been specified. Market penetration for most appliances is already outside the bounds of lower 48 experience and shows no signs of slowing down. However, many of the major appliances most

TABLE 5.2. Percent of Households Served by Electric Utilities in Railbelt Load Centers, 1980-2010

Year	Anchorage	Fairbanks	Glennallen-Valdez
1980[a]	100	91	71
1985[b]	100	93	80
1990[b]	100	96	90
1995[b]	100	100	100
2000[b]	100	100	100
2005[b]	100	100	100
2010[b]	100	100	100

(a) Source: Goldsmith and Huskey 1980b, Table C.13, C.14, C.15.
(b) The state is assumed to extend electrical service to all residents by 1995.

likely will never reach 100% market saturation for a variety of reasons, such as transient population, convenience of substitutes like laundromats, small housing units, etc. The assumptions in this secton reflect a compromise between rapid historical growth in appliance stocks in Alaska and approaching boundaries on market saturation.

Tables 5.3 through 5.6 show the default value and range for future market saturations of major appliances that can use one of several fuels in normal home installation. The table values are the expected percentage of housing units of a given type that will have the appliance in a given year and market area, and the subjective uncertain range that can be used instead of the default value if the Monte Carlo option is used. The table title indicates the type of house. The assumptions for each type of appliance are given below.

Hot Water

Hot water was available in nearly 99% of single-family homes in the Anchorage market area, according to the Battelle-Northwest end-use survey. It

TABLE 5.3. Market Saturations (Percent) of Large Appliances with Fuel Substitution Possibilities in Single-Family Homes, Railbelt Load Centers, 1980-2010

Load Center	Year	Water Heaters Default	Water Heaters Range	Clothes Dryers Default	Clothes Dryers Range	Range (cooking) Default	Range (cooking) Range	Saunas - Jacuzzis Default	Saunas - Jacuzzis Range
a. Anchorage	1980	98.6[a]	--	90.2	--	99.5[a]	--	14.1	
	1985	98.8	95-100	91.2	88-94	100.0	99-100	17.0	14-20
	1990	99.0	98-100	92.5	89-95	100.0	99-100	21.0	15-25
	1995	99.0	98-100	93.7	90-96	100.0	99-100	25.0	20-30
	2000	99.0	98-100	95.0	92-98	100	99-100	30.0	20-40
	2005	99.0	98-100	95.0	92-98	100	99-100	35.0	25-45
	2010	99.0	98-100	95.0	92-98	100	99-100	40.0	30-50
b. Fairbanks	1980	86.9[a]	--	81.4	--	100.0[a]	99-100	7.9	--
	1985	93.0	91-95	84.0	80-88	100.0	99-100	12.0	10-15
	1990	99.0	98-100	87.5	82-92	100.0	99-100	21.0	15-25
	1995	99.0	98-100	92.5	87-97	100.0	99-100	25.0	20-30
	2000	99.0	98-100	95.0	92-98	100.0	99-100	30.0	20-40
	2005	99.0	98-100	95.0	92-98	100.0	99-100	35.0	25-45
	2010	99.0	98-100	95.0	92-98	100.0	99-100	40.0	30-50
c. Glennallen-Valdez	1980	89.1[a]	--	87.1	--	100.0[a]	--	13.6	--
	1985	90.0	88-92	89.0	87-93	100.0	99-100	17.0	15-20
	1990	95.0	92-98	91.0	87-95	100.0	99-100	21.0	15-25
	1995	97.0	96-98	93.0	91-95	100.0	99-100	25.0	20-30
	2000	99.0	98-100	95.0	92-98	100.0	99-100	30.0	20-40
	2005	99.0	98-100	95.0	92-98	100.0	99-100	35.0	25-45
	2010	99.0	98-100	95.0	92-98	100.0	99-100	40.0	30-50

(a) For hot water and cooking, missing values on the Battelle-Northwest survey were not counted.

TABLE 5.4. Market Saturations (Percent) of Large Appliances with Fuel Substitution Possibilities in Mobile Homes, Railbelt Load Centers, 1980-2010

Load Center	Year	Water Heaters		Clothes Dryers		Range (cooking)		Saunas - Jacuzzis	
		Default	Range	Default	Range	Default	Range	Default	Range
a. Anchorage	1980	98.2[a]	--	79.0	--	95.7[a]	--	6.1	--
	1985	99.0	98-100	80.0	79-81	100.0	100-100	12.0	8-16
	1990	99.0	98-100	82.0	80-84	100.0	100-100	21.0	16-26
	1995	99.0	98-100	84.0	82-86	100.0	100-100	25.0	20-30
	2000	99.0	98-100	85.0	83-87	100.0	100-100	30.0	20-40
	2005	99.0	98-100	90.0	85-95	100.0	100-100	35.0	25-45
	2010	99.0	98-100	95.0	91-99	100.0	100-100	40.0	30-50
b. Fairbanks	1980	99.0[a]	--	92.3	--	98.6[a]	--	2.5	--
	1985	99.0	98-100	94.0	91-97	100.0	100-100	10.0	5-15
	1990	99.0	98-100	95.0	92-98	100.0	100-100	21.0	11-31
	1995	99.0	98-100	95.0	92-98	100.0	100-100	25.0	15-35
	2000	99.0	98-100	95.0	92-98	100.0	100-100	30.0	20-40
	2005	99.0	98-100	95.0	92-98	100.0	100-100	35.0	25-45
	2010	99.0	98-100	95.0	92-98	100.0	100-100	40.0	30-50
c. Glennallen-	1980	99.0[b]	--	86.4	--	100.0[a]	--	5.1	--
Valdez	1985	99.0	98-100	90.0	88-92	100.0	100-100	12.0	8-16
	1990	99.0	98-100	95.0	92-98	100.0	100-100	21.0	16-26
	1995	99.0	98-100	95.0	92-98	100.0	100-100	25.0	20-30
	2000	99.0	98-100	95.0	92-98	100.0	100-100	30.0	20-40
	2005	99.0	98-100	95.0	92-98	100.0	100-100	35.0	25-45
	2010	99.0	98-100	95.0	92-98	100.0	100-100	40.0	30-50

(a) For water heat and cooking, missing values on the Battelle-Northwest end-use survey were not counted.
(b) Glennallen-Valdez water heater percent for 1980 was adjusted downward to 99 to a low for some customers without hot water.

TABLE 5.5. Market Saturations (Percent) of Large Appliances with Fuel Substitution Possibilities in Duplexes, Railbelt Load Centers, 1980-2010

Load Center	Year	Water Heaters		Clothes Dryers		Range (cooking)		Saunas - Jacuzzis	
		Default	Range	Default	Range	Default	Range	Default	Range
a. Anchorage	1980	100.0[a]	--	90.0	--	96.4	--	16.9	--
	1985	100.0	100-100	91.0	90-92	100.0	100-100	18.0	16-20
	1990	100.0	100-100	92.5	90-95	100.0	100-100	21.0	18-24
	1995	100.0	100-100	93.0	91-96	100.0	100-100	25.0	20-30
	2000	100.0	100-100	95.0	92-98	100.0	100-100	30.0	20-40
	2005	100.0	100-100	95.0	92-98	100.0	100-100	35.0	25-45
	2010	100.0	100-100	95.0	92-98	100.0	100-100	40.0	30-50
b. Fairbanks	1980	100.0[a]	--	85.5[b]	--	100.0	--	8.2	--
	1985	100.0	100-100	91.0	90-92	100.0	100-100	12.0	8-16
	1990	100.0	100-100	92.5	90-95	100.0	100-100	21.0	16-26
	1995	100.0	100-100	93.0	91-96	100.0	100-100	25.0	20-30
	2000	100.0	100-100	95.0	92-98	100.0	100-100	30.0	20-40
	2005	100.0	100-100	95.0	92-98	100.0	100-100	35.0	25-45
	2010	100.0	100-100	95.0	92-98	100.0	100-100	40.0	30-50
c. Glennallen-	1980	100.0[a]	--	88.9	--	100.0	--	0.0	--
Valdez	1985	100.0	100-100	90.0	89-91	100.0	100-100	10.0	5-15
	1990	100.0	100-100	92.0	91-93	100.0	100-100	21.0	11-31
	1995	100.0	100-100	94.0	91-97	100.0	100-100	25.0	15-35
	2000	100.0	100-100	95.0	92-98	100.0	100-100	30.0	15-45
	2005	100.0	100-100	95.0	92-98	100.0	100-100	35.0	20-50
	2010	100.0	100-100	95.0	92-98	100.0	100-100	40.0	30-50

(a) Values from Battelle-Northwest end-use survey were adjusted to 100 percent for water heaters in 1980. For explanation, see text.
(b) 1980 Clothes dryer penetration in Fairbanks for 1980 adjusted downward by one to match the number of washers in duplexes.

TABLE 5.6. Market Saturations (Percent) of Large Appliances with Fuel Substitution Possibilities in Multifamily Homes, Railbelt Load Centers, 1980-2010

Load Center	Year	Water Heaters		Clothes Dryers		Range (cooking)		Saunas - Jacuzzis	
		Default	Range	Default	Range	Default	Range	Default	Range
a. Anchorage	1980	100.0[a]	--	75.7	--	98.2	--	13.6	--
	1985	100.0	100-100	83.0	82-84	100.0	100-100	17.0	14-20
	1990	100.0	100-100	83.5	82-85	100.0	100-100	21.0	16-26
	1995	100.0	100-100	84.0	82-86	100.0	100-100	25.0	20-30
	2000	100.0	100-100	85.0	83-87	100.0	100-100	30.0	20-40
	2005	100.0	100-100	90.0	85-95	100.0	100-100	35.0	25-45
	2010	100.0	100-100	95.0	92-97	100.0	100-100	40.0	30-50
b. Fairbanks	1980	100.0[a]	--	61.0	--	100.0	--	5.7	--
	1985	100.0	100-100	65.0	61-69	100.0	100-100	12.0	8-16
	1990	100.0	100-100	70	65-75	100	100-100	21.0	16-26
	1995	100.0	100-100	80	75-85	100.0	100-100	25.0	20-30
	2000	100.0	100-100	85.0	80-90	100.0	100-100	30.0	20-40
	2005	100.0	100-100	90.0	85-95	100.0	100-100	35.0	25-45
	2010	100.0	100-100	95.0	92-97	100.0	100-100	40.0	30-50
c. Glennallen-Valdez	1980	100.0[a]	--	75.0[b]	--	100.0	--	0.0	--
	1985	100.0	100-100	77.5	75-80	100.0	100-100	10.0	0-20
	1990	100.0	100-100	80.0	77-83	100.0	100-100	21.0	11-31
	1995	100.0	100-100	82.5	80-85	100.0	100-100	25.0	15-35
	2000	100.0	100-100	85.0	82-88	100.0	100-100	30.0	20-40
	2005	100.0	100-100	90.0	85-95	100.0	100-100	35.0	25-45
	2010	100.0	100-100	95.0	92-98	100.0	100-100	40.0	30-50

(a) Water heat survey numbers adjusted to 100 percent for 1980. For explanation, see text.
(b) Number of dryers in Glennallen-Valdez adjusted to 75 percent from 100 percent because of small sample size (7 units).

is assumed that 99% is a maximum for two reasons: the market saturation of hot water in the Western U.S. was 99% in the 1970 Census (Bureau of Census 1970); and Alaska can be expected to have rural cabin-like structures with limited electric service for some time to come. In the Fairbanks and Glennallen-Valdez market areas single-family saturations are projected to increase to the Anchorage level by 1990 and 2000, respectively. The end-use survey and 1970 Census both show saturations in the vicinity of 90% in these areas. Increasing urbanization in these two areas and better electric service should increase this percentage. Glennallen will remain sufficiently rural, however, to keep the pace somewhat slower.

The other tvpes of structures in the Battelle-Northwest survey showed market saturations of nearly 100% in all market areas. The exception was multifamily housing. However, the wording of the question in the survey upon which this calculation is based may have been interpreted as asking whether the respondent had a hot water tank in his unit rather than (as was intended) whether he had hot water available. A 100% market penetration for hot water in duplexes and multifamily buildings was assumed. Mobile homes were considered the same as single-family units.

Clothes Drier

The Battelle-Northwest survey and 1970 Census (Bureau of Census 1970) both show Railbelt market saturations for clothes driers far above the U.S. average. Information available from the 1980 U.S. Statistical Abstract for 1979 shows about 61.5% of electrically served housing units have an electric or gas drier (up from 44.6% in 1970) (Bureau of Census 1980b). In contrast, the Battelle survey showed market saturations ranging from 61% in Fairbanks multifamiuly structures to 100% in Glennallen-Valdez multifamily structures.[a] Single-family drier saturations ranged from 81% in Fairbanks to 90% in Anchorage. Because Alaska already has such high saturations, the forecast is outside the bounds of historical experience. A reasonable guess

(a) The 100% figure is believed to be an anomaly caused by the small group of multifamily housing units sampled in the Cooper Valley Electric Association (CVEA) market area. The true figure was assumed to be 75%.

is that no more than about 95% of single-family homes, mobile homes, and duplexes will ever have driers because of the availability of laundromats and because of the room taken up by washer-drier combinations in small housing units. For multifamily units, penetration is assumed to be much slower because of the space problem. Since washers and driers are now installed in pairs in most new housing, market saturations for driers (which are now about 2% below those for washers in most areas) will approach that for washers as old housing stock is replaced. In general, the lower the existing saturation, the greater is the uncertainty concerning its future growth rate. The uncertainty is reflected in wider ranges used in Table 5.7 for multifamily unit clothes driers.

Cooking Ranges

The Battelle-Northwest end-use survey indicated that between 96 and 100% of all households surveyed had a range available. The difference between 96 and 100% may be caused by the substitution of hot plates and broiler ovens (for which estimated national saturation in 1979 was about 26%) and microwave ovens (for which the estimated national 1979 saturation was 7.6%). Therefore, 100% of all units currently are assumed to have cooking facilities available by 1985. This percentage holds throughout the period.

Saunas, Jacuzzis, Etc.[a]

These units are a relatively new phenomenon in private homes, almost all having been installed since 1970. The Battelle-Northwest end-use survey found market saturations ranging from zero to 17%, depending on market area and housing type. Fourteen percent of Anchorage single-family households reported having one of these units. Among single-family homes built since 1975, the saturation was 21%. The 21% has been used as a target saturation on which other groups of housing will converge by 1990 through new construction and retrofit. The inflation-adjusted cost of saunas and jacuzzis, whirlpools, etc. are expected to drop somewhat as it does with any new appliance type. This could lead to much higher market saturations than currently exist. A

(a) Including hot tubs, whirlpool baths, and "total environment" units.

TABLE 5.7. Market Saturations (Percent) of Large Electric Appliances in Single-Family Homes, Railbelt Load Centers, 1980-2010

Load Center	Year	Refrigerators Default	Refrigerators Range	Freezers Default	Freezers Range	Dishwashers Default	Dishwashers Range	Clothes Washers Default	Clothes Washers Range
a. Anchorage	1980	100.0	--	88.3	--	78.2	--	91.7	--
	1985	100.0	98-102	90.0	85-95	85.0	80-90	92.0	90-94
	1990	100.0	98-102	90.0	85-95	90.0	85-95	92.5	90-95
	1995	100.0	98-102	90.0	85-95	90.0	85-95	93.7	91-96
	2000	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2005	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2010	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
b. Fairbanks	1980	100.0	--	84.9	--	53.8	--	84.9	--
	1985	100.0	98-102	88.0	86-90	79.0	75-85	86.0	84-88
	1990	100.0	98-102	90.0	85-95	90.0	85-95	87.5	85-90
	1995	100.0	98-102	90.0	85-95	90.0	85-95	92.5	90-954
	2000	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2005	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2010	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
c. Glennallen-Valdez	1980	100.0	--	95.7	--	64.3	--	87.1	--
	1985	100.0	98-102	93.0	91-95	85.0	80-90	90.0	88-92
	1990	100.0	98-102	90.0	85-95	90.0	85-95	92.5	90-95
	1995	100.0	98-102	90.0	85-95	90.0	85-95	93.7	91-96
	2000	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2005	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2010	100.0	98-102	90	85-95	90.0	85-95	95.0	92-98

very wide range of uncertainty is indicated, whereas the default saturation for saunas and jacuzzis is projected to be double the current level for new single-family homes by the year 2010.

Tables 5.7 through 5.10 indicate default market saturations and ranges of values for large household appliances that are almost always electric. These include refrigerators, freezers, dishwashers, and clothes washers. The table title indicates the housing type, and the table values show an expected market saturation for each appliance by market area and year. The ranges shown in the tables reflect the degree of uncertainty attached to the default value. The wider the range, the greater is this subjective uncertainty. The assumptions supporting the table values are given below by appliance.

Refrigerators

The Battelle-Northwest end-use survey found that virtually 100% of households had a refrigerator. The California Energy Commission found in 1976 that enough housing units had second refrigerators to raise total California market saturation to 113 to 116%. ISER, in their report to the Alaska State Legislature (Goldsmith and Huskey 1980b) assumed that this high percentage would likely not prevail in Alaska because of the cooler climate. In the RED model the ISER assumption is modified to permit a range of values from 98 to 102%.

Freezers

The end-use survey found market area-wide saturations of freezers ranging from about 80% in Fairbanks to about 90% in Glennallen-Valdez. These figures are 10 to 20% higher than assumed by ISER for 1980 for these areas, about 40% above 1970 Census values for the Railbelt, and 30 to 40% above the U.S. average. In other words, area-to-area comparisons and historical experience are not very helpful for predicting future saturations. For single-family homes and mobile homes, the maximum saturation has been assumed to just about have been reached because with better shopping facilities and increased urbanization, fewer freezers will be necessary for long-term food storage associated with bulk buying.

TABLE 5.8. Market Saturations (Percent) of Large Electric Appliances in Mobile Homes, Railbelt Load Centers, 1980-2010

Load Center	Year	Refrigerators Default	Refrigerators Range	Freezers Default	Freezers Range	Dishwashers Default	Dishwashers Range	Clothes Washers Default	Clothes Washers Range
a. Anchorage	1980	100.0	--	94.8	--	43.9	--	80.6	--
	1985	100.0	98-102	92.0	90-96	67.6	62-72	85.0	80-90
	1990	100.0	98-102	90.0	85-95	90.0	85-95	90.0	85-95
	1995	100.0	98-102	90.0	85-95	90.0	85-95	90.0	85-95
	2000	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2005	100.0	98-102	90.0	85-95	90.0	85-95	95	92-98
	2010	100.0	98-102	90.0	856-95	90.0	85-95	95.0	92-98
b. Fairbanks	1980	100.0	--	73.0	--	48.6	--	92.3	--
	1985	100.0	98-102	82.0	75-89	71.4	66-76	93.0	91-95
	1990	100.0	98-102	90.0	85-95	90.0	85-95	93.5	91-96
	1995	100.0	98-102	90.0	85-95	90.0	85-95	94.0	92-96
	2000	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2005	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2010	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
c. Glennallen-Valdez	1980	100.0	--	86.4	--	49.2	--	88.1	--
	1985	100.0	98-102	88.0	85-91	72.3	67-77	90.0	88-92
	1990	100.0	98-102	90.0	85-95	90.0	85-95	93.0	91-95
	1995	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-96
	2000	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2005	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98
	2010	100.0	98-102	90.0	85-95	90.0	85-95	95.0	92-98

TABLE 5.9. Market Saturations (Percent) of Large Electric Appliances in Duplexes, Railbelt Load Centers, 1980-2010

Load Center	Year	Refrigerators		Freezers		Dishwashers		Clothes Washers	
		Default	Range	Default	Range	Default	Range	Default	Range
a. Anchorage	1980	100.0	--	66.5	--	76.5	--	92.5	--
	1985	100.0	98-102	75.0	70-80	85.0	80-90	93.0	91-95
	1990	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	1995	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	2000	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	2005	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	2010	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
b. Fairbanks	1980	100.0	--	75.2	--	57.4	--	85.5	--
	1985	100.0	98-102	80.0	75-85	85.0	80-90	91.0	90-92
	1990	100.0	98-102	85.0	80-90	90.0	85-95	92.5	90-95
	1995	100.0	98-102	85.0	80-90	90.0	85-95	93.0	91-96
	2000	100.0	98-102	85.0	80-90	90	85-95	95.0	92-98
	2005	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	2010	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
c. Glennallen-Valdez	1980	100.0	--	77.8	--	55.6	--	90.0[a]	85-95
	1985	100.0	98-102	80.0	75-85	82.0	77-87	92.0	90-94
	1990	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	1995	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	2000	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	2005	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98
	2010	100.0	98-102	85.0	80-90	90.0	85-95	95.0	92-98

(a) Clothes washer 1980 saturation adjusted to 90 percent from 100 percent in Glennallen-Valdez because of small sample problem.

TABLE 5.10. Market Saturations (Percent) of Large Electric Appliances in Multifamily Homes, Railbelt Load Centers, 1980-2010

Load Center	Year	Refrigerators		Freezers		Dishwashers		Clothes Washers	
		Default	Range	Default	Range	Default	Range	Default	Range
a. Anchorage	1980	100.0	--	62.5	--	73.3	--	76.5	--
	1985	100.0	98-102	65.0	60-70	85.0	80-90	85.0	80-90
	1990	100.0	98-102	70.0	65-75	90.0	85-95	90.0	85-95
	1995	100.0	98-102	70.0	65-75	90.0	85-95	92.0	90-94
	2000	100.0	98-102	70.0	65-75	90.0	85-95	95.0	92-98
	2005	100.0	98-102	70.0	65-75	90.0	85-95	95.0	92-98
	2010	100.0	98-102	70.0	65-75	90	85-95	95.0	92-98
b. Fairbanks	1980	100.0	--	57.2	--	23.3	--	63.8	--
	1985	100.0	98-102	65.0	60-70	34.0	30-39	68.0	63-72
	1990	100.0	98-102	70.0	65-75	50.0	45-55	70.0	65-75
	1995	100.0	98-102	70.0	65-75	74.0	70-79	80.0	75-85
	2000	100.0	98-102	70.0	65-75	90.0	85-95	85.0	80-90
	2005	100.0	98-102	70.0	65-75	90.0	85-95	90.0	85-95
	2010	100.0	98-102	70.0	65-75	90.0	85-95	95.0	92-98
c. Glennallen-	1980	100.0	98-102	14.3	--	28.6	--	77.0	--
Valdez	1985	100.0	98-102	20.0	15-25	42.0	37-47	78.0	73-83
	1990	100.0	98-102	30.0	20-40	62.0	57-67	80.0	75-85
	1995	100.0	98-102	35.0	30-40	90.0	85-95	82.0	77-87
	2000	100.0	98-102	40.0	35-45	90.0	85-95	85.0	80-90
	2005	100.0	98-102	45.0	40-50	90.0	85-95	90.0	85-95
	2010	100.0	98-102	50.0	45-55	90.0	85-95	95.0	92-98

(a) Clothes washer 1980 saturation adjusted from 100 percent to 77.0 percent (2 percent above dryer saturation) because of small sample problem.

For duplexes and multifamily units, the percent of saturation should remain significantly lower. The tenants in such units tend to be more transient and are probably less involved in Alaskan hunting, fishing, and gardening pursuits than most Alaskans. Consequently, they would have less demand for freezers. Second, rental units tend to be smaller. Consequently, renters might tend to substitute rented commercial cold-storage locker space for a freezer to conserve scarce living space in duplexes and multifamily units. The range of uncertainty is shown to be quite broad, since market penetration has been rapid in the last 10 years, but the maximum appears to have been reached in some cases.

Dishwashers

The Battelle-Northwest end-use survey found market saturations for dishwashers well above the existing U.S. average. In the U.S. as a whole, the 1979 saturation was about 41% of homes served by electricity (Bureau of Census 1980b), but this percentage ranged from 50% in Fairbanks to 75% in Anchorage survey homes. Saturations have increased by about 50 percentage points in all three Railbelt load centers since 1970, again outside the range of historical experience. (Using this experience, ISER (Goldsmith and Huskey 1980b) projected 1978 market saturations of 50% in Anchorage and 36% in Fairbanks.) Since the rate of increase in market saturation was very rapid in the 1970s, but increases in saturation in Anchorage in particular may slow down soon, a maximum saturation of 90% was assumed for all homes. The annual rates of saturation growth for the 1970s were then projected for each region: 9% per year for Anchorage, 8% per year for Fairbanks, and 23% per year for Glennallen-Valdez. The latter rate was considered too high to be credible for forecasting, so Fairbanks' rate was used in Glennallen-Valdez. In each table, these rates of growth were assumed to prevail until the 90% maximum was reached. The growth rate was then assumed to fall to zero. A wide range of uncertainty is assumed for dishwasher saturations because of the tenuous nature of the required assumptions.

Clothes Washers

The Battelle-Northwest end-use survey found that clothes washer saturations ranged from about 84% in Fairbanks to 89% in Anchorage. These figures are well above the 73% reported for the U.S. in 1979 in the 1980 Statistical Abstract (Bureau of Census 1980b). It also represents about 10 to 15 percentage points growth since the 1970 census. The rate of saturation increase did not slow down appreciably in the 1970s compared to the 1960s; consequently, market saturation may have not yet approached its maximum. For forecasting, the maximum penetration is assumed to be 95%. Different types of housing reach this maximum at different rates. In particular, since single-family homes are already 85 to 90% saturated, they reach 95% slowly, achieving this level by the year 2000. Some markets are closer to being completely saturated. Even at low rates of growth they reach 95% somewhat earlier. In no case is clothes-washer saturation allowed to be below that for clothes driers. The Battelle-Northwest survey generally found that washer saturation was one to two percentage points higher than that for dryers. Where this was not the case (e.g., duplexes in Fairbanks) the difference appears to have occurred because of the small number of households in the category. The market saturations for washers and driers gradually converge, since they are now usually installed in pairs. Multifamily saturation of washers and driers grows the slowest, reaching 95% by 2010 in Fairbanks and Glennallen-Valdez.

Fuel Mode Splits

The fuel-mode splits presented in Table 5.11 were also derived from the Battelle-Northwest end-use survey. These parameters are assumed to remain fixed over the forecast period, as the cross-price elasticity adjustment handles fuel switching. Several adjustments have been made to the Glennallen-Valdez duplex and multifamily splits because the number of respondents in these categories was limited.

Consumption of Electricity per Unit

The average kilowatt hour consumption figures are primarily based on the Midwest Research Institute's findings on the subject (MRI 1979). Below is a brief discussion of each parameter.

TABLE 5.11. Percentage of Appliances Using Electricity and Average Annual Electricity Consumption, Railbelt Load Centers, 1980

	Anchorage					Fairbanks					Glennallen-Valdez				
	Percentage Using Electricity				Average Annual kWh	Percentage Using Electricity				Average Annual kWh	Percentage Using Electricity				Average Annual kWh
Appliance	SF	MH	DP	MF	Consumption	SF	MH	DP	MF	Consumption	SF	MH	DP	MF	Consumption
Space Heat															
Single Family	16.0	NA	NA	NA	32,850	9.7	NA	NA	NA	43,380	0.7	NA	NA	NA	29,970
Mobile Home	NA	0.7	NA	NA	24,570	NA	0.0	NA	NA	33,210	NA	0.7	NA	NA	22,860
Duplex	NA	NA	22.8	NA	21,780	NA	NA	11.7	NA	28,710	NA	NA	0.7	NA	19,710
Multi Family	NA	NA	NA	44.4	15,390	NA	NA	NA	14.8	19,080	NA	NA	NA	0.7	13,140
Water Heaters	36.5	50.4	44.0	60.9	3,475	55.1	71.3	71.8	47.0	3,475	17.1	25.9	10.0(a)	16.7	3,475
Clothes Dryers	84.3	88.1	81.3	86.6	1,032	96.2	94.6	94.4	100.0	1,032	59.8	62.0	87.5	85.7	1,032
Cooking Ranges	75.8	23.2	85.2	88.2	1,200	79.0	48.2	95.0	97.1	1,200	39.1	15.5	66.7	71.4	1,200
Sauna-Jacuzzis	93.5	100.0	93.7	81.8	1,300	61.8	100.0	60.8	100.0	300	89.5	100.0	77.3(b)	90.9(b)	300
Refrigerators	100.0	100.0	100.0	100.0	1,250	100.0	100.0	100.0	100.0	1,250	100.0	100.0	100.0	100.0	1,250
Freezers	100.0	100.0	100.0	100.0	1,342	100.0	100.0	100.0	100.0	1,342	100.0	100.0	100.0	100.0	1,342
Dishwashers	100.0	100.0	100.0	100.0	230	100.0	100.0	100.0	100.0	230	100.0	100.0	100.0	100.0	230
Additional Water Heating	36.5	50.4	44.0	60.9	700	55.1	71.3	71.8	47.0	700	17.1	25.9	10.0(a)	16.7	700
Clothes Washers	100.0	100.0	100.0	100.0	70	100.0	100.0	100.0	100.0	70	100.0	100.0	100.0	100.0	70
Additional Water Heating	36.5	50.4	44.0	60.9	1,050	55.1	71.3	71.8	47.0	1,050	17.1	25.9	10.0(a)	16.7	1,050
Miscellaneous	100.0	100.0	100.0	100.0	2,110	100.0	100.0	100.0	100.0	2,466	100.0	100.0	100.0	100.0	2,333

(a) The BNW survey revealed this fuel mode split to be 0. However, this result seems very implausible given the responses for other dwelling types and the limited number of respondents. Therefore, 10% was assumed to be a more descriptive number.
(b) Due to insufficient responses, these figures are the averages of the other two regions.

Space Heat

For space heating, the average annual consumption figures derived by ISER are used (Goldsmith and Huskey 1980b). These figures were derived based on heating degree days, floor space, and average consumption of all electric homes within the Railbelt region and were adjusted down by 10% to allow for additional conservation in the building stock since ISER's study.

Waterheaters

The average consumption for waterheaters is based on the California Energy Commission's estimates (CEC 1976) because the CEC separates out consumption related to clothes washers and dishwashers. Unfortunately, the CEC could not separate the consumption used for dishwashing without dishwashers, so the figure was adjusted upwards by 15% to account for this for the colder-water inlet temperature in Alaska.

Clothes Dryers

For clothes dryers, average consumption is the figure reported by MRI. ISER (MRI 1979) picked a lower estimate based on household size, but the colder climate in Alaska should also raise the estimated use of dryers. This is reflected in high saturation values for this appliance.

Cooking-Ranges

This category is broadly interpreted as production of heat for cooking purposes. The figure reported was derived by ISER with a similar definition.

Miscellaneous Appliances

For miscellaneous appliances, estimates of consumption were originally prepared by ISER by subtracting estimated large appliance electricity consumption for 1978 from total 1978 consumption/residential customer (Goldsmith and Huskey 1980b). Lighting was inferred from national statistics and increased to 1000 kWh/year/customer. The remainder was charged to small appliances. Research for the RED Model checked ISER's work by assuming: 1) televisions (rated at 400 kWh/year) are included in small appliances; and 2) the ISER estimate of 480 kWh/year/customer for headbolt heaters is replaced with load center-specific figures derived from load-center specific usage data produced by the Battelle-Northwest end-use survey and National Oceanic and Atmospheric Administration (NOAA) data on normal minimum temperatures (NOAA 1979); and 3) 1000 kWh/year lighting. The revised estimates for block heaters are as follows: Anchorage, 459 kWh/year/customer; Fairbanks, 1127 kWh/year/customer; Glennallen-Valdez 398 kWh/year/customer. Because the results were broadly consistent with ISER's figures, ISER's totals were used (Goldsmith and Huskey 1980b).

Saunas-Jacuzzis

The authors informally contacted several suppliers of saunas, jacuzzis, and hot tubs and were told that the consumption of these devices ranged from 100 to 3000 kWh annually. A figure of 300 kWh annually was used for the existing stock (which probably contains several bathtub whirlpools) and about 1300 kWh (Hunt and Jurewitz 1981) for new additions to the stock.

Refrigerators

The ISER number was chosen because it is consistent with estimates by Merchandising Week (1973) and because electricity consumption for refrigeration should be lower in Alaska due to the lower ambient air temperature.

Freezers

This figure showed little variation between Merchandising Week, MRI, and ISER. The MRI figure was chosen.

Dishwashers

This figure is the mean of the Edison Electric Institute reported by MRI and MRI figures.

Dishwasher and Clothes Washer Water

These values are from the CEC (1976).

Electrical Capacity Growth

The growth rates in electric capacity (Table 5.12) were derived by ISER (Goldsmith and Huskey 1980b). The growth rate for capacity of saunas and jacuzzis is assumed to be the same as refrigerators. The consumption of new appliances was also derived by ISER.

TABLE 5.12. Growth Rates in Electric Appliance Capacity and Initial Annual Average Consumption for New Appliances

Appliance	Average Annual kWh Consumption for New Appliances (1985)			Growth Rate in Electric Capacity Post 1985 (annual)
	Anchorage	Fairbanks	Glennallen-Valdez	
Space Heat				
Single Family	40,100	53,000	36,600	0.01
Mobile Homes	30,000	40,600	27,900	0.01
Duplexes	26,600	35,100	24,100	0.01
Multifamily	18,800	23,300	16,100	0.01
Water Heaters	3,650	3,650	3,650	0.005
Clothes Dryers	1,032	1,032	1,032	0.0
Cooking Ranges	1,250	1,250	1,250	0.0
Sauna-Jacuzzi	1,309	1,309	1,309	0.0
Refrigerators	1,560	1,560	1,560	0.01
Freezers	1,550	1,550	1,550	0.01
Dishwashers	230	230	230	0.005
Additional Water Heating	740	740	740	0.0
Clothes Washers	70	70	70	0.0
Additional Water Heating	1,050	1,050	1,050	0.0
Miscellaneous Appliances	2,160	2,536	2,403	(a)

(a) Incremental growth of 50 kWh per customer in Anchorage per 5-year period; 70 kWh in Fairbanks and Glennallen-Valdez.

Appliance Survival

Table 5.13 presents the percentage of appliances' remaining t forecasts periods after their purchase. These figures were derived by ISER based on Hausman's work (1979) with implicit discount rates for room air conditioners. He found that the stock of a particular vintage of air conditioners was fairly well approximated by a Weibull distribution. By substituting differing lifetimes (EPRI 1979) for alternative appliances, ISER used his results to derive the figures in Table 5.13. For saunas and jacuzzis RED assumes the appliance lifetime was comparable to clothes washers.

Price Elasticities

The final parameters used in the Residential Module are the price elasticities shown in Table 5.14. The ranges of elasticities were picked to include the results of several studies (Taylor 1975; Maddala, Chern and Gill 1978; Baughman, Joskow and Kamat 1979; Halversen 1978; EPRI 1977a, 1977b). The short-run default values were shifted towards the inelastic range of the distribution since it is difficult for the populace to switch fuels in the short run, while the long-run default values were assumed to be approximately the midpoints of the ranges.

TABLE 5.13. Percent of Appliances Remaining in Service Years After Purchase, Railbelt Region

a. Old Appliances	5	10	15	20	25	30
Space Heat (All)	0.90	0.80	0.6	0.3	0.1	0.0
Water Heaters	0.6	0.3	0.1	0.0	0.0	0.0
Clothes Dryers	0.8	0.6	0.3	0.1	0.0	0.0
Ranges-Cooking	0.6	0.3	0.1	0.0	0.0	0.0
Saunas-Jacuzzis	0.5	0.3	0.1	0.0	0.0	0.0
Refrigerators	0.8	0.6	0.3	0.1	0.0	0.0
Freezers	0.9	0.8	0.6	0.3	0.1	0.0
Dishwashers	0.6	0.3	0.1	0.0	0.0	0.0
Clothes Washers	0.6	0.3	0.1	0.0	0.0	0.0
b. New Appliances						
Space Heat (All)						
Water Heaters	0.75	0.35	0.1	0.0	0.0	0.0
Clothes Dryers	1.00	0.75	0.35	0.1	0.0	0.0
Ranges-Cooking	0.75	0.35	0.1	0.0	0.0	0.0
Saunas-Jacuzzis	1.00	0.75	0.35	0.1	0.0	0.0
Refrigerators	1.00	0.75	0.35	0.1	0.0	0.0
Freezers	1.00	1.00	0.75	0.35	0.1	0.0
Dishwashers	0.75	0.35	0.1	0.0	0.0	0.0
Clothes Washers	0.75	0.35	0.1	0.0	0.0	0.0

Source: ISER (Goldsmith and Huskey 1980b) except for saunas-jacuzzis, which is author assumption.

TABLE 5.14. Price Elasticities for Residential Electricity Use

	Short Run		Long Run	
	Default	Range	Default	Range
Own-Price Elasticity	-0.15	(-0.08) - (-0.54)	-1.5	(-1.02) - (2.0)
Oil Cross-Price Elasticity	0.01	0.01 - 0.03	0.13	0.05 - 0.21
Gas Cross-Price Elasticity	0.5	0.05 - 0.10	0.5	0.17 - 0.81

6.0 THE BUSINESS CONSUMPTION MODULE

The Business Module forecasts the requirements for electricity in the business and government segments of the Railbelt economy. The figures predicted here are before the impacts of explicit conservation policy are considered. Conservation policy is handled in the Conservation Module.

MECHANISM

The Business Consumption Module uses a forecast of the stock of floor space (a proxy for the stock of capital equipment) to predict the level of business electricity consumption. The predicted consumption of electricity is then adjusted for price impacts to yield the price-adjusted forecast of business electricity sales.

INPUTS AND OUTPUTS

Table 6.1 presents the inputs and outputs of the Business Consumption Module. Load-center-specific forecasts of employment, regional population, the relative price level, and statewide wage rates are exogenous to RED. For the Railbelt Alternative Energy Study, these come from forecasts of the ISER Man in the Arctic Program (MAP) model. The use per square foot of building space is assigned in the Uncertainty Module. The output of the Business Consumption Module is the price-adjusted forecast of electricity requirements of the business sector before the impacts of subsidized conservation are considered.

MODEL STRUCTURE

Figure 6.1 presents a flowchart of the module. The first step is to construct proxies for regional income (by multiplying regional employment and the statewide wage rate) and the Anchorage Consumer Price Index (CPI). Next, econometric coefficients are applied to estimate the percentage change in the stock of floor space by year (rather than by five-year forecast period). By first converting this forecast to predicted stocks and then picking out the forecast years, each forecast year's stock of floor space is found.

TABLE 6.1. Inputs and Outputs of the Business Consumption Module

a) Inputs

Symbol	Name	From
TEMP	Total Regional Employment	Forecast File (exogenous)
POP	Regional Population	Forecast File (exogenous)
CPI	Consumer Price Index, Anchorage	Forecast File (exogenous)
WR99	Statewide Average Wage Rate	Forecast File (exogenous)
BBETA	Electricity Consumption Floor Space Elasticity	Uncertainty Module (parameter)

b) Outputs

Symbol	Name	From
BUSCON	Price-Adjusted Business Consumption	Peak Demand and Conservation Modules

Multiplying the floor space stock by the econometrically-derived use per square foot yields a preliminary forecast of business requirements, which is then adjusted for price impacts.

To prepare a forecast of the floor space stock, RED uses preliminary results from Staloff and Adams.[a] They developed a simultaneous demand and supply model of commercial floor space using pooled cross-section/time-series data for the 48 contiguous states. In their preliminary formulation, the percentage change in the stock of floor space is a function of the changes in: the annual change of the nominal interest rate, the annual percentage changes of the Gross National Product deflator, the annual percentage change in regional income, and the annual percentage change in regional population, as well as some cross-product terms:

(a) Staloff, S. J. and R. C. Adams. 1981 (Draft). "The Development of BPA Region Commercial Floor Space Model." Battelle, Pacific Northwest Laboratories, Richland, Washington.

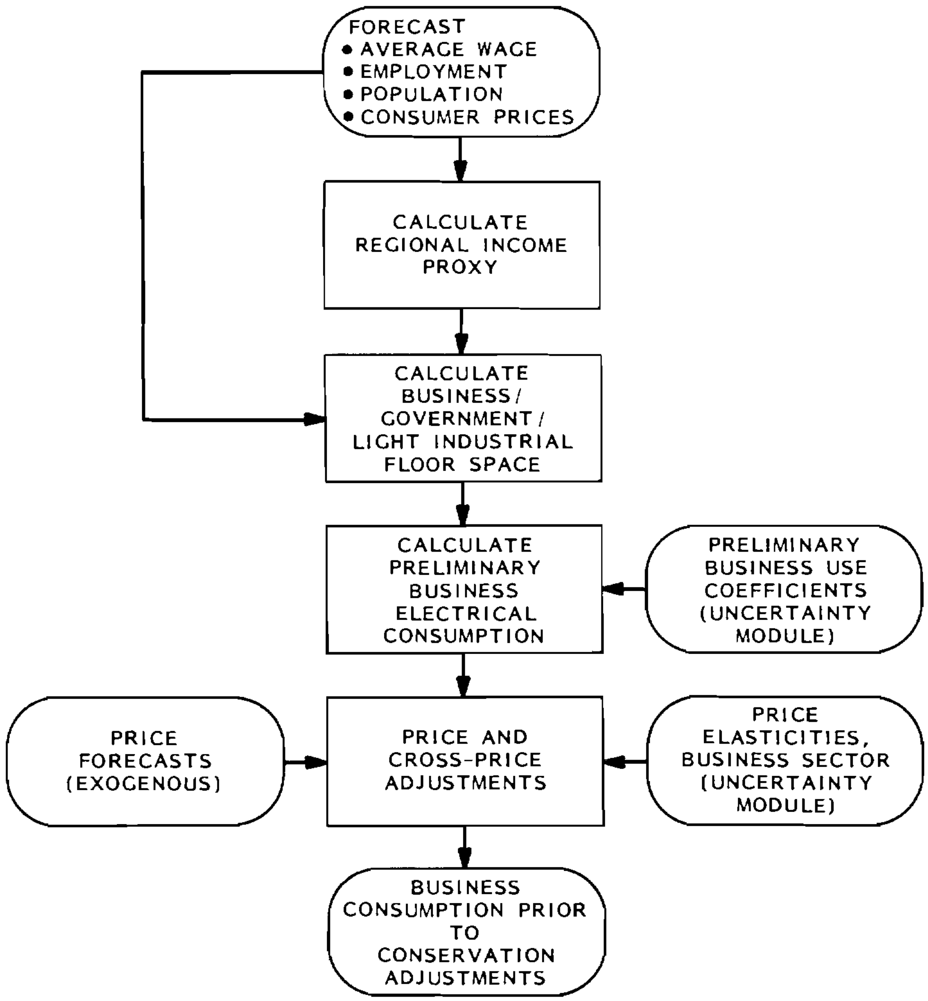

FIGURE 6.1. RED Business Consumption Module

$$\begin{aligned}\Delta/\mathrm{Stock}_{i\ell}/ = {} & \beta_1 \Delta\Delta r + \beta_2\, \Delta/\mathrm{GNPDEF}_\ell/ + \beta_3 \Delta/\mathrm{POP}_{i\ell}/ \\ & + \beta_4\, \Delta/\mathrm{INC}_{i\ell}/ + 2\beta_5\, \Delta r_\ell/\mathrm{GNPDEF}_\ell/ + \\ & 2\beta_6\, \Delta r_\ell/\mathrm{POP}_{i\ell}/ + 2\beta_7\, \Delta r/\mathrm{INC}_{i\ell}/ + \\ & 2\beta_8/\mathrm{GNPDEF}_\ell//\mathrm{INC}_{i\ell}/ + 2\beta_9/\mathrm{POP}_{i\ell}//\mathrm{INC}_{i\ell}/\end{aligned} \qquad (6.1)$$

where

$Stock$ = floor space stock

$\beta_1 - \beta_9$ = parameters

Δ = symbol for the first difference (annual change)

GNPDEF = gross national product price deflator

POP = population

INC = income

i = index for the region

ℓ = index for the year

/ / = symbol for the annual percentage change

r = nominal interest

The Business Consumption Module uses the Anchorage CPI as a proxy for the GNP price deflators. It is assumed (as historically revealed) that the nominal interest rate is approximately three percentage points above the measure of inflation. A proxy for regional income is derived by multiplying regional employment by the statewide average wage rate.

Once the forecast of the percentage change in the stock of floor space is found, the level of the stock is easily constructed by using an "observed" stock level as a reference point. The module then predicts the nonprice adjusted requirements, based on a regression equation:

$$PRECON_{it} = \exp\left[BETA_i + BBETA_i \times \ln\left(STOCK_{it}\right)\right] \qquad (6.2)$$

where

PRECON = nonprice adjusted business consumption

BETA = parameter equal to regression equation intercept

BBETA = percentage change in business consumption for a one percent change in stock (floor space elasticity).

t = index for the forecast year (t = 1980, 1985, ..., 2010).

Finally, price adjustments are made with the price adjustment mechanism (See equations 5.12 - 5.13):

$$BUSCON_{it} = PRECON_{it} \times OPA_{it} \times CPA_{it} \quad (6.3)$$

where

BUSCON = price-adjusted business requirements (MWh)

OPA = own-price adjustment

CPA = cross-price adjustment.

The price-adjusted business requirements are then passed to the Conservation and Peak Demand Modules.

PARAMETERS

Floor Space Stock Equations

The parameters used to forecast the floor space stock were extracted from work in progress at Battelle-Northwest for the Bonneville Power Administration. Staloff and Adams have developed a theoretical and empirical formulation for the demand and supply of floor space.[a] Using three-stage least squares multiple regression, they estimated their system of equations using pooled cross-section/time-series data for the years 1971-1977 for the 48 contiguous states. Table 6.2 presents the estimated coefficients.

TABLE 6.2. Floor Space Equation Parameters

Parameter	Coefficient	Standard Error	T-Statistic
$\beta 1$	-0.1291	0.00345	-3.75
$\beta 2$	1.2753	0.2566	-4.97
$\beta 3$	0.3553	0.0302	11.76
$\beta 4$	-0.113	0.0037	-3.04
$\beta 5$	0.1929	0.0355	5.43
$\beta 6$	-0.0947	0.0078	-12.09
$\beta 7$	-0.0078	0.0008	-9.92
$\beta 8$	-0.0116	0.0253	-0.46
$\beta 9$	-0.0412	0.0061	-6.68

(a) Staloff, S. J. and R. C. Adams. 1981 (Draft).

Business Electricity Usage Parameters

These parameters were estimated with regression analysis. Using historical data on regional income and population, the GNP price deflator, and treasury bill rates, a historical backcast of the stock of floor space in each load center was obtained using the supply equation presented in Equation 6.3. Then, using historical large and small commercial consumption, the following regression equations were estimated:

$$\ln(CON_{it}) = BETA_i + BBETA_i \times \ln(STOCK_{it}) + \varepsilon_{it} \qquad (6.4)$$

where

CON = historical business section consumption (MWh)

BETA = intercept

BBETA = regression coefficient

STOCK = estimated stock of floor space, hundreds of square feet

ε = stochastic error term.

Table 6.3 presents the results of the regression analysis. The parameters BBETA can be allowed to vary within a normal distribution, truncated at the 95% confidence intervals.

Business Price Elasticities

The elasticities used in the price adjustment mechanism are extremely important. Table 6.4 presents the elasticities used in the Business Consumption Module. The ranges of the elasticities were picked to incorporate the results of several electricity demand studies (Taylor 1975; Maddala, Chern and Gill 1978; Baughman et al. 1979; Halvorsen 1978; EPRI 1977a and 1977b). The default own-price elasticities (both short-run and long-run) were assumed to have values towards the lower half of the distribution due to lack of close substitutes for electricity in many applications, such as lighting. Conversely, the default cross-price elasticities were assumed to lie at the approximate midpoint of their range.

TABLE 6.3. Business Consumption Equation Results

	Anchorage	Fairbanks	Glennallen-Valdez
BETA	-4.7963	1.4394	8.2046
standard error	0.6280	0.6981	0.1122
t-statistic	-7.6368	2.0619	73.1098
BBETA	1.4288	0.9536	0.1977
standard error	0.0491	0.0620	0.0138
t-statistic	29.1159	15.3762	12.8917
range[(a)]	1.346 to 1.522	0.833 to 1.074	0.151 to 0.244
$\overline{R}^2$	0.9906	0.9716	0.9659

(a) 95% confidence interval.

TABLE 6.4. Price Elasticities for Business Electricity Consumption

Measure	Default	Range	Default	Range
Own-Price Elasticity	-0.3	-0.2 to -0.54	-1.0	-0.87 to -1.36
Oil-Cross Elasticity	0.03	0.01 to 0.05	0.2	0.15 to 0.31
Gas-Cross Elasticity	0.05	0.01 to 0.1	0.3	0.18 to 0.41

7.0 THE CONSERVATION MODULE

The purpose of the Conservation Module is to account for the electricity savings that can be obtained with a given set of conservation technologies and government policies, together with the associated costs of these savings. The peak demand or capacity savings of the technologies set are calculated in the Peak Demand Module.

MECHANISM

The fuel price adjustments in the Residential Consumption and Business Consumption Modules account for market-induced technology-related conservation impacts, as well as reductions in the use of appliances and changes in the manner in which they are used. The Conservation Module identifies the technological portion of these impacts by estimating those savings and costs associated with a given set of conservation technologies. Furthermore, if the government attempts to intervene in the marketplace to induce conservation via loan programs, grants, or other policy actions, then the Conservation Module accounts for the effects of this policy-induced conservation on demands for electric energy and generating capacity.

RED separates conserved energy into two parts: energy saved from the actions of residential consumers and energy saved from reduced energy use in the business and government sectors. Figure 7.1 provides a flow chart of the process employed.

A separate interactive program (CONSER) is called outside of RED to prepare a conservation data file. This file contains information on the costs, energy savings, and the level of market acceptance of various conservation options. For the residential sector, CONSER queries the user for the technical parameters of each option (up to ten options may be included). Based on a user-supplied forecast of electricity prices and the costs associated with each option, CONSER calculates the internal rate-of-return on each technology. The user compares this rate to a bank passbook savings rate. If the user decides, based on this comparison, that the option should be included in the analysis, CONSER calculates the payback period for each

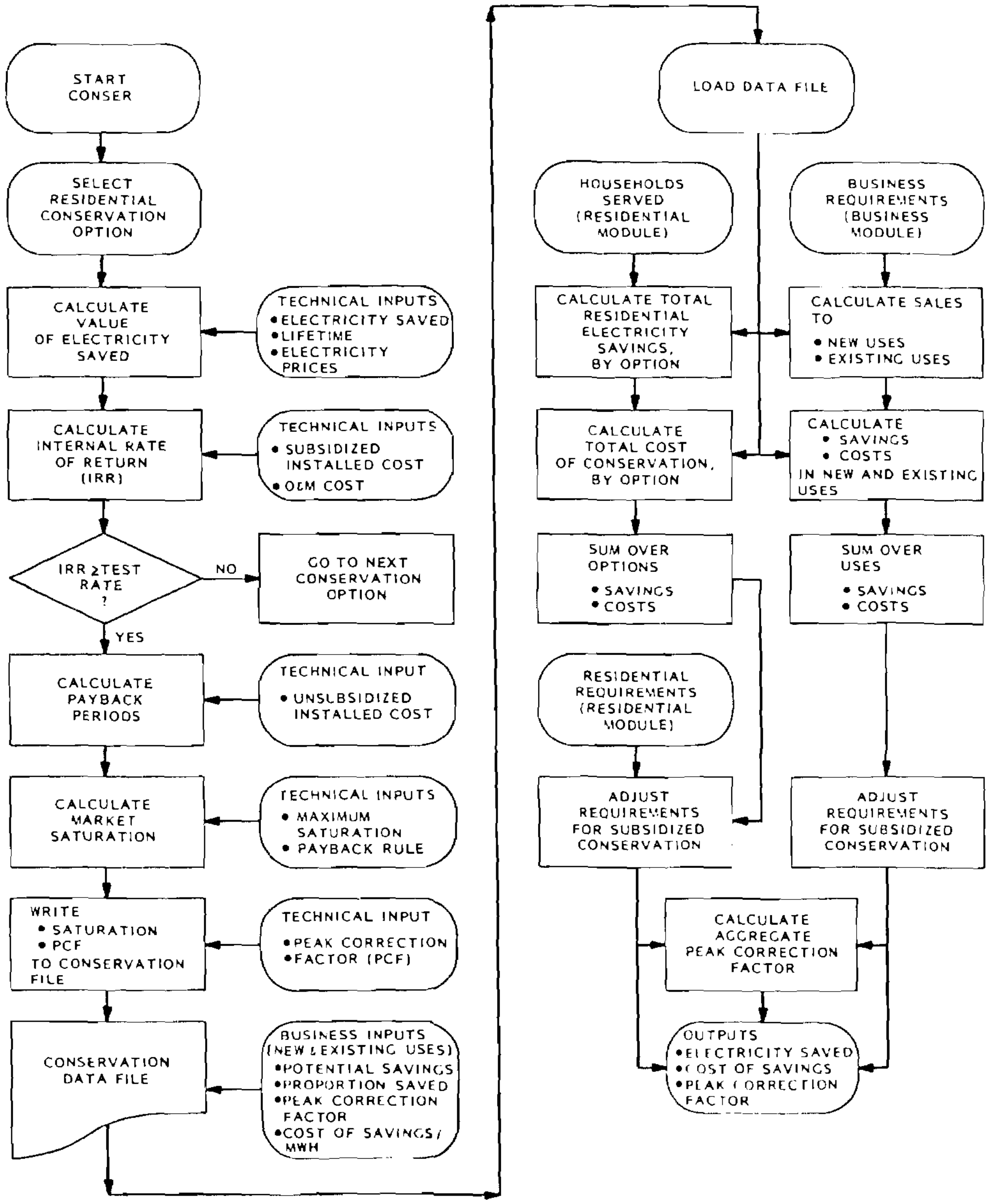

FIGURE 7.1. RED Conservation Module

option. CONSER then writes the default values and range of values for the option's market saturation rate to an output data file. The user is then queried for the market saturation of electricity in the use that the conservation option offsets (e.g., electric water heating). This market saturation is also written to the output data file.

Government residential conservation programs primarily reduce the effective purchase price of conservation options to the consumer. Therefore, CONSER next requests the user's estimate of consumer purchase and installation costs for each option with and without government subsidization. The saturation of each technology with and without subsidization is calculated and is written to the output data file.

For the business sector, CONSER requests the potential proportion of predicted electricity use that might be saved through conservation, the estimated proportion of these potential conservation savings that are realized, and the costs per kWh for conservation savings in existing and new buildings. These values are also written to the output data file, which now becomes an input data file for the Conservation Module.

RED uses the residential conservation information in the CONSER data file to account for the impacts of the conservation technologies under consideration. First, the amounts of conservation occurring in the residential sector with and without government subsidization are calculated by multiplying together the electric use saturation rate, the conservation saturation rate, and the number of households. Next, the level of policy-induced conservation is calculated by subtracting the nonsubsidized conservation savings from the subsidized figure. Finally, this figure is subtracted from the price-adjusted residential requirements to derive the utilities' total residential sales.

The business conservation calculation separately addresses the sales to new and existing uses, and two potential pools of electricity savings are calculated. For simplicity, existing uses are defined as the previous forecast periods' electricity requirements, whereas new uses are the difference between the previous period's requirements and the current period's requirements. The two potential pools of savings are the sales to new uses and retrofits times user-supplied potential savings rates (for new uses and retrofits). The predicted level of savings in each case is found by multiplying the potential pools of savings times user-supplied conservation saturations with and without government intervention. Finally, the total policy-induced savings are derived by subtracting the savings without government intervention from sales with government intervention for both new and existing uses. Total price adjusted requirements, minus policy-induced business conservation, equals utilities' total sales to business.

The economic costs of the residential conservation technology package are found by multiplying together the government subsidized conservation saturation rate; the electric saturation rate; the number of households; and the cost to consumers per installation without government intervention for each conservation option; and summing over options. For the economic costs of business conservation, the total megawatt hours saved by government subsidized conservation is multiplied by the cost per megawatt hour saved.

Finally, the Conservation Module helps calculate the effect of conservation on peak demand. Unfortunately, not all conservation technologies can be given credit for displacing the demand for peak generating capacity. Therefore, CONSER queries the user for a peak correction factor, a variable that takes on a value between zero and one if the option receives credit for producing some portion of its energy savings during the peak demand period; otherwise the value is zero. These peak correction factors for each option are aggregated in RED. First, they are weighted by the proportion of total policy-induced electricity savings each option represents during a given forecast period. Next, the weighted correction factors are summed together. The resulting aggregated peak correction factor is sent to the peak demand model to calculate the peak savings of the set of conservation technologies.

INPUTS AND OUTPUTS

The inputs and outputs of the Conservation Module are summarized in Table 7.1. The potential market for the conservation option is defined by the total number of households served (THHS) and the saturation of the electrical devices (ESAT) whose use of electricity can be displaced by investment in a particular conservation option. ESAT equals the total market saturation of the applicance times the fuel mode split. The total number of households served is calculated in the housing module, while ESAT is interactively entered by the user. RCSAT, the penetration of the potential market by the

TABLE 7.1. Inputs and Outputs of the Conservation Module

a) Inputs

Symbol	Name	From
THHS	Total households served	Residential Module
TECH	Technical energy savings	CONSER, Interactive Input
COSTI	Installation and purchase cost of the residential conservation device	CONSER, Interactive Input
COSTO	Operation and maintenance costs of the residential conservation device	CONSER, Interactive Input
RCSAT	Residential saturation of the device (with and without government intervention)	CONSER, Interactive Input
ESAT	Residential electric use saturation	CONSER, Interactive Input
PRES	Expected residential electricity price	CONSER, Interactive Input
RESCON	Price-adjusted residential consumption	Residential Module
CF	Peak correction factor	CONSER, Interactive Input
PPES	Potential proportion of electricity saved in business in new and retrofit uses	CONSER, Interactive Input
BCSAT	Business conservation saturation rate (with and without government intervention)	CONSER, Interactive Input Uncertainty Module
COST	Cost per megawatt hour saved in business	CONSER, Interactive Input
BUSCON	Business price-adjusted consumption	Business Module

b) Outputs

Symbol	Name	To
TCONSAV	Total electricity saved (business plus residential)	Report
TCONCOST	Total cost of conservation (business plus residential)	Report
ADRESCON	Adjusted residential consumption	Miscellaneous and Peak Demand Modules
ADBUSCON	Adjusted business consumption	Miscellaneous and Peak Demand Modules
ACF	Aggregate peak correction factor	Peak Demand Model

conservation technology, is determined within the CONSER parameter routine. The technical energy savings and the costs of residential conservation devices (both installation and maintenance) are interactively specified within CONSER by the user.

The business segments of CONSER also query the user for the potential and actual saturations of electricity conservation in the business sector and the costs per megawatt hour saved for business investments in conservation.

Finally, the correction factors are decimal fractions which are interactively supplied by the user to CONSER and which reflect the extent to which conservation options receive credit for peak savings.

The outputs of the Conservation Module are the final electricity sales to the business and residential sectors, and the electricity savings of the conservation technology set considered in a given run of the RED model.

MODEL STRUCTURE

The price adjustment mechanisms used in the Business and Residential Consumption Modules employ price elasticities derived from studies that did not distinguish among the impacts of conservation technologies and other effects of energy price changes. Since conservation of electricity is argued to be induced either by energy price changes or by market intervention to encourage conservation, the treatment of conservation in RED was cautiously developed to eliminate the possibility of double counting energy savings and costs.

In RED's formulation, the Conservation Module serves primarily as an accounting mechanism that tracks the impacts of a given set of technology options in the residential sector and the aggregate level of conservation in the business sector. However, since government policies and programs could have a significant, direct impact upon the level of conservation adopted, and since the incremental impacts of these actions are not incorporated in the price adjustment process of the Residential and Business Consumption Modules, the Conservation Module explicitly calculates these impacts and accordingly adjusts the forecasted sales to consumers.

Scenario Preparation (CONSER Program)

The calculations of the Conservation Module require scenarios of the saturation of conservation options, the expected electricity savings, and their associated costs. To reduce the amount of data entry in scenario preparation, and to facilitate the use of a broad set of conservation technologies and government policy options, a separate program (CONSER) queries the user for information necessary to calculate the saturations, savings, and costs. These parameters are then written to a data file where they can be accessed by the remainder of the Conservation Module. Two steps are required: 1) determining if an option will achieve market acceptance; and 2) calculating market saturations for options gaining acceptance.

The first step is to determine whether a specific conservation option will achieve market acceptance. For the residential sector, the way RED identifies acceptable options is to compare them with other investments available to the consumer. Conservation is an investment with a financial yield that can be calculated and compared with other investment options. By comparing the internal rate-of-return (IRR) of a conservation option with the market rate of interest, one can determine whether conservation options' return is sufficient to encourage market acceptance.

The market rate of interest to which RED compares the internal rate-of-return is the standard commercial bank passbook interest rate. Passbook accounts have several characteristics:

1. They are virtually risk free.
2. They are extremely liquid.
3. They have trivial requirements as to the size of the initial deposit.
4. They are readily available to everyone.

Investments in conservation technologies, however, are characterized by the following:

1. risky
2. difficult to liquidate
3. (sometimes) require a large initial payment.

These factors would cause most homeowners-investors to require a higher rate-of-return on conservation than those on passbook accounts to invest in conservation. Therefore, a conservation option can pass the internal rate-market interest test even though it might not be adopted. Such a comparison insures that every option that could achieve market acceptance is included in the portfolio of conservation technologies to be considered.

The IRR is calculated with the following formula:

$$\sum_{\ell=0}^{T} \frac{ES_{i\ell k} - C_{i\ell k}}{(1 + \rho_{ik})^{\ell}} = 0 \tag{7.1}$$

where

T = lifetime of the device (maximum of 30 years)

ρ = internal rate-of-return

ℓ = subscript for the year. Takes on values 1 to 30

ES = value of electricity saved

C = total cost of the option in the year

i = subscript for the load center

k = subscript for the option.

The value of electricity savings is based on the energy prices the consumer expects. It is calculated by querying user for price forecasts and the electricity savings (in kWh) for each option and multiplying:

$$ES_{i\ell k} = PRES_{i\ell} \times TECH_{ik} \tag{7.2}$$

where

$PRES_{i\ell}$ = dollars per kWh in load center i at time ℓ

$TECH_{ik}$ = annual kWh savings in region i per installation of device k.

The cost ($C_{i\ell k}$) is the 1980 dollar installation and purchase cost in the year the device is purchased and the annual maintenance and operating 1980 dollar costs in all remaining periods.

Recognizing that initial cost is a major barrier to conservation, the Congress has provided incentives for individuals to install energy conserving equipment. Furthermore, the State of Alaska has also instituted several programs aimed to promote installation of conservation equipment. Because the main impact of these programs is to reduce the initial cost of conservation, CONSER uses the subsidized installation and purchase costs of the device to forecast whether a device will achieve additional market acceptance over an unsubsidized case.

As previously stated, CONSER requests the expected electricity price forecast for each year, the operating and maintenance costs, the kWh savings and the government subsidized purchase and installation costs of the device for each region. CONSER calculates the internal rate-of-return of the option, prints this information, and asks the user if the option is to be used. If it is, then the unsubsidized costs of purchasing and installing the option are also requested.

If the scenario to be considered does not include government intervention, the installation and purchase costs entered for the subsidized and unsubsidized cases should be the same (and equal to the unsubsidized costs).

The next step of scenario preparation is to determine the market saturation rate of each conservation option. RED employs a payback decision rule to determine the default value and the range of the conservation saturation rate. Since the expected value of electricity savings probably is not constant across time, the payback period is calculated by dividing the installation and purchase costs by the cumulative net value of electricity savings (value of energy savings minus operating and maintenance costs), starting with the first year and continuing until the ratio is less than one. The number of years required to drive the ratio to less than one is the payback period.

The payback period is calculated for both the subsidized and nonsubsidized cases. Since the subsidized case usually will have lower installation and purchase costs, the payback periods for the subsidized case will usually be lower and the conservation saturation rates will usually be higher.

CONSER also requests the name of the conservation option, a forecast of the market saturation rates for electric devices from which the option displaces consumption, and the peak correction factor for each conservation option. The saturation of electric devices is used within the Conservation Module to define the potential market of the conservation option, whereas the peak correction factor indicates the extent to which the option displaces electricity consumption at the peak. This information, as well as the costs and saturation of the conservation option (for the unsubsidized and subsidized cases), are written to a data file for later access by the remainder of the Conservation Module.

Funding constraints in the Railbelt Alternatives Study prohibited the development of detailed cost and performance data for business conservation applications. CONSER, therefore, requires the user to provide the following for both new and retrofit uses: the potential proportion of electricity that conservation technology can displace and an estimate of the proportion of those potential savings actually realized for subsidized and unsubsidized cases. CONSER also requests the cost per megawatt hour saved for both cases and the peak correction factor for new and retrofit uses.

This business sector information is also written to CONSER's output data file. By running CONSER with several different technology packages and government policy packages, conservation scenario files can be easily constructed for later analysis within RED.

Residential Conservation

Using the information from the data file that CONSER creates, the calculation of electricity saved by the set of technologies is straightforward. By multiplying the electric device saturation and the incremental number of households served, the total number of potential applications of the conservation device is found. The incremental number of households served in the first forecast period (1980) is zero, since the current consumption rates already include the current level of conservation.

By next multiplying the potential number of uses by the savings per installation and the saturation of the conservation option, the amount of electricity saved is derived:

$$CONSAV_{itkj} = RCSAT_{ikj} \times TECH_{ik} \times (ESAT_{itk} \times THHS_{it} - ESAT_{i(t-1)k} \times THHS_{i(t-1)}) \qquad (7.3)$$

where

CONSAV = electricity saved (kWh)
RCSAT = conservation saturation rate
TECH = electricity savings per installation (kWh)
ESAT = electric device saturation rates
THHS = total households served
t = denotes the forecast period (1,2,3,...,7)
j = denotes subsidized (j=1) or nonsubsidized (j=o).

The total electricity displaced through the residential conservation set considered is found by summing across the options (subscript k):

$$RCONSAV_{it1} = \sum_{k=1}^{K} CONSAV_{itk1} \qquad (7.4)$$

where

RCONSAV = residential electricity conserved (kWh)
K = total number of residential options considered.

Since the price adjustment mechanism does not account for government-induced conservation, the model next adjusts residential sales by the incremental conservation attributable to government programs:

$$ADRESCON_{it} = RESCON_{it} - (RCONSAV_{it1} - RCONSAV_{ito}) \qquad (7.5)$$

where

ADRESCON = final electricity requirements of residential consumers

RESCON = price-adjusted residential consumption.

The electrical device saturation and the incremental number of households define the number of potential applications. The cost of purchasing and installing the option is calculated by multiplying the potential number of new uses by COSTI (the installation and purchase costs per option). Next, by multiplying COSTO (annual operations and maintenance costs per option) by the cumulation of previous forecast periods' potential uses, the operating and maintenance costs are found. Finally, by summing all these components, the total annual costs associated with conservation savings in a given forecast period can be found. During any forecast year, the annual costs are equal to one year's total installation costs, plus operating costs associated with all previous additions to stock:

$$CONCOST_{itkj} = \Big[COSTI_{ikj} \times RCSAT_{itkj} \times (ESAT_{itk} \times THHS_{it} - ESAT_{i(t-1)k} \times THHS_{1(t-1)})/5 + COSTO_{ik} \times \sum_{h=1}^{t} RCSAT_{ikj} \times (ESAT_{ihkj} \times THHS_{ih} - ESAT_{ihkj} \times THHS_{i(h-1)}\Big] \quad (7.6)$$

where

CONCOST = the option's total annual cost

COSTI = unit cost in 1980 dollars for purchasing and installing the conservation option

COSTO = unit cost in 1980 dollars of operating and maintaining the conservation option

h = forecast period subscript. Can take on values 1 to t.

By summing over the options, the total costs of the residential conservation set is found.

$$RCONCOST_{itj} = \sum_{k=1}^{K} CONCOST_{itkj} \qquad (7.7)$$

where

RCONCOST = present value of the total costs of the set of residential conservation options.

The total costs of conservation are the unsubsidized total costs ($RCONCOST_{ito}$), consumers pay the subsidized costs ($RCONSAV_{it1}$), and government pays the difference ($RCONCOST_{ito}$ - $RCONCOST_{it1}$).

Business Conservation

For business conservation impacts, funding constraints prohibited collection of detailed cost and performance data. Fortunately, a limited number of studies have estimated the potential energy savings and associated costs for aggregate conservation investments in new and existing buildings.

RED separates the conservation impacts for the business sector into two parts: those arising from retrofitting existing buildings, and those arising from incorporating conservation technologies in new construction. As in the residential segment of the Conservation Module, the potential pool of electricity that can be displaced must be identified for both new construction and retrofits. This "pool" is determined by the state of conservation technology and is supplied to the conservation module from the CONSER output file. The actual amount of conservation that occurs depends upon the price of electricity and competing fuels, and upon the cost and performance characteristics of the options available. This is also supplied by CONSER.

In RED, the potential pool of displaced electricity for businesses is derived by first separating business sales into sales to existing structures and sales to new structures. For simplicity, the change from the previous periods' business requirements as calculated by the Business Consumption Module is assumed to be the sales to new buildings:

$$SALNB_{it} = BUSCON_{it} - BUSCON_{i(t-1)} \tag{7.8}$$

where

SALNB = sales to new buildings

BUSCON = business consumption prior to conservation adjustments.

Therefore, the sales to existing buildings are the sales in the previous period:

$$SALEX_{it} = BUSCON_{i(t-1)} \tag{7.9}$$

where

SALEX = sales to existing buildings.

To find the potential pool of electricity use displaced through retrofits and incorporation of conservation options in new buildings, the Conservation Module multiplies the disaggregated sales figures times the potential percentage of electricity saved in new and retrofit buildings:

$$POTNB_{it} = SALNB_{it} \times PPES_{itN} \tag{7.10a}$$

$$POTEX_{it} = SALEX_{it} \times PPES_{itE} \tag{7.10b}$$

where

POTNB = potential amount of displaced electricity in new buildings

PPES = proportion of electricity that technically can be displaced via retrofit or incorporation of conservation options in new buildings

POTEX = potential amount of displaced electricity in existing buildings

E = subscript for existing buildings

N = subscript for new buildings.

These figures, however, only provide the technically feasible amount of electricity that could be displaced. Market forces determine what level of the potential electricity savings will be achieved.

In the residential segment of the Conservation Module, RED used an internal rate-of-return test and a payback period decision rule to determine first, whether an option would achieve market acceptance, and second, what level of acceptance it would achieve. As mentioned above, the information available for business conservation does not permit such an analysis. Therefore, the model user is required to assume a level of potential market saturation. The saturation rates (one for retrofits, one for new buildings) must reflect the prices of fuels (including electricity), the costs of the package of options employed, and the electricity savings expected for subsidized and nonsubsidized cases.

The saturation rates are obtained from the data file CONSER creates. The displaced electricity can be found by multiplying the total saturation rates by the total potential pool of electricity savings:

$$BCONSAV_{itNj} = BCSAT_{itN} \times POTNB_{itj} \quad (7.11a)$$

$$BCONSAV_{itEj} = BCSAT_{itE} \times POTEX_{itj} \quad (7.11b)$$

where

BCONSAV = electricity savings

BCSAT = saturation rate for conservation options in business.

As in the residential sector, the business requirements must be adjusted for the incremental impact of government programs:

$$ADBUSCON_{it} = BUSCON_{it} - (BCONSAV_{itN1} - BCONSAV_{itNo}) - (BCONSAV_{itE1} - BCONSAV_{itEo}) \quad (7.12)$$

where

ADBUSCON = adjusted business consumption.

The total cost of the conservation set in a given future forecast year is given by multiplying the 1980 dollar cost per megawatt-hour saved by the conservation savings in each use:

$$BCONCOST_{itj} = (BCONSAV_{itEj} \times COST_{iEj} + BCONSAV_{itN1} \times COST_{iN1}) \qquad (7.13)$$

where

BCONCOST = business conservation costs, future forecast year

COST = 1980 dollar costs per megawatt hour saved.

The total costs of the conservation in a future forecast year to "society" is the nonsubsidized costs ($BCONCOST_{ito}$), whereas the value of the subsidy in that year is ($BCONCOST_{ito} - BCONCOST_{it1}$), and businesses bear only the subsidized costs ($BCONCOST_{it1}$).

Peak Correction Factors

The last item to be calculated is the aggregate peak correction factor for the incremental impact of government conservation programs on peak demand. This factor is calculated by weighting each option's peak correction factor by the option's proportion of incremental conservation:

$$ACF_{it} = \sum_{k=1}^{K} \frac{(CONSAV_{itk1} - CONSAV_{itko}) \times CF_k}{(RCONSAV_{it1} - RCONSAV_{ito}) + (BCONSAV_{it1} - BCONSAV_{ito})}$$

$$+ \frac{(BCONSAV_{itE1} - BCONSAV_{itEo}) \times CF_E + (BCONSAV_{itN1} - BCONSAV_{itNo}) \times CF_N}{(RCONSAV_{it1} - RCONSAV_{ito}) + (BCONSAV_{it1} - BCONSAV_{ito})} \qquad (7.14)$$

where

ACF = aggregate peak correction factor

CF = option-specific peak correction factor, equal to the proportion of the electrical demand of displaced appliances that can be displaced at the peak demand period of the year (e.g., January).

PARAMETERS

One of the requirements of the Alaska state program whereby homeowners request state money to install conservation measures is that the payback period for the measure be less than seven years. Therefore, if a conservation option's payback period is assumed to be greater than seven years, the options market penetration will be very limited, effectively zero. However, if the option pays for itself within the first year, then the option would penetrate the entire potential market immediately. The relationship between payback period and penetration rate for payback periods between zero and seven years is assumed to be linear. A range of 15% on these values is arbitrarily assumed. Table 7.2 presents these market penetration parameters.

TABLE 7.2. Payback Periods and Assumed Market Saturation Rates for Residential Conservation Options

Payback Period (years)	Assumed Saturation (percent)	Assumed Range (percent)
0	100.0	--
1	87.5	80-95
2	75.0	67.5-82.5
3	62.5	55-70
4	50.0	42.5-57.5
5	37.5	30-45
6	25.0	17.5-32.5
7	12.5	5-20
8	0	0-5

Source: Author Assumption

8.0 THE MISCELLANEOUS MODULE

MECHANISM

The Miscellaneous Module uses outputs from several other modules to forecast electricity used but not accounted for in the other modules, namely, street lighting, second homes, and vacant housing.

INPUTS AND OUTPUTS

This module uses the forecasts of electrical requirements of the residential and business sectors and the vacant housing stock. The only output is miscellaneous requirements. Table 8.1 provides a summary of the inputs and outputs of this module.

TABLE 8.1. Inputs and Outputs of the Miscellaneous Module

a) Inputs

Symbol	Name	From
ADBUSCON	Adjusted Business Requirements	Conservation Module
ADRESCON	Adjusted Residential Requirements	Conservation Module
VACHG	Vacant Housing	Housing Module

b) Outputs

Symbol	Name	To
MISCON	Miscellaneous Requirements	Peak Demand Module

MODULE STRUCTURE

Figure 8.1 provides a flowchart of this module. For street lighting, the requirements are assumed to be a constant proportion of conservation adjusted business and residential requirements:

$$SR_{it} = s1 \times (ADBUSCON_{it} + ADRESCON_{it}) \qquad (8.1)$$

where

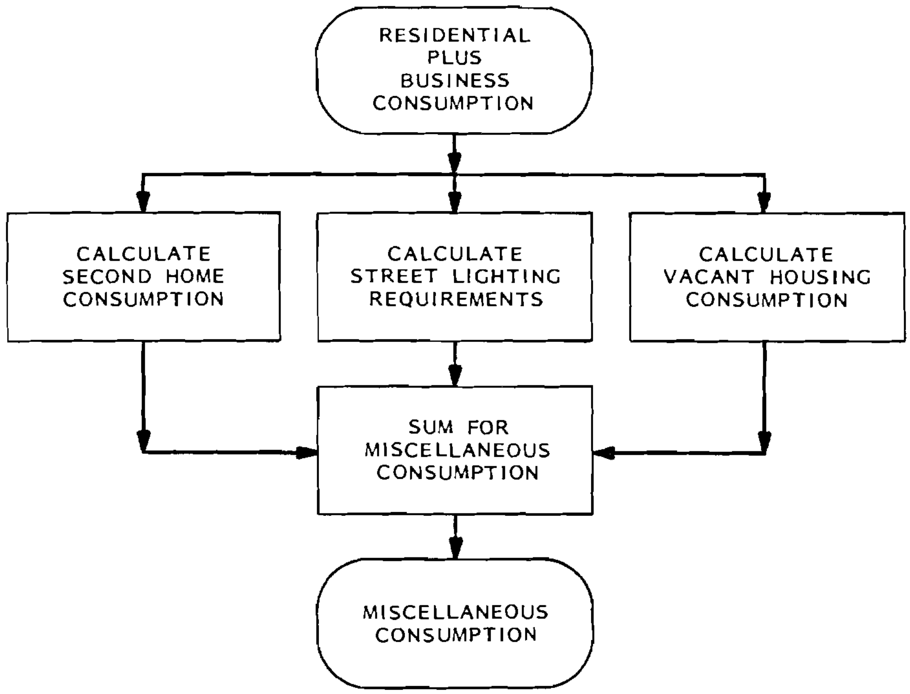

FIGURE 8.1. RED Miscellaneous Module

SR = street lighting requirements

ADBUSCON = business requirements after adjustment for the incremental conservation investments

ADRESCON = final electricity requirements of residential consumers

i = subscipt for load center

t = forecast period (1,2,3...,7)

sl = street lighting parameter.

For second-home consumption, RED calculates the number of second homes as a fixed proportion of the total number of households. A fixed consumption factor is then applied:

$$SHR_{it} = sh \times THH_{it} \times shkWh \tag{8.2}$$

where

SHR = second home requirements

THH = total number of households

sh = proportion of total households having a second home

shkWh = consumption factor.

Finally, the use of electricity by vacant housing is a fixed consumption factor times the number of vacant houses:

$$VHR_{it} = vh \times VACHG_{it} \tag{8.3}$$

where

VHR = vacant housing requirements

VACHG = number of vacant houses

vh = assumed consumption per vacant dwelling unit.

Total miscellaneous requirements are found by summing the three components above:

$$MISCON_{it} = SR_{it} + SHR_{it} + VHR_{it} \tag{8.4}$$

where

MISCON = miscellaneous electricity consumption.

PARAMETERS

Table 8.2 gives the parameter values used for the Miscellaneous Module. These parameters are all based on the authors' assumption because no source of information is available.

TABLE 8.2. Parameters for the Miscellaneous Module

Symbol	Name	Value
Sl	Street lighting[a]	0.01
sh	Proportion of households having a second home[b]	0.025
shkWh	Per unit second-home consumption[b]	500 kWh
Vh	Consumption in vacant housing[c]	300 kWh

(a) 1980 ratio of street lighting to business plus residential sales.
(b) O. Scott Goldsmith, ISER, personal communication.
(c) Author assumption. Reflects reduced level of use of all appliances.

9.0 THE PEAK DEMAND MODULE

Up to this point, only the method to forecast the total amount of electricity demanded in a year has been considered. However, for capacity planning, the maximum amount of electricity demanded (or peak demand) is probably more important. Peak demand identifies the amount of capacity that must be available to meet electricity requirements at the time of maximum demand.

MECHANISM

The Peak Demand Module uses regional load factors to forecast peak demand. The load factor is the average demand for capacity throughout the year divided by the peak demand for capacity in the year. RED first calculates the peak demand without the peak savings of government-induced conservation. Next, the peak savings of the incremental government-induced conservation is calculated, taking into account the mix of conservation technologies being considered. Finally, by netting out the peak savings, RED calculates the peak demand the system must meet.

INPUTS AND OUTPUTS

Table 9.1 provides a summary of the inputs and outputs of the Peak Demand Module. The load factors (LF) are generated by the Uncertainty Module, whereas the aggregate peak correction factor (ACF) comes from the Conservation Module. The business, residential, and miscellaneous requirements (BUSCON, RESCON, and MISCON) come from the Business, Residential, and Miscellaneous Modules, whereas the conservation adjusted requirements (ADRESCON and ADBUSCON) come from the Conservation Module. The outputs of this module are: 1) the peak demand in each regional load center at the point of sale to final users, and 2) the incremental peak savings of subsidized conservation.

MODULE STRUCTURE

Figure 9.1 provides a flowchart of this module. First, the peak demand without subsidized conservation is calculated. This is done by dividing the

TABLE 9.1. Inputs and Outputs of the Peak Demand Module

a) Inputs

Symbol	Name	From
LF	Regional load factor	Uncertainty Module
RESCON	Residential electricity sales before adjustment for subsidized conservation	Residential Consumption Module
BUSCON	Business requirements prior to adjustment for subsidized conservation	Business Consumption Module
ADRESCON	Subsidized conservation-adjusted residential requirements	Conservation Module
ADBUSCON	Business requirements adjusted for subsidized conservation	Conservation Module
ACF	Aggregate peak correction factor	Conservation Module

b) Outputs

Symbol	Name	To
FPD	Peak demand	Report
PS	Incremental peak savings	Report

total electricity requirements in each region by the product of the load factor times the number of hours in the year. Next, the same operation is performed on the increment to conservation due to subsidized conservation investments. This yields the preliminary peak savings. RED then adjusts the peak savings by multiplying the aggregate peak correction factor times the peak savings. The corrected peak savings are then subtracted from the peak demand calculated in the first step to derive the regional peak demand at the point of sale.

The first step is to calculate the total electricity requirements without subsidized conservation by adding the residential, business, and miscellaneous requirements:

$$TOTREQB_{it} = BUSCON_{it} + RESCON_{it} + MISCON_{it} \qquad (9.1)$$

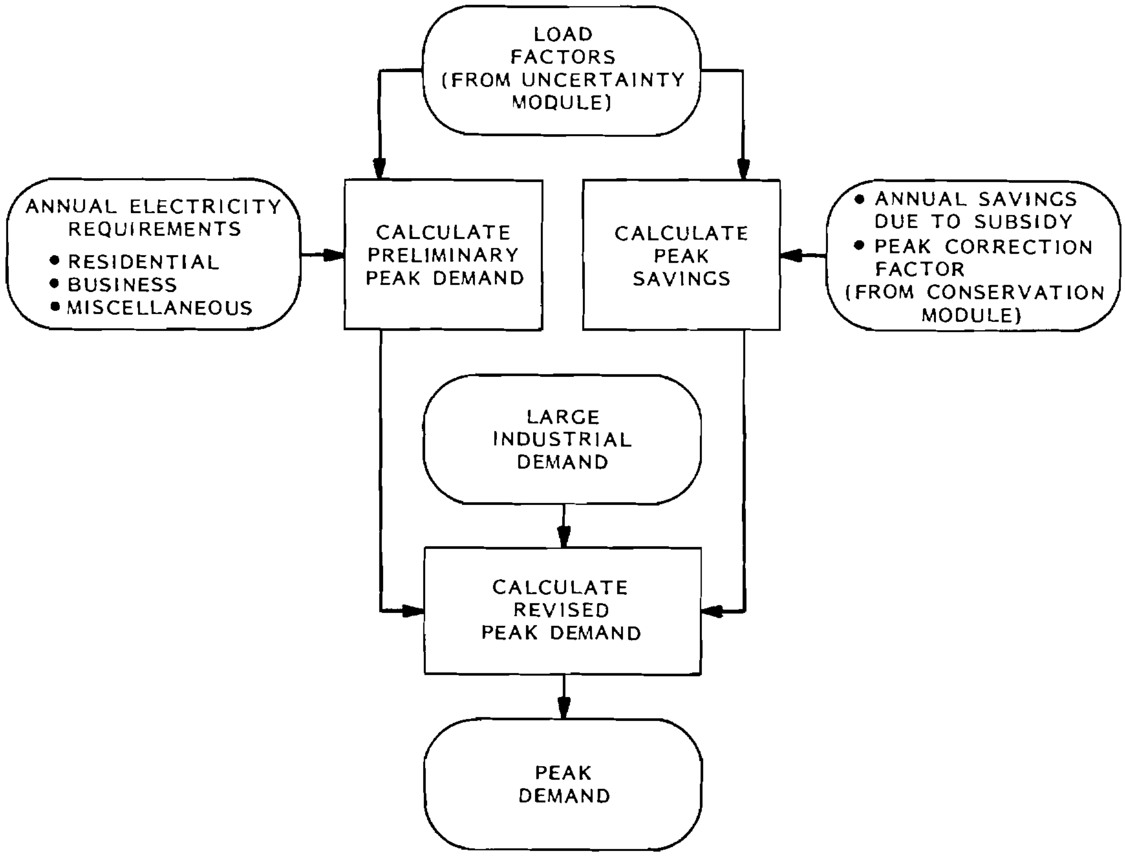

FIGURE 9.1. RED Peak Demand Module

where

TOTREQB = total electricity requirements before conservation adjustment (MWh)

BUSCON = business requirements before conservation adjustment (MWh)

RESCON = residential requirements before conservation adjustment (MWh)

MISCON = miscellaneous requirements (MWh)

i = index for the load center

t = index for forecast period (t = 1,2,...,7).

Next, the Peak Demand Module calculates the peak demand without accounting for the incremental conservation due to subsidized investments in conservation by applying the load factor:

$$PD_{pit} = \frac{TOTREQB_{it}}{LF_{it} \times 8760} \tag{9.2}$$

where

PD = Peak Demand (MW)

LF = Load Factor

8760 = number of hours in a year

p = index denoting preliminary.

To calculate the peak savings due to subsidized conservation investments, RED first must find the incremental number of megawatt hours saved:

$$TOTREQS_{it} = BUSCON_{it} - ADBUSCON_{it} + RESCON_{it} - ADRESCON_{it} \tag{9.3}$$

where

TOTREQS = incremental megawatt hours saved by subsidized conservation investments

ADBUSCON = business requirements after adjustment for the incremental impact of subsidized conservation

ADRESCON = residential requirements after adjustment for the incremental impact of subsidized conservation.

Next, peak savings is found by multiplying the incremental electricity saved by the aggregate peak correction factor and applying the load factor:

$$PS_{it} = ACF_{it} \times \frac{TOTREQS_{it}}{LF_{it} \times 8760} \tag{9.4}$$

where

PS = peak savings (MW)

ACF = aggregate peak correction factor.

Finally, by subtracting the peak savings from the preliminary peak demand, the final peak demand for each region is derived:

$$FPD_{it} = PD_{pit} - PS_{it} \tag{9.5}$$

where

FPD = index denoting final peak demand.

PARAMETERS

The only parameters in the Peak Demand Module are the system load factors assumed for the three load centers: Anchorage, Fairbanks, and Glennallen-Valdez. These load factors are shown in Table 9.2. The default values for Anchorage and Fairbanks were derived by weighting the 10-year average load factors reported by Woodward Clyde by the 1978 peak demands for each utility (Smith and Kirkwood 1980). For Glennallen-valdez, the default value was assumed to be the average of the Fairbanks and Anchorage values.

For the range of the parameter values, the minimum and maximum values reported for the 1970-78 period by each major utility were used. Unfortunately, no information was available for the range of the load factor for Glennallen-Valdez, so the range was assumed to be the average of Fairbanks and Anchorage.

TABLE 9.2. Assumed Load Factors for Railbelt Load Centers

Load Center	Load Factor (%) Default	Range
Anchorage	55.73	49.2-63.4
Fairbanks	48.99	41.6-59.1
Glennallen-Valdez	52.16	45.4-61.3

10.0 RATE MODEL

The Rate Model is a separate program used to interface RED and the Alaska Railbelt Elective Energy Planning model (AREEP). This model employs information on demand from a previous run of RED and the cost of power from AREEP to generate a forecast of electricity rates in Anchorage and Fairbanks.[a]

MECHANISM

The Rate Model uses the cost of power, regional electricity consumption, and user-supplied cost allocation factors (costs all load centers) to derive load center cost of power series. Next, the user can choose to specify the rates for a customer class (business or residential) and allow the model to solve for the other series, or can use a historical (default) or user-supplied price differential weight to derive the rates for both customer classes.

INPUTS AND OUTPUTS

Table 10.1 presents the inputs and outputs of this model. The inputs are electricity sales by customer class and the cost of power. The only outputs of the model are the rates for the business and residential customer classes.

MODEL STRUCTURE

Figure 10.1 provides a flow chart of this model. The cost of power obtained from AREEP contains a charge for the Anchorage-Fairbanks transmission intertie. The Rate Model, however, differentiates between the rates for the Anchorage and Fairbanks load centers by netting out the average intertie cost, then adding back a charge for each load center's proportion of the cost of the intertie.

Using the regionally differentiated cost of power series obtained above, the next step is to construct rates that will exactly cover that series. The user is offered two choices: either use price weight (the business rate is

TABLE 10.1. Inputs and Outputs of the Rate Model

(a) Inputs

Symbol	Variable	From
ACP	AREEP cost of power	AREEP
TS	Total electricity sales (by load center)	RED
BS	Business Sales (by load center)	RED
RS	Residential Sales (by load center)	RED

(b) Outputs

Symbol	Variable	To
BR	Business Rates	RED
RR	Residential Rates	RED

(a) Because electricity is very expensive in the Glennallen-Valdez area, it is necessary to exercise extreme caution in forecasting rates for this load center. Therefore, the Rate Model currently requires that rates remain at their 1980 levels or be exogenously entered.

1.10 of the residential rate, for example) or specify the rates for one class, and let the model solve for what the rates must be in the other. The result is a rate forecast for the two load centers.

To obtain the average charge for the intertie embedded in the AREEP cost of power, the cost of the intertie is divided by total electricity sales in the two regions.

$$ARIC = \frac{TCI}{\sum_{\ell = 5}^{31} \sum_{r = 1}^{2} TS_{\ell r}} \qquad (10.1)$$

where

ARIC = average intertie cost

TCI = total intertie cost

$TS_{\ell r}$ = total electricity sales in year ℓ in load center.

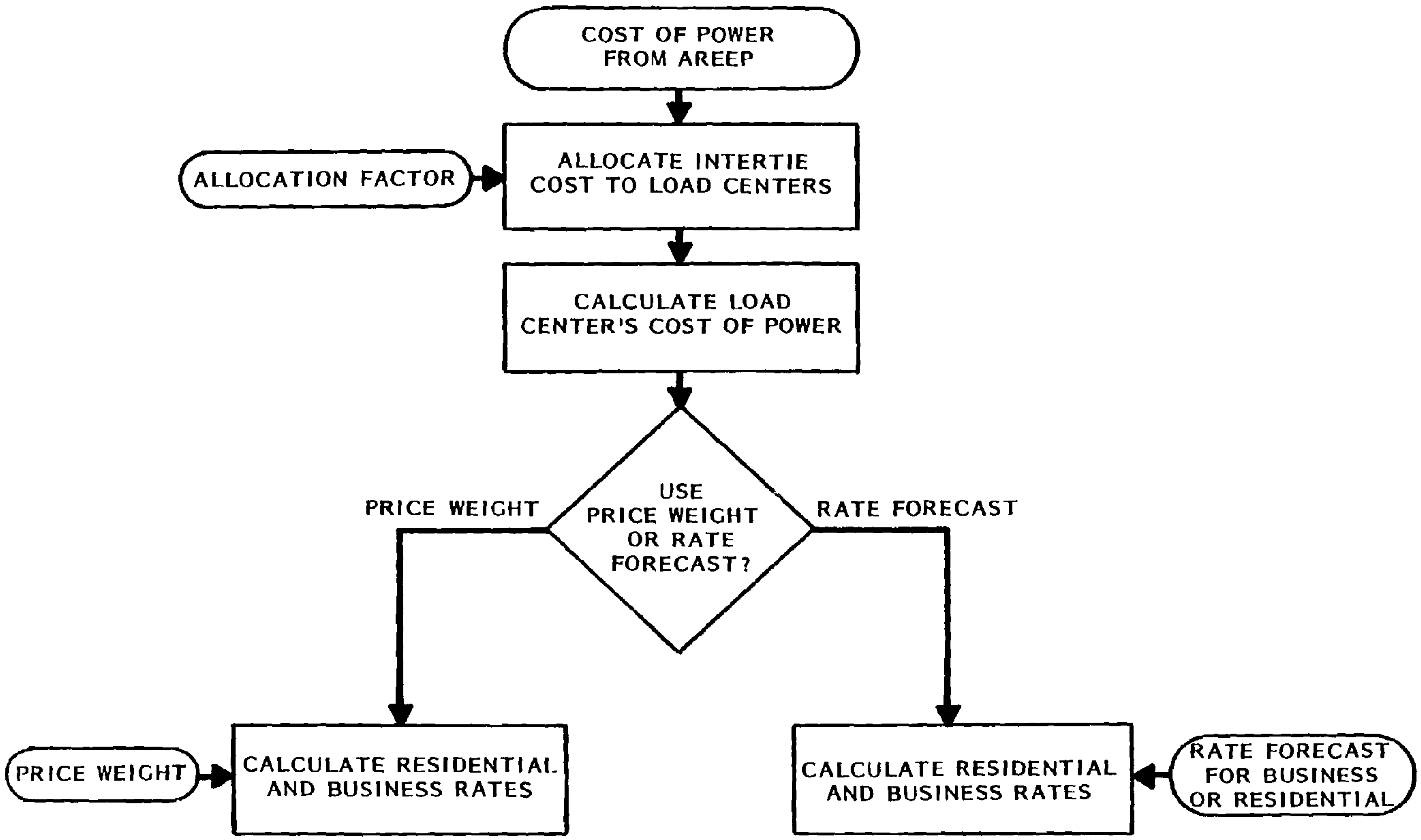

FIGURE 10.1. Structure of the Rate Model

The load center cost of power is found by allocating the interties cost to the two load centers, dividing by sales at each load center, then replacing the average intertie charge with the new load center intertie charge:

$$ARSC_{rt} = ACP_t + \frac{AF_r * TCI}{\sum_{\ell=5}^{31} TS_{\ell r}} - ARIC \qquad (10.2)$$

where

ARSC = average load center system cost

ACP = AREEP cost of power

AF_r = user supplied allocation factor ($0 \leq AF \leq 1$; $AF + (1-AF) \leq 1$) at load center r

t = forecast period (1,2,3...,7).

If the user chooses to use price weights, the rates are found by solving the following equations:

$$BR_{rt} = (1 + wf)\ RR_{rt} \qquad (10.3)$$

where

BR = business rate

RR = residential rate

wf = weighting factor (user supplied or default valve).

$$TS_{r\ell} * ARSC_{r\ell} = RR_{r\ell} * RS_{r\ell} + BR_{r\ell} * BS_{r\ell} \qquad (10.4)$$

where

RS = residential sales

BS = business sales.

To get the residential rate series, the right hand side of equation 10.3 is substituted into equation 10.4. The business rates then drop out of equation 10.3.

If the user specifies the rates for one customer class, then the model solves equation 10.4 for the missing rate series.

PARAMETERS

The only parameters in the Rate Model are the initial prices for 1980 (Table 10.2) the Anchorage-Fairbanks intertie cost and the default price weights (Table 10.3). The intertie cost is from Gilbert Commonwealth (Gilbert/Commonwealth 1981), and the default price weights were obtained from the 1980 rates.

TABLE 10.2. 1980 Load Center Electricity Rates ($/kWh)

	Business	Residential
Anchorage	0.37	0.031
Fairbanks	0.82	0.074
Glennallen-Valdez	0.131	0.128

TABLE 10.3. Miscellaneous Rate Model Parameters

Intertie Cost	$130,800,000
Weighting Factor	0.108

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