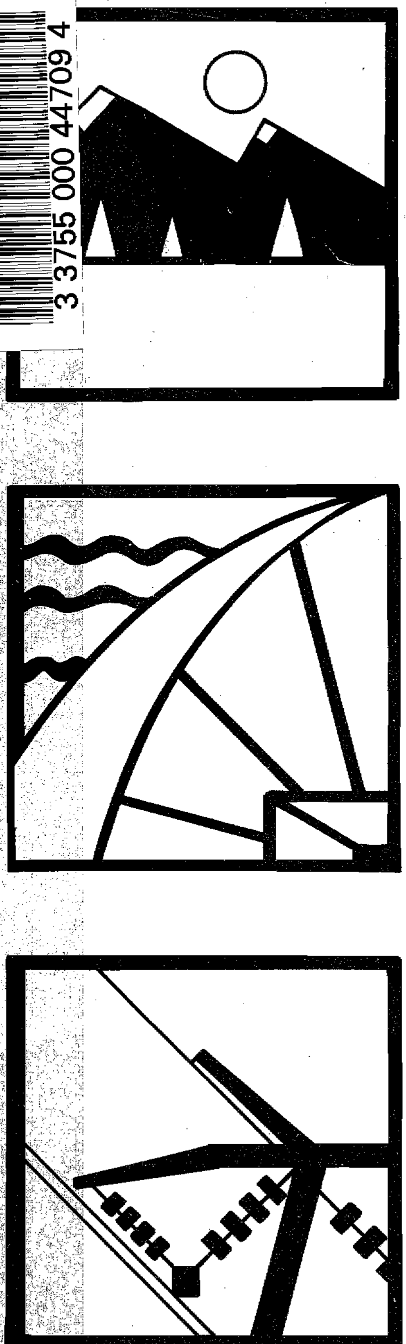

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

TASK 1 - POWER STUDIES

SUBTASK 1.01 CLOSEOUT REPORT
REVIEW OF ISER WORK

DECEMBER, 1980

ACRES

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

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ACRES AMERICAN INCORPORATED

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1 - INTRODUCTION

1.1 - Background

The Acres American Incorporated Plan of Study (POS) for the Susitna Hydroelectric Project was issued by the Alaska Power Authority for public review and comment in February 1980. Revision 1 to the POS was issued in September 1980 to take account of modifications made as a result of comments received from various sources. These modifications included removal from the original scope of work a substantial portion of Task 1, Power Studies in which load forecasting and power alternatives had originally been proposed. Load forecasting was consequently carried out under separate contract by the Institute of Social and Economic Research of the University of Alaska (ISER). However, Subtask 1.01 which deals with the selection of an energy growth forecast for the south-central Alaska Railbelt Region was retained in its entirety as a part of the POS.

This report presents the work undertaken by Acres American Inc. (Acres) and its sub-contractor Woodward-Clyde Consultants (WCC) in Subtask 1.01, Review of ISER Work Plan and Methodologies. The report contains a review of ISER's projections of electricity power consumption for the Railbelt and addresses specific issues related to the methodology. The report also recommends a range of electricity consumption projections, for use in subsequent tasks of the POS for the proposed Susitna Hydroelectric Project.

1.2 - Report Contents

This report is structured in five sections. Section 2 is a summary of the work undertaken and the findings that have been obtained. Section 3 describes in detail the scope of work, approach employed and a historical record of significant events that occurred during the study period. A critique of ISER's work is presented in Section 4 where specific issues are raised and implications discussed. In Section 5 a comparison is made of ISER's forecast with those developed by others in recent years and the main reasons for the differences between them are discussed. Finally, Section 6 concludes with the main findings that have been obtained and recommendations for further work.

An in-depth review of ISER's model structure, assumptions and results is conducted in Appendix A. In a further series of Appendices, B through F, critiques of the ISER forecast, by WCC and other agencies, are also presented.

2 - SUMMARY

This section summarizes the work undertaken in Subtask 1.01 and the findings that have been obtained.

2.1 - Scope of Work

As stated in the February 1980 Plan of Study for the Susitna Project, one of the main objectives of Task 1 - Power Studies was to select forecasts of electric load growth in the Railbelt and determine the future need for electric power in the region. To support this overall objective, Subtask 1.01 was defined as a review of the ISER forecasting methodology with the intent to develop a sound understanding of the methodology and projections. An additional objective of this study is to establish a basis for development of appropriate future generation expansion scenarios for the Railbelt Region.

2.2 - Electricity Consumption Forecasts

The results of ISER's work were documented in a final report to the House Power Alternatives Study Committee of the State of Alaska and the Alaska Power Authority, which was issued in June 1980. The ISER forecasts were based on economic growth projections for three areas which comprise the Railbelt: the Anchorage region, including the Matanuska-Susitna, Kenai and Seward Census Divisions; the Fairbanks and Southeast Fairbanks Census Divisions; and the Valdez Census Division. ISER expects electric power consumption of the Alaskan Railbelt to continue to grow over the next 30 years as the economy expands. The rates of growth will be conditioned by a large number of economic, demographic, and electricity consumption factors. To bound the alternative rates of growth, ISER defined three alternative economic futures as the likely economic conditions under which future electricity power consumption would occur. Electrical energy sales for the Railbelt Region are projected to grow from a 1980 value of 3,101 GWh to a minimum of 4,807 GWh and respective medium and maximum values of 6,141 GWh and 8,927 GWh, by 2010. The results are summarized in Table 2.1, and are substantially less than previous forecasts prepared by other agencies such as the Alaska Power Administration.

2.3 - ISER Forecasting Model

ISER's projections of electricity power consumption for the Railbelt are a product of five linked components:

- MAP, which is a state-of-the-art econometric model of Alaska's economy.

- A model of household formation.

- A regional allocation model which estimates economic activity and population in the Railbelt and its subregions given the MAP forecasts.

- A housing stock model which estimates housing stock by type.

- A model of utility load growth using a detailed end-use approach for the residential sector, and aggregate consumption approaches for the commercial-industrial-government and miscellaneous sectors.

To run these model components, two sets of input information were used. The first is a set of assumptions concerning future economic activity in Alaska's basic industries and future levels of State Government expenditure. The second is a series of assumptions concerning fuel and appliance choice and capacity for the end-use sectors. These different assumptions resulted in nine economic growth futures and two electricity end-use scenarios. Only three of the nine economic growth futures were run entirely through the models.

2.4 - Findings and Recommendations

ISER's model was subjected to a detail evaluation. This evaluation was focused on three areas: model structure, data base and economic scenarios, and model parameters. A number of significant areas of concern emerged:

- The full range of economic scenarios has not been estimated by the model. Only three scenarios representing moderate government expenditure and alternative economic growth were used in projecting future Railbelt electricity power consumption.

- The existing set of scenarios does not sufficiently cover a feasible range of alternative futures. The high economic growth and high government expenditure scenario is conservative. A higher growth scenario can be formulated to represent stable industrial growth with higher government expenditure without necessarily depleting the State's fund balance. At the same time, the low growth scenario can be made lower by formulating a scenario representing a contraction of the Alaskan economy.

- There is a paucity of data for calibrating an econometric end-use model in Alaska. The data base limits the robustness of the model, particularly the end-use components of the model.

- Recognizing that the poor data base in Alaska limits the ability to structure an econometric end-use model in sufficient detail, the existing model is weakest in the commercial-industrial-government component. This component at present is highly aggregated and cannot sufficiently respond to the specific assumptions developed in the economic scenarios. Since this component currently accounts for about 52 percent of total Railbelt utility sales, this deficiency is significant.

- The parameter fuel mode split presently employed in the model is based on judgmental assumptions. This parameter is too important to be made on this basis. Fuel choice is determined on the basis of relative fuel prices and fuel availability, which also change over time. These have not been explicitly entered into the fuel mode split parameter. Hence, the accuracy of the assumed existing fuel mode split values cannot be realistically tested.

- The model contains many assumptions about other parameter values, such as household formation rates, appliance saturation rates, growth in appliance size, etc. which have not been fully tested. At the same time no sensitivity analysis was conducted to understand the impact of these assumptions.

The implications of these problems in predicting future Railbelt electricity requirements require a thorough analysis. However, some of the outcomes of these problems can be estimated or deduced. These are:

- The upper and lower bounds of the existing scenario set have been evaluated as approximations to the model estimations. These are estimated to be 14.0 million MWh for the upper bound and 5.4 million MWh for the lower bound in year 2010. The range of forecasts is therefore wider than that provided by ISER. (See Figure 2.1).

- The inclusion of a scenario with stable industrial growth and a higher government expenditure, will drive electricity consumption projections to a level higher than the ISER upper bound. The opposite results would occur for an economic depression scenario, where future consumption levels would be lower than the ISER lower bound. The range of forecasts will therefore be wider than the existing set, covering a more feasible range of alternatives.

- A thorough investigation of the fuel mode split parameter may lead to different values than those assumed. If an analysis of price and availability of fuels indicates that future electricity prices will be lower than those of other substitutable fuels, the fuel mode split would drive the electricity projections to levels higher than the existing set. If the price of electricity is more expensive relative to other fuels, the opposite results would occur.

Other problems such as a poor data base, inadequate structural detail in the commercial-industrial-government component, and untested parameter assumptions cannot be reliably assessed without further detailed analysis. The quality of the data base can only improve with time, but for the present only reasonable assumptions in the model can alleviate the problem. Other problems require a thorough analysis to understand the extent of the implications.

In view of these problems, there are doubts concerning the efficacy of ISER's projections. However, many of these problems are not insurmountable and can be put to rest with time and effort. Hence it is recommended that these issues be investigated and resolved so that applying these projections to electricity generation planning in the Railbelt can be undertaken with reasonable confidence.

TABLE 2.1 SUMMARY OF ISER FORECASTS (GWh)

	Railbelt Utility Sales				Military Net Generation	Self-supplied Industry Net Generation			
	L	M	H	ME	M	L	M	H	ME
1980	2,390	2,390	2,390	2,390	334	414	414	414	414
1985	2,921	3,171	3,561	3,171	334	414	571	847	571
1990	3,236	3,599	4,282	3,599	334	414	571	981	571
1995	3,976	4,601	5,789	4,617	334	414	571	981	571
2000	5,101	5,730	7,192	6,525	334	414	571	981	571
2005	5,617	6,742	9,177	8,219	334	414	571	981	571
2010	6,179	7,952	11,736	10,142	334	414	571	981	571

Abbreviations:

L = Low Economic Growth - Moderate Government Expenditure.

M = Moderate Economic Growth - Moderate Government Expenditure.

H = High Economic Growth - Moderate Government Expenditure.

ME = Moderate Economic Growth - Moderate Government Expenditure with shift to electric space heat and appliances in residential sector.

3 - SCOPE OF WORK

3.1 - Objectives

As stated in the POS, this task has the following objectives:

- Critically review the work of ISER in forecasting electricity power consumption in the Railbelt.

- Reach a thorough understanding of the assumptions used by ISER in its work.

- Coordinate with ISER on electricity consumption forecasts required by Acres in its subsequent work.

3.2 - Approach

The approach that has been adopted in satisfying these objectives is straightforward. The approach is comprised of the following steps:

- Review ISER's forecasting methodology to develop a sound understanding of model structure, assumptions, and the data base.

- Evaluate ISER's methodology and identify issues that affect the efficacy of the projections.

- Assess the implications of these issues in projecting electricity power consumption for the Railbelt.

- Compare Railbelt electricity projections in recent years to posit ISER's forecasts and identify the basic differences between them.

These steps lead to understanding of the efficacy of the ISER projections so that subsequent tasks in the proposed Hydroelectric Power Project can proceed apace.

The work was undertaken by Acres through its subcontractor Woodward Clyde Consultants (WCC) and in close consultation with ISER and other Alaska agencies staff.

3.3 - Record of Events

A number of events took place during the execution of the Subtask which had significant impact on the outcome of the study. The major events are summarized below:

January 1, 1980	- Commencement of Susitna Hyroelectric Project.
January 7, 1980	- Meeting at ISER offices in Anchorage to discuss ISER approach to energy use forecasting. Attendees: Scott Goldsmith, Lee Huskey (ISER); Jim Landman (Acres); Craig Kirkwood (WCC).

February 15, 1980 - Meeting of Alaskan economists at ISER offices in Anchorage, to participate in discussions of the State's economic future.

February 20, 1980 - Meeting at WCC offices in San Francisco to exchange ideas on improvement of ISER methodology. Attendees: Craig Kirkwood, Perry Sioshansi, Gary Smith (WCC); Peter Sandor (Acres); Scott Goldsmith ISER).

March 14, 1980 - ISER releases draft report.

March 20 and 21, 1980 - Meeting at Acres' and ISER offices in Anchorage to discuss ISER draft report and possible improvements. Attendees: Jim Landman (part time), C.A. Debelius (part time), Peter Sandor (Acres); Scott Goldsmith (ISER); Robert Mohn (APA, part time).

April 1980 - Woodward-Clyde issues critique on ISER draft report.

April 14 and 16, 1980 - Meeting at ISER offices in Anchorage to discuss ISER draft findings. Attendees: C.A. Debelius, John Hayden, Jim Landman, John Lawrence (all part time), Songthara Omkar, Alex Vircol (Acres); Scott Goldsmith (ISER).

April 18, 1980 - Meeting at WCC offices in San Francisco to discuss ways of improving Subtask 1.01 work. Attendees: Jim Landman, Songthara Omkar, Alex Vircol (Acres); Craig Kirkwood, Perry Sioshansi, Gary Smith (part time) (WCC).

May and June, 1980 - ISER releases final report.

June, 1980 - Alaskan Legislature withdraws funding from Acres Susitna Hydroelectric Project study for power study work.

June 10, 1980 - Meeting held in APA offices in Anchorage with Railbelt utility managers and ISER to discuss ISER forecast.

June 11, 1980 - Public workshop held at Anchorage Community College for discussion of ISER forecast.

4 - CRITIQUE OF ISER MODEL

In this section a summary review and critique of ISER's forecasting methodology on future Railbelt electricity requirements is presented. The purpose is to address specific issues in the methodology that may have a significant impact on future electricity requirements in the Railbelt. The critique covers three main areas: model structure; database; and economic scenarios and model parameters. An assessment of the implications of the issues raised in the critique is also included. Critiques made by others will also be discussed.

4.1 - Model Structure

ISER's econometric end-use model is based on the proposition that energy is consumed to pursue human activities which are dependent on underlying economic conditions. ISER's model, therefore, begins with a projection of State employment, population and households (MAP and Household Formation Models). State projections are then regionalized to produce Railbelt projections (Regional Allocation Model). Railbelt projections of households and population are then input into the housing stock model to determine future housing stock and distribution by type. Finally, all economic projections together with end-use parameters are entered into the end-use models to forecast electricity consumption for residential space heating, residential nonspace heating, commercial-industrial-government requirements, and miscellaneous requirements in the Railbelt. A review of the ISER model is presented in Appendix A and illustrated diagrammatically in Figure A.1.

The basic structure of the model is quite logical and allows a delineation between economic models and electricity consumption models. The critique follows this delineation.

(a) Economic Models

Economic models in this context consist of the MAP, Household Formation, Regional Allocation and Housing Stock models. The present relationship between these models implies that the Regional Allocation Model and Househould Formation Model are both linked to the MAP Model and Housing Stock Model, but not to one another. This means that the Regional Allocation Model only regionalized the MAP projections of population and employment while future household formation is regionalized downstream in the Housing Stock Model. This is unnecessarily complicated and it would be simpler to regionalize households in the Regional Allocation Model. Hence this requires the Household Formation Model to be linked to the Regional Allocation Model and not the Housing Stock Model. Although this modification would lead to a more elegant structure, it would not necessarily improve the quality of the forecasts.

The structure of the individual economic models deserves some comment. The MAP model is probably the best macroeconomic model available in Alaska at this time and hence its use is highly appropriate. The remaining economic models are developed specifically for the task at hand and these are simple and practical models. For example, the Household Formation Model is an accounting model which is driven by assumed household formation rates, while the Regional Allocation Model is a regional shares model which reflects the comparative advantage and scale of the regional economy. In the Housing Stock Model a stock adjustment procedure is employed which is driven by scrappage rates, vacancy rates, and housing choice. Scrappage rates and vacancy rates are assumed to follow the national trend while housing choice is a function of family size and age of household head in the region.

Because of the simplicity of these models, the question arises whether those other than the MAP model sufficiently explain the variation in the endogenous variables and whether more underlying economic factors should be incorporated. One way of investigating this is to review the statistical performance of those models that were subject to statistical estimation. The Regional Allocation Model and Housing Stock Model were two such models and the results obtained by the former satisfied most statistical criteria while the latter did not. Specifically, the housing choice equations of the Housing Stock Model gave poor explanatory power. Nevertheless the independent variables such as family size and age of household head were statistically significant in some cases. A respecification of housing choice equations employing housing income and family size variables, might be more appropriate and lead to statistically valid results. In the case of the Household Formation Model no statistical estimation was conducted as this is an accounting model based on assumed household formation rates.

(b) End-Use Models

The end-use models have six components:

- Residential Nonspace Heating Electricity Requirements.
- Residential Space Heating Electricity Requirements.
- Commercial-Industrial-Government Electricity Requirements.
- Miscellaneous Electricity Sales.
- Military Net Generation.
- Self-supplied Industry Net Generation.

The present relationship between economic models and end-use models is that economic models would predict the basic consumption units such as household, housing stock and employees, for input into electricity end-use models. The structure at present implies a direct linkage from economic projections to electricity requirements, hence bypassing the development of a total energy demand component by end-use sectors and the splitting of energy demand by fuel type. The drawback with such an approach is that it does not allow an explicit investigation of interfuel substitution for various end-use sectors which can take place because of technological considerations, price changes, or government energy policies. These are crucial factors in determining future energy demand by fuel type, particularly in the long run.

The first four models listed above forecast total utility sales for the Railbelt, while the two remaining models forecast self-supplied electricity requirements. In discussing these individual models, the focus will be on sales models.

(i) Residential Nonspace Heating Electricity Requirements

This sector in 1978 consumed 635,000 MWh which accounted for 29 percent of total electricity sales in the Railbelt. To forecast how much electricity this sector will consume in future years, a detailed end-use model was developed. The model disaggregates household appliances into water heaters, clothes dryers, refrigerators, etc, and the electricity requirement for each type of appliance is calculated as a function of households, appliance saturation rate, fuel mode split, average annual consumption and household size. Several of these variables such as the appliance saturation rate and fuel mode split have economic content and require an analysis of consumer preferences. This is important in order to understand future changes. However, this has not been done in any explicit way.

(ii) Residential Space Heating Electricity Requirements

In 1978, residential space heating in the Railbelt consumed 395,000 MWh. This represents 18 percent of total utililty sales in the Railbelt. Future electricity requirements for residential space heating are projected by an end-use model which is disaggregated into housing types such as single family, duplex, multi-family, etc. Electricity space heating requirements for each housing type are determined as a function of number of housing units, fuel mode split and average consumption levels. This model is therefore quite detailed. Again, several of these factors have economic content, particularly fuel mode split, but the model does not incorporate them in any explicit way. Hence, this model is more of an engineering end-use model.

(iii) Commercial-Industrial-Government Electricity Requirement

Electricity consumption in this sector amounted to 1,156 MWh in 1978 or 52 percent of Railbelt utility sales. This is a large end-use sector compared to 29 percent for residential nonspace heating and 19 percent for residential space heating. However, the model employed to forecast future electricity requirements for this sector is simply a function of nonagricultural wage and salary employment and average electricity consumption per employee. Future levels of employment are obtained through the economic models while average electricity consumption per employee is calculated as a function of time and energy conservation standards of new buildings.

This model is highly simplified and is not a true end-use model. It does not distinguish between space heating and nonspace heating, nor does it differentiate between various types of buildings (e.g. shopping plazas, office buildings, institutional buildings, industrial facilities, etc.) which have heterogeneous electricity requirements. A number of reasons warrant a departure from the existing structure to a more detailed structure. First, the electricity consumption per employee variable as presently defined, assumes a homogeneous electricity consumption pattern for commercial, industrial and government sectors while in reality the intensity of electricity usage varies substantially between sectors and type of buildings. Second, future employment grows at different rates for different economic sectors with different electricity intensities, thus rendering the use of an average electricity consumption per employee highly restrictive. Third, an end-use sector such as this which accounts for 52 percent of Railbelt utility sales warrants a more rigorous analysis with a greater level of disaggregation of end-uses.

(iv) Miscellaneous Electricity Requirements

This is a small component of Railbelt electricity consumption which accounted for about 1 percent in 1978. The model is disaggregated into street lighting and recreational home electricity requirements. Street lighting is calculated as a fixed percentage of future residential and commercial-industrial-government requirements while recreational home is calculated as a function of household electricity consumption and a proportion of households. Because it is a small component, the model does not require a detailed structure.

4.2 - Database

In general an EEU model requires a large data base for calibration. The data base must have a sufficiently long time series with information at a micro level. In this section some observations are made on the data base used for calibrating the ISER model.

(a) Economic and Demographic Data

This refers to all of the data required to calibrate the economic models. The MAP Model, which is a moderately detailed econometric model of the Alaskan economy, is run on time series data. The data series, however, is limited in length but the statistical results of the estimated equations are adequate by conventional statistical criteria. The Household Formation Model is an accounting model based on Alaskan household formation rates derived from the 1970 census with yearly changes to these rates keyed to future national trends prepared by the Bureau of the Census. The Regional Allocation Model employs pooled time series cross section data based on Alaska labor divisions from 1965 to 1976 to capture the effect of time and structural differences in the regional economy. The Housing Stock Model requires more substantive data because of the larger number of variables. Future housing vacancy rates and removal rates are assumed to follow national trends; an additional set of vacancy rates was also used to represent maximum rates based on the Anchorage Real Estate Report, 1979. Data for housing choice equations were based on the 1978 survey of Anchorage population conducted by the Urban Observatory of the University of Alaska.

It is therefore apparent that only the MAP and Regional Allocation Models were run on time series data. The Household Formation and Housing Stock Models were run on data based on assumptions keyed to national trends or cross section data for a specific year. There is a need to collect more Alaskan data covering a longer historical period for calibration so that the robustness of the models can be ascertained.

(b) End-Use Model Data

The database required to run end-use models is extensive. A large number of parameters such as appliance saturation rates, fuel mode split, electricity consumption levels, etc. were included. To obtain the current values for most of these parameters, calculations were performed with data from a variety of sources. These sources include utility authorities, the Alaskan Census of housing statistics, studies conducted elsewhere, etc. Some of the data used covered a sufficiently long historical period (e.g. utility sales) while others were older data covering a shorter period (i.e. 1960 and 1979 Census of Housing, Detailed Housing Characteristics: Alaska). There is indeed a paucity of data especially at the micro level, to calibrate the end-use models. Little can be done at this point, except to make reasonable assumptions for the models.

4.3 - Economic Scenarios

Three economic growth scenarios and three state government expenditure scenarios were formulated to provide a total of nine scenarios. Economic growth scenarios and state government scenarios are addressed separately below.

(a) Economic Growth Scenarios

Three alternative futures of basic sector industry growth were formulated to represent high, moderate and low scenarios. These were based on different assumptions concerning future employment and output of basic sector industries. It is useful to understand the nature of these scenarios by examining the timing and growth of basic sector industries.

The assumed growth of basic sector industries for the three scenarios are illustrated on an industry-by-industry basis in Figures 4.1 to 4.3. By comparing between figures, the relative rate of development for each industry for the different growth scenarios can be inspected. Basic sector industry employment are also consolidated for the high, moderate and low scenarios and illustrated in Figure 4.4. It is evident from these figures that the economic development is assumed to take place mainly during 1980 to 1985 and thereafter grow more slowly to 2000.

Annual growth rates of total exogenous employment for these scenarios are also calculated at 5-year intervals and shown in Figure 4.4. These growth rates illustrate more clearly the bunching of special projects and economic events during 1980 to 1985. This is most conspicuous for the high scenario which has an annual growth rate of 5.4 percent during this period. This is followed by a decline until the period of 1990 to 1995 when economic growth increases again, particularly in the moderate and high scenarios when Outer Continental Shelf Petroleum development takes place. The period 1995 to 2000 experiences a decline.

It is clear that these scenarios do not depict two other possibilities: stable industrial growth in the State, and economic depression in the State. These two scenarios warrant inclusion to the existing set, so that the alternative economic futures of Alaska are bounded consistently. In formulating these scenarios, it is possible that the stable industrial growth scenario should at least include a "special project" to supply the State energy base (such as the Susitna Hydroelectric Project or other alternative[s]) together with a stable expansion of the industrial base. On the other hand, the depression scenario could depict an economic contraction of the Alaskan economy.

(b) State Government Expenditure Scenarios

Three State government expenditure levels were defined to represent high, moderate and low scenarios. These scenarios assume that real per capita expenditure consume a growing, constant, and declining proportion of real per capita income. All scenarios lead to a positive fund balance for the State by year 2000, with the lowest level at $48.8 billion (current dollars) for the high economic growth and high government expenditure scenario. Although the State is currently legislativly bound to retain a fixed proportion of oil royalties in this fund, it is reasonable to expect that this legislation may be altered in the future to have some limit on the total amount retained.

(c) Scenarios for Model Runs

Although nine economic scenarios were defined, not all were run through the entire model. The MAP and Household Formation Models were run on all nine scenarios. However, the Regional Allocation Model and the end-use models were run on only three economic scenarios. These scenarios are those with the moderate State Government expenditure and the alternative economic growth scenarios. The reason given is that these were the more likely scenarios. It is difficult to rationalize why this course of action was chosen. At the very least the upper and lower bounds of the nine scenarios should have been included so that the full range of forecasts can be defined.

4.4 - Model Parameters

(a) Fuel mode Split

This parameter is defined as the proportion of appliances using a particular energy fuel in the ISER model. Current values of this parameter were estimated from the 1960 and 1970 Alaskan Census of housing data and information from utility, home construction and real estate personnel. Future values were estimated in increments -- that is, fuel mode split for new appliances coming into the stock -- based on assumptions reflecting past trends observed in 1960 and 1970, and future preferences for electric appliances. However, in reality, the future fuel mode split will be influenced by relative prices of fuels, relative prices of appliances, consumer tastes, etc. The methods employed have not made these factors explicit.

In the case of relative fuel prices, it has been implied that the current price of electricity relative to other fuels will remain in effect throughout the forecasting period. An alternative to this scenario was also formulated whereby a price induced shift toward electricity would take place. Neither of these assumptions are considered adequate for forecasting future electricity consumption. Relative fuel prices play a crucial role in interfuel substitution and consumer purchase decisions, and therefore must be analyzed explicity. The analysis must provide a better understanding of the prices and availability of fuels that could compete with electricity in end-use applications.

(b) Other End-Use Parameters

These include a large number of parameters such as appliance saturation rates, appliance size, appliance electricity consumption rates, etc. In calculating the future values of these parameters, a number of assumptions were made. These assumptions are important as the end-use models are driven by them. However, no analysis was conducted to determine whether the electricity forecasts were sensitive to these assumptions. Some sensitivity analysis is warranted to provide an understanding of the sensitivities involved.

4.5 - Implications of Model Limitations

In this section, the limitations that have been pointed out above are assessed. Some of these limitations will have significant implications on the forecast, while others are difficult to assess without a thorough investigation. For those limitations that can be assessed at the present time, the implications will be expressed in terms of directional change of electricity forecasts.

(a) Economic Scenarios

There are three problems associated with economic scenarios:

- The Upper Bound (High Economic Growth and High Government Expenditure) and Lower Bound (Low Economic Growth and Low Government Expenditure) of scenario sets were not run.

- The existing scenario set does not incorporate alternative futures depicting stable industrial growth and economic depression.

- The future State Government expenditure for the high scenario is not sufficiently high.

(i) Upper and Lower Bound Limitations

To assess the impact of the upper and lower bounds of the existing scenario set, estimates of electricity consumption for these scenarios have been prepared. These estimates were calculated by the following steps:

- Regionalize future State projections of employment, households and housing stock (Tables 4.1 to 4.3).

- Calculate future electricity requirements per consumption unit for residential space heating, residential non space heating, and commercial-industrial-government electricity requirements (Tables 4.4 to 4.6)

- Multiply future electricity requirements per consumption unit for residential space heating, residential non space heating, and commercial-industrial-government electricity requirements (Table 4.4 to 4.6)

- Multiply the sum of residential electricity requirements and commercial-industrial-government electricity requirements by a fixed percentage to obtain miscellaneous utility sales (Table 4.7).

- Sum all end-use components to obtain future utility sales (Table 4.7).

These estimates, which are approximations of the upper and lower bounds of the scenario set, indicate a wider range of alternative utility sales than those developed by ISER. Figure 4.5 illustrates these differences graphically.

(ii) Economic Growth Scenario Alternatives

The second problem is associated with the formulation of economic growth scenarios. All of these scenarios indicate a relatively rapid increase in economic growth during the period 1980 to 1985 followed by a much slower growth thereafter. However, none represent the two possible extreme economic futures in which future industrialization occurs with greater expansion of energy intensive industries to tap the State's vast energy resources or that of a gloomy future with economic contraction.

Treatment of these futures is essential so that the implications for electricity generation planning can properly be assessed. It is possible to deduce what the impact on utility sales will be for these extreme futures. The industrialization case will lead to greater economic growth and hence drive up future utility sales to a level higher than the existing upper bound. In the other extreme, an economic contraction will depress future utility sales to a level lower than the existing lower bound.

(iii) Future State Government Expenditures

The assumption on future State Government expenditures also warrants a reexamination. At present, the high State Government expenditure and high economic growth scenario gives a fund balance of $48.8 billion (current dollars) in the year 2000, which is the lowest of all scenarios. This is a large surplus which indicates that the State Government could still increase its expenditure substantially. Admittedly, this is largely a matter of government policy and hence difficult to predict. However, this is well within the realm of possibility and should be included so that the range of alternative futures can be ascertained. The implication of a higher State Government expenditure is that the econometric end-use model will produce higher electricity sales forecasts.

(b) Model Structure

Although a number of problems on model structure have been identified, the most serious lies with the commercial-industrial-government component. Currently, this is an aggregate consumption model which combines the three sectors together. It would be far more meaningful and sensible to disaggregate into individual sectors and relate electricity requirements to square footage per employee. The main reason for such a disaggregation is that the degrees of energy intensiveness between different sectors are widely different. Even in the industrial sector, energy intensiveness varies according to specific industries, e.g. the aluminum industry is highly electricity intensive compared to forestry or fisheries. This approach is warranted even if it means collecting some original data. About 52 percent of current electricity sales is attributed to this component and hence greater effort is required. At present it is not possible to deduce whether a more detailed approach would lead to higher or lower forecasts, but the need for such efforts is clearly required.

(c) Fuel Mode Split

Two crucial but interrelated factors affecting the fuel mode split, are relative prices and the availability of fuel. The concept of opportunity cost could be applied to determine future fuel prices and hence lead to a better understanding of consumer preferences on alternative fuels. At present, the future values of the fuel mode split are predicated on two assumptions: that existing relative prices of fuels will continue into the future, and a shift towards electricity will occur because electricity will become relatively inexpensive. These assumptions need to be tested through such an analysis. If it is found that electricity prices are less expensive than other competing fuels, then the fuel mode split for electricity will shift upwards and drive electricity sales to higher levels. If the relative price of electricity is higher, then future electricity sales will be lower. It is not possible to predict which event will occur in the absence of a thorough analysis, but it is clear what the alternative directional changes could be.

(d) Other Model Parameters

A large number of parameters employed in the electricity end-use and electricity aggregate consumption models are engineering end-use data. Others such as appliance saturation rates and utilization rates have economic content. Since the values of these parameters were based on assumptions derived from a limited data base, the degree of certainty that can be attached to these values is difficult to ascertain. At a minimum, a detailed sensitivity analysis should have been conducted based on alternative assumptions. Alternatively, a more rigorous approach could be adopted in which these parameter values are statistically estimated with microdata on price, income, temperature, etc. Without further analyses it is not possible at this time to state what the implications will be in regard to future electricity consumption.

(e) Data Base

In general, there is a paucity of data in Alaska to adequately calibrate an econometric end-use model of electricity power consumption. The problem is most acute in the household formation, housing stock, and end-use models. The quality of the data base will improve with time, as the time series lengthens and more data is accumulated at the micro level. For the present, sound judgement on assumptions and sensitivity analysis are the only tools available to counter this problem.

4.6 - Critiques by Others

Apart from the foregoing, a number of critiques on the ISER forecasts have also been made by individuals and agencies which are involved in one way or another in the future growth of electrical demand in the Railbelt. Copies of these critiques are attached as Appendices B through F to this report. The sources of these critiques are:

- the Alaska Pacific Bank
- Woodward-Clyde Consultants
- Energy Probe
- Golden Valley Electric Association
- Alaska Rural Electric Cooperative Association
- Anchorage Municipal Electric Light & Power
- Public issues raised during workshops

The points raised in these critiques are many and varied. Although each critique differs somewhat in perspective, two main points emerge which essentially support the finding of the Acres review:

- the ISER model has certain deficiencies which require resolution

- the range of ISER forecasts is not sufficiently wide.

TABLE 4.1: RAILBELT EMPLOYMENT ESTIMATES FOR LOWER AND UPPER BOUNDS(10^3)

LOWER BOUND[1]

Year	Low Economic Growth - Moderate Government Expenditure State (1)	Railbelt (2)	Ratio (3) = (2)÷(1)	Low Economic Growth - Low Government Expenditure State (4)	Railbelt (5) = (3)x(4)
1980	210	133	.63	210	133
1985	243	150	.62	230	143
1990	254	157	.62	238	147
1995	287	180	.63	259	163
2000	332	209	.63	287	180
2005	-	220	-	-	189
2010	-	230	-	-	199

UPPER BOUND[2]

Year	High Economic Growth - Moderate Government Expenditure State (1)	Railbelt (2)	Ratio (3) = (2)÷(1)	High Economic Growth - High Government Expenditure State (4)	Railbelt (5) = (3)x(4)
1980	210	133	.63	210	133
1985	293	183	.63	304	191
1990	330	203	.62	354	219
1995	404	249	.62	445	276
2000	454	285	.63	510	321
2005	-	334	-	-	390
2010	-	393	-	-	475

(1) For 2000 and beyond, estimates based on 1 percent annual growth rate

(2) For 2000 and beyond, estimates based on 4 percent annual growth rate

TABLE 4.2: ESTIMATING RAILBELT HOUSEHOLDS FOR LOWER AND UPPER BOUNDS (10^3)

LOWER BOUND[1]

Year	Low Economic Growth - Moderate Government Expenditure			Low Economic Growth - Low Government Expenditure	
	State (1)	Railbelt (2)	Ratio (3) = (2)÷(1)	State (4)	Railbelt (5) = (3)x(4)
1980	133	87	.65	133	87
1985	158	108	.68	153	104
1990	174	122	.69	167	115
1995	200	138	.69	186	128
2000	235	163	.69	211	146
2005	-	171	-	-	153
2010	-	179	-	-	161

UPPER BOUND[2]

Year	High Economic Growth - Moderate Government Expenditure			High Economic Growth - High Government Expenditure	
	State (1)	Railbelt (2)	Ratio (3) = (2)÷(1)	State (4)	Railbelt (5) = (3)x(4)
1980	133	87	.65	133	87
1985	175	116	.66	179	118
1990	210	141	.67	221	148
1995	262	177	.67	282	189
2000	312	212	.68	343	233
2005	-	249	-	-	283
2010	-	294	-	-	345

(1) For 2000 and beyond, estimates based on 1 percent annual growth rate

(2) For 2000 and beyond, estimates based on 4 percent annual growth rate

TABLE 4.3: RAILBELT HOUSING STOCK ESTIMATES FOR LOWER AND UPPER BOUNDS(10^3)

LOWER BOUND

Year	Low Economic Growth - Moderate Government Expenditure			Low Economic Growth - Low Government Expenditure	
	Railbelt Households (1)	Railbelt Housing Stock (2)	Ratio (3) = (1)÷(2)	Railbelt Households (4)	Railbelt Housing Stock (5) = (4)÷(s)
1980	87	90	.96	87	90
1985	108	108	1.0	104	104
1990	121	117	1.034	115	111
1995	138	138	1.0	128	128
2000	171	171	1.0	153	153
2005	171	171	1.0	153	153
2010	179	178	1.0	161	161

UPPER BOUND

Year	High Economic Growth - Moderate Government Expenditure			High Economic Growth - High Government Expenditure	
	Railbelt Households (1)	Railbelt Housing Stock (2)	Ratio (3) = (1)÷(2)	Railbelt Households (4)	Railbelt Housing Stock (5) = (4)÷(3)
1980	87	90	.96	87	90
1985	116	116	1.0	118	118
1990	141	141	1.0	148	148
1995	177	177	1.0	189	189
2000	212	213	1.0	233	233
2005	249	249	1.0	283	283
2010	294	296	.99	345	348

TABLE 4.4: RAILBELT RESIDENTIAL NONSPACE HEATING ELECTRICITY ESTIMATES FOR LOWER AND UPPER BOUNDS

LOWER BOUND

	Low Economic Growth - Moderate Government Expenditure			Low Economic Growth - Low Government Expenditure	
Year	Households (10^3) (1)	Electricity Req. (10^3 MWh) (2)	Electricity Req./Household (10^3 MWh) (3) = (2)÷(1)	Households (10^3) (4)	Electricity Req. (10^3 MWh) (5) = (4)÷(3)
1980	87	671	7.71	87	671
1985	108	826	7.65	104	796
1990	122	950	7.78	115	895
1995	138	1136	8.23	128	1054
2000	163	1404	8.61	146	1258
2005	171	1553	9.08	153	1389
2010	179	1711	9.55	161	1538

UPPER BOUND

	High Economic Growth - Moderate Government Expenditure			High Economic Growth - High Government Expenditure	
Year	Households (10^3) (1)	Electricity Req. (10^3 MWh) (2)	Electricity Req./Household (10^3 MWh) (3) = (2)÷(1)	Households (10^3) (4)	Electricity reg. (10^3 MWh) (5) = (4)÷(3)
1980	87	671	7.71	87	671
1985	116	913	7.87	118	929
1990	141	195	7.20	148	1065
1995	177	1478	8.35	189	1578
2000	212	1851	8.73	233	2034
2005	249	2282	9.16	283	2592
2010	294	2835	9.64	345	3326

TABLE 4.5: RAILBELT RESIDENTIAL SPACE HEATING ELECTRICITY ESTIMATES FOR LOWER AND UPPER BOUNDS

LOWER BOUND

	Low Economic Growth - Moderate Government Expenditure			Low Economic Growth - Low Government Expenditure	
Year	Housing Stock (10^3) (1)	Electricity Req. (10^3 MWh) (2)	Electricity Req./Housing Unit (10^3 MWh) (3) = (2)÷(1)	Housing Stock (10^3) (4)	Electricity Req. (10^3 MWh) (5) = (4)x(3)
1980	90	446	4.95	90	446
1985	108	524	4.85	104	505
1990	117	583	4.98	111	553
1995	138	680	4.93	128	631
2000	161	841	5.22	144	752
2005	171	917	5.36	153	820
2010	178	995	5.59	161	900

UPPER BOUND

	High Economic Growth - Moderate Government Expenditure			High Economic Growth - High Government Expenditure	
Year	Housing Stock (10^3) (1)	Electricity Req. (10^3 MWh) (2)	Electricity Req./Housing Unit (10^3 MWh) (3) = (2)÷(1)	Housing Stock (10^3) (4)	Electricity Req. (10^3 MWh) (5) = (4)x(3)
1980	90	446	4.95	90	446
1985	110	569	5.17	118	610
1990	141	686	4.86	148	720
1995	177	881	4.98	189	941
2000	213	1104	5.18	233	1208
2005	249	1350	5.42	283	1534
2010	296	1646	5.56	345	1918

TABLE 4.6: COMMERCIAL-INDUSTRIAL GOVERNMENT ELECTRICITY ESTIMATES FOR LOWER AND UPPER BOUNDS

LOWER BOUND

Year	Low Economic Growth - Moderate Government Expenditure			Low Economic Growth - Low Government Expenditure	
	Employment (10^3) (1)	Electricity Req. (10^3 MWh) (2)	Electricity Req./Employee (10^3 MWh) (3) = (2)÷(1)	Employment (10^3) (4)	Electricity Req. (10^3 MWh) (5) = (4)x(3)
1980	133	1248	9.38	133	1248
1985	150	1541	10.27	143	1469
1990	157	1670	10.64	147	1563
1995	180	2119	11.77	163	1919
2000	209	2803	13.41	180	2414
2005	220	3089	14.04	189	2654
2010	230	3410	14.83	199	2950

UPPER BOUND

Year	High Economic Growth - Moderate Government Expenditure			High Economic Growth - High Government Expenditure	
	Employment (10^3) (1)	Electricity Req. (10^3 MWh) (2)	Electricity Req./Employee (10^3 MWh) (3) = (2)÷(1)	Employment (10^3) (4)	Electricity Req. (10^3 MWh) (5) = (4)x(3)
1980	133	1248	9.38	133	1248
1985	183	2042	11.16	191	2131
1990	203	2423	11.93	219	2614
1995	249	3370	13.53	276	3735
2000	285	4163	14.61	321	4689
2005	334	5451	16.32	390	6365
2010	393	7136	18.16	475	8626

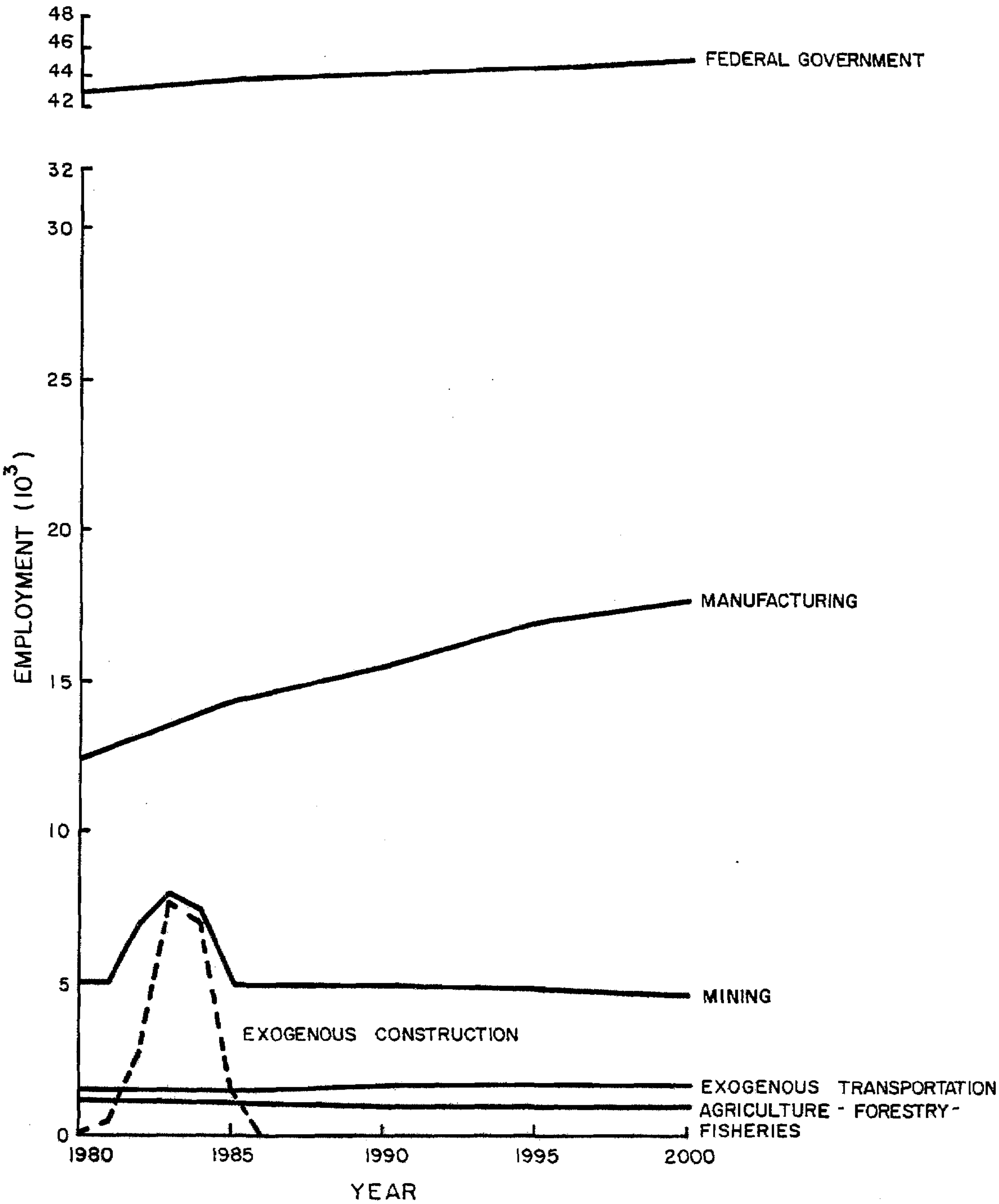
TABLE 4.7: RAILBELT UTILITY SALES ESTIMATES FOR LOWER AND UPPER BOUNDS (10^3 MWh)

LOWER BOUND

Year	Residential Nonspace Heating (1)	Residential Space Heating (2)	Commercial-Industrial - Government Reg. (3)	Miscellaneous Reg. (4)=[(1)+(2)+(3)]x.01	Total Utility Sales (5)=(1)+(2)+(3)+(4)
1980	671	446	1248	24	2389
1985	796	505	1469	28	2798
1990	895	553	1563	30	3041
1995	1054	631	1919	36	3640
2000	1258	752	2414	44	4468
2005	1389	820	2654	49	4912
2010	1538	900	2950	54	5442

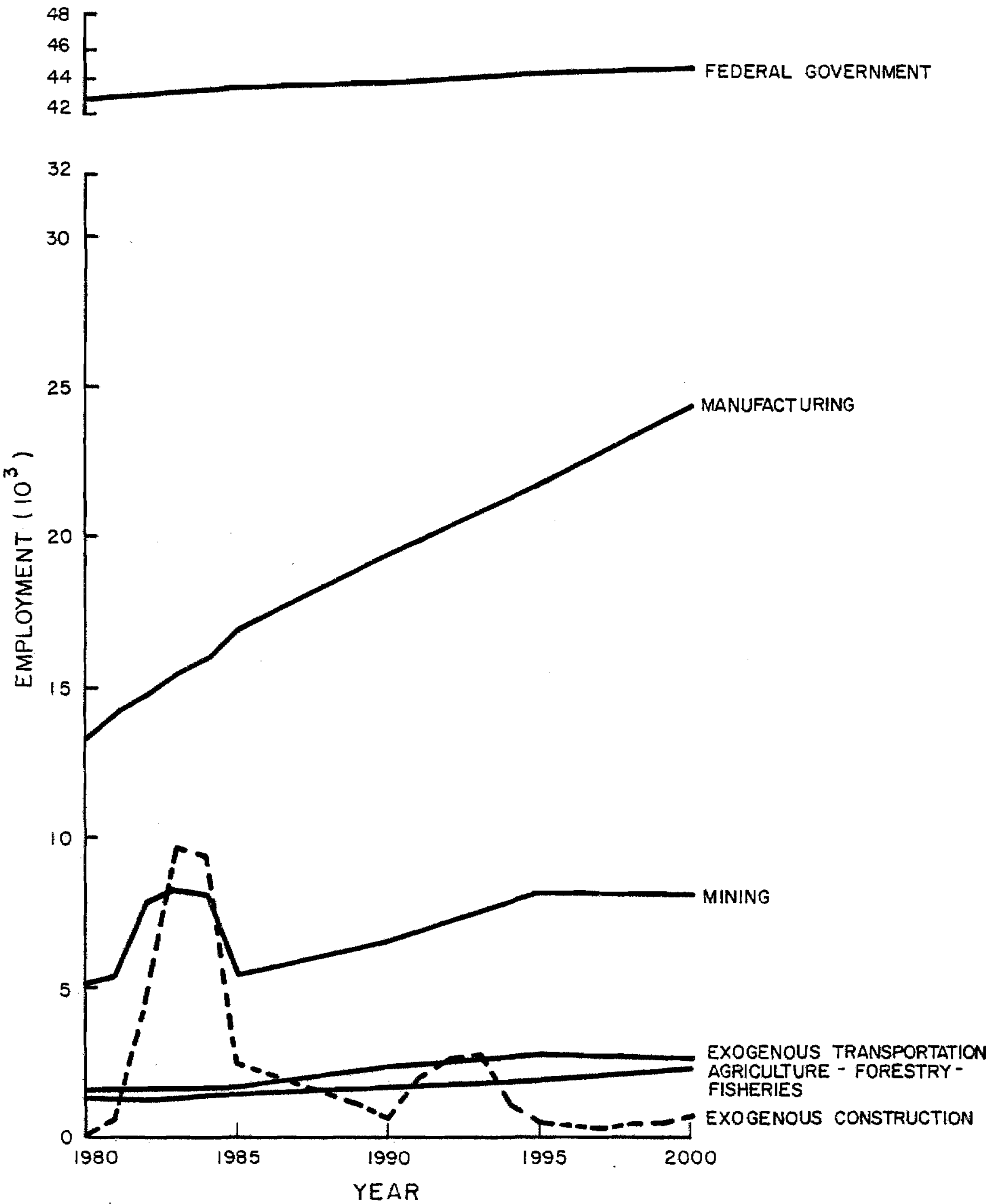
UPPER BOUND

Year	Residential Nonspace Heating (1)	Residential Space Heating (2)	Commercial-Industrial - Government Reg. (3)	Miscellaneous Reg. (4)=[(1)+(2)+(3)]x.01	Total Utility Sales (5)=(1)+(2)+(3)+(4)
1980	671	446	1248	24	2389
1985	929	610	2131	37	3707
1990	1065	720	2614	44	4443
1995	1578	941	3735	63	6317
2000	2034	1208	4689	79	8010
2005	2592	1534	6365	105	1059
2010	3329	1918	8626	139	14009



LOW ECONOMIC GROWTH EMPLOYMENT SCENARIOS

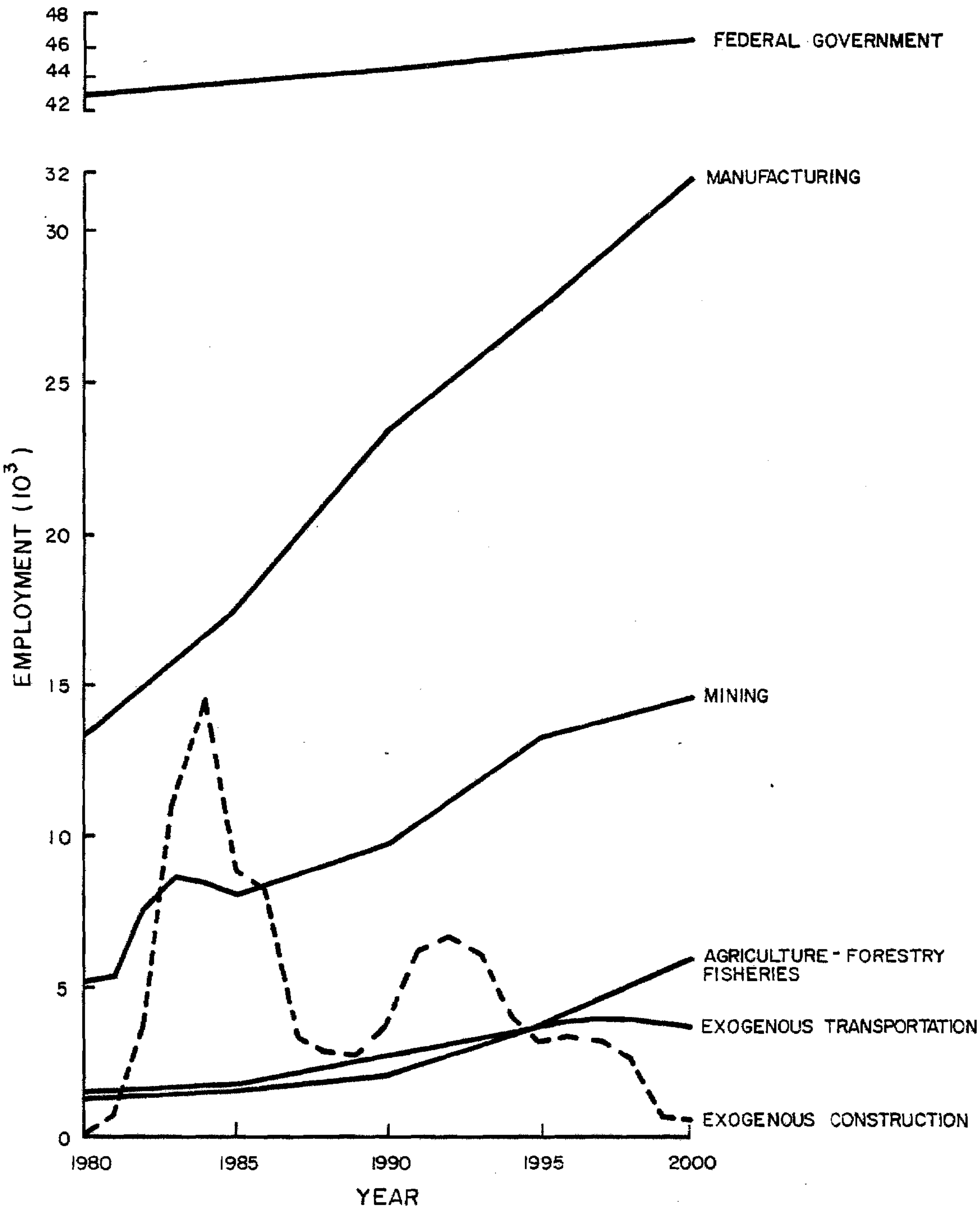
FIGURE 4.1



MODERATE ECONOMIC GROWTH EMPLOYMENT SCENARIOS

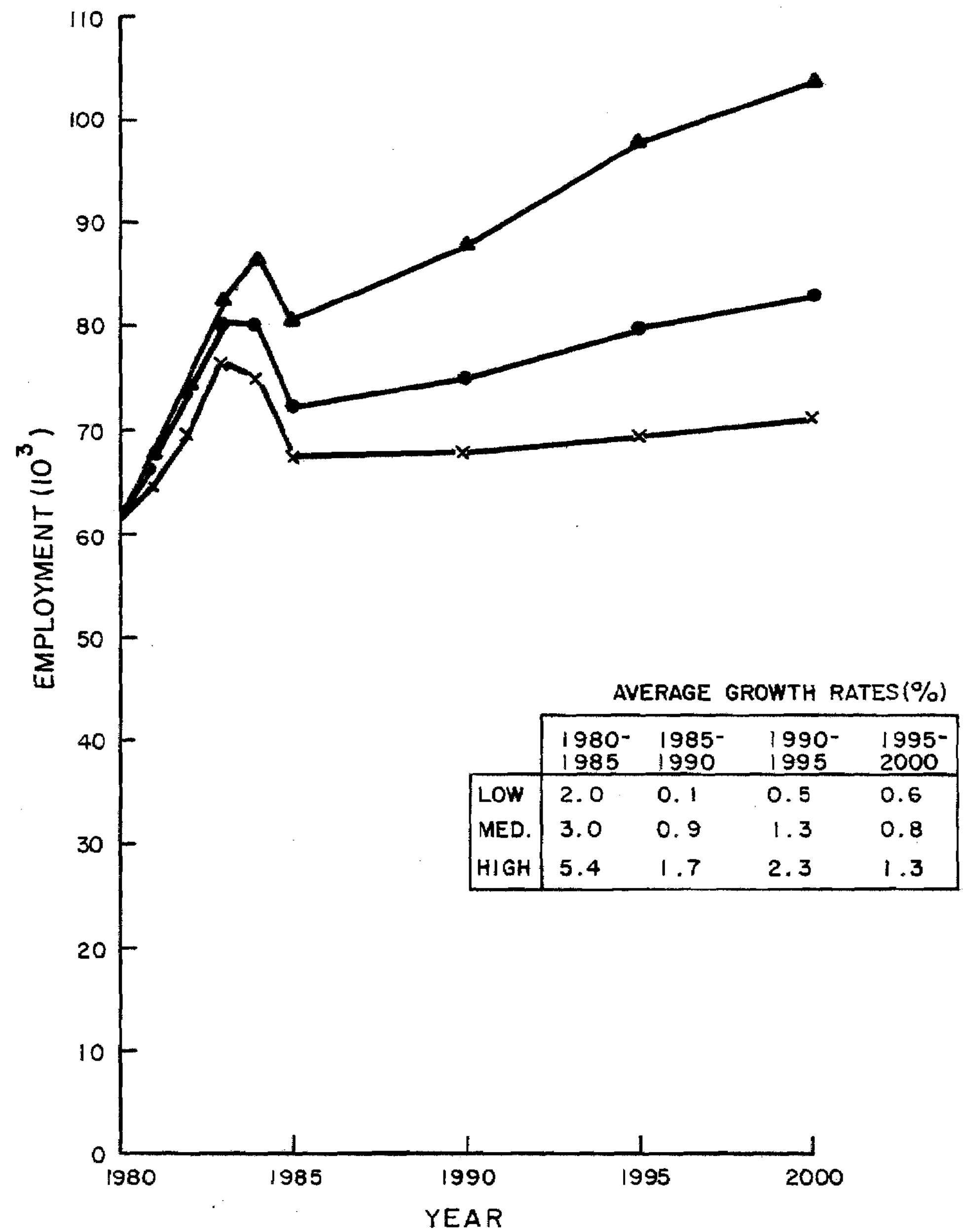
ACRES

FIGURE 4.2



HIGH ECONOMIC GROWTH EMPLOYMENT SCENARIOS

FIGURE 4.3

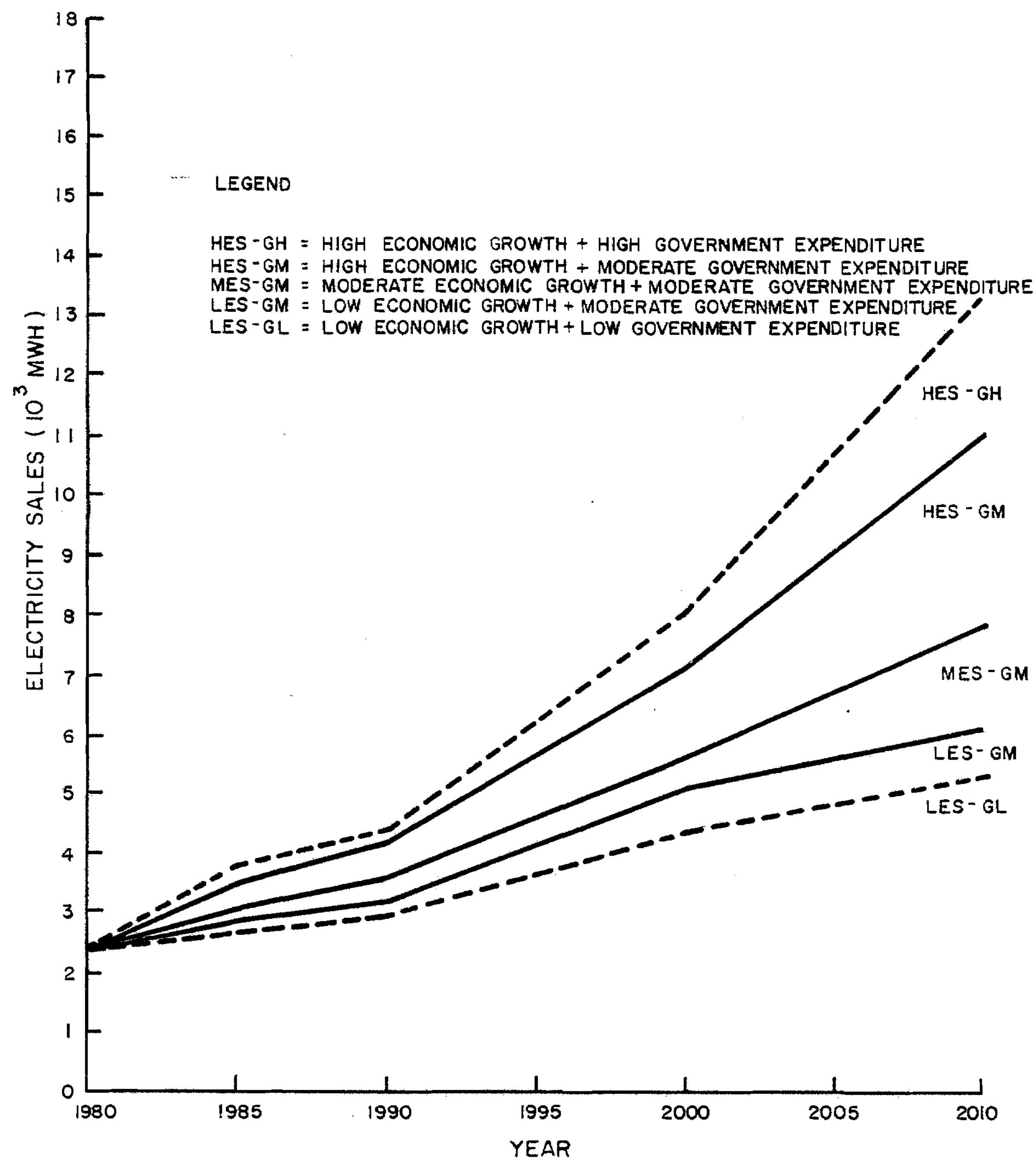


AVERAGE GROWTH RATES(%)

	1980-1985	1985-1990	1990-1995	1995-2000
LOW	2.0	0.1	0.5	0.6
MED.	3.0	0.9	1.3	0.8
HIGH	5.4	1.7	2.3	1.3

TOTAL EXOGENOUS EMPLOYMENT SCENARIOS

FIGURE 4.4



ALTERNATIVE UTILITY SALES FORECASTS

FIGURE 4.5

5 - COMPARISON OF RAILBELT ELECTRICITY CONSUMPTION FORECASTS

In this section electricity consumption forecasts developed for the Railbelt in recent years are reviewed. These reviews will be brief and include a comparison of forecasts. The purpose is to compare ISER's forecasts with previous work and to understand some of the factors that cause basic differences between them.

5.1 - Recent Forecasts

Electricity consumption forecasts developed since 1975 are reviewed briefly below:

(a) Southcentral Railbelt area, Alaska: Interim Feasibility Report: Hydroelectric Power and Related Purposes for the Upper Susitna River Basin, Alaska District Corps of Engineers, Department of the Army, 1975.

This study is an update of a previous Alaska Power Administration report* with some changes in assumptions which result in a lower demand projection. In this study, only the Railbelt was analyzed and hence the Southcentral and Yukon regions defined in the previous study were exluded. The most significant change is a reduction in the projected industrial load. A population growth rate of 3 percent annually was assumed in the study, resulting in estimates of 410,000 in 1980 and rising to 740,000 in 2000. Projections of load growth are shown in Table 5.1

(b) Electric Power in Alaska, 1976-1995, Institute of Economic and Social Research, University of Alaska, 1976.

This study forecasted electricity requirements for Alaska based on a model of the State economy and detailed assumptions concerning customer growth and average consumption rates. Two sets of economic assumptions and four set of electricity use assumptions were employed. Economic assumptions were based on 3.4 percent and 4.8 percent population growth. Military electricity requirements were assumed to remain constant over time while self-supplied industrial requirements were not forecasted. The range of utility sales is shown in Table 5.2.

(c) Alaskan Electric Power: An Analysis of Future Requirements and Supply Alternatives for the Railbelt Region, Battelle Pacific Northwest Laboratories for Alaska Division of Energy and Power Development and the Alaskan Power Authority, 1978.

This study did not conduct an analysis of load growth but instead based its forecasts on earlier studies, including those of ISER, Alaska Power Administration and several Railbelt utilities. Industrial scenarios were modified to reflect developments at the time. The resulting projections are shown in Table 5.3.

* 1974 Alaska Power Survey, U.S. Department of Interior, Alaska Power Administration, 1974.

(d) Upper Susitna River Project Market Analyses, U.S. Department of Energy, Alaska Power Administration, 1979

This study is a continuation of the previous work done by the Alaska Power Administration. Electricity power consumption was projected for utility, military, and self-supplied industry sectors. Utility requirements were projected on the basis of population estimates (provided by ISER econometric and demographic models) and average annual consumption per capita estimates. Future annual consumption per capita were assumed to decline because of conservation measures, appliance saturation, etc. Three different growth rates were used to represent this trend. Future population estimates were based on high and low growth.

Military requirements were projected on the basis of assumptions representing high, moderate and low growth. The growth rates of +1%, 0% and -1% were used to represent high, moderate and low growth respectively.

The self-supplied industrial load projections were based upon earlier work by Battelle and the Alaska Power Administration.

The results are summarized in Table 5.4.

5.2 - Comparison of Forecasts

A comparison of these recent projections is shown in Table 5.5. These figures are extracted from ISER's recent study. Using 1980 as the base year for comparison, it can be seen that all of the previous forecasts were significantly in excess of the actual 1980 demand.

5.3 - Differences between Current ISER Forecasts and Previous Forecasts

The growth rates of the current ISER forecasts are significantly lower than previous forecasts. The differences are mainly attributed to assumptions concerning economic growth and electricity consumption rates.

Differences in economic growth among the various studies have given rise to widely different economic projections. These differences are mainly due to inconsistent assumptions on the type, size and timing of projects and other economic events. In general, the present ISER projection of economic activities is lower than previous studies.

Differences in electricity consumption projections are mainly due to different assumptions on per capita consumption growth rate. The present ISER study has generally lower growth rate assumptions because of explicit estimates of saturation, end-use patterns and conservation measures.

TABLE 5.1: ALASKA POWER ADMINISTRATION FORECASTS, 1975

Type of Load	Actual Requirements				Estimated Future Requirements			
	1974		1980		1990		2000	
Area	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh
Utilities			High Rate of Growth					
Anchorage	284	1,305	650	2,850	1,570	6,880	4,430	15,020
Fairbanks	83	330	160	700	380	1,660	800	3,500
Total	367	1,635	810	3,550	1,950	8,540	4,230	18,520
			Likely Mid-Range Growth					
Anchorage			590	2,580	1,190	5,210	2,150	9,420
Fairbanks			150	660	290	1,270	510	2,230
Total			740	3,240	1,480	6,480	2,660	11,650
			Lower Rate of Growth					
Anchorage			550	2,410	1,010	4,420	1,500	6,570
Fairbanks			140	610	240	1,050	350	1,530
Total			690	3,020	1,250	5,470	1,850	8,100

TABLE 5.1: (continued)

Type of Load	Actual Requirements				Estimated Future Requirements			
	1974		1980		1990		2000	
Area	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh
National Defense								
Anchorage	33	155	35	170	40	190	45	220
Fairbanks	41	197	45	220	50	240	55	260
Total	74	352	80	390	90	430	100	480
Industrial			High Rate of Development Assumed					
Anchorage	10	45	100	710	2,910	20,390	2,920	20,460
Fairbanks	--	--	---	---	--	--	--	--
			Mid-Range Development Assumed					
Anchorage			50	350	100	710	410	2,870
Fairbanks			--	-	-	-	-	-
			Low Development Assumed					
Anchorage			20	140	50	350	100	710
Fairbanks			-	-	-	-	-	-

TABLE 5.1: (continued)

Type of Load	Actual Requirements				Estimated Future Requirements			
	1974		1980		1990		2000	
Area	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh	Peak Demand 1000kw	Annual Energy Million/kwh	Peak Demand 1000 kw	Annual Energy Million/kwh
Combined Utility, National Defense, and Industrial Power Requirements								
Higher Growth Rate								
Anchorage	327	1,505	785	3,730	4,520	27,460	6,395	35,700
Fairbanks	124	527	205	920	430	1,900	855	3,760
Total	451	2,032	990	4,650	4,950	29,360	7,250	39,460
Likely Mid-Range Growth Rate								
Anchorage			675	3,100	1,330	6,110	2,605	12,510
Fairbanks			195	880	340	1,510	565	2,490
Total			870	3,980	1,670	7,620	3,170	15,000
Lower Growth Rate								
Anchorage			605	2,720	1,100	4,960	1,645	7,500
Fairbanks			185	830	290	1,290	405	1,790
Total			790	3,550	1,390	6,250	2,050	9,290

TABLE 5.2: 1976 ISER ELECTRIC POWER REQUIREMENTS PROJECTIONS

Anchorage, Southcentral, & Fairbanks	Total Energy Sales			Average Annual Growth Rates		
	1974	1985	1995	1975-1980	1975-1985	1975-1995
LOWEST	1,468	3,697	8,092	9.1	8.8	8.5
HIGHEST	1,468	7,787	20,984	17.6	16.4	13.5

TABLE 5.3: RANGE OF RAILBELT ANNUAL CONSUMPTION

(Includes use by utility and industrial customers likely to be part of an intertied system. Excludes national defense and non-intertied users).

Year	Annual Consumption	Compound Annual Growth Rate
1974	1.6 B kWh	
1980	2.6 to 3.4 B kWh	8.4 to 13.4 (1974-1980)
1990	8.5 to 10.8 B Kwh	9.6 to 15.3 (1980-1990)
2000	16.0 to 22.5 B kWh	4.0 to 10.2 (1990-2000)

TABLE 5.4: RAILBELT AREA ENERGY FORECAST (GWH)

	1977 (Historic)	1980	1990	2000	2025
Utility:					
High		3,410	8,200	16,920	38,020
Mid	2,273	3,155	6,110	10,940	17,770
Low		2,920	4,550	7,070	8,110
National Defense:					
High		348	384	425	544
Mid	338	338	338	338	338
Low		330	299	270	210
Self-Supplied Industry:					
High		170	2,100	3,590	8,490
Mid	70	170	630	1,460	3,470
Low		141	370	550	1,310
Total:					
High		3,928	10,684	20,935	47,054
Mid	2,681	3,663	7,078	12,738	21,578
Low		3,391	5,219	7,890	9,630
Trend @ 1973-77 annual/growth:		(3,215)	(10,270)	(33,000)	(601,000)

TABLE 5.5: COMPARISON OF PAST PROJECTIONS OF RAILBELT ELECTRIC POWER REQUIREMENTS (1980 Base Year)[1]

	Net Energy (10^3 MWH)[2]		Annual Growth Rate of Net Energy Between Forecast Year & 1980			
Case	Year of Publication	Year of Forecast	Forecast for 1980	Implicit in Forecast	Actual	Percent Error in Forecast of Growth Rate to 1980 (%)
(a)	1975	1,851	3,240	11.9	7.3	+ 63
(b)	1976	2,093	2,985	9.3	5.9	+ 58
(c)	1978	2,397	3,000	11.9	4.8	+148
(d)	1979	2,469	3,155	27.8	6.5	+328

(1) Assuming 1980 Net Energy consisting of 2,390 MWh of sales plus 10 percent losses.

(2) Net Energy figures calculated from sales plus 10 percent for losses.

6 - FINDINGS AND RECOMMENDATIONS

6.1 - Findings

In the preceding sections of this report ISER's projections of electric power consumption for the Railbelt have been reviewed and evaluated. A number of significant areas of concern have emerged:

- The full range of economic scenarios has not been estimated by the model. Only three scenarios representing moderate government expenditure and alternative economic growth were used in projecting future Railbelt electricity power consumption.
- The existing set of scenarios does not sufficiently cover a feasible range of alternative futures. The high economic growth and high government expenditure scenario is conservative. A higher growth scenario can be formulated to represent stable industrial growth with higher government expenditure without necessarily depleting the State's fund balance. At the same time, the low growth scenario can be made lower by formulating a scenario representing a contraction of the Alaskan economy.
- There is a paucity of data for calibrating an econometric end-use model in Alaska. The data base limits the robustness of the model, particularly the end-use components of the model.
- Recognizing that the poor data base in Alaska limits the ability to structure an econometric end-use model in sufficient detail, the existing model is weakest in the commercial-industrial-government component. This component at present is highly aggregated and cannot sufficiently respond to the specific assumptions developed in the economic scenarios. Since this component currently accounts for about 52 percent of total Railbelt utility sales, this deficiency is significant.
- The parameter fuel mode split presently employed in the model is based on judgemental assumptions. This parameter is too important to be made on this basis. Fuel choice is determined on the basis of relative fuel prices and fuel availability, which also change over time. These have not been explicity entered into the fuel mode split parameter. Hence, the accuracy of the assumed existing fuel mode split values cannot be realistically tested.
- The model contains many assumptions about other parameter values, such as household formation rates, appliance saturation rates, growth in appliance size etc. which have not been fully tested. At the same time no sensitivity analysis was conducted to understand the impact of these assumptions.

The implications of these problems in predicting future Railbelt electricity requirements are not easy to assess. They require a thorough analysis. However, some of the outcomes of these problems can be estimated or deduced. These are:

- The upper and lower bounds of the existing scenario set have been evaluated as approximations to the model estimations. These are estimated to be 14.0 million MWh for the upper bound and 5.4 million MWh for the lower bound in year 2010. The range of forecasts is therefore wider than that provided by ISER.

- The inclusion of a scenario with stable industrial growth and higher government expenditure, will drive electricity consumption projections to a level higher than the ISER upper bound. The opposite results would occur for an economic depression scenario, where future consumption levels would be lower than the ISER lower bound. The range of forecasts will therefore be wider than the existing set, covering a more feasible range of alternatives.

- A thorough investigation of the fuel mode split parameter may lead to different values than those assumed. If an analysis of price and availability of fuels indicates that future electricity prices will be lower than those of other subsitutable fuels, the fuel mode split would drive the electricity projections to levels higher than the existing set. If the price of electricity is more expensive relative to other fuels, the opposite results would occur.

Other problems such as a poor data base, inadequate structural detail in the commercial-industrial-government component, and untested parameter assumptions cannot be reliably assessed without futher detailed analysis. The quality of data base can only improve with time, but for the present only reasonable assumptions in the model can alleviate the problem. Other problems require a thorough analysis to understand the extent of the implications.

6.2 - Recommendations

In view of these problems, the efficacy of ISER's projections of Railbelt electricity power consumption is questioned. However, many of these problems are not insurmountable and can be put to rest with greater effort. Hence we recommend that these issues be further investigated and resolved so that the application of the resulting projections to electricity generation planning in the Railbelt can be undertaken with reasonable confidence.

APPENDIX A

REVIEW OF ISER FORECASTING MODEL

APPENDIX A - REVIEW OF ISER FORECASTING MODEL

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APPENDIX A - REVIEW OF ISER FORECASTING MODEL

In this Appendix a detailed review of ISER's electric power consumption model for the Railbelt region is presented. The purpose is to obtain a comprehensive understanding of how electric power consumption forecasts in the Railbelt were developed by ISER. The review is organized in three parts:

- Model Structure

- Scenarios and Model Parameters

- Economic Projections and Electricity Consumption Forecasts.

A.1 - Structure of the ISER Model

ISER's electric power consumption forecasting model for the Railbelt region employs an econometric end-use (EEU) approach. EEU is based on the proposition that energy is consumed by capital items (e.g. household appliances, space heating systems, automobiles etc.) which perform specific activities (e.g. cooking, heating, transportation, etc.). It has two distinct features: econometric models which forecast future levels of economic activities and end-use models which forecast future amount and type of energy consumed in the pursuit of economic activities.

In ISER's model structure, the prediction of future levels of economic activity (e.g. employment, population, households, and housing stock) by region is obtained by four models in the following sequence:

- the Man-in-the-Arctic Model (MAP)

- Household Formation Model

- Regional Allocation Model

- Housing Stock Model.

Future levels of electricity consumption are projected by end-use models which consist of six components:

- Residential Non-space Heating Electricity Requirement

- Residential Space Heating Electricity Requirement

- Commercial Industrial Electricity Requirement

- Miscellaneous Electricity Requirement

- Military Net Generation.

- Self-sufficient Industry Net Generation

The summation of the first four end-use components will produce total utility sales for the Railbelt region: the total electric power consumption for the region is obtained by adding Military and Self-Supplied Industry Net Generation to total utility sales.

The basic structure of ISER's econometric end-use model is illustrated in Figure A.1. A brief description of the individual moaels is provided below.

A.1.1 - The MAP Economic Model

MAP is an econometric model of the State of Alaska developed by ISER for the Man-in-the-Artic Program. The model consists of three interrelated components:

- economic model

- demographic model

- fiscal model

The significance of MAP lies in its projection of future economic activity which is used for electricity consumption forecasting.

In the economic model, the economy is divided into basic and non-basic sectors. The basic sector is comprised of the following industries:

- mining

- agriculture - forestry - fisheries

- manufacturing

- federal government

- export component of construction and transportation.

The level of output in the basic sectors is determined outside the economic model. The non-basic sectors of the model are:

- wholesale and retail trade

- finance - insurance - real estate

- services

- communication

- utilities

- endogenous construction and transportation.

The level of economic model simultaneously determines income, output and employment levels for the State.

The demographic model projects population levels on the basis of future births, deaths and migration. Future births and deaths of the civilian population are determined by age-sex-race fertility rates and survival rates; the national increase in population is the number of births net of deaths. Total civilian population is obtained by adding net civilian migration to the national increase. Net migration is determined by the relative economic opportunities in the state. Finally, total population is obtained by adding total civilian population with an exogenous estimate of military population.

The fiscal model is the final component in the MAP model. The model calculates taxes, personal expenditures, state government employment and government expenditures on capital improvements. These calculations are based on an assumed state spending rule. The model is linked to the assumed economic model by providing information on taxes and capital improvement expenditures; the former is used to calculate disposable income, while the latter is used to determine part of construction employment.

In the present study, the MAP model has been updated to incorporate the most recent information. This updating included a respecification of equations in order to capture the buoyancy of the economy in the post pipeline period. The fiscal model has also been modified to reflect changes in tax regulations which essentially eliminated individual income taxes for State residents.

A.1.2 - Household Formation Model

The household formation model determines future household levels on the basis of future population and the age-sex distribution. It is an accounting model which depends on the cohort specific rate of household formation, and changes in those rates. Input is required from the MAP model in the form of projected level and age-sex distribution of the population. The structure of the model is presented in Table A.1.

A.1.3 - Regional Allocation Model

This model regionalizes the economic projections to determine the level of economic activity in the Railbelt. The method used is a regional shares model. Regional shares are estimated as a function of basic sector activity and dummy variables representing comparative advantage and scale of regional economy. The estimation is based on pooled-time series cross-section technique because of short data series and the need to capture regional variation.

The model consists of four equations which regionalize the following:

- direct support sector employment including construction and transportation (RESA)
- other support sector employment, e.g. trade services, finance, etc. (RESB)
- population (RPOP)
- State and local government employment (REGSL).

The functions of these equations are specified as shown in Table A.2.

The regions defined in this model are Anchorage, Kenai, Seward, Matanuska, Fairbanks and Valdez. Regional totals are obtained by multiplying State totals with regional shares.

A.1.4 - Housing Stock Model

The housing stock model projects the number of households by region and the distribution of households by housing type. The housing types included in this model are single-family, duplex, multi-family, and mobile homes.

The projection of total number of households for different regions by the model is obtained by dividing the regional population by population per occupied dwelling unit. On-base households are assumed to be constant over the forecasting period and subtracted from total households to find total off-base households (see Table A.3).

Housing stocks are projected for off-base households only. The methodology is based on stock adjustment technique. The technique attempts to incorporate factors such as income, family size, tenure, and changes in housing type distribution.

A series of equations make up the model as shown in Table A.3. Initially, the model postulates that the demand for housing type T (H_i^T) is the product of the total housing units (HH_i) and the demand coefficient for type T (HD^T). Next, the initial stock of housing of type i in any period is defined as last period's housing stock of that type (S_i^T ( )) minus the removals from the stock since the previous period. The net demand for type T (ND_i^T) is defined as the total demand of housing type T (H_i^T) less the initial housing stock of type eT (S_i^T).

Construction of new housing is determined by the net demand. If the net demand for all types of housing is positive, new construction (NC_i^T) equals net demand plus the equilibrium amount of vacant housing. However, if the net demand for a particular housing type is negative, an adjustment is required. The adjustment assumes that single-family mobile homes, multi-family, and duplexes are close subsitutes.

This means that when one housing type has excess supply, it is filled by households with the other housing type demand. Once these adjustments are made, new construction occurs.

A.1.5 - Residential Nonspace Heating Electricity Requirements Model

This model includes the following appliances:

- water heater

- range (cooking)

- clothes dryer
- refrigerator
- freezer
- dishwasher
- clothes washer
- television
- air conditioner
- small appliances

The electricity requirement for appliance type j at time t for region r is the product of five factors:

- number of households (HH_t)
- appliance saturation rate ($S_j t$)
- fuel mode split ($FMS_{j,e,t}$)
- average annual consumption ($KWH_{j,t}$)
- average household size (AHS_{jt}).

The equation is shown in Table A.4 (a).

Note that AHS_{jt} equals 1 for clothes washer, water heater and clothes dryer, and 0 for others. Total electricity requirements is the sum of all appliances j.

This model is linked to the MAP model through the household variable (HH_t). The remaining variables such as appliance saturation rates (S_{jt}), fuel mode split ($FMS_{j,e,t}$) and average annual consumption ($KWH_{j,t}$) are exogenously determined. A brief explantion is given below.

Saturation rates on major appliances were estimated for 1978 to represent current usage rates since current data on saturation rates were not available. The estimation was based on past trends in saturation rates in Alaska, other States and national trends; two years' data, 1960 and 1970, were used. Future Alaskan saturation rates were projected in a similar manner following the long-run national trend.

Fuel mode split was calculated as the proportion of appliances of type j, which use electricity. Data to calculate current fuel mode split for major appliances were not available and hence 1960 and 1970 Alaskan Census of Housing data were used. An important element in calculating future mode split is the future stock of appliances using electricity. The future stock is estimated by a stock adjustment method which embodies an explicit assumption on proportion of new appliances using electricity.

Average annual electricity consumption of appliances is calculated as a function of the age distribution of the appliance stock and the electicity requirement for each vintage. In estimating electricity requirements for new appliances added to the stock, Federal mandatory improvements in appliance efficiency and changes in appliance size are two important factors taken into account.

A.1.6 - Residential Space Heating Electricity Requirements

The residential space heating model is disaggregated into four housing types:

- single family
- duplex
- multi-family
- mobile home.

The electricity space heating requirement for housing type j is defined as the product of the following factors:

- number of housing units of type j (HT_j)
- fuel mode split ($FMS_{j,e,t}$)
- average level of consumption ($KWH_{j,t}$).

The model is linked to the housing stock model through the housing unit variable. Other components are determined exogenously and a brief explanation is given below.

The fuel mode split is calculated as the proportion of houses using electricity for space heating in housing type j. The number of houses using electricity in future years is obtained by a stock adjustment method. Implicit in this method is the assumption concerning fuel mode split of new houses of type j added to the stock.

Electricity requirement per unit of housing type j is calculated as the weighted average of the per unit requirement of space heating appliance of the different vintages in the stock. The electricity requirement for each vintage is based on, among other factors, the Federal mandatory energy savings.

A.1.7 - Commercial-Industrial-Government Electricity Requirement Model

Total electricity requirements for the commercial-industrial sector are defined as the product of non-agricultural wage and salary employment and average electricity consumption per employee (see Table 4.4.(b)). Electricity consumption per employee is a function of time and implementation of conservation standards. This implies that new electricity users in this sector will have different electricity requirements than previous customers.

A.1.8 - Miscellaneous Electricity Utility Sales Model

This model estimates two remaining sectors of electricity consumption: street lighting and recreational homes. Street lighting requirement in time t is calculated as a fixed percentage of the total of residential (space heating and non-space heating) and commercial-industrial-government electricity requirement. Recreational home consumption is calculated as the product of a fixed level of electricity consumption and a fixed proportion of households in time t.

A.1.9 - Military Electricity Requirements

For a number of reasons, including a lack of historical data series, no model was built to correlate military electricity consumption with causal factors. Hence, future electricity requirements for the military are assumed to be the same as the current level.

A.1.10 - Self-Supplied Industrial Electrical Requirements

No model was built to project future self-generated electricity for industry. Existing users are identified and current electricity consumption is determined from APA sources. New users and consumption levels are identified from economic scenarios.

A.2 - Economic Scenarios

Three economic growth scenarios and three state government fiscal scenarios were formulated for MAP. These represent a total of nine economic scenarios.

The economic growth scenarios describe the alternative futures of basic sector industries in the state economy. Different assumptions on future employment and output for basic sector industries such as mining manufacturing, agriculture, forestry, fisheries, federal government, exogenous construction and exogenous transportation define high, moderate and low growth scenarios. In defining these scenarios, special projects and other economic events expected to occur prior to 2000 were identified. The following is a brief description of the timing and nature of future projects for each scenario.

A.2.1 - Low Economic Growth Scenarios

Low growth assumes the following events to take place for each of the exogenous industries. (See also Figure 4.2).

(a) Mining

Prudhoe Bay Petroleum Production - Production from the Sadlerochit formation and Kaparuk formation is assumed. Construction of the project will take place during 1982 to 1984 with peak employment of 2917 in 1983. Mining employment for 1980 to 2000 assumes a long run average of 1802 per year.

- Upper Cook Inlet Petroleum Production - Declining oil production will be replaced by rising gas production to maintain current levels of employment. Employment for 1980 to 2000 will be 705 workers per year.

- Other Mining - Reduction in mining employment will take place as a result of land policy or world market conditions. Employment will decline at 1 percent per year from present levels.

(b) Agriculture -- Forestry -- Fisheries

- Agriculture - Unfavorable conditions for agricultural development will occur. Agriculture will disappear in Alaska by 1992.

- Forestry - This is a small component and is discussed under manufacturing industry.

- Fisheries - Existing fishery industry levels will be maintained but no bottom fish development will occur. Employment will remain at 1000 per year.

(c) Manufacturing

- Seafood Processing - Moderate growth in seafood processing will take place to accommodate the expanding catch in existing fisheries. A 22 percent increase is assumed during 1980 to 2000.

- Lumber--Wood Products--Pulp - Japanese market conditions and the Forest Service allowable annual cut will increase employment levels to accommodate production of 960 million board feet of lumber.

- Petrochemicals - Current developments in Kenai will continue. No expansion is expected.

- Other Manufacturing - Extension of existing production for local markets is assumed. Output will grow at 1 percent per year.

(d) Federal Government

Civilian employment is assumed to grow at .05 percent per year while military employment levels will stay constant.

(e) Exogenous Construction

This portion of the industry is that which serves special projects. Two projects are envisaged:

- TransAlaska Pipeline - Although completed in 1977, additional construction of four pump stations is assumed. Construction will be completed by 1982 with employment for 90 workers annually. Pipeline operations will also employ 1000 people annually during the forecast period.

- Northwest Gasline - Construction of a natural gas pipeline from Prudhoe Bay and an associated gas facility on the North slope from 1981 to 1985 will take place with peak employment of 7823 in 1983. Operations will begin in 1986 continuing to 2000 with employment for 400 petroleum workers and 200 transport workers.

(f) Exogenous Transportation

This portion of transportation is that which serves special construction projects. These are the TransAlaska Pipeline and the Northwest Gasline. Only the operations employment levels are included as exogenous transportation.

A.2.2 - Moderate Economic Growth Scenario

This scenario reflects a faster growth rate than the low scenario. The economic events envisaged to take place during 1980 to 2000 are described below (see also Figure 4.2).

(a) Mining

- Prudhoe Bay Petroleum Production - Same as in Low Growth Scenario.

- Upper Cook Inlet Petroleum Production - Same as in Low Growth Scenario.

- National Petroleum Reserve in Alaska Petroleum Production - Pertroleum production will continue in two fields with 1.2 billion barrels equivalent of oil and gas. Leased between 1995 and 2013, development will begin in 1998. Average mining employment of 286 a year from 1998 to 2000 is assumed.

- Outer Continental Shelf (OCS) Petroleum Production - Production in six OCS lease scale areas is assumed, with mining employment peaking at 4,900 workers in 1990.

- Beluga Coal Production - Moderate development of coal for export is assumed, with operations employment of 210 per year from 1988 to 2000.

- Other Mining - No expansion is assumed. Employment will stay constant at current level of 2350 per year.

(b) Agriculture--Forestry--Fisheries

- Agriculture - Low development is assumed because of priorities to recreation or lack of markets. Employment will grow to 1037 by 2000.

- Forestry - Discussed in manufacturing sector.

- Fisheries - Existing fishery levels will be maintained and bottom-fishery industry will expand. Employment levels will increase to 1228 by 2000.

(c) Manufacturing

- Seafood Processing - Expansion of existing fisheries and bottom-fishery will lead to increased outputs for existing fisheries by 149 percent and for bottom-fishery by 49 percent, between 1980 and 2000.

- Lumber-Wood Products-Pulp - Same as in low scenario.

- Petrochemicals - Expansion is assumed to take place with the development of a Pacific LNG facility, a fuels refinery in the Alpetco project and LNG facilities associated with OCS activity in Western Alaska. The Alpetco and Pacific LNG projects will create operations employment of 518 per year starting in 1985 and 100 per year starting in 1986, respectively.

- Other Manufacturing - Expansion of manufacturing of locally consumed goods will take place. Output will increase at 2 percent per year.

(d) Federal Government

Same growth as in low scenario.

(e) Exogenous Construction

- Northwest Gasline - Same as low scenario.

- Alpetco Project - Construction employment will be 900 per year from 1982 to 1984.

- Pacific LNG Project - Construction will take place during the period from 1982 to 1984, with peak employment of 1323 per year in 1984.

- Outer Continental Shelf Petroleum Production - Construction employment will peak at 3,300 workers in 1992.

- National Petroleum Reserve in Alaska - Construction employment is mentioned but no figures are given.

- Beluga Coal Production - Construction will take place during the period from 1985 to 1990, with peak employment of 400 in 1987.

(f) Exogenous Transportation

As in low scenario, this sector includes the operations employment for the TransAlaska Pipeline and the Northwest Gasline. Transporation employment in OCS petroleum development is also included.

A.2.3 - High Economic Growth Scenario

This scenario represents the fastest rate of economic growth. Greater economic expansion in the state is envisaged. The nature and timing of economic events are described below (see also Figure 4.3)

(a) Mining

- Prudhoe Bay Petroleum Production - Same as low and medium scenario.

- Upper Cook Inlet Petroleum Production - Same as low and medium scenarios.

- National Petroleum Reserve in Alaska - Production is assumed in five fields with a total reserve of 2.5 million barrels equivalent of oil and gas. This project will begin in 1985 with average mining employment of 460 per year.

- Outer Continental Shelf Petroleum Production - Production is assumed in eleven OCS lease scale areas with different start-up dates beginning in 1979. Mining employment will peak at 9066 per year in 2000.

- Beluga Coal Production - Major development of Beluga coal for export will take place during 1988 to 2000, with mining employment of 379 per year.

- U.S. Borax Mining - Development and exploration is assumed to begin in 1980. Mining employment of 440 per year will begin in 1993.

- Other Mining - Other mining opportunities will expand with employment growing at 1 percent per year.

(b) Agriculture--Forestry--Fisheries

- Agriculture - Major development of agriculture will take place in Alaska. Employment will reach 4600 by 2000.

- Forestry - Discussed in manufacturing sector.

- Fisheries - Level of employment in existing fisheries will be maintained. Major development of bottom fishery will take place, with employment in fisheries increasing to 1350 by 2000.

(c) Manufacturing

- Seafood Processing - Because of expansion in fisheries, the seafood processing industry will increase output by 157 percent between 1980 and 2000.

- Lumber-Wood Products-Pulp - Due to favorable markets and increased annual allowable cut, employment will expand to accommodate an annual cut of approximately 1.3 million board feet by 2000.

- Petrochemicals - Two petrochemical projects over and above that described in the medium scenario are included. The first is a moderate petrochemical facility at Fairbanks employing 600 workers per year between 1987 and 2000. The second is a major development of the Alpetco project employing 1925 workers per year between 1987 and 2000.

- Other Manufacturing - Output in other manufacturing is assumed to increase at 3 percent per year to serve local markets.

(d) Federal Government

Civilian federal government employment is assumed to grow at 1 percent per year. Military employment will remain constant.

(e) Exogenous Construction

- Northwest Gasline - Same as low and medium scenarios.

- Alpetco Project - Major development will increase construction activity from 1982 to 1986. Construction employment will peak at 3,500 per year.

- Pacific LNG - Same as medium scenario.

- Outer Continental Shelf Petroleum Production - Increased development will require construction employment to peak at 5,300 per year in 1992.

- National Petroleum Reserve - Construction employment will increase because of increased development.

- Beluga Coal Production - Construction will peak at employment of 400 in 1987.

- State Capital Move - The movement of the state capital to Willow will begin in 1983 and be completed in 1996. Construction employment will reach a peak of 1560 per year in 1990.

(f) Exogenous Transportation

Employment in exogenous transportation is assumed to be higher than the medium scenario. This increase is attributed to expansion of OCS production in eleven lease scale areas.

A.2.4. - State Government Scenarios

In defining scenarios for State government expenditures, ISER mentions that past state fiscal policy is not appropriate for determining future policies. Two reasons are given: first, the production at Prudhoe Bay has led to state revenues overtaking state expenditures and this will continue to increase in future; second, the establishment of the Permanent Fund, tax reduction programs, and wealth sharing programs will constrain the use of petroleum revenues.

ISER, therefore, assumes that future state fiscal policy can follow one of three separate directions. These directions are defined by the growth of real per capita state expenditures. They assume that real per capita expenditures consume a growing, constant, and declining proportion of real per capita income. Hence, three scenarios for state government expenditure representing high, medium and low are established.

A.3 - Housing and Population Model Parameters

A.3.1 - Household Formation

This model requires two sets of parameter assumptions: initial household formation rates and yearly changes in those rates. The initial set of household formation rates is derived from the 1970 census (Bureau of Census, 1970 Census of Population Detailed Characteristics: Alaska, 1972). The yearly changes in household formation rates are based on estimates by the Bureau of Census (Bureau of Census, Projections of the Number of Households and Families 1979 to 1995, 1979) and are assumed to be constant throughout the forecast period. Both sets of parameters are shown in Tables A.5 and A.6.

A.3.2 - Regional Allocation

Regional shares for population (RPOP), direct support sector employment (RESA), other support sector employment (RESB), and State and local government employment (REESL) are estimated by a pooled time series-cross-section technique. These equations are reproduced in Table A.7 (DA, DK, DS, DM, DF and DF represent dummy variables for Anchorage, Kenai, Seward, Matanuska, Fairbanks, and Valdez, respectively).

A.3.3 - Housing Stock

Housing stock projections are determined by the following parameters:

- number of people per occupied dwelling

- number of people per occupied dwelling unit (PPODU) to determine the number of households in a given regional population

- removal rates to determine proportion of houses removed from the housing stock

- vacancy rates to determine number of vacant housing

- housing demand coeffficents (HDT) to determine demand distribution by housing type.

The initial people per occupied dwelling unit rates are shown in Table A.8. Future housing removal rates were assumed to grow toward the U.S. average of between two and four percent for a five-year period. These rates are shown in Table A.9.

Two vacancy rates representing normal and maximum vacancies were used. The normal vacancy rates were based on ten-year U.S. averages for owner and renter units (Bureau of the Census, Housing Vacancies: Fourth Quarter, 1979, 1980). Maximum rates were based on Anchorage experience (Anchorage Real Estate Research Report, 1979). The assumed rates are also shown in Table A.9.

Housing demand coefficients by housing type were determined by housing choice regressions. Data from existing survey data for Anchorage and a 1978 Anchorage Population survey conducted by the Urban Observatory of Alaska were used in the regression. Housing choice was specified as a function of age of household head and family size. The derived equations are shown in Table A.10.

A.4 - Electricity Model Parameters:

A.4.1 - Base Case

Energy consumption behavior in the base case is based on a number of assumptions which generally reflect a continuation of existing trends and federal energy conservation programs. One of the most important assumptions in the base case is that the present relative price of electricity is projected to continue into the future so that no major shift toward or away from electricity usage occurs. Detailed assumptions employed are discussed in the ISER report. The following presents the parameter values assumed by ISER:

(a) Residential Non-Space Heating

A large number of parameters enter this model. These are divided into major appliances and small appliances. For major appliances the parameters are:

- appliance saturation rates
- conservation target for new appliance
- appliance lifetime
- appliance capacity growth rates
- incremental mode split
- household size adjustment factor
- appliance consumption in 1980
- average annual new appliance consumption
- historical electric appliance stock growth rates.

For small appliances, the parameters include:

- average annual consumption level in 1980

- annual increment to small appliance consumption.

These parameters are shown in Table A.11 and A.12. The assumptions and data used to calculate these parameters are discussed extensively in Appendix E.1 of the ISER report.

(b) Residential Space Heating

Parameters used in this model consist of the following:

- average annual unit consumption in 1980 by housing type

- average annual unit consumption in 1985 by housing type

- growth in unit size

- average unit lifetime

- incremental mode split

- conservation target for new appliances

- retrofitting co-efficients.

These parameters are reproduced in Table A.13. The assumptions and data sources used in the calculation are comprehensively discussed in Appendix E of ISER's report.

(c) - Commercial-Industrial-Government

Parameters used in this model are:

- average consumption per employee for 1980

- average consumption per employee for 1980-1985

- subsequent increases to incremental consumption per employee

- design performance efficiency targets.

Electricity consumption parameters are estimated by using historical Railbelt employment data and historical electricity consumption data for commercial-industrial-government customers. Incremental consumption in future are assumed to reflect trends during the period 1973 to 1978. Design and performance efficiency standards are based on a review of national studies on potential energy conservation impacts of Federal conservation programs in the commercial, industrial and government sections. The review leads to a set of assumptions on electricity requirement reduction for new buildings. The calculated parameters are shown in Table A.14.

(d) - Miscellaneous

This small category consists of street lighting and second homes electricity sales. Street lighting is assumed to 1 percent of all other end-use components. For second homes, the parameters are difficult to estimate because of intractable data. It is therefore assumed that 25 percent of households have second homes (based on census information) and that 50 percent are located in the Railbelt.

A.4.2 - Case of Price Induced Shift to Electricity

For this scenario, ISER conducted a background review of factors involved in the choice of space heating. A number of factors were identified, the most important being the system cost, which includes the initial capital outlay and lifetime fuel costs. Recent relative prices of fuel in the Railbelt were examined and it was discovered that natural gas was cheapest wherever it was available, while fuel oil and electricity varied according to different parts in the Railbelt. In most areas, the price of electricity was higher than fuel oil. Where the prices of fuel oil and electricity were comparable the electricity was produced by cheap natural gas or coal.

For electricity to become the lease expensive space heating fuel in different parts of the Railbelt, it was found that the prices of fuel oil and natural gas would have to change in the following directions:

- Anchorage - relative price of natural gas to be increased 3 times

- Fairbanks - relative price of fuel oil to be increased 2-1/2 times

- Glennallen-Valdez - relative price of fuel oil to be increased 3-1/2 times.

In an attempt to provide greater insight into future changes of relative prices and availabity of fuel, the conditions under which such changes could take place were reviewed. However, no attempt was made to analyze how these conditions would change in future; instead, it was assumed that electricity would become less expensive than other fuels.

(a) - Parameters for Price Induced Shift

Parameter values are based on the assumption that the price advantage of electricity will occur during the forecast period but will not be of a substantial magnitude. This leads to a shift towards electricity for space heating beginning in the period 1995 to 2000 for Anchorage and Fairbanks, and 1990 to 1995 for Glennallen- Valdez. The shift is assumed to follow the natural gas pattern observed in Fairbanks in the early 1970's where new installations were predominant but existing units were not retrofitted. In addition, the relative price advantage of electricity will enable electric appliances to be more attractive. Therefore, the incremental mode splits for water heaters and cooking appliances also increase during the period. It is also assumed that the shift towards electricity will take place only in the residential sector.

A.5 - Economic Projections

The forecasts obtained by the ISER model are presented below:

A.5.1 - MAP Projections

The MAP model projects future economic activity for the period 1980 to 2000. Nine economic scenarios were formulated to bound the continuum of alternative economic growth scenarios in Alaska. Accordingly, nine projections of population and employment were obtained. Three projections representing high, moderate and low economic growth plus moderate government expenditure scenarios and two projections representing upper (high economic growth and high government expenditure) and lower bounds (low economic growth and low government expenditure) are shown in Table A.16.

As a check for consistency in these projections, ISER examined whether the State could make the required level of expenditure without running out of money or requiring large increases in taxes. The check indicated that the State's fund balance is positive in all scenarios in 2000. The lowest level of fund balance is $48.8 billion (current dollars) and this occurs in 2000 for the high economic growth-high government expenditure scenario.

A.5.2 - Future Household Formation

Nine projections of household formation based on alternative economic scenarios were produced by the household formation model for the period 1980 to 2000. Three projections representing moderate government expenditure plus alternative economic growth scenarios, and two projections representing upper and lower bounds are shown in Table A.17.

A.5.3 - Regional Growth

The projections of state population and employment were regionalized by the regional shares model for Anchorage, Fairbanks and Valdez regions. Although nine economic scenarios were formulated, only three scenarios were run through the regional shares model for the period 1980 to 2000. These scenarios are those representing high, moderate, and low economic growth with moderate government expenditure. The reason given for choosing these scenarios is that they reflect the most likely range of future growth. percent Projections beyond 2000 were assumed to grow at 1 percent, 2 percent and 3 percent for the three scenarios. These projections together with future households by regions (estimated by housing stock model), are shown in Table A.18.

A.5.4 - Future Railbelt Housing Stock

Future Railbelt housing stocks are projected by the housing stock model for three economic scenarios. The scenarios are the same as those used in regional projections, and the forecasts are broken down by housing type and different regions of the Railbelt. The projections are shown in Table A.19.

A.6 - Future Railbelt Electricity Consumption

A.6.1 - Base Case

Model parameters representing the base case are combined with three economic scenarios to produce electricity consumption forecasts by end-use sectors. The forecasts are discussed below:

(a) - Residential Nonspace Heating

Electricity consumption forecasts are produced for major and small appliances for Anchorage, Fairbanks and Valdez regions. These forecasts are shown in Table A.20. Large appliances consistently consume more electricity than small appliances for all scenarios. In terms of regions, Anchorage consumes more electricity for appliances compared to other regions because of greater household concentration. For the Railbelt as a whole, this end-use sector is expected to consume electricity ranging from 0.7 million MWh to 1.1 million MWh in 2010.

(b) - Residential Space Heating

Future residential space heating electricity requirements for Anchorage, Fairbanks and Valdez regions are shown in Table A.21. Anchorage accounts for a substantial portion of electricity consumption because of greater household concentration. Electricity consumption in this end-use sector for the Railbelt will range from a low of 1 million MWh to a high of 1.6 million MWh in 2010.

(c) - Commercial-Industrial-Government

Future electricity requirement in this sector is shown in Table A.22. Again, Anchorage accounts for a substantial portion followed by Fairbanks and Valdez. For the Railbelt region, electricity requirement is expected to range from a low of 3.4 million MWh to a high of 7.1 million MWh in 2010.

(d) - Miscellaneous

This sector which accounts for street lighting and electricity for recreational homes is relatively small. Forecasts are shown in Table A.23.

(e) - Military and Self-Supplied Industrial

The forecasts for these two sectors are shown in Table A.24.

A.6.2 - The Case of Price-Induced Shift Toward Electricity

The shift toward electricity case is estimated only for the residential sector with a moderate growth scenario. The forecasts are shown in Table A.25.

A.6.3 - Summary of Electricity Consumption Forecasts

Future total utilitly sales for the Railbelt by end-use sectors are shown in Table A.25. Future utility sales by regions in the Railbelt and military plus self-supplied industrial net generation are summarized and shown in Table A.26.

TABLE A.1 - HOUSEHOLD FORMATION MODEL

$$HH_{ij} = (CNNP_{ij} - CPGO_{ij})\ HHR_{ij} + (NAIP_{ij} - NPGO_{ij}) + MHH_{ij}$$

where:

HH = total number of households in the State

$CNNP_{ij}$ = civilian non-natives in sex cohort j and age cohort i.

$CPGO_{ij}$ = civilian non-natives in group quarters in sex cohort i and age cohort j.

HHR_{ij} = civilian non-natives household formation rate in sex cohort i and age cohort j.

$NATP_{ij}$ = natives in sex cohort i age cohort j.

$NPGQ_{ij}$ = natives in group quarters in sex cohort i and age cohort j.

$NHHR_{ij}$ = natives household formation rates in sex cohort i and age cohort j.

MHH_{ij} = military household in sex cohort i and age cohort j.

TABLE A.2 - REGIONAL ALLOCATION MODEL

$RESA_j$	=	f ($LRPOP_i$, $L298_i$, Di)
$RESB_i$	=	f ($RR3EB_i$, $LRPOP_i$, Di)
$RPOP_i$	=	f ($RESB_j$, $RReEB_i$, Di)
$REGSL_i$	=	f ($LRPOP_i$, Di)

where:

RESA	=	direct support sector employment including construction and transportation
RESB	=	other support sector employment, e.g. trade services, finance etc.
RPOP	=	population
REGSL	=	state and local government employment
$LRPOP_i$	=	lagged share of population in region i
$L298_i$	=	lagged share of change in total employment in region
D_i	=	dummy variable for region i
$RR3EB_i$	=	share of basic sector employment in region i

TABLE A.3 - HOUSING STOCK MODEL

(a) Number of Households

$THH_i = POP_i/PPODU$
$HH_i = THH_i - BHH_i$

where:

THH_i = total number of households in region i
POP_i = population in region i
$PPODU_i$ = population per occupied dwelling unit in region i
HH_i = total off-base households in region i
BHH_i = on-base households in region i

(b) Demand

$$H_i^T = HH_i * HD_i^T.$$

$$S_i^T = S_i^T(-1) - S_i^T * r.$$

$$ND_i^T = H_i^T - S_i^T.$$

$$NC_i^T = ND_i^T + V_i * H_i^T.$$

where:

H_i^T = demand for housing type T in region i

HD_i^T = demand coefficent for type T in region i

S_i^T = initial stock of housing

r = number of removals

ND_i^T = net demand

NC_i^T = new unit housing

$V_i^i H_i^T$ = unit, minimum amount of vacant homes.

TABLE A.4: ELECTRICITY REQUIRMENTS MODELS

(a) Residential NonSpace Heating

$REQ_{j,t} = HH_t * S_{jt} * FMS * KWH_{j,t} * AHS_{j,t}$

$REQ_t = \Sigma_j REQ_j, t$

where:

$REQ_{j,t}$	= The electricity requirement for appliance type j at time t for region r
HH_c	= number of households
$S_j t$	= appliance saturation rate
$FMS_{j,e,t}$	= fuel model split
$KNA_{j,t}$	= average annual consumption
$AHS_{j,t}$	= average household size
REQ_t	= total electricty requirements for appliances j

(b) Commercial-Industrial-Government

$CIREQ_t = EM_t * CIKWH_t$

where:

$CIREQ_t$	= commercial-industrial-electricity
EM_t	= nonagricultural wage and salary employment in time t
$CIKWH_t$	= average electricity consumption in time t

TABLE A.5: 1970 ALASKA CIVILIAN POPULATION HOUSEHOLD FORMATION RATES (HHR_{ij})

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

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

TABLE A.6: YEARLY PERCENT CHANGE IN HOUSEHOLD FORMATION RATE ($CHHR_{ij}$)

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

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

<u>TABLE A.7: REGIONAL ALLOCATION MODEL PARAMETERS</u>

$$\mathrm{REGSL} = \underset{(3.48)^{1}}{.246} * \mathrm{LRPOP} + \underset{(6.99)^{1}}{.224} * \mathrm{DA} + \underset{(10.07)^{1}}{.124} * \mathrm{DF} + \underset{(3.56)^{1}}{.025} * \mathrm{DK}$$

$$+ \underset{(3.15)^{1}}{.021} * \mathrm{DM} + \underset{(1.41)}{.009} * \mathrm{DS} + \underset{(2.x8)^{1}}{.018} * \mathrm{DV} \qquad R^2 = .987$$

$$\mathrm{RESA} = \underset{(4.73)^{1}}{1.357} * \mathrm{L298} + \underset{(3.44)^{1}}{.744} * \mathrm{LRPOP} + \underset{(1.67)^{1}}{.148} * \mathrm{DA} + \underset{(1.27)}{.045} * \mathrm{DF}$$

$$+ \underset{(2.36)^{1}}{.025} * \mathrm{DK} - \underset{(-1.07)}{.008} * \mathrm{DM} - \underset{(-.45)}{.003} * \mathrm{DS} + \underset{(.45)}{.003} * \mathrm{DV} \qquad R^2 = .987$$

$$\mathrm{RESB} = \underset{(3.26)^{1}}{.269} * \mathrm{LRPOP} + \underset{(1.31)}{.086} * \mathrm{RR3EB} + \underset{(11.46)^{1}}{.409} * \mathrm{DA} + \underset{(1.94)^{1}}{.111} * \mathrm{DF}$$

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

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

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

---

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

TABLE A.8 INITIAL PEOPLE PER OCCUPIED DWELLING UNITS

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

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

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

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

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

TABLE A.9 ASSUMED HOUSING REMOVAL AND VACANCY RATES

(a) Removal Rates

1975-1980	1980-1985	1985-1990	1990-1995	1992-2000
1.0%	1.25%	1.50%	1.75%	2.0%

(b) Vacancy Rates

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

TABLE A.10: HOUSING CHOICE REGRESSIONS

Single Family

$$SF = .461 - .303 * S1 - .175 * S2 + .08 * S4 + .182 * A2$$

(70.36)[1] (20.52)[1] (1.87) (12.24)[1]

$$+ .317 * A3 + .380 * A4 \qquad \bar{R}^2 = .153$$

(47.33)[1] (43.85)[1]

Multifamily

$$MF = .383 + .225 * S1 + .086 * S2 - .09 * S4 - .203 * A2$$

(50.75)[1] (6.46)[1] (3.07) (19.84)[1]

$$- .280 * A3 - .352 * A4 \qquad \bar{R}^2 = .128$$

(47.96)[1] (49.02)[1]

Mobile Home

$$MH = .097 + .068 * S1 + .039 * S2 + .014 * S4 + .008 * A2$$

(7.01)[1] (1.98) (.121) (.043)

$$.020 * A3 - .016 * A4 \qquad \bar{R}^2 = .005$$

(.366) (.151)

Family Size	
S1	<2
S2	-3
S4	5<

Age of Household Head	
A2	25-30
A3	30-55
A4	55<

TABLE A.11: MODEL PARAMETERS: RESIDENTIAL NON-SPACE HEAT APPLIANCES

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

TABLE A.11: (continued)

Parameter		Region		
		Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Saturation Rates ($S_{j,t}$)				
CLOTHES WASHER	1980	.77	.75	.66
	1985	.78	.76	.68
	1990	.79	.77	.70
	1995	.80	.78	.72
	2000	.81	.79	.73
	2005	.82	.80	.74
	2010	.83	.81	.75
TELE-VISION	1980	1.50	1.51	.85
	1985	1.55	1.56	1.00
	1990	1.60	1.60	1.10
	1995	1.64	1.64	1.19
	2000	1.68	1.68	1.27
	2005	1.71	1.71	1.34
	2010	1.74	1.74	1.41
AIR-CON-	1980+	0	.01	0
Incremental Electrical Appliance Mode Split ($msi_{j,e,t}$)				
msi_{WH}	1980+	.35	.05	.04
msi_{C}	1980+	.66	.85	.04
msi_{CD}	1980+	.90	.98	.75
msi (other)	1980+	1.0	1.0	1.0

TABLE A.11: (continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Annual Appliance for New Appliances ($cs_{j,1980}$)			
Water Heater		.14	
Cooking		.03	
Clothes Dryer		.06	
Refrigerator		.29	
Freezer		.21	
Dishwasher		.18	
Clothes Washer		.29	
Television		.32	
Air Conditioner		.21	
Average Annual New Appliance Consumption ($kWh_{j,1985}$)			
Water Heater		.005	
Cooking		0	
Clothes Dryer		0	
Refrigerator		.01	
Freezer		.01	
Dishwasher Water		.005	
Clothes Washer		0	
Television		0	
Air Conditioner		0	

TABLE A.11: (continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Conservative Target for New Appliances ($cs_{j,1985}$)			
Water Heater		3,475	
Cooking		1,200	
Clothes Dryer		1,000	
Refrigerator		1,250	
Freezer		1,350	
Dishwasher		230	
Diswasher Water		700	
Clothes Washer		70	
Clothes Washer Water		1,050	
Television		400	
Air Conditioner		400	
Growth in Appliance Size ($kwhg_j$)			
Water Heater		3.650	
Cooking		1,250	
Clothes Dryer		1,000	
Refrigerator		1,560	
Freezer		1,550	
Dishwasher		230	
Dishwasher Water		740	
Clothes Washer		70	
Clothes Washer Water		1,050	
Television		400	
Air Conditioner		400	

TABLE A.11: (continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Annual Appliance for New Appliances ($cs_{j,1980}$)			
Water Heater		.14	
Cooking		.03	
Clothes Dryer		.06	
Refrigerator		.29	
Freezer		.21	
Dishwasher		.18	
Clothes Washer		.29	
Television		.32	
Air Conditioner		.21	
Average Annual New Appliance Consumption ($kWh_{j,1985}$)			
Water Heater		.005	
Cooking		0	
Clothes Dryer		0	
Refrigerator		.01	
Freezer		.01	
Dishwasher Water		.005	
Clothes Washer		0	
Television		0	
Air Conditioner		0	

TABLE A.11: (continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Lifetime of Appliance (ex_j)			
Water Heater		10	
Cooking		10	
Clothes Dryer		15	
Refrigerator		15	
Freezer		20	
Dishwasher		10	
Clothes Washer		10	
Television		10	
Air Conditioner		10	
Historical Electric Appliance Stock Growth Rates (g_j)			
Water Heater	.05	.03	.15
Cooking	.05	.03	.10
Clothes Dryer	.06	.04	.14
Refrigerator	.05	.03	.10
Freezer	.05	.03	.11
Dishwasher Water	.09	.04	.25
Clothes Washer	.06	.04	.12
Television	.07	.04	.20
Air Conditioner	0	.03	0

TABLE A.12: MODEL PARAMETERS: SMALL RESIDENTIAL APPLIANCES

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Annual Consumption Level (Kwh) 1980			
Electric lights	1,000	1,000	1,000
Assorted appliances	1,010	1,466	1,333
Annual Increment to Small Appliance Consumption (nKWH)	50	70	70

TABLE A.13: MODEL PARAMETERS: RESIDENTIAL SPACE HEATING

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Annual Unit Consumption (Existing Units) ($kwh_{j,1980}$)			
Single Family	36,500	48,200	33,300
Duplex	24,200	31,900	21,900
Multifamily	17,100	21,200	14,600
Mobile Home	27,300	36,900	25,400
Average Annual Unit Consumption (new Units) ($kwh_{j,1985}$)			
Single Family	40,100	53,000	36,600
Duplex	26,600	35,100	24,100
Multifamily	18,800	23,300	16,100
Mobile Home	30,000	40,600	27,900
Growth in Unit Size ($kwhg_j$)			
Single Family		.01	
Duplex		.01	
Multifamily		.01	
Mobile Home		.01	
Average Unit lifetime (ex_j)			
Single Family		20	
Duplex		20	
Multifamily		20	
Mobile Home		20	

TABLE A.13: (continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Incremental Electrical Appliance Mode Split ($msi_{j,e,t,}$)			
$msi_{SF,1980+}$	.19	.01	.02
$msi_{DP,1980+}$	.19	0	0
$msi_{MF,1980+}$	.19	0	0
$msi_{MH,1980+}$	.19	.01	0
Conservation Target for New Appliances ($cs_{j,1985}$)			
Single Family		.05	
Duplex		.05	
Multifamily		.05	
Mobile Home		0	
Utilization Rates ($UT_{j,e,t}$)			
$UT_{SF,1980+}$		1	
$UT_{DP,1980+}$		1	
$UT_{MF,1980+}$		1	
$UT_{MH,1980+}$		1	

TABLE A.13: (continued)

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Retrofitting Coefficients			
$(ret^{m}_{j,e,t})$			
$ret^{1980}_{SF,1985}$	.02	.04	.03
$ret^{1980}_{DP,1985}$	0	0	0
$ret^{1980}_{MF,1985}$	0	0	0
$ret^{1980}_{MH,1985}$	0	0	0

TABLE A.14: COMMERCIAL-INDUSTRIAL-GOVERNMENT MODEL PARAMETER

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
Average Consumption per employee in 1980	10.675	10.983	9.178
Average Consumption rate for 1981 to 1985 incremental employees	15.156	18.537	12.979
Subsequent Increases to Incremental Consumption Rate (nKWh)	3.020	3.707	2.596
Design and Performance Efficiency TArgets			
1985	0	0	0
1990	.05	.05	.05
1995+	.1	.1	.1

TABLE A.15: PARAMETER VAULES: THE PRICE INDUCED SHIFT TOWARD ELECTRICITY CONSUMPTION IN THE RESIDENTIAL SECTOR CASE

Parameter	Region		
	Greater Anchorage Area	Greater Fairbanks Area	Glennallen-Valdez Area
SPACE HEAT incremental mode split ($msi_{j,t}$)			
SINGLE FAMILY			
1985	.19	.01	.02
1990	.19	.01	.02
1995	.19	.01	.9
2000+	.19	.9	.9
DUPLEX			
1985	.19	0	0
1990	.19	0	0
1995	.19	0	.9
2000+	.9	.9	.9
MULTIFAMILY			
1985	.19	0	0
1990	.19	0	0
1995	.19	0	.9
2000+	.9	.9	.9
MOBILE HOME			
1985	.19	.01	0
1990	.19	.01	0
1995	.19	.01	.9
2000+	.9	.9	.9
APPLIANCES incremental mode split ($msi_{j,e,t}$)			
WATER HEATING			
1985	.35	.5	.4
1990	.35	.5	.4
1995	.35	.5	.9
2000+	.9	.9	.9
COOKING			
1985	.66	.85	.4
1990	.66	.85	.4
1995	.66	.85	.9
2000+	.9	.85	.9

TABLE A.16: MAP PROJECTIONS

	LE-LG	LE-MG	ME-MG	HE-MG	HE-HG
Employment					
1980	211	211	211	211	211
1985	231	244	262	291	304
1990	238	254	281	330	354
1995	259	287	329	405	445
2000	288	332	372	455	510
Population:					
1980	422	422	422	422	422
1985	467	481	504	536	550
1990	490	512	547	615	645
1995	528	565	625	733	786
2000	514	636	700	831	908

LE-LG - Low Economic Growth - Low Government Expenditure
LE-MG - Low Economic Growth - Moderate Government Expenditure
ME-MG - Moderate Economic Growth - Moderate Government Expenditure
HE-MG - High Economic Growth - Moderate Government Expenditure
HE-HG - High Economic Growth - High Government Expenditure

TABLE A.17: HOUSEHOLD FORMATION*

Year	LE-LG	LE-MG	ME-MG	HE-MG	HE-HG
1980	133	133	133	133	133
1985	153	158	165	175	179
1990	167	174	187	210	221
1995	186	200	222	262	261
2000	211	235	260	312	343

* LE-LG - Low Economic Growth - Low Government Expediture
LE-MG - Low Economic Growth - Moderate Government Expenditure
ME-MG - Moderate Economic Growth - Moderate Government Expenditure
HE-MG - High Economic Growth - Moderate Government Expenditure
HE-HG - High Economic Growth - High Government Expenditure

TABLE A.18: REGIONAL PROJECTIONS

	Low Economic Growth-Mod. Govt. Expenditures			Mod. Economic Growth-Mod. Govt. Expenditures			High Economic Growth-Mod. Govt. Expenditures		
	Employment	Population	Households	Employment	Population	Households	Employment	Population	Households
ANCHORAGE									
1980	102,529	219,303	68,224	102,529	219,303	68,224	102,529	219,303	68,224
1985	111,118	248,850	85,177	119,352	260,034	85,805	132,186	275,848	89,515
1990	116,939	265,539	94,528	128,267	282,766	97,827	148,498	314,247	108,048
1995	134,425	293,381	108,377	151,735	322,582	116,718	185,601	375.483	136,364
2000	157,268	329,865	127,099	173,021	361,239	137,172	211,011	427,146	163,560
2005	165,290	346,691	133,582	191,029	398,837	151,449	248,203	502,433	192,388
2010	173,722	364,376	140,396	210,912	440,348	167,212	291,950	590,989	226,278
FAIRBANKS									
1980	29,641	59,268	17,114	29,641	59,268	17,114	29,641	59,268	17,114
1985	36,508	70,276	21,152	38,813	73,072	22,118	43,223	78,354	24,121
1990	37,270	74,187	23,530	40,485	78,911	25,330	47,638	88,555	28,711
1995	41,729	81,966	27,433	46,840	89,840	30,414	57,492	104,871	36,287
2000	48,326	92,159	32,712	53,068	100,111	35,843	65,852	118,836	43,716
2005	50,791	96,861	34,381	58,591	110,531	39,574	77,459	139,782	51,422
2010	53,382	101,802	36,134	64,134	122,035	43,692	91,111	164,419	60,836
VALDEZ									
1980	2,146	5,821	1,876	2,146	5,821	1,878	2,146	5,821	1,878
1985	2,967	6,739	2,255	3,782	8,063	2,698	7,464	9,660	3,182
1990	3,328	7,163	2,491	4,241	8,768	3,059	7,323	11,080	3,830
1995	3,532	7,914	2,853	4,713	10,003	3,628	7,358	12,467	4,522
2000	4,033	8,898	3,354	5,237	11,201	4,197	7,717	13,296	5,060
2005	4,239	9,352	3,525	5,782	12,367	4,634	9.077	15,640	5,952
2010	4,455	9,829	3,705	6,384	13,654	5,116	10,677	18,396	7,001

TABLE A.19: RAILBELT HOUSING STOCK FORECASTS (000)

(a) Low Econ. Growth-Mod. Govt. Expend.

	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total
Single Family	37	9	.5	47	50	11	.7	62	66	15	1.1	82	72	17	1.3	90
Multi-Family	19	5	.2	24	25	7	.3	32	36	10	.5	47	40	11	.6	52
Mobile Home	9	2	.6	12	12	3	.6	15	16	4	.6	21	18	5	.7	24
Duplex	6	1	.2	7	6	1	.2	7	9	2	.2	12	10	2	.2	12

(b) Mod. Econ. Growth-Mod. Govt. Expend.

	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total
Single Family				47	53	12	.9	65	72	17	1.5	91	88	21	1.9	111
Multi-Family				24	28	7	.4	35	41	10	.7	52	50	14	.9	65
Mobile Home				12	12	3	.7	16	18	5	.6	24	22	6	.8	29
Duplex				7	7	1	.2	8	10	2	.2	12	12	2	.3	14

(c) High Econ. Growth-Mod. Govt. Expend.

	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total	Anch.	Fair.	Vald.	Total
Single Family				47	58	14	1.2	73	85	20	1.9	107	118	29	2.7	150
Multi Family				24	31	9	.5	41	49	14	.9	64	68	19	1.3	88
Mobile Family				12	14	4	.8	19	21	6	.8	28	29	8	1.1	38
Duplex				7	7	1	.2	8	12	2	.2	14	17	3	.3	20

TABLE A.20: FUTURE RAILBELT RESIDENTIAL NON-SPACE HEATING ELECTRICITY REQUIREMENTS

(a) Low Economic Growth-Moderate Government Expenditure

		Large Appliance							
Year	Anc.	Fair.	Vald.	Total	Anc.	Fair.	Vald.	Total	All Appliance for Railbelt
1980	382	95	6	483	144	41	3	188	671
1985	444	118	8	570	193	58	5	256	826
1990	489	135	9	633	238	73	6	317	950
2000	679	194	12	885	385	125	9	519	1404
2010	795	230	15	1040	494	165	12	671	1711

(b) Moderate Economic Growth - Moderate Government Expenditure

		Large Appliance							
Year	Anc.	Fair.	Vald.	Total	Anc.	Fair.	Vald.	Total	All Appliance for Railbelt
1980	382	95	6	483	144	41	3	188	671
1985	464	123	9	596	203	60	5	268	864
1990	523	142	10	675	255	78	7	340	1015
2000	753	211	15	979	427	137	12	576	1555
2010	975	278	21	1274	604	200	17	821	2095

(c) High Economic Growth - Moderate Government Expenditure

		Large Appliance							
Year	Anc.	Fair.	Vald.	Total	Anc.	Fair.	Vald.	Total	All Appliance for Railbelt
1980	82	95	6	483	144	41	3	188	671
1985	485	134	11	630	211	66	6	283	913
1990	574	162	13	749	282	89	9	380	1129
2000	886	257	18	1161	509	167	14	690	1851
2010	1302	387	28	1717	817	278	23	1118	2835

TABLE A.21: FUTURE RAILBELT RESIDENTIAL SPACE HEATING ELECTRICAL REQUIREMENTS

(a) Low Growth

Year	Anc.	Fair.	Vald.	Total
1980	395	51	0	446
1985	476	48	0	524
1990	539	44	0	583
2000	816	24	1	840
2010	982	12	1	995

(b) Moderate Growth

Year	Anc.	Fair.	Vald.	Total
1980	395	51	-	446
1985	508	48	-	556
1990	578	44	1	623
2000	906	25	1	932
2010	1198	15	2	1215

(b) High Growth

Year	Anc.	Fair.	Vald.	Total
1980	395	51	0	446
1985	220	48	1	569
1990	640	45	1	686
2000	1076	27	1	1104
2010	1623	21	2	1646

TABLE A.22: COMMERCIAL-INDUSTRIAL-GOVERNMENT REQUIREMENTS

(a) Low Economic Growth-Moderate Government Expenditure

Year	Anc.	Fair.	Vald.	Total
1980	966	255	27	1248
1985	1113	389	39	1541
1990	1218	408	44	1670
2000	2060	686	57	2803
2010	2487	857	66	3410

(b) Moderate Economic Growth - Moderate Government Expenditure

Year	Anc.	Fair.	Vald.	Total
1980	966	255	27	1248
1985	1238	431	49	1718
1990	1397	470	56	1923
2000	2319	792	73	3184
2010	3301	1161	99	4561

(c) High Economic Growth - Moderate Government Expenditure

Year	Anc.	Fair.	Vald.	Total
1980	966	255	27	1248
1985	1432	513	97	2042
1990	1719	609	95	2423
2000	2991	1070	102	4163
2010	5094	1874	168	7136

TABLE A.23: MISCELLANEOUS ELECTRICITY REQUIREMENTS

(a) Low Economic Growth-Moderate Government Expenditure

Year	Anc.	Fair.	Vald.	Total
1980	20	4	1	25
1985	23	6	1	30
1990	26	7	1	34
2000	41	11	1	53
2010	49	13	1	63

(b) Moderate Economic Growth - Moderate Government Expenditure

Year	Anc.	Fair.	Vald.	Total
1980	20	4	1	25
1985	25	7	1	33
1990	29	8	1	38
2000	46	12	1	59
2010	63	17	1	81

(c) High Economic Growth - Moderate Government Expenditure

Year	Anc.	Fair.	Vald.	Total
1980	20	4	1	25
1985	28	8	1	37
1990	34	9	1	44
2000	57	16	1	74
2010	91	26	2	119

TABLE A.24: FUTURE MILITARY AND SELF-SUPPLIED INDUSTRIAL REQUIREMENTS

Year	Military Net Generation	Self-Supplied Industry Net Generation		
		Low	Moderate	High
1980	334	414	571	847
1985	334	414	571	847
1990	334	414	571	981
1995	334	414	571	981
2000	334	414	571	981
2005	334	414	571	981
2010	334	414	571	981

TABLE A.25: RAILBELT UTILITY SALES PROJECTIONS BY END USE SECTION (10^3 MWh)

(a) THE BASE CASE

	Low Economic Growth Moderate Equipment Expenditure				Moderate Economic Growth Moderate Equipment Expenditure				High Economic Growth Moderate Equipment Expenditure			
Year	Residential	Commerical Industrial	Misc.	Total	Residential	Commercial Industrial	Misc.	Total	Residential	Commercial Industrial	Misc.	Total
1980	1117	1248	25	2390	1117	1248	25	2390	117	1248	25	2390
1985	1350	1541	30	2921	1533	1718	33	3171	1482	2042	37	3561
1990	1533	1670	34	3237	1638	1932	38	3599	1815	2423	44	4282
2000	2244	2803	53	5100	2487	3184	59	5730	2955	4163	74	7166
2010	2706	3410	63	6179	3310	4561	81	7952	4481	7136	119	11736
Annual Growth Rate	3.0%	3.4$	3.1%	3.2%	3.7%	4.4%	4.0%	4.1%	4.7%	6.0%	5.3%	5.4%

(b) PRICE INDUCED SHIFT TOWARDS ELECTRICITY

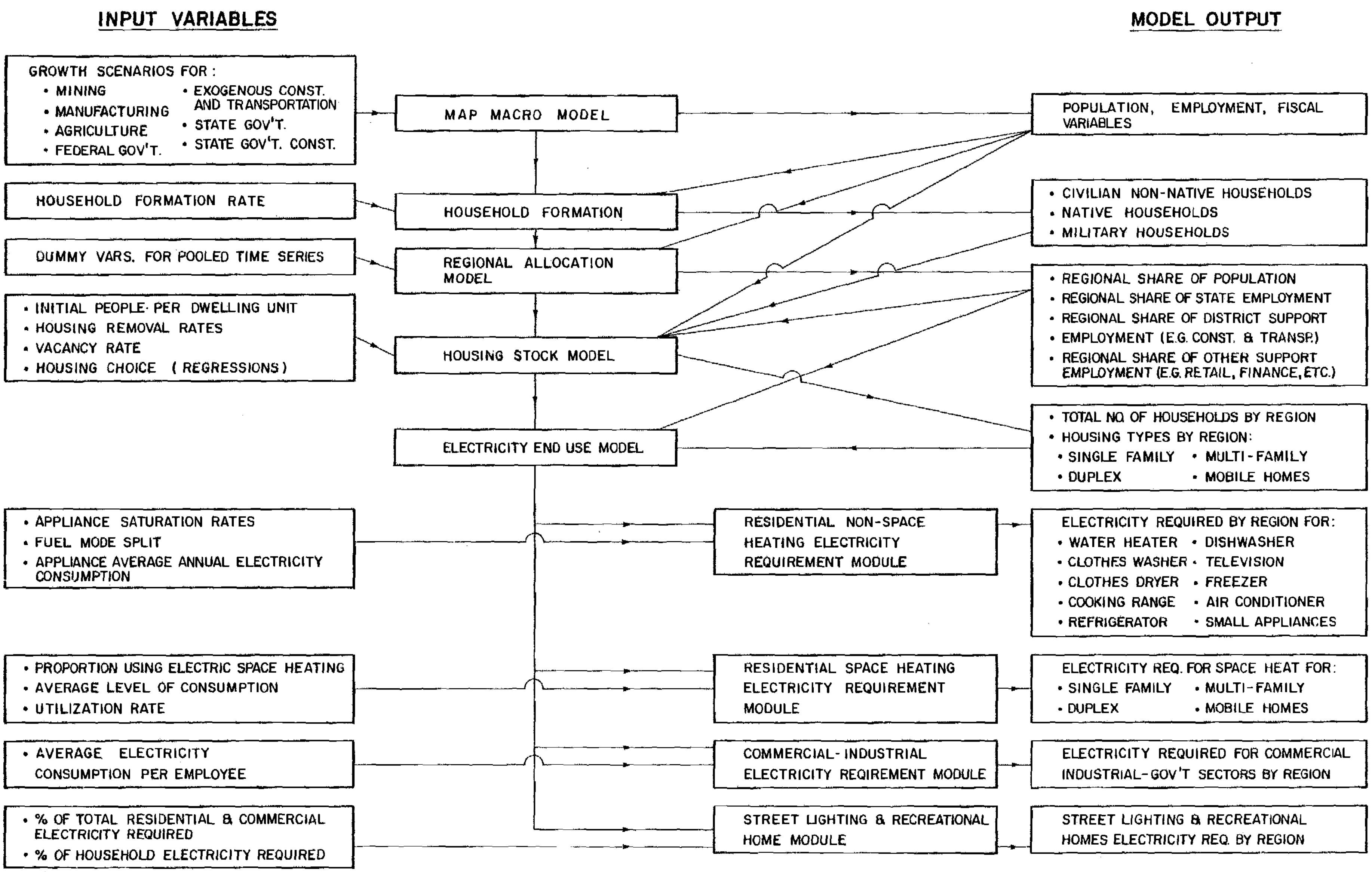
MODERATE ECONOMIC GROWTH SCENARIO - MODERATE GOVERNMENT EXPENDITURE

Year	Commercial - Industrial - Government
1980	1248
1985	1718
1990	1923
2000	3184
2010	3561

TABLE A.26: PROJECT ELECTRIC UTILITY SALES AND MILITARY PLUS SELF-SUPPLIED INDUSTRIAL NET GENERATION (10^3 MWh)

	Utility Sales						
	Anchorage	Fairbanks	Anchorage+ Fairbanks	Glennallen-Valdex	Total Utility Sales	Military Net Generation	Self-Supplied Industry Net Generation
1978	1,747	427	2,174	38	2,212	334	414
1980	1,907	446	2,353	37	2,390	334	414
1985							
L	2,249	619	2,868	53	2,921		414
M	2,438	669	3,107	64	3,171	334	571
H	2,676	769	3,445	116	3,561		847
M-E	2,438	669	3,107	64	3,171		571
1990							
L	2,510	666	3,176	60	3,236		414
M	2,782	742	3,524	75	3,599	334	571
H	3,249	914	4,163	119	4,282		981
M-E	2,782	742	3,524	75	3,599		571
1995							
L	3,097	813	3,910	66	3,976		414
M	3,564	949	4,513	88	4,601	334	571
H	4,438	1,227	5,665	124	5,789		981
M-E	3,564	949	4,513	104	4,617		571
2000							
L	3,981	1,040	5,021	80	5,101		414
M	4,451	1,177	5,628	102	5,730	334	571
H	5,519	1,537	7,056	136	7,192		981
M-E	4,973	1,416	6,389	136	6,525		571
2005							
L	4,375	1,154	5,529	88	5,617		414
M	5,226	1,397	6,623	119	6,742	334	571
H	7,013	1,988	9,001	176	9,177		981
M-E	6,220	1,834	8,054	165	8,219		571
2010							
L	4,807	1,277	6,084	95	6,179		414
M	6,141	1,671	7,812	140	7,952	334	571
H	8,927	2,586	11,513	223	11,736		981
M-E	7,624	2,318	9,942	200	10,142		571

L = Low Economic Growth - Moderate Government Expenditure
M = Moderate " " - " " "
H = High " " - " " "
M-E = Moderate " " - " " "
with shift to electric space and appliances in residential sector.



ISER ECONOMETRIC END-USE FORECASTING MODELS

FIGURE A-1

APPENDIX B

CRITIQUE OF ISER
REPORT BY ALASKA PACIFIC BANK

AUGUST 27, 1980

AlaskaPacificBank
A Subsidiary of Alaska Pacific Bancorporation

August 27, 1980

Mr. Eric Yould
Executive Director
Alaska Power Authority
333 West Fourth Avenue
Anchorage, Alaska 99501

Dear Eric:

Concerning the employment and population projections prepared by ISER which you sent for our review, I would agree with you that they appear low. Generally speaking, we can make a strong case for a version closer to their high economic development/high government spending scenario.

While we are not prepared to provide you with detailed projectons, it is my comment that a more aggressive estimate for Alaska average annual employment growth between 1980 and 1985 would be about 6.5%. I would expect this average annual rate of growth to slow somewhat during the 1985-1990 period, to perhaps the 5.5% area, unless, of course, we can count on some definite progress in our resource development projects. That represents at least a 6% average annual rate of growth for Alaska employment during the decade of the 1980's.

Beyond 1990, an average annual rate of growth in the neighborhood of 3.5% for each of the five-year periods may be a conservative number, but the current uncertainty associated with our future development makes it a minimum rate. Keep in mind, also, that any growth during that period will be advancing from a higher base which, no doubt, will translate into a slower rate of change.

Obviously, these rates of growth reflect the assumption for gasline construction in the mid-1980's. However, as you know, there are a myriad of other energy resource related projects possible in Alaska in the future, and although the employment impact of these separate projects probably will be less significant than the trans-Alaska oil pipeline construction project, each event can be expected to make its own contribution. Unfortunately, the timing of these major events is the one factor missing from any analysis, and, therefore, more precise employment forecasting at this time is difficult and perhaps misleading. I note, however, that ISER omits discussion of a gas liquids project per se, and I find it difficult to believe that federal government employment in Alaska will slow as suggested.

In terms of the population impact of future development in Alaska, the average annual rates of growth may be closer to 4% for the 1980's and 2% for the 1990's. Obviously, once again these numbers depend on various resource development assumptions, but for your information they result from a population to employment ratio of 2.2 in 1985 and 2.0 in 1990.

The chart below summarizes this brief analysis.

Estimated
Average Annual Rates of Growth

Alaska Employment		Alaska Population	
1960 - 1970	5%	1960 - 1970	3%
1970 - 1980	6%	1970 - 1980	3%
1980 - 1990	6%	1980 - 1990	4%
1980 - 1985	6.5%	1980 - 1985	3.9%
1985 - 1990	5.5%	1985 - 1990	3.7%
Beyond 1990	3.5%	Beyond 1990	2%

Generally speaking, the ISER pattern of growth appears reasonable if the majority of our resource development for the time being takes place in the mid-80's, followed by a period of slower growth in the late 1980's absent any new, major projects. However, as stated above, the huge quantity of Alaska's energy-related resources augers for our future development at some point. Therefore, it would seem reasonable that Alaska's near-time future employment growth can be expected to remain at least as healthy as it has been in the recent past.

I remain available to you if you wish to discuss these estimates further.

Sincerely,

M. L. Couch
Assistant Vice President

S36A/X

APPENDIX C

CRITIQUES OF ISER
REPORTS BY WOODWARD
CLYDE CONSULTANTS

APRIL/JULY, 1980

Review of

The University of Alaska Institute of
Social and Economic Research Report

"Electric Power Consumption for the Railbelt:
A Projection of Requirements"

by

Craig W. Kirkwood
F. Perry Sioshansi

July 1980

Woodward-Clyde Consultants
3 Embarcadero Center, Suite 700
San Francisco, CA 94111

INTRODUCTION

This document constitutes the written critique of the University of Alaska Institute of Social and Economic Research (ISER) final report [S. Goldsmith and L. Huskey, "Electric Power Consumption for the Railbelt: A Projection of Requirements," May and June 1980] as required by Section 1.1.5 of the Scope of Work for agreement no. P5700.10.21 between Woodward-Clyde Consultants (WCC) and Acres American Incorporated (Acres). In accordance with a letter of May 14, 1980 from Acres, this review is brief. Primarily it is an update of WCC's review of the ISER draft report [C. W. Kirkwood and F. P. Sioshansi, "Review of ISER Draft Report", April 1980]. For a complete review of the ISER electric demand forecasting work, this earlier document should be read in conjunction with the current critique.

The conclusions reported here are based on a review of all three parts of the ISER final report: the Executive Summary dated May 16, 1980, the main body dated June 1980 and the Technical Appendices dated May 23, 1980. Additional perspective was gained by WCC attendance at a workshop for Railbelt utility representatives on June 10, 1980 and a public workshop on June 11, 1980. At these workshops Scott Goldsmith of ISER presented the results of the ISER study and answered questions.

REVIEW CONCLUSIONS

ISER's work is the first attempt to construct an econometric/end use electric energy demand forecasting model for the Alaska Railbelt. It is the most comprehensive look at future Railbelt electric energy needs to date. Given the difficulty of obtaining much of the needed data and the limited time available, the ISER work is a major achievement. However, there are significant limitations in the work which restrict its usefulness in a study of alternatives for meeting the Railbelt's future need for electric power.

Most of our conclusions reported earlier regarding the work discussed in ISER's draft report apply to the final report as well. In particular, we conclude the following:

- ISER's overall approach, utilizing economic and population projections coupled with an end-use model to forecast total electric energy demand, is sound.
- The modeling work suffers from a lack of some important data and the poor quality of other data. Substantial improvements in this would require an ongoing data collection program over a period of years.
- It does not appear that a structured approach was used to develop input scenarios regarding possible future development in the Railbelt. In particular, the scenarios appear to represent only the personal professional views of the authors with no systematic attempt to incorporate other points of view.
- Uncertainties associated with the forecasts are treated in a crude manner. Because of this it is difficult to determine the significance of these uncertainties for power system planning.
- Only very limited sensitivity analysis was carried out to study the implications of varying the input assumptions used in the forecasting model.
- For the above reasons, the forecasts made by ISER are not necessarily superior to those provided by a simpler analysis approach.

IMPLICATIONS OF OTHER WORK

The ISER final report contains a summary of other electric demand forecasting studies that have been carried out for the Railbelt. In general, previous studies have forecast greater future demand than the current ISER study.

At the utility and public workshops, Professor Goldsmith commented that he believes other studies done during the last decade were overly influenced by the high rate of development occurring during the oil pipeline construction period. However, he also noted that the scenario approach to forecasting, which is used in the ISER work, may be myopic and, as a result of this, underestimate future growth. He discussed steps taken in the ISER study to counter this tendency. In addition, he noted that previous studies that used the scenario approach have not systematically underestimated the Railbelt growth that has actually occurred to date, although the details of the growth have turned out to be somewhat different than what was forecast.

An important reason for the differences in forecasted energy demand growth between the ISER study and previous studies is the difference in forecasted population growth. The factors influencing future population growth in the Railbelt are subject to many uncertainties. The assumptions about these factors that were made in the ISER study should be given careful consideration since the authors of the study have considerable knowledge and experience regarding Railbelt development. However, as the utility and public workshops made clear, there are other reasonable points of view about these factors that might lead to substantially different forecasts of future electric energy demand.

STRENGTHS AND LIMITATIONS OF ISER WORK

A well-constructed econometric/end-use model can be a powerful tool for studying the possible implications of proposed energy-related actions or policy changes. However, past experience indicates that substantial time and resources must be invested to achieve reasonably defensible results with such a model.

The ISER work to date provides a solid basis for development of an econometric/end-use model. However, we believe that at its current stage of development, the ISER model does not give results that are more defensible than those of previous forecasting studies. The previous studies were, however, limited, one-time efforts while the ISER work could form the basis for an ongoing modeling and data collection effort to develop a sophisticated energy forecasting tool for the Railbelt.

Regardless of what model is used to forecast future electric energy demand, there will be substantial uncertainties about many of the input assumptions made in the model. These will lead to substantial uncertainties in the forecasted electric energy demand. For example, Professor Goldsmith commented in the public workshop that he believed there was approximately a 20 or 25 percent chance the actual future demand would be below the "low" forecast presented in the ISER final report and a similar chance it would be above the "high" forecast.

With this degree of uncertainty, there are reasonably likely levels of future electric demand so low that the Susitna Project could provide more electric energy than would be needed. There are also reasonably likely levels of demand for which substantially more capacity would be needed than could be provided by the Susitna Project.

It appears desirable to analyze the over- and under-capacity risks associated with Susitna Project planning in the presence of these large uncertainties about future demand for electricity. Such an analysis requires that uncertainties be treated explicitly in the demand forecasts. This is not done in the ISER work; this is a major limitation of the work with regard to its usefulness for the Susitna Project.

A second, related limitation is that the input assumptions and scenarios used in the modeling work represent only the judgments of ISER professionals. While these experts are very knowledgeable about potential future Railbelt developments, it appears from the utility and public workshops that there are other knowledgeable individuals who have somewhat different views about the future of the Railbelt. It seems desirable to have these views incorporated into the demand forecasting work. This was not done systematically in the ISER work.

REVIEW OF ISER DRAFT REPORT

by

Craig W. Kirkwood
F. Perry Sioshansi

April 1980

Woodward-Clyde Consultants
Three Embarcadero Center, Suite 700, San Francisco, CA 94111

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1.0

INTRODUCTION

This document constitutes the written critique of the University of Alaska Institute of Social and Economic Research (ISER) draft report as required by Section 1.1.5 of the Scope of Work for agreement no. P5700.10.21 between Woodward-Clyde Consultants (WCC) and Acres American Incorporated (Acres).

Under Subtask 1.01 of the abovementioned Scope of Work, WCC is to review the methods investigated by ISER for possible use in its forecasting, and to assess the strengths and weaknesses of the methods selected by ISER for its forecasting. This review and assessment is to include consideration of the techniques and methods investigated by ISER for use in:

1) Projecting economic development,

2) Selecting input scenarios for its economic development models,

3) Developing its econometric-end-use mode for forecasting electricity load requirements, and

4) Considering the uncertainties in its forecasts.

In addition, the review is to consider the quantity and accuracy of the data used in the ISER forecasting methods. Furthermore, WCC is to assess the implications for the ISER work of the work done by others in the area of energy and economic development in the Railbelt Region.

These issues are addressed here to the degree possible given the information in ISER's draft report. It should be noted that ISER refers to their draft report as a "progress report." However, it is clear from discussions with them that this report is the draft report called for in Clause I of the contract between the State of Alaska Legislative Affairs Agency and ISER. Hence, it is this report that WCC is to review under its agreement with Acres to critique the ISER draft report.

This review is organized into the following sections:

1) a summary of the general conclusions of our review
2) a detailed review of the draft report
3) a consideration of the implications for the ISER work of the work done by others, and
4) an assessment of the strengths and limitations of the ISER work.

2.0

OVERALL REVIEW CONCLUSIONS

2.1 GENERAL CONCLUSIONS

ISER's basic approach to forecasting total electric energy demand is state-of-the art. Because the approach requires substantial model development effort and an extensive data base, it has generally only been attempted by large utilities or other organizations with substantial resources. Althouth the basic approach that ISER has taken is sound, the specific methodology they have developed to implement the approach has serious technical deficiencies which substantially limit the defensibility of the results obtained. In addition, there are serious weaknesses in the data base that ISER is using to support their modeling work.

Most of the methodological weaknesses could be corrected with several person-months of additional development work by knowledgeable analysts. Some deficiencies in the data base could also be corrected with several additional person-months of data collection. Additional work would also be required to adequately document the methodology and data base.

However, even with this additional work, certain types of data that are important for defensible forecasting using ISER's approach could only be collected by a well-designed data-gathering program over a period of some years. This length of time is necessary to obtain information on variations in electric energy consumption patterns as weather conditions change with the seasons.

With the additional model development, data collection and documentation effort, defensible forecasts could be produced for use in the Susitina Project power studies. However, the sophisticated methods that are being used by ISER will probably not produce forecasts that are, on the whole, necessarily more defensible than what could be obtained using considerably simpler methods. This is because there are substantial uncertainties about some of the major inputs needed by any model that forecasts future Railbelt development. The variations in the forecasts resulting from plausible variations in these uncertain input quantities will probably be greater than errors that may result from using a simplified forecasting model.

2.2 SPECIFIC CONCLUSIONS

Our specific conclusions regarding the work presented in ISER's draft report are summarized in this section. The results of our detailed review of the draft report (which serve as the basis for these conclusions) are presented in Section 3.

We conclude the following:

- ISER's overall approach, utilizing economic and population projections coupled with an end-use model to forecast total electric energy demand, is sound. However, their methodology for implementing this approach has numerous technical and procedural flaws. In addition, there are numerous deficiencies in the way they have implemented this methodology.

- Many of the methodological deficiencies could be reduced with moderate additional effort by knowledgeable analysts. Similarly, substantial improvements in the implementation should be possible with moderate additional work.

- Some deficiencies in the current work are due to lack of some important data and the poor quality of other data. Some improvement in data would be possible with a short-term data collection program. However, major improvements can only be achieved by an ongoing data collection program over a period of years.

- End-use models, by their nature, require an extensive data base. Due to the current lack of quality data, the forecasts made using the ISER end-use model are not necessarily superior to those provided by a simpler analysis approach. Based on our review of other applications of end-use models, we expect that the defensibility of the end-use model results will improve over time as better data become available.

- At present, ISER's end-use model is incomplete and poorly documented. In particular, distinctions between the residential and commercial/industrial sectors are not well addressed. The treatment of the commercial/industrial sector is very weak, and within the residential sector not enough emphasis has been placed on analyzing various types of residential housing and their associated electric demands.

- The documentation in the draft report is generally poor. Many important assumptions are not substantiated while others are not explicitly stated. A systematic documentation of all input assumptions, and the rationale for making them, is highly desirable.

- The draft report does not indicate that any structured approach was used to develop input scenarios regarding possible future developments in the Railbelt. In view of the dynamic political climate and great uncertainties about the future of Alaska, it is essential that input scenarios be carefully selected if the resulting forecasts are to be defensible.

- The draft report indicates an inadequate review of existing literature and data sources regarding modeling and forecasting demand for electricity. Some of ISER's model components could be substantially improved by adopting existing similar models or model components.

Any one of these deficiencies would compromise the defensibility of ISER's forecasts for the purposes of the Susitna Project. In our judgment, the combination of all the above deficiencies means that ISER's current forecasts would not be able to withstand critical review well enough to serve as a defensible basis for assessing the need for the power the Sustina Project would provide.

We have provided specific suggestions for overcoming many of the deficiencies as part of our detailed critique in Section 3. Some of the deficiencies can be overcome without excessive delay or effort. Other deficiencies, particularly data inadequacies, would require more effort and time to improve.

There are some important issues related to the Susitna Project power studies that are not directly addressed by the ISER work. Consideration of these issues goes beyond just a review of ISER's work, so further discussion of them will be deferred until Section 5 where there is an assessment of the strengths and limitations of ISER's work with regard to the Susitna Project power studies.

3.0

DETAILED REVIEW OF DRAFT REPORT

This section contains a detailed review of the ISER draft report. In keeping with the scope of work for our review, this section considers the following:

1) Alternative forecasting methods considered by ISER,
2) The forecasting methodology used,
3) Quantity and accuracy of the data used, and
4) Methods used to consider uncertainties.

Because of serious editorial problems with the ISER draft report, it is often difficult to be certain exactly what was done.

In what follows, page numbers in parentheses refer to pages in the ISER draft report unless otherwise noted. In numerous places we have suggested further work that could be done or additional sources of information that we believe would be useful for ISER's work. Strictly speaking, these suggestions are beyond the immediate scope of our review. Ultimate responsibility for the total electric energy demand forecasting work rests with ISER, of course.

3.1 ALTERNATIVE FORECASTING METHODS CONSIDERED BY ISER

The draft report contains no discussion of alternative forecasting methods considered by ISER before adopting their present methodology.

From our discussions with ISER it appears that they considered various alternative forecasting methods. It would be helpful to discuss what alternative methods were considered and the rationale for selecting the methodology used. ISER's contract with the Alaska Legislative Affairs Agency calls for a report on this topic in mid-January 1980; this has still not been delivered.

Considerable research has been carried out elsewhere in the U.S. on forecasting electric power demand, and ISER appears to be unfamiliar with this literature. There are no references to this work in ISER's draft report. Several references and data sources are suggested in our discussion in the following section.

3.2 FORECASTING METHODOLOGY

The forecasting methodology used by ISER is presented in Part II of their draft report. The methodology consists of eleven components:

- I. Economic Growth Scenarios
- II. MAP Statewide Econometric and Demographic Model
- II.A. Household Formation Model
- III. Regional Allocation Model
- IV. Appliance Saturation and Energy Utilization Model
- V. Final Energy Demand Model
- VI. Housing and Appliance Stock Model
- VII. Energy Availability Scenarios

VIII. Mode Split Model

IX. Energy Efficiency Model

X. Energy Requirements by Fuel Type Model

Each of these is separately discussed below.

3.2.1 Economic Growth Scenarios

This model component is critical as it influences every other aspect of the model. At present, this component is inadequately defined, as well as poorly structured and presented. Although further discussion of economic scenarios is presented in Part III (pp. 3.10-3.16), even with this added discussion, the scenarios are inadequate and poorly documented.

Major problems are that relationships between endogenous and exogenous variables are not well defined and that the sources and relative magnitudes of impacts for given scenarios are not discussed. This is a significant shortcoming since several major exogenous factors are the basic driving forces of the Alaskan economy. These exogenous variables influence three major sectors which, in turn, affect everything else in the economy (see Figure 3.1). To develop credible economic scenarios, one must start with a clear specification of these basic entities and their interrelationships. Particular attention, for example, should be given to state government policies. The role of the federal government must also be considered, particularly as it applies to energy policies.

Major Exogenous Variables

- National/International Economy
- World Market Fuel Prices
- National Energy Policies
- State Government Investment/Expenditures
- Discovery of Major New Fuel Reserves in Alaska

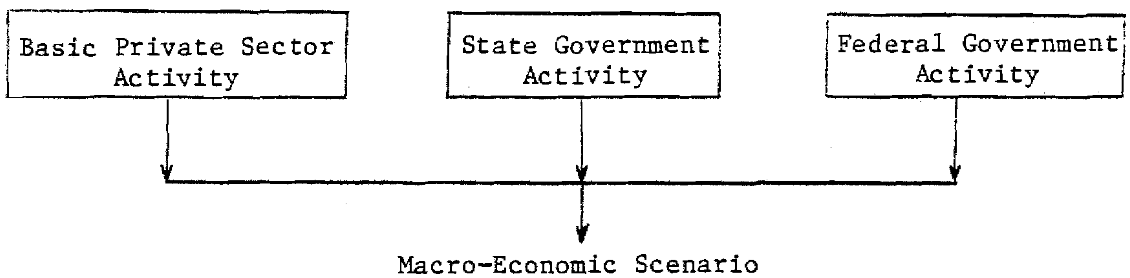

Figure 3.1. MAJOR EXOGENOUS VARIABLES AND ECONOMIC SCENARIOS

The role of the private sector must be defined in the context of state and federal regulations and policies.

A defensible scenario combines reasonable and internally consistent assumptions about these basic sectors. ISER's scenarios are not well documented and presented. For example, their "High Scenario" (pp. 3.14-3.16) results in construction employments (Table 3, p. 3.19) which are not only low but, in fact, incredible for the 1990-2000 period. Part of this problem (which is also present in the "low" and "moderate" scenarios) may be attributed to myopia. ISER only considers projects that are currently being considered and can be expected to be completed by 1990. This implicitly assumes that no additional projects will start in the 1990s. At the very least it seems appropriate to assume a continuing, reasonably healthy level of construction activity under the "high" scenario.

Another shortcoming of ISER's work is the absence of direct or induced state government investment/expenditure (although part of the indirect involvement may be implicit in ISER's "Industry Assumptions" [pp. 3.11-3.16] regarding industries such as agriculture and fisheries). In view of Alaska's large expected budget surplus for the next couple of decades* and of the potential for further exploration, development,

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*According to a recent article in the Wall Street Journal, "The extra money will total $53 billion over the next 10 years and a further $44 billion in the succeeding decade" (Wall Street Journal, 1980).

and export of oil and natural gas, particular attention should be devoted to the role of state government. The high scenario, in particular, should consider a sizable and increasing state government surplus which can be used to accelerate economic development and growth.

Furthermore, the effect of state and/or federal regulatory decisions, energy and conservation policies, and politically induced legislations are not considered. Any of these factors could have a significant impact on the Alaskan economy and demand for electricity in the Railbelt.

To illustrate the importance of carefully considering input scenarios, consider the possibility of a trans-Canada natural gas pipeline or an LNG facility on the Kenai Peninsula. Currently, all utilities in the Anchorage area use natural gas, at rates far below the world market price, to generate electricity, and their customers enjoy some of the lowest electricity rates in the nation. As a result, many homes are electrically heated. If the natural gas were to be exported the local utilities might be forced to pay higher prices which would be passed on to their customers. Under these circumstances, electric space heating might no longer remain attractive. The long-term effect of this on future electricity consumption is likely to be sizable. There is currently strong opposition by some of the gas burning utilities to such an eventuality. Hence, it may be politically unpopular to vote for the gas pipeline or LNG plant. On the other hand, federal regulations may make it progressively more difficult to use natural gas for power generation when other alternatives are available. This example illustrates the importance of well thought-out and consistent scenarios.

ISER's "Current Status" (p. 2.5) is clearly not adequate, and their proposed "Future Work" (p. 2.5) does not appear adequate to provide defensible scenarios.

3.2.2 MAP Statewide Econometric and Demographic Model*

The current MAP model appears to be a defensible method for providing overall population, employment, and income level forecasts for Alaska for the Susitna Project. In the long-run, however, MAP should be modified to better accommodate policy type variables and macro-economic scenarios. The link between the national and Alaskan economies should also be strengthened using a national macro-economic model (such as those available from Data Resources, Inc. and Chase Econometrics). Variables other than wage differentials (e.g., low mortgage rates, lower taxes, etc.) may attract people to Alaska in the future and should be considered and appropriately modeled. A particularly useful economic/ demographic model which may be of value to ISER's subsequent work is the model jointly developed by New England Power Pool (NEPOOL) and Battelle Columbus Laboratories (1977).

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*Our comments on the MAP model are based on documentation provided by ISER dated May 31, 1979: "Man-In-The-Arctic-Program," compiled by Oliver Scott Goldsmith, Institute of Social & Economic Research, University of Alaska, Anchorage, Alaska.

3.2.3 Household Formation Model

ISER has linked this model to the MAP model. In our judgment, it would be better to link this model to the Regional Allocation Model. It appears simpler to allocate total population to the Railbelt area first and then forecast household formation rates for the Railbelt. ISER's modeling component diagram does not show this subcomponent and its relationship to the housing and appliance stock model (p. 2.1).

Particular reasons for recommending the above modification are: (1) the Railbelt area comprises Alaska's most developed and populous region and better data (compared to the rest of Alaska) is available for this area, (2) the Railbelt has a relatively low percentage of natives (whose household formation and size patterns are not as well understood), and (3) the modification would simplify the link between the MAP and Regional Allocation Models.

Since similar models have been developed previously and adjustments for Alaska's unique characteristics could have been readily made, we are not sure why ISER developed their own model. The present model is fairly crude and its forecasts depend on several key assumptions that are not adequately documented. ISER's claim that "In reality, the complexity of the household formation decision and the important recent structural changes make any statistical estimates of this relation questionable" (p. 2.9) is only partially true. While there are disagreements between demographers on future rates of household formation, certain qualitative trends are likely to continue and can provide useful forecasting bounds (for example, see Slater 1980; NEPOOL and Battelle 1977; U.S. Department of Commerce, Projections of the Population of the US: 1977-2050, 1976).

Despite these shortcomings the ISER model could provide adequate results which could be tested against more detailed models. This would provide an opportunity to fine tune their model and calibrate its parameters. However, we were not able to verify if the model is appropriately formulated because ISER's intermediate results (such as the average number of people per household, etc.) are not presented in the draft report. We recommend that such information be summarized in their final report and that they compare this information to national trends and trend forecasts. Furthermore, we recommend that ISER perform sensitivity analyses on the key assumptions used and present these results in summary form. Their statement, "The future household formation rates are assumed to follow the pattern of change projected at the national level," (p. 2-10) requires substantiation.

3.2.4 Regional Allocation Model

This model component converts MAP's statewide projections to corresponding projections for the Railbelt area, bypassing the development of a separate regional economic model. This is a reasonable approach because many development and construction activities are likely to take place outside the Railbelt which affect the residential and commercial activities in the Railbelt. This is true because of the central geographical location of the area and the fact that more than three quarters of the state's population lives within its boundaries.

ISER's present approach appears to be based on a continuation of historical trends and past relationships between various regions. While we do not recommend a detailed analysis of regional economics and growth patterns, it is suggested that analysis of historical regional growth trends be complemented by a study of their relative potential for future development and economic activity. For example, some regions of the state may be expected to prosper more than proportionately as a result of new discoveries of natural resources (e.g., oil, natural gas, wood products) and subsequent development of these resources. Such possibilities should be considered in the context of the overall economic scenarios to produce consistent and credible results.

ISER's "Current Status" (p. 2.14) indicates that this model component requires additional work. Their present documentation does not clearly indicate exactly which factors are assumed to determine each region's share of activity (p. 2.13). Better documentation would be necessary to judge the validity of ISER's assumptions. It would be adviseable to perform sensitivity analysis to identify and better define the most influential parameters.

3.2.5 General Comments Regarding Remaining Model Components

Following a review of several other forecasting approaches (in particular NEPOOL and Battelle 1977; Pacific Gas and Electric Co., California Energy Commission, Burbank 1979; Comerford 1979; Thomas 1979; Torrence and Maxwell 1979; Fitzpatrick 1979; National Research Council 1978; and DRI 1976), taking into account Alaska's unique characteristics, data inadequacies, and ISER's time and resource constraints, we conclude that a reasonably sophisticated and defensible electric demand forecasting model of the type ISER is developing should include the following four major components (Figure 3.2):

- Scenarios that provide the primary exogenous inputs of the model (as discussed in Section 3.2.1),
- Economic projections that take various scenarios and other data as input and generate forecasts of population, employment, income, and so on using econometric models,
- End-use models that convert the output of the economic projections into forecasts of electric appliance ownership (purchase/replacement) and utilization taking into account factors such as price of alternative fuels, income of the household, regulations on average efficiency of electric appliances and so on (Note that a direct link between the scenarios and the end-use models is required.), and
- Electricity demand projections that simply sum total electricity consumption across individual consuming units using information generated in the previous two steps.

These components should be linked so their interdependencies are technically correct and logically consistent. ISER's present model components (p. 2.1) do not fully satisfy either qualification. Figure 3.3, a more detailed version of Figure 3.2, shows the subcomponents of a reasonably sophisticated and defensible model and their interdependence. A comparison of this figure and that shown in ISER's report (p. 2.1) suggests how ISER's model components might be rearranged and what new components are necessary. (Some of these subcomponents may already be implicit in ISER's work but not specifically referred to or presented.) The suggested rearrangement should not involve substantial additional work and would result in a better structured and more defensible model.

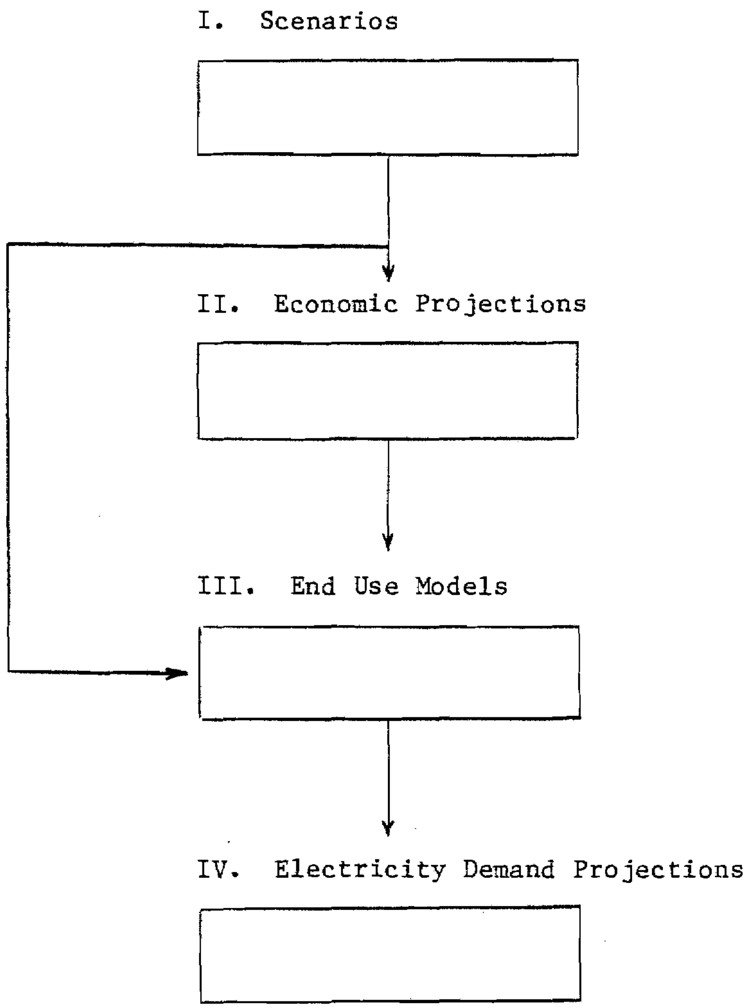

Figure 3.2. MAJOR COMPONENTS OF AN ELECTRIC DEMAND FORECASTING MODEL

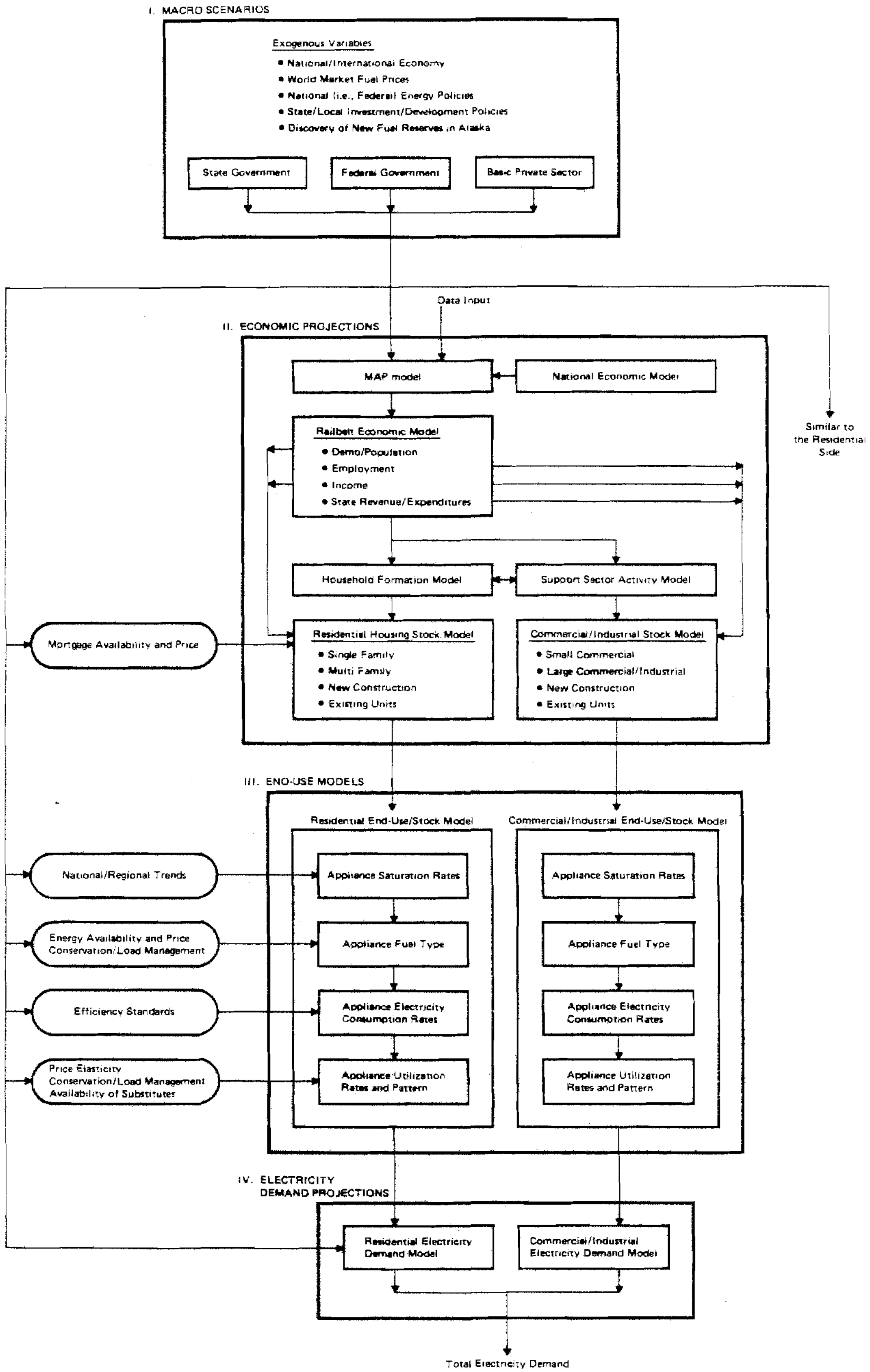

Figure 3.3. DETAILED COMPONENTS OF AN ELECTRIC DEMAND FORECASTING MODEL

3.2.6 Appliance Saturation and Energy Utilization Model

This section of ISER's model is poorly documented. The assumptions/ results presented in Part III are difficult to interpret and are generally shown in unconventional units and terms. The assumptions made about future saturation and utilization rates, when presented, are unsubstantiated. Substantial additional work and better documentation and presentation are required on this model component.

It would aid the reader if a summary table were included, showing for residential and commercial customers:

1) Saturation rates for major appliances, both historical and projected (%),

2) Average consumption rates for appliances, both historical and projected (kWh/unit/yr), and

3) Average utilization rates per appliance, both historical and projected (kWh/household/yr).

Since this type of data is available for many lower 48 utilities, (for example, see Table 3.1) a rough check on the validity of the projected rates could be made if this information was presented. The information in this proposed table, coupled with information on numbers of households, would allow a computation of total demand per household, which could also be compared to national data (for example, see Tables 3.2 and 3.3). Much of the desired information is in the report, but one has to sift through several tables and do additional calculations to convert it to the desired format.

Table 3.1. COMPONENTS OF RESIDENTIAL USE PER CUSTOMER+

	Annual Kilowatthours		
	kWh/Unit	1976 Saturation	kWh/Cust.
Frost-free refrigerator	1400	0.678	949
Refrigerator	860	0.493	424
Freezer	1400	0.271	379
Color television	500	1.048	524
B&W television	235	0.924	217
Water heater	4500	0.067	302
Electric range	1200	0.474	569
Clothes washer	103	0.837	86
Electric dryer	993	0.455	452
Dishwasher	363	0.517	188
Air conditioner, window	390	1.020	398
Air conditioner, central	3200	0.115	368
Lighting	1000	1.000	1000
Small appliances	300	1.000	300
Heating plant	560	0.975	546
			6702 kWh*

*6702 kWh/customer compares with an actual 1976 experience of 6689 kWh.

**1.92 kW/customer compares with an actual 1976 experience of 1.90 kW.

+Data abstracted from "Peak Load Forecasting Methodology" by George L. Fitzpatrick, Long Island Lighting Company, Mineola, New York. Presented in EPRI Symposium on Electric Load Forecasting (Fitzpatrick 1979).

Table 3.2. POPULATION, HOUSEHOLDS, AND CUSTOMERS+

Calendar Year	Population*	Population per Household	Households*	Households per Residential Customer	Residential Customers*
1950	5059	3.80	1331	1.37	970
1955	5071	3.70	1371	1.12	1229
1960	5349	3.61	1483	1.05	1418
1965	5630	3.44	1635	1.00	1635
1970	5882	3.23	1819	0.97	1868
1975	6285	3.09	2033	0.92	2203
1980	6630	2.93	2265	0.90	2509
1985	6940	2.72	2550	0.89	2852
1990	7252	2.61	2783	0.89	3143

*1970 TVA region (thousands).

+Table reproduced from "Three Methods of Forecasting Residential Loads" by James Torrence and Lynn C. Maxwell, Tennessee Valley Authority, Chattanooga, Tennessee. Presented in EPRI Symposium on Electric Load Forecasting (Torrence and Maxwell 1979).

Table 3.3. APPLIANCE SATURATIONS AND CONTRIBUTIONS TO ANNUAL AVERAGE RESIDENTIAL USE+

	Calendar Year 1976			Calendar Year 1986			
	Saturation (%)	Average Use of Appliance (kWh)	Contribution to Annual Average Use (kWh)	Saturation (%)	Average Use of Appliance (kWh)	Contribution to Annual Average Use (kWh)	Annual Growth Rate (%) 1976-86
Electric heater	44	9300	4,092	55	8580	4,720	
Range	80	1330	1,064	86	1210	1,040	
Water heater	73	5000	3,650	84	5000	4,200	
Air conditioner	63	2900	1,827	81	2650	2,145	
Refrigerator	99	1220	1,208	100	1560	1,560	
Freezer	47	1075	505	56	1180	665	
Washer	74	100	74	75	100	75	
Dryer	45	1370	616	5	1350	760	
Dishwasher	24	350	84	40	330	130	
Lighting, TV, other			1,797			3,210	
Average use			14,917			18,505	2.2
Average customers (1000s)			2,251.0			2,918	2.6
Energy use (10^6 kWh)			33,577.4			53,998	4.9

+See footnote for Table 3-2.

Several important types of appliances (lighting, TV, refrigerators) are apparently combined together under the heading "non-substitute electric" (p. 3.27). We suggest that all "major" appliances be separately accounted for. The reason for this being that improvements in efficiency standards, price elasticity of demand, and numerous other variables are likely to affect these appliances in different ways, hence the need for separate record keeping. Other small electrical appliances can then be combined under one category. Electric cars should be considered for the period 1990-2010, since they may become commercially available during that time frame (Burbank 1979; EPRI Journal 1979).

There is little documentation presented on per unit comsumption of various appliances, their saturation rates, average useful life, and expected improvements in efficiency. What little data is presented is fragmentary and divided between Parts I and III of the report. Apparently, ISER has not utilized the available information from several generally quoted sources such as:

- Association of Home Appliance Manufacturers (AHAM) - Information on average size, consumption, and replacement of major appliances.
- Federal Energy Administration (FEA) - Information on energy efficiency targets for major appliances.
- Electrical Power Research Institute (EPRI) - Information on electrical load forecasting and modeling. In particular, the following four reports:

  (1) "How Electrical Utilities Forecast: EPRI Symposium Proceedings," EA-1035-SR, March 1979.

(2) "Patterns of Energy Use by Electrical Appliances," Report prepared by Midwest Research Institute (MRI), EA-682, January 1979.

(3) "Analysis of Household Appliance Choice," Report prepared by Charles River Associates, Inc. (CRA), EA-1100, June 1979.

(4) "Electric Load Forecasting: Probing the Issues with Models - Final Report," Report prepared by Stanford University EA-1075, April 1979.

- Edison Electric Institute (EEI) - Various reports.
- Bureau of the Census, Statistical Abstracts of the U.S., Electrical Appliances, various years.

Other useful data sources include:

- FEA Electric Pricing Experiments - Conducted on ten regions of the country and more underway in other areas. Questionnaire surveys were used for each pricing experiment and a complete documentation on all of these data sets should be available shortly. Detailed information on housing type, income, age, number and types of appliances, and utilization rates are included in these data sets.
- "Models for Long Range forecasting of Electric Energy and Demand," models and report jointly developed by the New England Power Pool (NEPOOL) and Battelle Columbus Laboratories, June 30, 1977 (revised and updated version forthcoming).
- Washington Center for Metropolitan Studies (WCMS) - Conducted two national surveys on number and ages of household residents, household income, attitudes toward energy consumption, insulation type used and extensive information on appilance ownership and utilization.
- San Diego Gas and Electric - Conducted extensive customer surveys on a number of household and appliance characteristics and use pattern.
- A.C. Nielsen Co. - Conducted a survey for the State of Illinois which was restricted to single family dwellings.

Failure to consider the various available data sources is a significant deficiency of ISER's present work.

ISER's definition of the saturation rate, defined as "the number of appliances divided by the number of consumers" (p. 2.17) is unconventional. This makes it more difficult to interpret and compare their assumptions/results to other studies. The conventional definition of the saturation rate uses number of households (as opposed to number of consumers) and makes more intuitive sense since many appliances (e.g., black and white TVs) are approaching 100 percent saturation by this definition (U.S. Department of Commerce).

The "logistic curve" (p. 2.17) is not completely defined in the draft report. A simpler approach might be to extract useful information from the EPRI reports (ii) and (iii) mentioned above and to calibrate this model to fit Alaskan data. The above two studies identify several relevant attributes affecting the choice and use patterns of most common appliances and can provide the basis for better end-use modeling as well.

While we agree with ISER's statement that "it does not appear cost-effective to construct detailed models for predicting changes in [saturation and utilization] rates" (p. 2.18), we believe that development of simple, common sense models based on results of similar studies elsewhere (e.g., Thomas 1979) would be desirable.

The following are a number of other specific comments/suggestions which may be useful in ISER's subsequent work on the appliance saturation and energy utilization model. Some of these comments/suggestions are applicable to other model components as well.

- More emphasis should be placed on forecasting per capita and per customer electricity demand and cost. The relationship between cost of electicity and utilization rate (i.e., price elasticity of demand) should be considered.

- If possible, develop relative cost of labor ratios (Alaska vs. national average) for some major commercial/industrial sectors (Burbank 1979). This information would be useful in determining which commercial/industrial sectors may attract workers from the lower 48 states.

- Consider the effect of new energy efficiency standards mandated by Federal Energy Administration (FEA)--now part of DOE (FEA 1977). For example, a 50 percent energy use reduction for certain types of end-use by 1990 may not be unreasonable (Burbank 1979). Higher and lower energy efficiency improvements should be considered in the context of appropriate economic and regulatory scenarios (see Figure 3.3).

- Consider the possibility of different rate structure for electric space heating (as was once the case in the Anchorage area) and declining vs. inverted block rates.

- Consider establishment of time-of-day-pricing in the 1990s and beyond, particularly for large users. Also consider the potential for heat pumps and heat storage systems in the same time frame.

- Consider higher insulation standards in response to:

  (1) higher electricity rates (i.e., voluntary action due to economic inducements),

  (2) regulations, either forced or through incentives.

- Consider the implications of the following two events on demand for electricity:

  (1) price of natural gas (used for power generation) rising to world market price, and/or

(2) a federally imposed ban on use of natural gas for power generation.

3.2.7 Final Energy Demand Model

ISER's current model forecasts total energy demand (in BTUs) followed by a second model component which breaks total energy demand into subcomponents (e.g., electricity, gas, oil). For the purposes of the Susitna Project, this two-step approach is unnecessarily complicated. It would be sufficient to directly forecast electric energy demand. The two-step approach is more involved and produces results which are not of immediate interest in the context of the Susitna Project. Furthermore, to obtain defensible results, the approach requires simultaneous analysis of mode splits (between various fuel types) and supply and demand (one for each fuel type). This, in turn, requires development of a series of internally consistent and plausible scenarios concerning the supply of, and demand for, each fuel type at various prices. To date, ISER has not undertaken this complete of an analysis.

The approach we recommend, given ISER's limited resources, is to concentrate on electricity demand and derive it in a one-step process using an end-use model. The advantage of a well thought-out end-use model is that it can generate electricity demand projections directly taking as input data on number of households and housing units, income, assumptions about relative fuel prices, and several other parameters. Similar studies have been carried out in the lower 48 (e.g., Burbank 1979) and would be relevant to the present study.

The "Sources of Variation" (p. 2.19) listed in ISER's draft report leave out several important variables (e.g., rise in price of energy relative to labor and commodities). ISER's "Methodology" section suggests, "For the commercial-industrial sector, there is no data on average conversion efficiency, so no final demand model exists" (p. 2.19). If this is true, then additional effort in this area is required. This is not mentioned in their "Future Work" section.

Finally, ISER's implicit assumptions suggest that total energy demand is not sensitive to price. This is clearly implied by the figure on p. 2.1 where energy availability and price scenarios and energy efficiency models follow the final energy demand model. This assumes perfect price inelasticity in demand for energy. It is a strong assumption and requires further substantiation.

3.2.8 Housing & Appliance Stock Model

The "Model Description" (p. 2.22) for this model component indicates that ISER has projected future housing stock on the basis of local and national trends. An approach more in keeping with the rest of ISER's forecasting methodology would be to develop a model incorporating demographic information, particularly household formation rates and income/employment data, into a demand for housing function which can then be broken down into single-family and multi-family components taking income, housing supply, and mortgage availability into account. The model need not be complicated, and the required effort need not be substantial. Models of this type have been developed (e.g., NEPOOL and Battelle 1977) and can be readily modified for the present study. Since Alaskan mortgage rates are currently subsidized by the state government and may continue to be influenced by forces other than availability and cost of funds in financial markets, they should be accounted for as part of the state government scenarios.

Single-family units should be separated from multi-family units. Similarly, new homes/businesses should be distinguished from older homes/businesses since their energy consumption rates and patterns generally differ. A flow diagram similar to Figure 3.4 would be helpful.

We do not fully agree with ISER's statement that estimation of housing stock and mode split should be carried out "on the basis of housing demand without significant supply constraints" (p. 2.21). Both housing demand and mode split decisions are sensitive to supply conditions although they tend to be sluggish. A supply crunch, for example, can increase the cost of housing and affect the ratio of single-family to multi-family units. A similar result can also occur if the supply of available funds for housing dries up or government subsidies on mortgage rates are removed.

In the lower 48, housing vacancy rates, particularly for owner-occupied single-family dwellings, are quite low. (The U.S. national average for 1976 was 1.2 percent, U.S. Department of Commerce, Statistical Abstracts 1976). From ISER's discussion of the topic it appears that this is not the case in Alaska. The same apparently applies to second

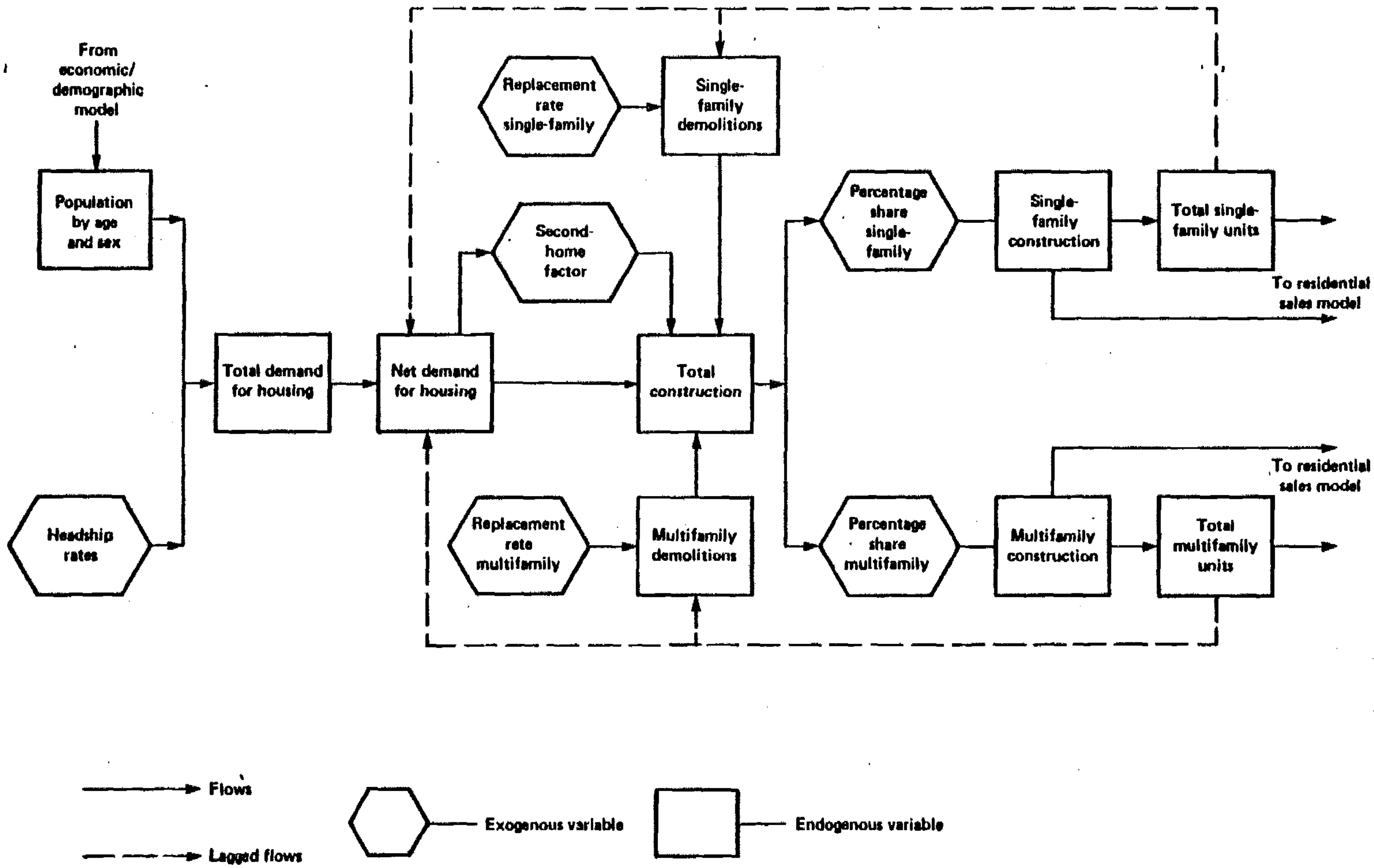

Figure 3.4. Housing Unit Model

Source: See Table 3.2.

homes. If this is the case, better discussion, documentation and modeling of vacancy rates and second homes is required.

ISER's discussion on "preference" (as opposed to "affordability") for a housing type and "household head age" as explanatory variables (p. 2.22) are not strictly correct. The two most important determinants of housing type are household income and size (U.S. Department of Commerce, Statistical Abstracts). (Age of the household head is sometimes used as a surrogate for income and/or family size.)

ISER proposes to project housing mode split on the basis of local national trends in Part II (p. 2.22). What they have actually done, however, is to take the present mode split percentages and assume that they remain constant over time (see p. 3.7 and pp. 3.21-3.23). In the absence of more documentation and better substantiation, this assumption is clearly unacceptable. Since housing mode split is an important parameter affecting all subsequent work, small variations in this split can lead to significant variations in electricity demand.

3.2.9 Energy Availability Scenarios

This model component, which would more accurately be called "Energy Price and Availability Scenarios," is treated as a separate model component. In our view, energy price and availability are more defensibly treated as outputs of the economic scenarios already discussed. This distinction is important because energy scenarios are a major component of any economic scenario developed and should be consistent with the other scenario assumptions and implications. For this reason, energy price and availability scenarios should be carefully integrated with other endogenous and exogenous variables, such as state and federal government regulations or policies; relative price of alternative fuels in the world market over time; and critical energy related projects such as an LNG plant on Kenai Peninsula or the trans-Canadian gas pipeline.

A defensible scenario considers a consistent sequence of events/decisions over time and makes reasonable assumptions about its implications. According to their draft report (p. 2.24), ISER has not developed such scenarios. This is a critical step in any forecasting model and particularly in energy forecasting. No one can expect to accurately predict the future, and so scenario generation is designed to allow analysis of a number of "what if" questions in order to show the sensitivity of the projections to variations in important parameters. The results obtained allow a study of the implications of given decisions/policies under a variety of assumptions about the future.

It is difficult to evalute ISER's work on this aspect of the problem since very little is presented about it in the draft report. In particular, it is not clear if ISER's energy price and availability scenarios are consistent with the more general macro-economic scenarios affecting the MAP model.

3.2.10 Mode Split Model

According to ISER's stated "Objective" this model component determines "the proportion of consumers owning a particular appliance, type of housing, or type of commercial-industrial space that utilizes a particular fuel type" (p. 2.25). It describes the process by which a consuming unit decides to purchase new, or replace existing, appliances. The single most important "appliance" under consideration is, of course, space heating. Other appliances are not as energy intensive individually, but they become significant collectively. For certain appliances (e.g., lighting) the choice of fuel types is fairly limited, whereas in other cases several alternative fuel types may be available, each with its particular attributes. The question addressed in this model component is which alternative fuel type will be chosen when several are available.

This problem is a typical marketing problem and can be analyzed in two stages. The first stage deals with the question of whether to buy a new appliance and/or replace an existing one (Theil 1967; Charles River Associates 1979). The second stage considers the type of appliance (e.g., size, fuel type, model) chosen once a decision has been reached to purchase a new appliance or replace an old one (McFadden 1974; Theil 1971; Domenich et al. 1976).

ISER's initial approach (p. 2.26), if used in a dynamic context, appears adequate. This approach is, however, considerably simplified before it is considered ready to apply through a number of unrealistic assumptions (p. 2.27) and reduced to the form presented on page 2.28. This simplified approach is crude, and many of its important parameters (e.g., replacement and saturation rates) appear to be judgmentally set (e.g., p. 3.28).

In addition, there is a discrepancy between what is proposed in Part II (pp. 2.25-2.28) and what is actually carried out in Part III (e.g., p. 3.7 and pp. 3.21-3.23). Percentages of residential units on electric space heating, for example, are assumed to remain constant (pp. 3.21-3.23) at their present levels (p. 1.8) over the next thirty years (also see, e.g., pp. 3.27-3.29). It is misleading to present a mode split model in Part II, since it is not actually used.*

As already pointed out, an important component of the mode split model should be its sensitivity to economic and fuel price and availability scenarios. Based on what is presented in Part III, ISER's current approach is inadequate. There is nothing in the draft report to indicate that these deficiencies will be addressed in future work.

In modeling mode splits it is desirable to distinguish purchase/replacements in three appliance markets that are known to differ on their choice of appliances (Burbank 1979):

*Strictly speaking, ISER's report refers to what appear to be input assumptions/results as "electric power requirement worksheet" (pp. 3.20 - 3.38). In the absence of better clarification, we assume that what is presented in these "worksheets" are indeed assumptions that are fed into the model by the modelers.

- the new housing (residential or commercial) market,
- the replacement market, and
- the existing market.

New homes or commercial establishments consider all available alternatives and purchase appliances based on several important parameters such as:

- perceived initial costs,
- perceived operating and maintenance costs,
- perceived availability and cost of fuel, and
- perceived safety and convenience.

New homes and commercial establishments have great flexibility in their choice and take long-run marketability of the home/establishment into account (NEPOOL and Battelle 1977).

The replacement market deals with existing homes or commercial establishments with particular appliances that are wearing out, becoming obsolete, or becoming uneconomical to operate. This market does not have the flexibility of the new market (e.g., lack of duct work may make it difficult/expensive to add central forced air heating systems.

The third market consists of existing houses or commercial establishments without particular appliances which are considering purchase of new appliances. It also includes households/establishments that are considering duplicating appliances (e.g., second TV).

A complete housing stock model would provide information on new and existing housing stocks which could be used to provide input regarding the above markets. At a minimum the new housing market should be distinguished from the other two and treated separately. Similarly, single-family dwellings should be distinguished from multi-family units, and small commercial (e.g., small retail) from large commercial. Their use patterns and available choices are different enough to warrant separate treatment.

3.2.11 Energy Efficiency Model

We recommend including this model as an integral part of the end-use model (Figure 3.3), since the decision to purchase a particular appliance and appliance fuel type is affected by its perceived operating and maintenance costs which are dependent on its fuel conversion efficiency. As currently presented in ISER's work, a person's purchase decison is unaffected by improvements in efficiency standards because the model component which considers this follows the mode split model.

The current model's only function is specification of appliance fuel efficiency (p. 2.30) which is, apparently, judgmentally set. BTU demand for various appliances and efficiencies of electric conversion are, for example, set without any supporting rationale (e.g., pp. 3.27-3.29). Specification of appliance fuel efficiency, should be part of the input scenarios that are fed into the end-use model and should be consistent with FEA's efficiency standard targets (FEA 1977).

3.2.12 Energy Requirements By Fuel Type

No comments.

3.3 QUANTITY AND ACCURACY OF DATA

A defensible forecast requires reasonably complete data in addition to a logical, well-structured, and technically correct model. Our comments in Section 3.2 were directed at ISER's model. In this section, we consider the accuracy and adequacy of the available data.

End-use models are data intensive because many parameters have to be identified and specified over time. Based on our experience and review of other end-use models (e.g., those of the California Energy Commission and Pacific Gas and Electric Company), these models generally take several years of data gathering and calibration before they can provide completely defensible forecasts. For this reason we believe that ISER's end-use model cannot be realistically expected to become fully operational in the short-run. ISER has undertaken an ambitious task in attempting to put together an end-use model for the Railbelt area. Their model should provide more defensible forecasts as additional data are collected and the remaining deficiencies of the model are rectified.

The quantity and quality of Anchorage data could be improved. The data for the Fairbanks area is even less satisfactory. More specifically, the following comments are addressed at data and input assumptions presented in Parts I and III.

- The documentation and discussion of the end-use inventory should be presented separately from the data, which belong in an appendix.
- Factual data should be distinguished from assumed data.

- Factual data should be appropriately referenced. Assumed or estimated data should be substantiated and discussed to the extent possible. Judgmental assumptions should be distinguished from assumptions based on historical trends or similar studies done elsewhere.

- Each data sheet and inventory table should come complete with its footnotes and references.

- It appears that the key on p. 1.7 contains much redundant information (i.e., only three pieces of information are necessary to complete the remaining five blank spaces). If so, a more compact format, with instructions on how to obtain additional information could be presented.

- Many important input assumptions (e.g., percent of year-round housing units [p. 1.15] and electric consumption for space heating [p. 1.14]) are crudely estimated. Substantial additional effort appears necessary to improve these rough estimates.

- In cases where national (as opposed to Alaskan) data is used (e.g., p. 1.18), judgmental adjustments for Alaska, based on the available information, seem appropriate.

- Estimates regarding all-electric homes and electric space heating are crucial. ISER's rough estimates (p. 1.20) should be better substantiated and double checked to the extent possible.

- Appliance unit demands, energy efficiencies and annual consumption rates (pp. 1.30-1.33) should be augmented with more recent and accurate data (e.g., [Fitzpatrick 1979], [Charles River Associates 1979], [Midwest Research Institute 1979], [Edison Electric Institute]) and adjusted for Alaska.

- The flow pattern presented in Figure 1 (p. 3.2) is confusing.

- Assumptions stated on p. 3.7 are unsubstantiated. Each one of them is critical and requires careful consideration, evaluation and sensitivity analysis. As presently stated, they are clearly indefensible.

- The heading for Table 00 (p. 3.9) is incomplete.

- The "Electric Power Requirement Worksheets" (pp. 3.20-3.38) are undocumented and their assumptions are questionable and unsubstantiated. Many of the stated assumptions are dependent on future economic and energy scenarios. It is not clear if and how these scenarios will be integrated into more reasonable input assumptions and if and how sensitivity analysis will be performed.

- The Commercial/industrial sector requires a finer breakdown of the "General" category (p. 3.33) while certain other categories (e.g., Manufacturing and Warehouse) may be combined.

- Fairbanks area data appears non-existent (e.g., pp. 3.36-3.38) or of poor quality (e.g., p. 3.45). Better documentation of assumptions such as housing size and heat requirements (e.g., p. 3.40) is necessary.

3.4 METHODS USED BY ISER TO CONSIDER UNCERTAINTIES

The accuracy of total electric energy demand forecasts produced by ISER's models is affected by three major factors:

1) The degree to which the models accurately capture the true structure of energy use in the Railbelt,

2) The accuracy of data about current conditions in the Railbelt, and

3) The degree to which the assumed input scenarios for future economic development and energy use are accurate.

ISER's draft report, as well as our discussion elsewhere in this critique, shows that there are significant uncertainties about all three of these factors. It is important that these uncertainties be considered in the forecasting work in a systematic and realistic manner if the results are to be defensible. The draft report does not indicate how ISER intends to address these uncertainties. The steps generally used to address them include the following:

1) Sensitivity analyses to identify which structural features and input data most significantly affect the forecasts,

2) Additional modeling work or data collection where the sensitivity analyses indicate it is warranted, and

3) Incorporation of a broad range of viewpoints into the procedure for selecting input scenarios.

ISER has apparently not yet estabished methods for carrying out these steps. Although we foresee no particular difficulties in doing this, our experience indicates that carrying out the steps can be time-consuming.

4.0

IMPLICATIONS OF OTHER WORK

A review of several other electricity demand forecasts for the Railbelt region ([U.S. Department of Energy, Alaska Power Administration 1979], [U.S. Department of the Army, Corp of Engineers 1979], and [Battelle Pacific Northwest 1978]) indicates that past work has used less sophisticated methods than those proposed by ISER. None of these studies make use of end-use models. Generally, the studies are based on crude estimates of per capita energy demand and demand growth rates based on historical trends. The Corps of Engineers Report, for example, uses per capita consumption projections for "comparable regions in the Pacific Northwest, "(U.S. Department of the Army, Corps of Engineers 1979, Appendix, Part I, p. C-32) as the basis for its projections. The population projections used are typically those provided by ISER's previous MAP forecasts with a consideration of "low" and "high" growth scenarios.

Overall, these forecasts have limited defensibility since there is little documentation and specification of their critical parameters and input assumptions. Furthermore, various assumptions are not well integrated (e.g., population scenario, per capita consumption and energy price and availability scenarios are not necessarily consistent with one another). However, the assumptions are clearly stated and can be readily varied to produce alternative forecasts.

The two most recent power market analyses [U.S. Department of Energy, Alaska Power Administration 1979] and [U.S. Department of the Army, Corp of Engineers 1979] are based on ISER's MAP population projections (December 1978 revisions). These population projections, reproduced in Table 4.4 for easy reference, are higher than ISER's current projections (compare Table 8, p. 34 of [U.S. Department of Energy, Alaska Power Administration 1979] to Table O, p. 3.6 of [ISER 1980]). In fact, ISER's previous "low" projections for 1980, 1990, and 2000 exceed their respective present "medium range." Similarly, the previous "low" forecasts of total annual energy demand for 1980, 1990, and 2000, reproduced in Table 4.5 for easy reference, exceed ISER's present "medium range" forecasts (compare Table 10, p. 40 of [U.S. Department of Energy, Alaska Power Administration 1979] to Table OO, p. 3.9 of [ISER 1980]). Most of the discrepancy between these two population forecasts appears to be the result of updating of the MAP model; the previous population forecasts were based on a MAP model calibration using data up to 1973 where the more recent forecasts are apparently based on a recalibration of MAP which includes data up to 1978, including post Arab oil embargo data.

Table 4.4 COMPARISON OF ISER'S POPULATION PROJECTIONS [ISER 1980, TABLE O, P. 3.6] TO THE ALASKA POWER ADMINISTRATION'S POPULATION PROJECTIONS [U.S. DOE, ALASKA POWER ADMINISTRATION 1979, TABLE 8, P. 34] FOR THE RAILBELT AREA

population in thousands, rounded to nearest full thousand

	ISER's "Medium Case Scenario" Projections		APA's Projections			
			Anchorage Area+		Fairbanks Area+	
Year	Anchorage Area*	Fairbanks Area*	"Low"	"High"	"Low"	"High"
1980	208	61	240	270	60	62
1990	286	78	299	407	75	95
2000	371	97	424	651	90	140

*ISER uses Anchorage-Matanuska Susitna and Fairbanks-Southeast Fairbanks, respectively.

+APA uses Anchorage-Cook Inlet and Fairbanks-Tanana Valley, respectively.

Table 4.5. COMPARISON OF ISER'S "DRY RUN" ELECTRIC POWER DEMAND PROJECTIONS [ISER 1980, TABLE 00, P. 3.9] AND THE ALASKA POWER ADMINISTRATION'S PROJECTIONS [U.S. DOE, ALASKA POWER ADMINISTRATION 1979, TABLE 12, P. 46] FOR THE RAILBELT AREA*

Total Annual Electric Demand in GWh, rounded

Year	ISER'S Medium Case Scenario Projections	APA's Projections Low	Medium	High
1980	2,200	3,400	3,700	3,900
1990	3,800	5,200	7,100	11,000
2000	5,700	7,900	12,700	21,000

*Includes the entire Railbelt area.

5.0

STRENGTHS AND LIMITATIONS OF ISER WORK

ISER's work has the ambitious objective of accomplishing the first integrated combination of economic and end-use models for the Railbelt region. This is a major undertaking. It requires a systematic inventory of current end-use devices, their replacement, and utilization rates, efficiency levels and use patterns over time. In addition, future purchase/replacement decisions have to be modeled and integrated with various possible assumptions about relative price and availability of alternative fuels, energy efficiency standards, as well as policies and regulations on conservation.

A well integrated economic/end-use model can be a powerful planning tool for considering the possible implications of proposed actions or policy changes. However, attempts to develop such models by electric utilities and regulatory commissions in the lower 48 states have been carried out with substantially more resources than the work by ISER. Generally, it has taken two or more years of data collection, model specification and calibration to achieve reasonably defensible results.

Our review of ISER's present work indicates that substantial additional work will be required before their model becomes fully integrated and operational. This assessment is based on our conclusions (see Section 2) that serious deficiencies exist in ISER's work to date. (A detailed discussion of these deficiencies is presented in Section 3.) At the present state of development, the model's forecasts are not necessarily more accurate or defensible than forecasts from a less sophisticated approach. This is true because:

- ISER's present model is not complete nor fully integrated,
- The model is based on an incomplete and possibly inaccurate data base, and
- The selection and specification of input scenarios is not adequately addressed.

Additional work would substantially improve the defensibility of ISER's forecasts. However, there are other important issues related to the Susitna Project power studies that are not directly addressed by the ISER work, at least as it is presented in the draft report. These are not, strictly speaking, technical deficiencies in the work but rather limitations on the scope of what ISER is attempting to do. However, they may limit the ultimate usefulness for the Susitna Project of ISER's work.

A variety of studies have been carried out during the last two decades to assess future electricity demand in the Railbelt. Several studies have assessed the desirability of building the Susitna Project. Generally, these studies have concluded that there will be a need for substantial additional electric generating capacity and that the Susitna Project would be a reasonable way to meet this need.

However, the Susitna Project continues to be highly controversial, with both support and opposition by substantial interest groups. There is no reason to believe that another forecasting study, regardless of how complex it is or how carefully it is carried out, will damp the controversy surrounding Susitna.

Fundamentally, the assessment of the need for the Susitna Project is not an issue that can be "resolved" by analysis. In view of the many uncertainties that exist regarding the future of the Railbelt, there is no way to assure that any forecast of future demand for electric energy is accurate. In view of this, the central focus of Susitna Project concerns with regard to the need for power might profitably be shifted from concern for forecasting by itself to the following question: "For what level of future demand is it prudent that the Alaska Power Authority plan in carrying out its responsibilities to the citizens of the Railbelt?"

Addressing this question requires some forecasting work; however, it also requires careful consideration of a variety of other factors. Given the enormous influence that the state government will have on developments over the next few decades, the question requires careful consideration of options open to the government during this period. Perhaps most importantly, it requires careful consideration of the consequences of having over- or under-generation capacity relative to the demand.

This last point warrants further discussion. An analysis of Table 4.5 shows that ISER's projected "medium case" total electric energy demand growth from 1980 to 2000 averages 4.9% per year while the Alaska Power Administration's "low", "medium" and "high" projections average, respectively, 4.3%, 6.4% and 8.8% annual growth over this period. Thus there is a range of 8.8%-4.3%=4.5% in the Alaska Power Administration's projected growth rates.

The differences between ISER's forecast and those of the Alaska Power Administration appear to be due mainly to updated initial conditions and differing estimates of future population growth. In both cases the MAP model was used to do the population estimation. Thus it seems likely that there is roughly the same level of uncertainly associated with ISER's forecasts as with the earlier forecasts by the Alaska Power Administration based on the MAP model. If we assume this then the growth rate might be as low as 4.9-4.5/2=2.7% or as high as 4.9+4.5/2=7.2%.

Using these growth rates, starting form a base of 2200 GWh in 1980, results in the following projections of total electric energy demand in 2010:

- For 2.7%/yr. growth: 4900 GWh
- For 4.9%/yr. growth: 9200 GWh
- For 7.2%/yr. growth: 17,700 GWh

Note that the range of these estimates is 12,800 GWh. The firm annual energy from the Susitna Project is estimated to be 6,100 GWh, so the uncertainty in the projections is as great as two Susitna Projects!

An important issue relative to the power studies for the Susitna Project is which demand figures should be used for planning purposes in view of this uncertainty. For example, if the APA plans on the assumption of 2.7%/yr. growth in demand, and the actual growth is 7.2%/yr. the consequences for the citizens of the Railbelt are likely to be very different than if plans are made for a 7.2%/yr. growth and the actual growth is 2.7%/yr.

Questions of this type are not addressed in the ISER work, except in a very indirect manner. Thus, we believe that even if the technical deficiencies in ISER's work are corrected, it will not address some important needs of the Susitna Project.

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APPENDIX D

CRITIQUE OF ISER REPORT BY ENERGY PROBE

JULY 30, 1980

Energy Probe / Enquête Energie

an evaluation of the ISER electricity demand forecast

July 30, 1980

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In December 1979, Energy Probe was awarded a contract by The House Power Alternatives Study Committee of The Alaska State Legislature to examine and evaluate an electricity demand forecasting model being developed by The University of Alaska's Institute of Social and Economic Research (ISER).

Energy Probe's work, along with research carried out by several other consultants retained by The Power Alternatives Study Committee was intended to provide a framework within which the proposed Susitna Hydroelectric Power Development could be evaluated. A working paper published in January 1980 presented an initial evaluation of the ISER model, primarily on the basis of ISER's "Detailed Work Plan".

The following is the final report prepared under Energy Probe's contract. It presents an evaluation of the ISER demand forecasting model in its present form; tests the sensitivity of Railbelt electricity demand to changes in various policy and technological factors; and outlines what the authors believe to be the appropriate interpretation and application of the forecast within the broader context of State energy policy development.

The views and conclusions presented herein are those of the authors alone, and do not necessarily reflect the position of The House Power Alternatives Study Committee.

TABLE OF CONTENTS

1. INTRODUCTION

The electricity demand forecasting model developed by the Institute for Social and Economic Research (ISER) is a major step forward for Alaskan energy planning. The ISER model is of a quality which is orders of magnitude ahead of previous forecasting models employed in the State.

This report seeks to accomplish three tasks. The first of these in an introduction to the structure and logic of the ISER model aimed at a non-technical audience. The second is a technical review of the ISER model with a focus on the methods employed and areas for further development. The third is a demonstration of the use of the model in documenting the effects of alternative energy policy assumptions on the model's output.

By far the most important of these is the third. Since Alaska's electricity future is not fixed but rather subject to both fate and policy intervention it is important to appreciate that any forecast depends on assumptions concerning factors which can and cannot be controlled.

On the fate side of the ledger are all those factors which are beyond the control of Alaskans. These include national economic policy to the extent that it sets the tone for state economic and social development and, more importantly, the future of resource discovery and exploitation in Alaska.

Manageable factors include the ways in which Alaskans actually use the energy which is available to them - whether they use is efficiently or inefficiently. A very clear example of the "manageability" of these factors is the recent energy conservation legislation which will undoubtedly influence energy use in the State.

Planning is a process by which those factors which are controllable are identified and managed to bring about a desirable future. In addition, planning seeks to identify items subject to fate to adequately prepare for the realization of a range of possible outcomes. A forecasting model is nothing other than an aid to clear thinking in this complex situation. A good forecasting model should be able to accommodate both controllable and non-controllable factors and progress logically to actual numeric forecasts. On this count the ISER model is exemplary.

In any forecasting environment assumptions are crucial; to the extent that they are hidden there is no clear link between policy and actual outcomes. To the extent that they are open and accessible they are the basis for analysis and action. On this count as well, the ISER model is excellent. Assumptions are clearly stated and readily changed. When the model is ultimately computerized the latter will become even easier and the model even more useful.

But what is most important to realize is that the ISER model is only a tool. Alaskans do to a large extent have control over many aspects of their energy future. In an appropriate planning environment, the ISER model can be utilized [illegible] means of making that future more desirable.

2. A USER'S GUIDE TO THE ISER FORECASTING MODEL

2.1 Introduction

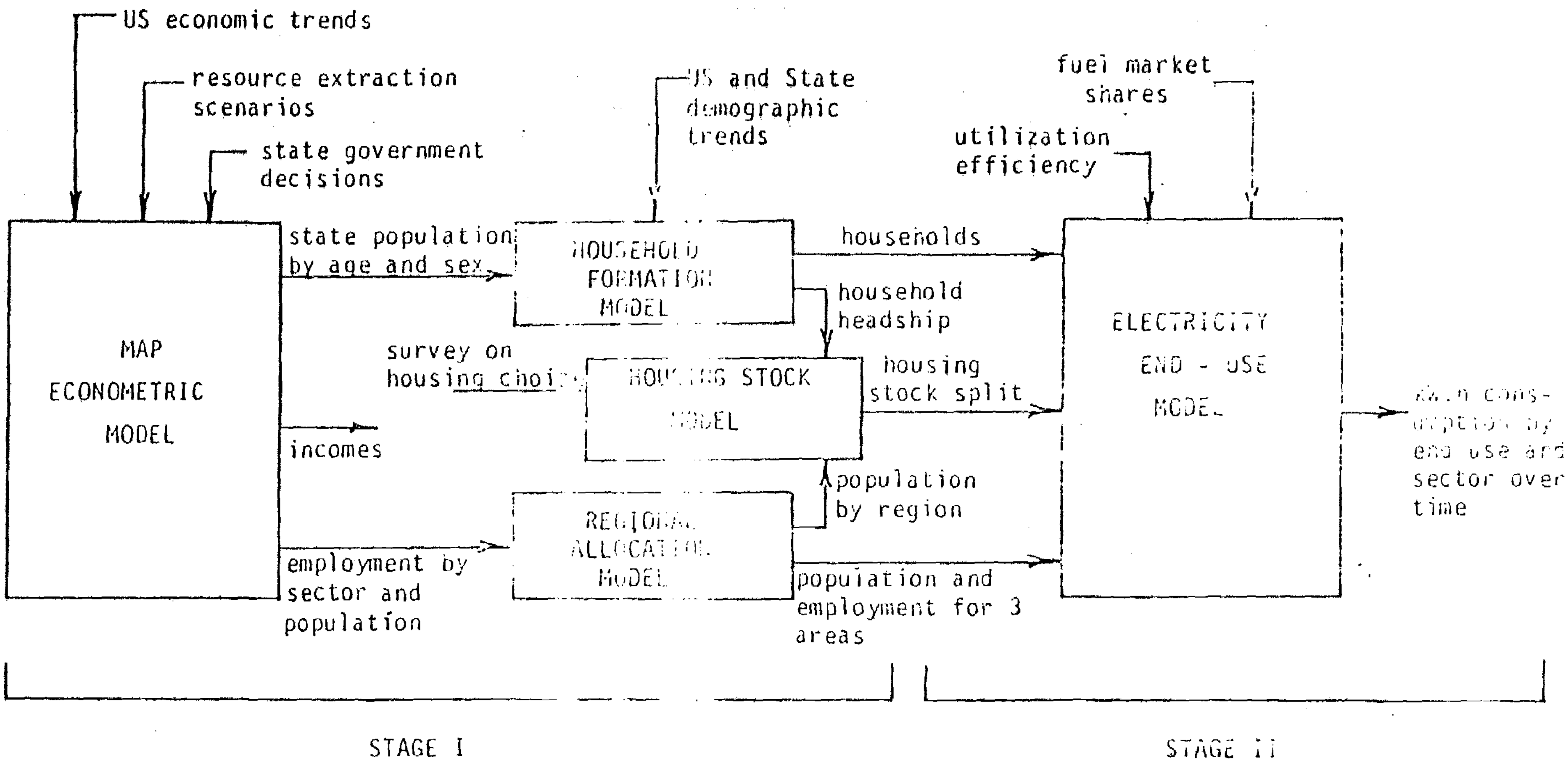
The ISER electricity demand forecasting model, while seemingly complex, has a very straightforward and logical structure and flow of information between components. The output of the model is projected values of electricity consumption for each of the three geographical areas of the Railbelt classified by final use (i.e. heating, lighting, etc.) and consuming sector (commercial, residential, etc.). In its current form the ISER model produces values for the years 1985, 1990, 1995, 2000, 2005 and 2010.

To accomplish this task the model relies on five specialized sub-models linked by key variables and driven by policy and technical assumptions and state and national trends. A flow diagram showing the sub-models and their linking and driving variables is given in Figure 2.1 below. Of the five sub-models, only the MAP econometric model was in existence prior to the Railbelt study; the remaining four were developed by ISER during the course of the study.

2.2 Stage I Components

In our earlier working paper (contained as the appendix to this report) we argued that the electricity demand forecasting process was essentially two-stage. In Stage I, basic

Figure 2.1: A Schematic of the ISER Electricity Demand Forecast



economic and demographic information is developed as input to an electricity demand model which we called Stage II. The final ISER model has this basic structure with the MAP, household formation, housing stock, and regional allocation models performing the Stage I function and the electricity end use models in the Stage II role.

2.2.1 The MAP Econometric Model

The basis of the Stage I function in the ISER model is MAP, a medium size econometric model which translates forecasted or assumed levels of national economic trends, state government activity, and developments in the Alaska resource sector into forecasted levels of statewide population by age and sex, employment by industrial sector, and income. While the MAP model is internally complex, its basic logic is that the State of Alaska will tend to follow national trends in economic development yet will deviate somewhat with resource sector and state government activity. These will cause the state to perform somewhat better or worse than the Outside. In periods of plenty, Alaska will attract immigrants seeking employment opportunities; in periods of relatively poor economic performance, people will tend to leave the State to seek opportunities in the lower-48.

As a result of this basic logic, MAP's output is quite sensitive to the national trends, resource activity, and state government actions assumed as input. Since MAP inputs directly into the electricity end use model, the final results of the forecasting process are equally sensitive to these crucial assumptions.

MAP's output, while technically quite reasonable, is not appropriate for direct input into the electricity model for two reasons. The first of these is that MAP produces forecasts for the entire state of which the Railbelt and its component areas are only a part, albeit an important one. Secondly, electricity consumption is more closely related to households and the number of housing units than to the number of individuals in the market area; MAP produces only the latter. The household formation, housing stock, and regional allocation models translate MAP output into final Stage I form.

2.2.2 The Household Formation Model

The household formation model groups individuals into household units on the basis of national and state demographic trends. The basic logic of this model is than an individual has a finite chance of being a household head; the probability of headship depends on the individual's age and sex. Applying these probabilities to MAP's output yields the number of households, a critical input into the electricity end use model, and the number of household heads by age and sex, an input into the housing stock model.

2.2.3 The Regional Allocation Model

The purpose of the regional allocation model is to allocate MAP's statewide forecasts of population to the regions of the Railbelt. The inherent logic of this model is that regional population shares are sensitive to employment opportunities in the various regions. These opportunities in turn depend on which industrial sector is predominant in the MAP forecast, and its likely location. The regional allocation model ultimately disaggregates MAP's statewide forecasts of employment and population into regional shares. This information serves as input into both the housing stock model and the electricity end use model.

2.2.4 The Housing Stock Model

Because heating of residences is an important use of electricity in the Railbelt; and because there are a number of different types of housing available (single family, duplex, apartments and mobile homes) it is necessary to forecast the numbers of each type of dwelling unit in each of the Railbelt regions. This task is accomplished in the housing stock model which combines the household headship information from the household formation model, the regional population information from the regional allocation model, and the results of an independent survey on housing choice, to produce the number of housing units by type and region for each of the forecast years.

The logic of the housing stock model is quite similar to that of the household formation model. After combining the household and population information to produce the number of households per region over the forecast period, the information on housing choice is applied to assign each household to a dwelling. The assignment is based on the probability that a household head of a particular age and sex will choose to live in either a single family, duplex, apartment or mobile housing unit. The housing stock model thus produces the last crucial item of Stage I information, namely, the number of housing units by type and region over the forecast period.

2.2.5 Stage I Summary

In summary, the Stage I portion of the electricity demand forecasting process is handled in the ISER model by MAP, the household formation model, the regional allocation model, and the housing stock model. MAP produces forecasts of statewide employment, population and income on the basis of national economic trends, acticity in the Alaska resource sector, and state government policy. The household formation model groups individuals into household units on the basis of state and national demographic trends. The regional allocation model assigns a portion of statewide population and employment to the regions of the Railbelt on the basis of the location of projected economic activity. The housing stock model produces forecasted counts of dwelling units by type on the basis of the output of the household formation model, the regional allocation model, and a survey of housing choices.

The regionally disaggregated employment, population and housing information is then passed forward to the electricity end use model for translation into projected requirements for electricity in the Railbelt.

Assumptions play a central role in determining the overall output of the Stage I part of ISER's model. While the most important of these are national economic trends, resource sector activities, and state government decisions which drive MAP, there are in addition national and state demographic trends and housing choice information which ultimately influence electricity consumption forecasts for space and water heating, and for other residential uses. Critical among these are the assumptions which lead to projections of household size: should these prove incorrect, or for that matter, should any assumption in the model prove incorrect, then the forecast as a whole becomes somewhat suspect.

2.3 Stage II: The Electricity End Use Model

The ISER electricity end use model translates the Stage I output into estimates of the final demand for electricity for each region and consuming sector in the Railbelt. The basic logic of virtually all components of ISER's Stage II model is that electricity is used in identifiable activities such as cooking, heating a building, etc. Each activity has an observed electricity "intensity", that is, a quantity of electrical energy required to fuel a single unit of the activity in question. Further, these intensities are subject to change over time. Combining this information with the output of Stage I, which projects the magnitude of specific activities over the forecast period, yields projections of electricity requirements for each activity in each region. These may be summed to give final forecast estimates.

Consider, for example, the activity of refrigeration. In 1980, a "typical" refrigerator in the Railbelt used about 1250 kWh per year. Over time this average intensity changes as older, smaller, manual-defrost models are replaced by newer, larger, forst-free units. Suppose, hypothetically, that a typical refrigerator in service in the year 1995 uses 1800 kWh annually as a result of fifteen years of replacement of worn out units with new large units and purchases of new units by newly formed households. If there are, say, 15,000 households forecasted to the located in the Fairbanks region in 1995 then the total energy requirement for refrigeration in Fairbanks in 1995 is 1800 kWh/household x 15000 households, or 27,000,000 kWh, assuming that each household has a refrigerator.

In actual fact, the ISER method does not work this way <u>mechanically</u>; however, logically and mathematically ISER's model follows this basic procedure for nearly all activities.

2.3.1 The Residential Sector

In the residential sector, ISER has identified seventeen separate activities for analysis. These are:

1. heating a single family home
2. heating a duplex
3. heating a multi-family unit
4. heating a mobile home
5. powering a water heater for general hot water needs
6. powering a water heater for hot water input into a dishwasher
7. powering a water heater for hot water input into a washing machine
8. powering an electric range
9. powering a clothes dryer
10. powering a refrigerator
11. powering a freezer
12. powering a television set
13. powering an air conditioner
14. powering a dishwasher exclusive of hot water needs
15. powering a washing machine exclusive of hot water needs
16. powering lights
17. powering small, unspecified appliances

In the model, activities 5 through 15 are treated similarly as they relate to energy for large appliances. Activities 1 through 4 are also similar as they deal with space heating. Activities 16 and 17 are dealt with as special cases.

In space heating, the basic unit of analysis is the individual <u>heating plant</u> of the dwelling unit. For an electrically heated dwelling unit this means either an electric furnace, a collection of baseboard or ceiling resistance units, or an electric heat pump. ISER has assumed the latter to be insignificant over the forecast period. Heating plants are classified according to their "vintage", that is, their period of installation. There are seven vintages of heating units, pre-1980, 1981 - 85, 1986 - 90, and so on.

Each vintage of heating plant has its own average electricity requirement which is based on the size, construction, and "retrofit" potential of the dwelling unit into which it was originally installed. For units built in 1980 and before, average consumption is simply the observed consumption of existing units with no conservation or retrofit over time. For new units, average consumption is the product of four terms: a base consumption level, a housing unit size coefficient, a conservation coefficient, and a retrofit coefficient. The base level gives the consumption of a typical electric unit currently being produced. The size coefficient factors this up over time to account for increasing dwelling unit sizes. The conservation coefficient factors the product down to account for improved heating techniques; and the retrofit factor further reduces this product to account for improvements to the dwelling unit's efficiency over the life of the heating plant. The average consumption of an electric heating plant can, therefore, increase or decrease with newer vintages depending on the assumptions made concerning base level consumption and the relative strengths of conservation and retrofit as opposed to increasing unit size.

Heating plants in the ISER model wear out over time, according to an expected lifetime schedule. A heating plant has an explicit probability of "surviving" from one forecast year to the next, which depends on the age of the heating unit.

For example, the probability that a heating plant installed in 1980 will still be in service in 1985 is much higher than the probability that a heating plant installed in 1980 will be in service in the year 2000.

When a heating plant "dies", the model assumes that, in effect, the housing unit dies with it. The heating unit is replaced with either an electric or non-electric heating plant according to specified probabilities of "capture" which run on the order of 9:1 in favour of non-electric units. If an electric heating plant is chosen, it is of the average consumption appropriate to the vintage of the replacement period. This assumes for all intents and purposes that either the dwelling unit itself is replaced with a new unit or that the dwelling undergoes major alterations to increase its size to approximate that of currently produced units.

There is a logic problem in this case which will be discussed in our technical review. Basically, the problem is that the replacement of electric units by non-electric units is likely overstated as is the alleged "growth" of units which switch from one electric heating plant to another in a particular period. In terms of electricity requirements, these tend to offset one another, to an unknown extent. We will assume that they offset one another exactly for the purposes of our subsequent analysis; however, we strongly recommend that the space heating section of the ISER model be reformulated in terms of dwellings rather than heating plants to more accurately reflect reality.

In operation the ISER electricity end use model accepts as input the number of dwelling units by type from the housing stock model of Stage I and works recursively through the forecast period by vintage. For a given forecast year, the difference between housing units required and those "surviving" from previous periods constitute new housing starts. The number of these which are electric is multiplied by the average consumption of electric units of the new vintage; together with the total consumption of previously built electric units this given electric space heating requirements for the forecast year.

Assumptions again are critical at this stage in the model. The most important are the relative effects of increasing size as compared to conservation and retrofit potential; additionally, the relative "capture" of electric as opposed to oil or gas heating is quite important.

For major appliances, the ISER electricity end use model follows a structure similar to that of the space heating segment. Each appliance is classified according to its vintage; for each vintage the average consumption is computed as the product of base level consumption, a size factor and a conservation factor. The appliances follow a survival schedule similar to that of heating plants; the number of appliances of a particular type in service at a point in time is the number of households times the probability that a household will own the appliance. In some cases, this probability is close to 1 already; for others it is more modest but is assumed to grow over the forecast period.

General water heating, for purposes other than clothes or dishwashing is adjusted downward to account for diminishing household size. Where alternative fuels exist, an explicit assumption is introduced to determine the electrical share.

Operationally, the model determines required additions to the appliance stock by subtracting required stock in a forecast year from "surviving" units from previous periods. As in the space heating model, the total energy consumption is the sum of the numbers of units of each [illegible] multiplied by the appropriate energy intensity per unit.

The remaining activities in the residential sector are lighting and powering small appliances. The ISER model assumes a constant electricity requirement of 1000 kWh per unit annually for lighting. This level is assumed constant over the forecast period with increasing lighting requirements arising from increased dwelling size offset by conservation and technical improvements in the efficiency of lighting devices. Small appliances begin with a base requirement (in Anchorage, this is 1010 kWh per year per housing unit), and grow by a constant amount in each five year forecast period to accommodate expanded use of existing small devices as well as the use of new small appliances which may come into use over the forecast period.

In summary, the residential portion of ISER's electricity end use model operates on seventeen identifiable activities. With the exception of lighting and small appliances, the model works with discrete vintages of consuming devices. It introduces explicit assumptions about the energy intensity and survival characteristics of each device and vintage and calculates the numbers of each vintage in service on the basis of output of the Stage I process, and, where appropriate, explicit assumptions about electricity's share and the proportion of households owning a particular energy using device.

2.3.2 The Commercial-Industrial-Government Sector

Because of data shortages the ISER electricity end use model is rather thin in the CIG sector. While there are certainly as many specific activities using electricity in this sector as in the residential sector, they are unknown at the present time. Consequently, the ISER model takes a "second best" approach to modelling electricity requirements for the CIG sector.

In the CIG portion of the end use model there is effectively only one activity, providing all the electricity required for a CIG employee to carry out his or her job. Included, or rather subsumed by this classification are lighting, heating, equipment operation, and all of the other activities specific to employment.

The CIG portion of the model employs a structure similar to that of heating and major appliances in the residential sector. Jobs are of one of seven vintages, depending on their creation date which is in turn related to the estimates of employment originating in the MAP model and allocated to regions by the regional allocation model. The basic logic is that the energy intensity of a particular job depends on the technology in place at the time of its creation; the job maintains essentially the same energy intensity over the forecast period although conservation may be factored in over time.

Explicit assumptions about per job energy intensities are a central feature of the CIG portion of the model; in ISER's forecast these are projected to grow nearly three-fold over the forecast period. Jobs created in the 2005 - 2010 period require about 30,000 kWh per year in the Anchorage region as compared to about 10,000 kWh per year for jobs created before 1980.

Operationally, the CIG model is virtually identical to the residential model except that it is driven by employment rather than the number of households. For a given forecast year, employment growth is calculated by subtracting existing employment from total employment. Energy intensities specific to the respective "vintages" of jobs are applied and the results summed to give overall CIG electricity requirements.

Because of the aggregate nature of CIG activity in the model, it is virtually impossible to identify all the assumptions upon which it is based. The actual parameters used in the forecast indicate that ISER was quite conservative in working with this portion of the model; a large amount of electricity growth per employee is foreseen. However, it is not clear in which of the specific activities of employment the growth is to occur.

2.3.3 Stage II Summary

The Stage II function of the ISER forecast method accepts input from Stage I and translates this info. into detailed projections of electricity requirements for each region of the Railbelt. The electricity end use model developed by ISER identified 18 electricity using activities, of which 17 are in the residential sector and 1 in the commercial-industrial-government sector. The model forecasts on the basis of the vintages of consuming devices. Explicit assumptions regarding numbers of devices in operation, energy intensity, and electricity's share of the fuel market are introduced where appropriate.

3. A TECHNICAL REVIEW OF THE ISER FORECASTING METHOD

3.1 Introduction

Prior to the development of ISER's electricity forecasting model, both ISER and Energy Probe agreed that the goal of ISER's research should be the development of an "econometric end-use" (EEU) forecasting model. The name is derived from econometric methods, which employ statistical techniques to estimate the effects of price, income, and other pertinent factors on demand, employment, or population change, and end-use methods, which seek to explain energy use according to its final use.

The EEU approach is rapidly gaining wide acceptance in the electric utility industry as the most [illegible] approach to the increasingly difficult task of demand forecasting. As mentioned in our working paper, EEU is a means to combine engineering information on final electricity usage with economic information which governs consumer choice.

In an ideal EEU model, not only would basic economic and demographic variables be modelled and forecasted econometrically, so too would information on devices which transform electricity into useful work. The number of appliances, for example, would depend on not only the number of households in a given period, but also on the current levels of energy and other prices, incomes, and even state fiscal policies.

The disadvantage of pure EEU is that it is extremely data-intensive. This proved most telling for ISER's research; a basic scarcity of data rendered EEU impracticable for Alaska at this time. Consequently, ISER opted for a "next best" strategy which combined an econometric model, MAP, with four new non-econometric models to produce the required forecast.

3.2 MAP

The basis of the ISER electricity forecasting model is MAP, a medium-size econometric model of the State of Alaska. MAP is appropriate for a large role in electricity forecasting because it was designed to deal with different possible events in the resource sector and different possible policies for state finance.

Technically, MAP is quite good, as we argued in our earlier Working Paper. It produces statewide forecasts of employment and population by age and sex on the basis of state and national trends and resource and state government activities. Unfortunately, MAP's output is not directly applicable to electricity forecasting for the Railbelt and we made a number of recommendations on improving this situation, the majority of which have been implemented by ISER in their subsequent work.

3.3 The Household Formation Model

We recommended that the demographic data output of MAP be expanded to include the number of households by age of head to complement MAP's population by age and sex. This was carried out by the addition of the household formation model.

The household formation model is an adequately developed method of accounting for households but relies only on demographic analysis for its aggregation of individuals; no economic activities modelled in MAP affect household formation.

3.4 The Regional Allocation Model

Since MAP produces statewide estimates of economic and demographic variables another required change was to distribute to Greater Anchorage, Fairbanks, and Glenallen-Valdez appropriate shares of statewide activity. The regional allocation model was developed to meet this requirement. This is extremely important because resource development projects used in projections of statewide activity could shift population and economic growth regionally within the state and even within the Railbelt.

The forecasting model must be capable of accommodating the possibility of a remote oil discovery leading to the expansion of communities outside the Railbelt grid, for example. Other scenarios might include projects which have a differential impact on the three Railbelt regions.

The ISER approach to this problem is acceptable. It appears to be a precise statistical allocation of regional activity based on resource sector employment and other factors. However, there has been so little variation in the regional proportions of activity in the years for which data is available that the regional allocation model has not been thoroughly tested.

While likely not as precise as it appears, the regional allocation model is adequate in the context of the present study; much more development would be required to adequately handle unusually-located resource projects or to expand the study area to other regions of Alaska.

3.5 The Housing Stock Model

The housing stock model is the final bridge between MAP and the electricity end use model. The most important aspect of this model is the projection of the relative proportions of single family, duplex, apartment, and mobile units.

Like the household formation model, the housing stock model is based only on demographic factors and not on the economic output of MAP. Beacuse of the lack of year-by-year housing data it is not possible to relate housing stock to construction activity, interest rates, and other influential variables which would clearly be desirable.

While the necessary data is missing it is possible to recreate it in the future on the basis of aerial photography, utility hookups, housing sales, and building permit activity. We strongly recommend this be done in future improvements to the ISER model.

3.6 The Electricity End Use Model - Residential Sector

The residential part of the end use model applies information on heating plant, appliance ownership, housing heating efficiency, and their changes over time to forecasts of households and housing units. The numerous ways in which this allows the analyst to examine the impact of alternative policy options is admirable; the detailed calculation process allows for changes in virtually any aspect of residential electricity consumption patterns.

A major problem in the model is the apparent confusion between housing stock attrition, which is not in the model but should be, and heating plant attrition, which is in the model but overly emphasized. Essentially, the rate of heating plant attrition is quite high, given that the heating units of concern are electric and consequently last indefinitely given repairs to small components.

The model should allow for a very slow loss of actual dwellings, especially mobile homes, and for a somewhat faster loss of heating plants to newer and more efficient designs. Consequently, the particular numerical values used by ISER which simultaneously understate attrition of buildings and overstate retrofit are open to question.

3.7 The Electricity End Use Model - CIG Sector

The commercial sector end use model is quite undeveloped and sparse in comparison to the residential model. Originally, ISER had intended to build the model on the basis of floor space in commercial, industrial, and government buildings with a very modest breakdown by type of activity. In the final analysis, employment was used as the benchmark for electricity use projections.

This is adequate for the present study but is difficult to interpret as end use analysis as no physical efficiency changes can be directly related per employee energy use. Clearly, a model based on physical attributes of structures, such as floor area, would be easier to relate directly to energy use.

Furthermore, the final results reflect no breakdown of commercial-industrial, government into sectors; and breakdowns published by ISER were generated by across-the-board allocations of final consumption.

The most important problem in the CIG forecast is that the per-employee energy consumption figures are based on 1973-78 changes in consumption per CIG customer, i.e. store, factory, etc. While these two years avoid the highest point in the pipeline boom which might exaggerate energy use, the 1978 figure may have been pushed up by the practices of the boom years (uninsulated buildings, lights on constantly, etc.) This may be an important biasing figure when translated forward into per employee values for future periods.

Alaska's [illegible] the strong possibility that a significant number of energy audits of residential and CIG customers will be carried out. The audits offer a prime opportunity to build a better data base which includes information on the physical characteristics of buildings. In the mean time, a close scrutiny of actual CIG electricity sales should offer a check on ISER's assumptions and should reveal whether the potential biases suggested above are in operation.

Eventually, more detail of the CIG sector must be built into the model. At the very least, information on principal activity, size of establishment, and region must be included. As we will note in the following section, the actual CIG forecast produced by ISER appears to be based on overly-rapid increases in energy use per employee in an era of growing energy awareness.

3.8 Summary

In summary, the ISER method is a major improvement over any other forecast methods which, to our knowledge, have been used in Alaska. It is a two part process with the Stage I model (MAP plus household formation, regional allocation, and housing stock extensions) feeding information on future households, employment, and housing stock into an electricity end-use model. The latter features an adequately comprehensive residential component but an underdeveloped commercial portion.

4. AN ANALYSIS OF THE ISER MODEL OUTPUT

4.1 Introduction

As indicated above, the ISER model forecasts Railbelt electricity consumption in terms of energy (or MWh) by end use and consuming sector, for each of the Railbelt's three divisions, for the years 1985, 1990, 1995, ..., 2010, and for each of three economic scenarios (which attempt to capture a reasonable range of economic development possibilities). Of the three economic scenarios - low, moderate and high economic growth - ISER considers the moderate case to be the "most probable". A summary of aggregate Railbelt electricity growth for each of these three scenarios is presented in Figure 4.1 following:

Figure 4.1: Summary of ISER Electricity Projections

	Low	Moderate	High
1985	2921 (GWh)	3171	3561
1990	3236	3599	4282
1995	3976	4601	5789
2000	5101	5730	7192
2005	5617	6742	9177
2010	6179	7952	11736
Annual Growth (%)			
1980-1990	3.08	4.18	6.00
1990-2000	4.66	4.76	5.32
2000-2010	1.94	3.33	5.02
Average Annual Growth 1980-2010 (%)			
	3.22	4.09	5.45

While ISER has considered and calculated the impacts on electricity demand of various economic scenarios, it has held constant through all its electricity demand projections its electricity end use assumptions, with the exception of the "moderate economic growth/shift to electricity" case. Because forecasts of electricity demand are highly sensitive to these end use assumptions, it is worth noting both the assumptions utilized in the ISER model, and the manner in which they were incorporated into the forecasts.

In summary, the following general assumptions have been utilized in ISER's end use calculations:

1. The electricity market is presently in relative equilibrium, except for space heating in Fairbanks, where a shift away from electric space heating is underway.
2. This equilibrium is expected to remain in effect throughout the forecast period because of relatively constant fuel price ratios.
3. The price of energy relative to other goods and services will continue to rise.
4. Rising real incomes will act to increase the demand for electricity.
5. Federal policies will be effective in the area of appliance energy conservation, but will have a much

smaller impact on building stock efficiencies.

6. No state conservation policies directed exclusively toward electricity will be implemented.

7. No significant state policies designed to alter the price or availability of alternative fuels are implemented.

8. No new electricity technologies will be introduced.

9. In terms of residential appliances:

    (a) saturation rates will track national trends;

    (b) for some appliances, reduced household size will act to reduce average electricity requirements;

    (c) consumption is sensitive to the appliance scrapping rate;

    (d) unspecified appliance consumption grows in order to accommodate the possibility of new domestic electricity applications.

10. In terms of residential space heating:

    (a) a slight trend toward single family homes is projected;

    (b) average housing unit size continues to grow;

    (c) natural gas availability will not significantly increase;

    (d) space heating alternatives such as oil, wood or coal will not greatly affect aggregate space heating demand;

(e) no significant increase in heat pumps occurs.

11. In terms of commercial-industrial-government use:

    (a) employment will grow more rapidly than the population;

    (b) no major conservation measures are anticipated;

    (c) the distribution of electricity end uses will not shift significantly.

12. Miscellaneous utility sales (street lighting and second home use) will grow at rates consistent with overall utility sales.

These assumptions enter the end use model through a series of calculations, as documented in the "User's Guide" section of this report.

Although ISER contends that these end use assumptions are "probable", we argue that in some cases they are unlikely, i.e. they indicate a growth rate in electricity demand which we believe to be too high. !!

In order to demonstrate the effects of utilizing different end use assumptions within the model, we have taken ISER's moderate economic growth case, and have developed two alternative end use scenarios for the Anchorage sub-region of the Railbelt. The first of these - Case "A" - indicates what we believe will be the result of the recent state conservation bill, combined with national trends in conservation policies and technologies.

Case "B" outlines what we believe would be the product of a conservation program more stringent than that presently contemplated by the State legislature, but which nonetheless lies well within the realm of the possible.

4.2 Case "A" End Use Scenario

4.2.1 Residential Space Heating Requirements

ISER's calculations for future residential space heating requirements employ a number of specific assumptions. The following figure indicates ISER's assumptions, and where applicable, our modifications for the Case "A" end use scenario.

These modifications seem appropriate to give the [illegible] intent of the recent energy conservation bill. Lower growth in dwelling unit size (assumption 2) is a reflection of a recent stabilization of dwelling unit size in the lower-48, and of smaller expected households.

The impact of the conservation, retrofit and unit size modification assumptions documented in Figure 4.2 is a reduction in Anchorage space heating requirements growth from ISER's expected 3.77% per annum to 1.98% per annum, a 47% reduction.

Figure 4.2: A Comparison of ISER and Case "A" Assumptions

I.S.E.R.	Case "A"
1. Additions to the housing stock will require about 10% more electricity for space heating than the average pre-1980 unit, reflecting larger unit size at the margin	1. no change
2. Average dwelling unit size for all unit types (single family, duplex, multi-family and mobile homes) will increase 5% per 5-yr. period throughout the forecast period	2. Lower growth in unit size is assumed. Single family and mobile units grow 15% larger by 1985 and then stabilize; multu-family and duplex units grow 20% larger by 1990 and then stabilize
3. Pre-1980stock will remain at present levels of efficiency throughout the forecast period (i.e. no retrofits assumed)	3. Retrofit schedules for Pre-1980 stock: (a) single family and duplex: 3% per 5-yr. period efficiency improvement, stabilizing at 1[illegible]% in 20[illegible] (b) multi-family: 2% per 5-yr. period efficiency improvement, stabilizing at 10% in [illegible] (c) mobile homes: no retrofits assumed
4. Post-1980 units will be 5% more efficient per square foot than pre-1980 units for all housing types throughout the forecast period	4. All post-1980 units will be 5% more efficient per square foot per 5-yr. period
5. Once built, new units will remain at constructed levels of efficiency throughout the forecast period, except for single family units, which will improve 2%	5. Once built, units conform to retrofit schedule as in (3) above, effective beginning 5 years after the completion date of the unit

4.2.2 Major Residential Appliance Energy Requirements

ISER's method of dealing with major appliances is similar to their space heating technique, with the exception of the retrofit parameter, which does not exist for appliances. In summary, ISER's appliance assumptions are as follows:

Figure 4.3: ISER's Major Appliance Assumptions

Appliance	kWh Requirements per Unit per Year	Unit Growth per 5-yr. Period	Efficiency Improvement over 1980
water heater	3650	2.5%	14%
stove	1250	0	3%
clothes dryer	1000	0	6%
refrigerator	1560	5.0%	29%
freezer	1550	5.0%	21%
television	400	0	30%
air conditioner	400	0	21%
dishwasher	230	0	0%
dishwasher (water)	740	2.5%	24%
clothes washer	70	0	0%
clothes washer (water)	1050	0	31%

Source: ISER Worksheets

In terms of a moderate conservation effort, these values, and especially the estimated reduction in demand attributable to conservation, seem quite reasonable. While not a function of state policy, appliance efficiencies have been the focus of much federal study; indications are that federal appliance efficiency standards will be realized. Therefore, for our Case

"A" scenario, we accept ISER's major appliance consumption. These assumptions yield a growth rate in major appliance energy demand in the Anchorage district of 3.17% per annum.

4.2.3 Unspecified Residential Appliance Requirements

ISER has disaggregated unspecified appliance energy demand into lighting (1000 kWh/household/year) and assorted appliances (1010 kWh/household/year and growing at 50 kWh/household/year). Because this classification net of lighting contains a very large number of appliances with extremely low utilization rates and energy requirements (i.e. an electric radio at 10 kWh/year), it is necessary to treat it as an aggregate. ISER's allowance of 50 kWh/household annual growth in assorted appliance energy demand, while holding lighting demand constant, seems reasonable given the uncertainty surrounding the actual appliance stock, its potential for efficiency improvements, and the possibility that new small appliances will enter the market in the future.

Thus, for our Case "A" scenario, we have accepted ISER's unspecified appliance assumptions, which yield a growth rate in Anchorage district of 4.9% per annum throughout the forecast period.

4.2.4 Residential Summary

In general, we find ISER's end use assumptions acceptable, escept for space heating electricity demand, which we believe are unrealistically high. Utilizing our assumptions for space heating while accepting ISER's appliance assumptions, results in a growth forecast for the Anchorage region of 3.36% per annum, compared to USER's 3.75%.

4.2.5 The Commercial-Industrial-Government Sector

ISER's Commercial-Industrial-Government sector (CIG) end use model is, because of serious data limitations, much less detailed than the residential end use model. In general, CIG employment for each of the snapshot years is multiplied by an electricity use per employee parameter, yielding total electricity consumption for that "vintage" of employee. Summing this figure with the electricity consumption of all previous "[illegible]" of employees yields total consumption for that year. The following values were used in the ISER CIG end use model.

Figure 4.4: ISER CIG Assumptions

Date	Base MWh/Employee	(1 - Cs)	(1 - ret)	Actual MWh/Employee
1980	10.675	1.0	1.0	10.675
1985	15.156	1.0	1.0	15.156
1990	18.180	.95	1.0	17.270
1995	21.200	.90	1.0	19.080
2000	24.220	.90	1.0	21.800
2005	27.240	.90	1.0	24.520
2010	30.26	.90	1.0	27.230

We have serious reservation about accepting the values used in the CIG end use model. It is difficult to imagine that electricity use per employee can nearly triple within the confines of existing CIG electricity applications. Such rapid growth in per employee electricity use seems to suggest that major new applications for electricity will be found. However, ISER's assumption that fuel price ratios will remain nearly constant throughout the forecast period seems to limit the potential for the development of new applications (notwithstanding actual unavailability of alternative fuels).

Secondly, ISER's assumes only a 10% reduction by 1990 in the efficiency with which each CIG employee utilizes electricity (the (1 - Cs) term above). Such a figure seems to underestimate commercial sector savings of 15 - 30% that are already being attained. (Ontario Hydro, for example, inhabits one of the world's most energy efficient commercial structures. Since the building's completion in 1976, Hydro has cut lighting loads by a further 15%).

While the lack of CIG data certainly suggests the need to be conservative, we believe the 10% conservation estimate is far too low.

And thirdly, ISER assumes that no retrofits will be conducted on the buildings inhabited by CIG employees (the (1 - ret) term remains constant at 1.0). Rising electricity prices seem to imply the incentive for major retrofitting on commercial structures.

For our Case "A" scenario, we will assume data values as follows:

(a) Per employee electricity utilization is allowed to grow, as ISER has forecast, to 1995, but remains stable at the 1995 level throughout the remainder of the forecast period;

(b) All stock is assumed to retrofit, resulting in a 2% savings per employee per 5-year period, effective from five years after the completion of the structure within which the CIG employee is assumed to work;

(c) While we have reservations about the 10% reduction in per employee energy consumption resulting from conservation, we will accept it for Case "A" (but will increase the role of conservation in our Case "B" analysis).

These amendments result in a reduction of the Anchorage district CIG electrical growth rate from ISER's 4.2% per annum to 3.6% per annum over the entire forecast period.

4.2.6 Summary of Case "A" Scenario

The following figure summarizes electrical demand growth in the Anchorage region according to our suggestions above. The effect of our revisions is to reduce overall growth in the Anchorage area by approximately .5% per year, from ISER's 3.98% to what we believe to be a more realistic 3.49%.

Figure 4.5: Case "A" Summary

Date	Space Heat	Major Appl.	Minor Appl.	C-I-G	Total	ISER Forecast Total
1985	492	464	203	1219	2378	2438
1990	556	523	255	1353	2687	2782
1995	660	628	334	1777	3399	3564
2000	784	753	427	2151	4115	4451
2005	848	858	509	2450	4665	5226
2010	903	975	604	2797	5279	6141

Average Annual Growth 1980 - 2010:

ISER: 3.98%
Energy Probe 3.49

4.3 Case "B" End Use Scenario

4.3.1 Residential Space Heating Requirements

Figure 4.6 below indicates the residential space heating assumptions utilized in our Case "B" end use scenario (reference should be made to Figure 4.2 for comparison with Case "A" and ISER assumptions).

Figure 4.6: Case "B" Assumptions (Residential Space Heat)

1. Single Family Dwellings:
    (a) Pre-1980 stock and 1985 stock retrofit so as to achieve improvement in efficiency of 4% per 5-year period compared to base 1980 and base 1985 requirements, stabilizing at 80% of base requirements
    (b) Base heating requirements for 1990 and successive stock vintages decrease as follows:
        1990 - 35000 kWh (based on 1980 house size)
        1995 - 30000 "
        2000 - 25000 "
        2005 - 20000 "
        2010 - 20000 "
    (c) unit size increases to 1.15 x 1980 value by 1995, then remains stable
    (d) 1985 stock has a (1 - Cs) of 0.95 (as per ISER); all other stock has a (1 - Cs) of 1.0 (conservation is accommodated through reductions to base requirements as per (b) above

2. Duplexes:
    (a) retrofit as per single family dwellings
    (b) Base heating requirements for 1990 and successive stock vintages decreases as follows:
        1990 - 23600 kWh (based on 1980 house size)
        [illegible] - [illegible] "
        2000 - [illegible] "
        2005 - 14600 "
        2010 - 14600 "
    (c) unit size increases to 1.2 x 1980 value by 2000, then remains stable
    (d) conservation treated as per single family dwellings

3. Multi-Family Dwellings:
    (a) all assumptions as per Case "A"

4. Mobile Homes:
    (a) all assumptions as per Case "A"

These Case "B" modifications to the ISER residential space heat forecast result in a growth reduction from ISER's 3.77% per annum to 1.77% per annum throughout the forecast period, a 53% reduction.

4.3.2 Major Residential Appliance Energy Requirements

Although ISER's model incorporates the effects of federally mandated appliance efficiency improvements, analysis by others has indicated that even greater gains are possible in this area. While the potential improvements in individual appliances vary greatly, it seems reasonable to suggest that on average, improvements in the range of 20% over and above present federal standards are possible. Thus, by using ISER's aggregate major appliance consumption data, and factoring in a 5% improvement by 1985; 10% by 1990; 15% by 1995; and 20% by 2000, a revised estimate of major appliance consumption can be developed. Such improvements would serve to reduce major appliance energy consumption growth from ISER's (and Case "A"'s) 3.17% per annum to 2.41% per annum throughout the entire forecast period.

4.3.3 Unspecified Residential Appliance Requirements

Again, because of the lack of appliance disaggregation in this category, it is impossible to deal explicitly with the effects of increasing saturation and improved unit efficiencies. However, by holding lighting requirements constant at 1000 kWh per year and allowing other appliance use to increase at a compound rate of 2% per annum per household, we believe we can present a reasonable estimate of the combined potential effects of both improved efficiency and growing saturation.

This would yield an annual growth rate in this end use of 4.26% compared to ISER and Case "A" growth of 4.9% per annum.

4.3.4 Residential Summary

The overall effect of the application of Case "B" assumptions to the ISER end use model is to reduce Anchorage residential sector growth from 3.75% per annum to 2.7% per annum throughout the 1980 - 2010 period.

4.3.5 The Commercial-Industrial-Government Sector

For our Case "B" scenario, we have assumed CIG data values as follows:

(a) per employee electricity utilization remains constant after 1985 at the 1985 level of 15.156 MWh. This value can be interpreted in two ways, as either accommodating a growing number of applications at increased efficiency or as accommodating the same number of applications at current levels of efficiency (or, of course, as a combination of these two factors).

(b) retrofitting on all vintages of stock is assumed to proceed at 5% per 5-year period over the base figure.

The effect of these assumptions is to reduce CIG sector consumption growth from ISER's 4.18% to 2.71% per annum.

4.3.6 Summary of Case "B" Scenario

The following diagram summarizes electrical demand growth in the Anchorage district according to Case "B" assumptions. Ovejall growth is forecast at 2.7% per annum compared to ISER's 3.98%.

Figure 4.7: Case "B" Summary

Date	Space Heat	Major Appl.	Minor Appl.	C-I-G	Total	ISER Forecast Total
1985	489	441	191	1190	2311	2438
1990	548	471	230	1267	2516	2782
1995	641	533	291	1558	3023	3564
2000	722	603	363	1798	3486	4451
2005	740	687	427	1967	3821	5226
2010	764	780	503	2152	4199	6141

Average Annual Growth 1980 - 2010

ISER:	3.98%
Energy Probe	2.70%

5. MAJOR CONCLUSIONS AND RECOMMENDATIONS

Although we have outlined many recommendations throughout the text of this report, we believe some are sufficiently important to be restated and explained in greater detail.

5.1 General Commentary

Although the ISER model in its present form is not EEU as both ISER and Energy Probe has desired initially, it nonetheless represents an enormous advance in the quality of electricity demand forecasting in the State of Alaska. ISER is to be commended on the extent to which they have incorporated available data, on the manner in which they have laid out their assumptions, and on their willingness [illegible] procedures and techniques. We believe that, our suggestions notwithstanding, the ISER model represents an excellent vehicle through which to view the State's electricity future.

5.2 Funding for Load Forecasting Research

Although demand forecasting is considered to be the most important element of the planning process; it continues to receive a disproportionately small share of overall research funding. If demand forecasting is to provide a useful guide to energy policy development, and if energy projects are to be evaluated with the highest possible degree of confidence, additional funds must be made available so that data can be collected and analyzed and the model structure improved.

5.3 ISER Model Automation

While the ISER MAP model is fully automated, the end use model at present consists of several hundred worksheets, changes to which must be made manually. In this form, the end use model is virtually inaccessible to analysts who might wish to test the effects of various end use assumptions: the development of a single alternative scenario for the entire Railbelt would take many days. This serves to limit the potential of the model as a policy analysis tool.

Ideally, the entire forecast model, that is, the MAP, household formation, housing, regional allocation and end use components, would be automated. We believe that such an effort should be made.

5.4 Future Use of the ISER Forecast

Because the ISER model represents such an advance over previous forecast methods, we believe that it should be utilized in the evaluation of future energy projects in the State. In other words, while specific assumptions can, of course, vary over time and among analysts, they should be incorporated, and the results viewed, within the context of the ISER forecast. Efforts should be made to improve the weak points of the forecast, the result of which would be a forecast structure which forms an excellent basis for project evaluation and policy analysis.

5.5 Data Collection

Data collection methods within the State should be improved, in at least the following ways:

(a) the results of the 1980 Census should be incorporated into the forecast at the earliest opportunity;

(b) air photo interpretation should be employed to reconstruct the building stock for the Railbelt;

(c) information from the energy auditing programs should be used to gain a fuller understanding of the CIG and residential building stocks.

5.6 Statewide Electricity Demand Forecasting

Data should be collected, and the ISER model revised and expanded, so that the model can be used to forecast electricity requirements for the entire State of Alaska. This will require several structural revisions to the model, especially with respect to the regional allocation component.

5.7 Peak Demand Forecasting

A peak demand forecasting method should be developed to be applicable to all Stage I and Stage II scenarios. This analysis should be conducted by estimating and summing the load characteristics of each individual end use. The potential for load management and the effects of time-of-day pricing should be considered in the research. However, at the present time, we do not believe that it would be worthwhile to develop an integrated energy/demand forecast.

5.8 Additional Stage I Scenario

At present, all three Stage I scenarios developed by ISER assume a steadily increasing level of State economic activity. However, the possibility of a significant slowdown in resource sector activity during the 1990's has been considered by a number of individuals, resulting from the depletion of the most accessible and least expensive natural gas and oil deposits. Given the real possibility and significant consequences of such a scenario, we believe that it would be worthwhile to model this possibility in the same fashion as ISER has modelled the three major scenarios to date.

5.9 Independent Expert Advice on the Load Forecast

It has been argued that an appropriate way to review and evaluate the ISER model results would be to draw together a group of individuals familiar with State economic and energy affairs. This group would evaluate the likelihood and feasibility of the model's assumptions, from which a fuller appreciation of the range of possible electrical futures could be obtained.

We believe that such an exercise might prove fruitful for two reasons. Firstly, such a group might achieve a consensus with respect to probable electrical futures (or, failing consensus, might better understand the assumptions about which the group cannot agree). Secondly, the logic behind the ISER method could be spread over a wider range of parties, resulting in a deeper appreciation of the factors affecting electricity growth and the role of State policy in these areas.

We should qualify the above, however, by stating that policy intervention can assist in determining the "probability" of a particular electrical future; thus this approach should be seen not as a substitute for, but rather as a complement to, continued energy policy research in the State.

APPENDIX

WORKING PAPER #1: A PRELIMINARY EVALUATION OF THE ISER ELECTRICITY DEMAND FORECAST

January 2, 1980 (amended for inclusion)

Preface

In October 1979, Energy Probe was asked by The House Power Alternatives Study Committee (HPASC) of The Alaska State Legislature to submit a proposal for a study that would evaluate the electricity demand forecasting method developed by The University of Alaska's Institute of Social and Economic Research (ISER). This report presents an initial evaluation of the ISER forecasting model and the Man in the Arctic (MAP) model on which, in part, the electricity demand forecast is based.

The present report draws on information contained within the Detailed Work Plan submitted November 14, 1979, by Dr. Scott Goldsmith of ISER; May 1979 MAP model documentation; various publications relevant to the future social and economic activity in the State of Alaska; and personal discussions with ISER personnel.

A further report will deal with the sensitivity of electricity growth in the Railbelt region of Alaska to policy and market induced changes in the social, economic and physical factors which influence electricity growth: and with an analysis of the appropriate role of electricity demand forecasts within the broader context of State energy policy development.

Because this report is a working document intended only for use by HPASC members and consultants, it is written in relatively technical language. Our final report will detail the three areas mentioned above in less technical terms.

The views expressed herein are those of the authors, and not necessarily The House Power Alternatives Study Committee.

1. Introduction

Electricity demand forecasting, like all quantitative forecasting, is an effort to view the past and present in a systematic way with a view towards making reasonable statements about the future. The basic problem is that the future is not known, and indeed cannot be known, even in a probabilistic sense. As a matter of fact, pretending to forecast the future is an indictable offence under the New York State Criminal Code (1). Similar provisions, we are certain, are in effect elsewhere.

However, analysts often find it necessary to fly in the face of strict legality when the viability of a large project hinges on the need for it in the future. Hence, forecasting has become an integral part of planning for investments in energy, transportation, housing, and a myriad of other functional service delivery areas. Forecasting the demand for such services comprises a two stage process. In the first stage, aggregate social and economic activity is projected into the future (using, for example, the ISER MAP model); the second stage translates this aggregate activity into a detailed forecast of the demand for the product or service in question.

Stage I models tend to be rather ubiquitous, finding application in a number of functional areas. MAP, for example, has been used in a variety of forecasting environments including energy impact analysis and fiscal forecasting. On the other hand, Stage II models are generally specialized and tailored to the problem at hand. In transportation planning, they are classified under the general heading of travel demand models. In energy demand forecasting, a number of different approaches have been developed, which have met with varying degrees of success. To the extent that a debate over appropriate forecasting <u>methods</u> exists, it is really a debate over the choice of a Stage II approach. In fact as we argue below, the choice of a Stage II approach essentially dictates the output and hence the structure of the Stage I model to be used.

The argument over Stage II models centers on the extent to which the model should deal with two distinct but equally important aspects of the problem. Given an aggregate forecast from Stage I, should a Stage II model focus on the specific <u>activity</u> involved or should it focus on the decision of the consuming unit? In forecasting within a policy [illegible] housing, for example, the latter dictates that we examine household budgets, prices and so on. However, a dwelling offers service far beyond simple shelter; amenity, proximity and opportunities for social interaction are but a few of these. Hence, the former approach would argue that the demand for housing is really a composite demand for the services offered by a structure. Energy and transportation are similar. Rarely are they required for their own sake; in reality they are crucial inputs into a number of satisfaction-yielding activities.

In electricity demand forecasting it was once possible to do a reasonable job of prediction by looking at a historical growth rate and simply plotting future levels of consumption against time. A draftsman with a French curve (or an engineer with semi-log paper) could make a reasonable guess at future demand by simple curve fitting and extrapolation. However, it is logically clear that the growth in electricity demand has little to do with the passage of time *per se*. Rather, it is related to individual <u>decisions</u> to engage in a growing number of electricity-using <u>activities</u> over time.

2. Stage II Modelling Approaches

Attempts to deal seriously with this complexity became necessary in the early years of the 1970's when historical rates of electricity growth ceased to be realized by most electrical utilities in North America. The formation of OPEC and the 1973 Arab oil embargo, with its subsequent increases in petroleum prices, ended the era of cheap energy; and all fuels, including electricity, rose in price rather dramatically. Unfortunately, the econometric demand forecasting models in use at this time (2) were incapable of dealing with such rapid changes and continued to point to historic or near-historic rates of electricity growth. ISER's 1975 electricity demand forecast for the State of Alaska (with which, we might add, ISER itself was not comfortable) is a case in point. The most telling criticism of its strict time-series econometric approach is that potentially ludicrous activity forecasts result. In ISER's 1975 effort, for example, initial results indicated a demand for electricity which implied 100% saturation of electric space heating in Fairbanks in the future. The point to be made here is that because individual activity levels are not explicitly identified in aggregate economic models, such models run the risk of implying physically unrealistic activity levels.

End use forecasting models in their pure form take the opposite approach by relying almost exclusively on activities, independent of the underlying economic conditions. The logic is simple: consuming units engage in various activities requiring energy. Energy growth can result from

(a) engaging in additional energy consuming activities;
(b) engaging in the same activities more intensively;
(c) [illegible]
(d) any combination of the [illegible]

The case of oral hygiene provides a humorous example. A household may switch from "manual" to electric toothbrushing, an additional energy using actitity. Given an electric toothbrush, members of the household may wish to brush more regularly. When the toothbrush wears out it may be replaced with a model which delivers fewer brush strokes per unit of energy input. In any of these cases, electricity use increases. In principle, it is possible to examine all electricity use in this manner, noting that all energy is used in a final form such as heat, light, motion or sound, and that it is transformed from its input form to its final end use form by a "device".

Again, in principle, electricity demand can be projected by forecasting the characteristics of devices and activities. This has become known as the engineering or end use approach to demand forecasting. The most telling criticism of this method in its pure form is that it is not sensitive to changes in prices, incomes and preferences, i.e. the decision aspect of the process modelled in Stage II. This is a generally accurate criticism whose resolution requires an examination of policies affecting the decisions of the individual consuming unit. In further work for HPASC, we will be discussing this problem.

For functional forecasting purposes, an approach is emerging which seeks to overcome the inherent difficulties of both extremes of Stage II modelling methods. The econometric-end use approach (EEU) attempts to deal with electricity use at the level of the activity while recognizing that the decision to own and operate a device, i.e. to engage in an activity at some level of intensity, is inherently a problem of microeconomic choice and is therefore sensitive to prices, incomes and the availability of alternatives (3).

In our opinion, an EEU approach is the only sensible way to forecast electricity demand and to justify a huge expenditure of public funds.

We are pleased that ISER agrees in principle with this general philosophy. The detailed work schedule circulated by ISER lays out a rather impressive work plan. We anticipate problems arising because of the extensive data requirements of EEU, which will be intensified by the basic data problems of Alaska: short time series and small population. However, we fully support ISER's desire to cast the net widely at first, while recognizing that data, and more importantly time and financial constraints will require the net to be drawn in somewhat.

At this point we would like to comment on the allocation of resources for independent demand forecasting relative to the magnitude of potential capital investments. Given the magnitude of the stakes for a project such as Susitna, i.e. a potential investment of billions of dollars, we feel that far too little money is being spent on this crucial element of project feasibility. ISER will likely argue, and justifiably so, that data is simply not available to construct a full scale EEU model. The missing data, however, is not of the variety which is impossible to collect. With additional resources made available, it could be gathered and incorporated into the forecast model, resulting in a forecast method with which all could be reasonably comfortable.

In the following pages we will review the EEU approach to Stage II and the requirements of a Stage I model to provide requisite inputs into EEU. Our goal is twofold: first to analyze and suggest approaches to particular problems for the benefit of ISER, and secondly to lay out the logic of ISER's forecasting proposal for the benefit of all consultants involved in HPASC studies. It is our hope that this will facilitate discussion and understanding of ISER's methods and in the longer term, identify avenues for potential policy intervention.

3. The Econometric-End Use Approach

EEU begins with the simple proposition that all energy is used in capital items or devices, which perform a specific task, i.e. an end use. Each device, by virtue of its design, has a specific energy input requirement for each unit of useful output, a concept similar to "First Law Efficiency". Devices are owned or rented and operated by consuming units. However, not all consuming units own all types of devices, nor do devices operate at all times.

Further, many devices may be powered by more than one fuel. The decisions to own or lease and operate a device are economic decisions made by the consuming unit in light of prices, incomes, preferences and available options. For a given period, say a year, the total energy required by a consuming unit to power a given device is by definition its hours of operation times its power requirement. If the device is electrically powered, this energy demand will contribute to an electricity demand estimate. Any portion of the electric power consumed by the economic unit which it generates itself, does not contribute to this utility forecast.

There are, of course, many consuming units and many devices. We may translate from the device level at the consuming unit by simply summing over devices and consuming units yielding the following expression for utility electric demand over a period of one year:

$$TUD = \sum_{k=1}^{N} \sum_{j=1}^{M} (D_{kj} \times E_{kj} \times I_{kj} \times R_{kj} - S_k) \qquad (1)$$

where

- TUD = total utility demand (kW.h)
- D_{kj} = 1 (if consuming unit k has device j)
  0 (if otherwise)
- E_{kj} = 1 (if device j is powered by electricity in consuming unit k)
  0 (if otherwise)
- I_{kj} = intensity of use of device j by consuming unit k (hours)
- R_{kj} = power requirement of device j by consuming unit k (kW)
- S_k = amount of self supplied electricity by consuming unit k (kW.h)
- N = total number of consuming units
- M = number of distinct devices

This is an accounting framework for utility demand (4). To operationalize it for forecasting purposes, each of the components must be related to known of "knowable" variables. Engineering knowledge and economic theory suggest potential relationships. Econometric or other techniques are used to estimate their direction and strength.

For operational purposes it is necessary to group consuming units into classes on the basis of predominant activity within the unit (i.e. residential, commercial, etc.), similarity in patterns of device ownership or energy requirements, or some other appropriate criterion. Clearly, there are losses in precision due to this sort of aggregation. After grouping consuming units into classes, the demand for utility electricity is obtained by the following expression:

$$TUD = \sum_{i=1}^{Q} CUD_i = \sum_{i=1}^{Q} \sum_{j=1}^{M} (N_i \times PD_{ij} \times PE_{ij} \times I_{ij} \times R_{ij} - S_i) \qquad (2)$$

where

CUD_i = the demand for electricity by class i (kWh)

N_i = the number of consuming units in class i

PD_{ij} = the proportion of class i consumers owning device j

PE_{ij} = the proportion of device j in class i that are electrically powered

I_{ij} = the average intensity of use of device j by members of class i (hours)

R_{ij} = the average power requirement of device j owned by members of class i (kW)

S_i = the amount of electricity self supplied by class i members (kWh)

Q = the number of consuming classes

The advantage of examining end use demand in this manner is obvious. Not only is it less data intensive than Equation (1), but also, key parameters become easier to pinpoint. For example, in an analysis of a subclass comprised of mobile homes built before 1970, space heating requirements would be rather similar.

Time, of course, is also a crucial consideration which must enter the model in a forecasting environment. The advantage of an end use model is that the factors developed above exhaust the realm of demand factors, and each will change over time. As time passes, classes of consuming units grow or decline, devices become more or less prevalent and more or less "electrical", self-supplied electricity may become more widely used, devices may be used more or less intensively, and device efficiencies will undoubtedly change. The latter is particularly important since many devices will be replaced over the forecast period and those which are not may be "retrofitted" to improve their performance.

While the passage of time is itself not the reason for change, the argument above suggests that it may prove fruitful to view demand growth in a temporal sense. At a point in time we begin with a "stock" of consuming units equipped with devices. Over the ensuing year the consuming unit may disappear, change or modify its collection of devices or means of powering them. In addition, new consuming units may be formed complete with new devices. Presumably these new devices would have energy consumption characteristics different from "old" devices. At the end of the year we witness a revised stock of existing consuming units and devices comprised of the previous year's units plus net increases. This may be taken a year at a time over the entire forecast period yielding electricity requirements for specific annual points and annual increments in demand.

4. The ISER Model and Suggested Approaches and Revisions

In the context of the Railbelt region, EEU makes a great deal of sense for the residential and commercial sectors which, taken together, account for about 86% of Alaska's total electricity demand. Because industrial development in Alaska is largely of the major project variety, it is best to examine these in a case by case manner. Further, with the exception of block heating in vehicles, the transportation sector currently uses an insignificant amount of electricity. Again, this is best viewed as a special case.

ISER's EEU model, Figure 1 in their "Detailed Work Plan", incorporates most of the features of an ideal EEU discussed above. It is a stock/flow model which segregates consuming units into "new" and "old" and deals with four residential subclasses, and segregates devices into six categories including an "other" category for minor appliances.

The commercial sector should be divided into at least the following groups:

(a) public/institutional buildings;
(b) large shopping plazas/office buildings (say larger than 100,000 or 250,000 square feet);
(c) other commercial buildings.

This would be fruitful for two reasons: within each group there are similar requirements for electricity; and policies/programs may be specifically tailored, at a later date, to this particular pattern of consumption and occupancy/ownership.

Missing in ISER's proposed model is a term to account for electricity or energy supplied by the consuming unit and hence not required from a central system. This should be added to the model even though it may not greatly affect the magnitude of the final forecast. A number of considerations warrant its inclusion, not the least of which is the possibility of co-generation of electricity and steam for space heating in large commercial establishments, schools, hospitals and the like.

The present ISER formulation allows for the scrapping of dwelling units but not for the replacement of appliances within existing units. A number of appliances ISER intends to consider have useful lives of substantially fewer years than either the forecast period or the structure. In ISER's model, this problem could be solved by adjusting the average consumption of appliances on an annual basis. It is better, however, not to confound the efficiency measure with the effect of new appliance stocks.

Given these structural refinements which we consider necessary, the ISER approach to residential and commercial electricity demand forecasting is methodologically sound. Since residential and commercial consumption in the Railbelt is quite important, it is necessary to examine the components of the EEU model and to suggest possible approaches to modelling each component. In this case we refer initially to our formulation of EEU above, and explicitly to these elements pertaining to Stage II.

In Equation (2), total utility demand was expressed as the sum of class demands. Class demand is a function of the number of units in the class, the proportion owning various devices, the proportion of these devices powered by electricity, the average intensity of each device's use, the average power requirements of the various devices and the amount of self supplied electricity. The number of consuming units in each class is essentially a modified form of the output of State I which we discuss below. The remaining factors are, however, Stage II concerns which we deal with in turn.

PDij, the proportion of class i units owning device j, is obviously a variable whose value lies between 0 and 1. For certain end uses, i.e. space heating, its value equals unity and will continue to do so over the forecast period. In other cases like clothes drying and refrigeration, its value is a matter of choice, and while perhaps initially close to unity, it is variable over the forecast period. In an ideal world we would hope to estimate this proportion on the basis of income level and distribution within the Railbelt region, bearing in mind that the decision to own a device also commits the owner to operating expenses over its lifetime. Hence the general price level of all competing fuels may be important.

PEij, the proportion of device j owned by class i which are electrically powered is also a variable whose value ranges from 0 to 1. Again, for certain end uses, especially refrigeration, its value is close to unity and will likely remain so over the forecast period. However, a great deal of choice exists in this area. A useful way to look at this problem has been proposed by Fuss who suggests the decision to engage in an activity with a specific fuel is essentially separable. In other words, given a decision to engage in an activity, the choice of fuel is essentially a separate question (5) made on the basis of relative prices.

The question of the treatment of conservation arises in this instance. If conservation is factored into average energy requirements, then no more need be said, However, if we view each or any device as having a "base-line" energy requirement, then any effort to reduce it involves an explicit tradeoff of electricity for conservation. In this sense, conservation is self-supply, and has an average supply price equal to the amortized annual cost of the conservation project divided by the number of kilowatt-hours displaced during a year. Marginal costs may be calculated by assuming, ideally, various levels of conservation and calculating, presumably, a step function for the fuel equivalent value of various conservation schemes. The same logic may be applied to renewable energy projects as well.

We feel it is useful to view conservation and renewables in this way when considering existing activities at a point in time. The major point is that given an existing activity, like space and water heating (the major ones) the consuming unit can choose not only to switch from one conventional fuel to another but can also choose to supply a portion of its requirements with conservation. In an oil heated home, for example, the household may switch to gas, electricity, or conservation for all or part of its heating on the basis of relative prices. Considering conservation as an explicit fuel represents a useful modification of interfuel substitution analysis.

Rij, the average power requirement of device j in class i, becomes basically an engineering design parameter when conservation is treated as a fuel. Consequently, it is a function mainly of vintage, not confounded by retrofit. One item that should be examined is the trend in device efficiencies over time. This may well be an appropriate area for regulation.

Iij, the average intensity of use of device j by class i members is also a consumer choice variable although to a limited extent in the major consumption categories. Actions like reducing inside temperatures and the like are evidence of the economizing behaviour of households under this category; how much further we can go in this area is certainly questionable. In this case, comfort and convenience bound choice from below. To the extent that there is flexibility it is likely price and income related.

The final term in our formulation is Si, the amount of self-supplied electricity by members of class i. In this instance we suggest that this term be kept pure in the sense that conservation not be viewed as self supply in this term. We include Si in the model for the reasons stated above. There is a price at which self generation or co-generation becomes attractive whether by means of water power, wind or conventional fuel. The model should be sensitive to this possibility.

The above relates to our formulation and also to ISER's model. The remaining terms in ISER's model relate to new household formation which we discuss below and the so-called "scrapping rates". Scrapping of a device involves not only physical deterioration but also economic considerations, one of which is the device's fuel requirements. Logically, the scrapping rate should increase with decreasing energy requirements for new models of a particular device. This is extraordinarily difficult to measure and project over time; however, it is something to be kept in mind.

Generally speaking, we are impressed with ISER's proposed method for handling the Stage II modelling of the residential and commercial sectors. With the modifications suggested above we can wholeheartedly endorse ISER's approach and we look forward to working with ISER on further questions of approach and sensitivity analysis. With respect to the ISER approach to non-residential and commercial use of electricity, we reserve judgement since the method has not yet been developed. We will, of course, comment at an appropriate time and we are confident that ISER will take a sound approach, based on their work to date.

5. Stage I Approaches

We not turn to the merits of the MAP model of the Alaskan economy as a Stage I model for EEU forecasting. Regional economic forecasting can take a number of forms. Some approaches being considered in the "Detailed Work Plan" are input-output analysis, the economic base approach, Curtis Harris' locationally efficient model, and the Delphi technique. These all have strong and weak points but none is a serious contendor to a moderately detailed econometric model like MAP.

What is required of the Stage I model? It must provide the number of consuming units in each class for the end use equation. That is, in the number of housing units of several types and the number of firms, employees, square footage or business volume for commercial and institutional units. It must be sensitive to the scenarios of fast, likely and slow growth mentioned in the "Detailed Work Plan". It must respond to changes in oil and gas pricing, energy and other major investment projects, national economic trends, and demographic realities including migration. While the current MAP model incorporates most of the latter functions, the restriction of demographic projections to persons (not households or families), the introduction of housing only through the dollar volume of construction, and the lack of other physical measures of economic activity closely related to the number and type of consuming units are major deficiencies. As noted in the "Detailed Work Plan", data must be gathered and incorporated into new versions of MAP.

What regional techniques must be added? In our opinion, none of the above mentioned techniques merit much effort.

Input-output analysis is appropriate when a region has a large industrial base which relies to a great extent on inter-industry sales. Alaska does not have such an economy yet, and the method's well known data intensity suggests that it need not be considered further. Shortcuts to true regional input-output data [illegible] - such as the use of technical coefficients borrowed from other studies - are inappropriate for an unusual state economy such as that of Alaska.

The strong points of economic base analysis - a technique which is useful when the regional economy pivots on clearly defined basic industries - are already contained within the MAP model. The simple economic base methods are too elementary; ISER is well beyond them already in its work. The same criticism holds for purely extrapolative methods. Just as ruler and graph paper are inappropriate for load forecasting, they are too simplistic for the economic part of econometric-end use analysis.

Curtis C. Harris developed a regional forecasting model at the detailed industry level based on short time series changes in output by industry and state and incorporating transportation costs estimated by optimization techniques. Alaska clearly is not likely to exhibit consistent locational cost patterns of industrial development necessary to take Harris' approach.

Delphi, a technological and political forecasting technique developed first at the Rand Corporation is unlikely to yield the moderately detailed consuming unit forecasts needed here. However, it may always be considered for developing scenarios for energy projects, general economic growth levels, or energy policy decisions. Hence it is not a Stage I model but a source of exogenous and policy variable values for any forecasting method.

Among general methods for forecasting regional economic activity, one not yet mentioned is shift-share analysis. This method is based on statistical estimation of the contribution to a state's industrial growth of industry factors and regional factors. It is an excellent basic method which is sufficiently incorporated in a MAP-style econometric approach. While both input-output and shift-share methods are usually performed with a great deal of industry detail, such detail is not needed in our Stage I approach.

What is needed is more detail aimed at household characteristics and building stock characteristics. While data sourc end points for households are well known and trusted, a region such as Alaska can have rapid and crucial post-Censal fluctuations in households and household size. As for buildings, only dwelling units are enumerated in the Census. Building stock estimates for non-residential units are rare above the city level (6). Land use surveys and Civil Defense surveys give spotty data sets, but the building stock is basically an unknown quantity for regions such as states. For the current research, increased information on the building stock is important.

As an expedient is is suggested that housing be looked at in detail (so as to allow better end use forecasts for space and water heating, lighting and appliance loads); that large commercial and institutional uses be examined through enumeration of structures; and that the rest be treated by the use of employment or sales estimates.

Recent efforts by others in energy forecasting [illegible] approaches:

(a) macroeconomic econometric models such as MAP;
(b) microeconomic simulations of consuming unit responses to changes in price, income and the availability of alternatives.

The former is necessary to introduce national and major regional trends. The latter is used to discover what the distributional effects of new pricing and supply levels will be.

A study commissioned by a number of New York consumer groups and carried out at Cornell University was used in testimony before the New York State Energy Master Plan Meetings in September 1979 (7). In this approach, Green, Mount and Saltzman utilized a four-sector economic/demographic state econometric model with a partially integrated energy sub-model. The four sectors were residential, industrial, commercial and transportation. All major energy types - electricity, oil, gas and coal - were forecasted simultaneously. This Cornell model as well as another model developed with end use detail by The New York State Energy Office, predicted significantly lower electricity requirements than has previous state plans. It should be noted that while the Cornell model is not extremely complicated (57 economic equations, 150 demographic equations) it contains household formation functions for each age-sex cohort. Unfortunately, the Cornell model does not give explicit place in its structure to self-supply wood space heating or conservation.

Furthermore, in the Cornell approach, a microeconomic simulation was linked to the macro model in order to relate income and price changes and restrictions on fuel supply to consumer demand for the different fuels (8). This, of course, requires an extensive data base of individual households studied by survey research methods. In this case a sample of 7000 households was utilized.

While such microsimulation may be beyond current possibilities in evaluating Susitna (and we are not convinced that such further study should be considered extravagent) it suggests again the need to make the energy forecasting version of MAP more oriented to consuming units, households, and the biggest devices of all, buildings.

Looking in more detail at MAP, based on the may 31 1979 documentation, we note that it has more than enough economic detail, but not enough demographic information because of households not appearing explicitly. Finally, a housing and/or buildings component is lacking; this is a critical shortcoming.

In the "Detailed Work Plan", we support most strongly Items A7 - 9 on electricity consumption; Item 10 on households, houses and appliances. These are more important, in our estimation, than the refinement of the MAP economic model *per se*. They should receive top priority.

Regional disaggregation (Task B) is important, but less so than getting on to EEU forecasting for the Railbelt region as a whole. Thus the items in "D" are crucial - interfuel substitution plus the addition of conservation.

A general evaluation of the MAP models serves to reveal several strengths in addition to the above shortcomings. First despite the limited length of the Alaska data series, the resulting equations are adequate by conventional statistical benchmarks, at least for forecasting use. The detailed fiscal and native/non-native/military results, needed for earlier applications, are well developed, but may not be particularly helpful in the current application.

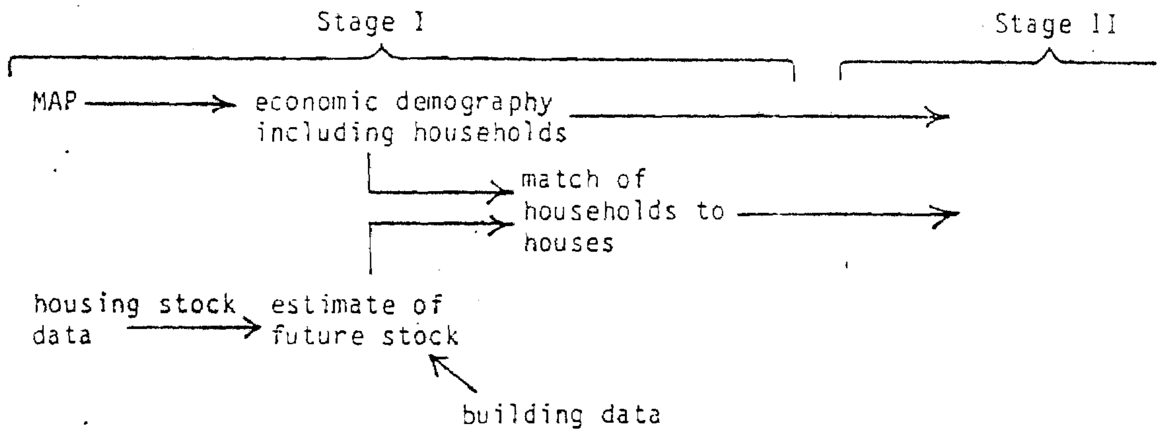
What is needed, more than any other modification, is a housing sub-model. Whether the data can be gathered for such an addition remains to be seen. Lacking a formal housing model, some intermediate step is required based on the housing stock data from the decennial censuses. A brief outline of each alternative is in order.

A full-blown econometric sub model for housing would flow from the following modifications to MAP:

(a) inclusion of household formation equations in the demographic sub-model;
(b) a set of equations for the housing stock (or alternatively changes to that stock) by age and type of unit.

Some of the crucial right hand variables would be from the construction and investment functions of the economic model as well as the household formation results.

If the time series data are lacking for the housing modifications to MAP, then the available census benchmarks - number of dwelling units by age and type - should be combined with recent data on housing starts, mobile home sales, building permits, etc., to update the distribution of the housing stock. This results in the following structure:



6. Conclusions

Energy demand forecasting, the most crucial element of energy policy develo[illegible], is [illegible] uncertainties. In order [illegible] procedures, the analyst is faced with the need to develop what amount to relatively more sophisticated [illegible] forecasts than has traditionally been the case.

Pure econometric and pure end use forecasts suffer inadequacies; hence, a blended approach combining the best elements of each is necessary. This blended EEU approach is difficult because of its data requirements and because modifications must be made to the structure of the underlying econometric and end use models on which it is based.

In the long run, an EEU forecasting system for Alaska can be developed with MAP, suitably modified, at its heart. Its data requirements are not yet attainable in a small region such as Alaska with a short data history. Therefore, in the short term, ad hoc forecasting must be carried out with the outputs of the current version of MAP. These outputs must be obtained by using a very wide range of input scenarios.

The most crucial shortcoming of the current version of MAP is the lack of a housing sector and this must be bridged by some reasonable, if imperfect method of estimating Alaskan housing stock and characteristics in recent years.

7. Footnotes

1. Joan Robinson, "What are the Questions?", Journal of Economic Literature 15, December 1977, p. 1322.
2. These are extremely expensive and sophisticated versions of semi-log paper. See Herman Daly, "Energy Demand Forecasting: Prediction or Planning?", Journal of The American Institute of Planners, January 1976.
3. Robert W. Shaw Jr., "New Factors in Utility Load Forecasting", Public Utilities Fortnightly, July 19, 1979, pp. 19 - 23.
4. Much as Dr. Goldsmith's is a stock/flow approach to accounting for demand.
5. M. A. Fuss, "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs", Journal of Econometrics 5, January 1977, pp. 89 - 116.
6. B. Jones, D. Manson, J. Mulford, M. Chain, The Estimation of Building Stocks and their Characteristics in Urban Areas, Program in Urban and Regional Studies, Cornell University, 1976.
7. W. Greene, T. Mount, and S. Saltzman, "Forecast of the Demand for Major Fuels in New York State 1980 - 1994", Technical Report, September 4, 1979.
8. S. Caldwell, W. Greene, T. Mount and S. Saltzman, "Forecasting Regional Energy Demand with Linked Macro/Micro Models", Working Paper in Planning #1, Department of City and Regional Planning, Cornell University, January 1979, forthcoming in Papers of the Regional Science Association 45.

A PRELIMINARY EVALUATION

OF

THE I.S.E.R. ELECTRICITY DEMAND FORECAST

(Working Paper #1)

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In October 1979, Energy Probe was asked by The House Power Alternatives Study Committee (HPASC) of the Alaska State Legislature to submit a proposal for a study that would evaluate the electricity demand forecasting method developed by the University of Alaska's Institute for Social and Economic Research (ISER). This report is the first of three to be prepared by Energy Probe, and presents an initial evaluation of the ISER forecasting model and the Man in the Arctic Project (MAP) model on which, in part, the electricity demand forecast is based.

The present report draws on information contained within the Detailed Work Plan submitted November 14, 1979 by Dr. Scott Goldsmith of ISER; May 1979 MAP model documentation; various publications relevant to the future social and economic activity in the state of Alaska; and personal discussions with ISER personnel.

Further reports in this series will deal with the sensitivity of electricity growth in the Railbelt region of Alaska to policy and market induced changes in the social, economic and physical factors which influence electricity growth; and with an analysis of the appropriate role and interpretation of electricity demand forecasts within the broader context of state energy policy development.

Because this report is a working document intended only for use by HPASC members and consultants, it is written in relatively technical language. Our final report, to be prepared by May 1980, will detail the three areas mentioned above in less technical language.

The views expressed herein are those of the authors, and not necessarily the House Power Alternatives Study Committee.

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1. INTRODUCTION

Electricity demand forecasting, like all quantitative forecasting, is an effort to view the past and present in a systematic way with a view towards making reasonable statements about the future. The basic problem is that the future is not known, and indeed cannot be known, even in a probabilistic sense. As a matter of fact, pretending to forecast the future is an indictable offence under the New York State criminal code. Similar provisions, we are certain, are in effect elsewhere.

However, analysts often find it necessary to fly in the face of strict legality when the viability of a large project hinges on the need for it in the future. Hence, forecasting has become an integral part of planning for investments in energy, transportation, housing and a myriad of other functional service delivery areas. Forecasting the demand for such services comprises a two-stage process. In the first stage, aggregate social and economic activity is projected into the future (using, for example, the ISER MAP model); the second stage translates this aggregate activity into a detailed forecast of the demand for the product or service in question.

Stage I models tend to be rather ubiquitous, finding application in a number of functional areas. MAP, for example, has been used in a variety of forecasting environments including energy impact analysis and fiscal forecasting. On the other hand, Stage II models are generally specialized and tailored to the problem at hand. In transportation planning, they are classified under the general heading of travel demand models. In energy demand forecasting, a number of different approaches have been developed, which have met with varying degrees of success. To the extent that a debate over appropriate forecasting methods exists, it is really a debate over the choice of a Stage II approach. In fact, as we argue below, the choice of a Stage II approach essentially dictates the output and hence the structure of the Stage I model to be used.

The argument over Stage II models centers on the extent to which the model should deal with two distinct but equally important aspects of the problem. Given an aggregate forecast from Stage I, should a Stage II model focus on the specific activity involved or should it focus on the decision of the consuming unit? In forecasting within a policy environment concerned with housing, for example, the latter dictates that we examine household budgets, prices and so on. However, a dwelling offers service far beyond simple shelter; amenity, proximity and opportunities for social interaction are but a few of these. Hence, the former approach would argue that the demand for housing is really a composite demand for the services offered by a structure. Transportation and energy are similar. Rarely are they required for their own sake; in reality they are crucial inputs into a number of satisfaction yielding activities.

In electricity demand forecasting it was once possible to do a reasonable job of prediction by looking at a historical rate of growth and simply plotting future levels of consumption against time. A draftsman with a French curve (or an engineer with semi-log paper) could make a reasonable guess at future demand by simple curve fitting and extrapolation. However, it is logically clear that the growth in the demand for electricity has little to do with the passage of time *per se*. Rather, it is related to individual *decisions* to engage in a growing number of electricity using *activities* over time.

2. STAGE II MODELLING APPROACHES

Attempts to deal seriously with this complexity became necessary in the early years of the 1970's when historical rates of electricity growth ceased to be realized by most electrical utilities in North America. The formation of OPEC and the 1973 Arab oil embargo, with its subsequent increases in petroleum prices, ended the era of cheap energy; and all fuels, including electricity, rose in price rather dramatically. Unfortunately,

the econometric demand forecasting models in use at this time were incapable of dealing with such rapid changes and continued to point to historic or near-historic rates of electricity growth. ISER's 1975 electricity demand forecast for the State of Alaska (with which, we might add, ISER itself was not comfortable) is a case in point. The most telling criticism of its strict time-series econometric approach is that potentially ludicrous activity forecasts result. In ISER's 1975 effort, initial results indicated a demand for electricity which implied 100% saturation of electric space heating in Fairbanks in the future. The point to be made here is that because individual activity levels are not explicitly identified in aggregate economic models, such models run the risk of implying physically unrealistic activity levels.

End use forecasting models in their pure form take the opposite approach by relying almost exclusively on activities, independent of the underlying economic conditions. The logic is simple: consuming units engage in various activities requiring energy. Energy growth can result from

(a) engaging in additional energy consuming activities;
(b) engaging in the same activities more intensively;
(c) engaging in the same activities less efficiently;
(d) any combination of the above.

The case of oral hygiene provides a humorous example. A household may switch from "manual" to electric toothbrushing, an additional energy using activity. Given an electric toothbrush, members of the household may wish to brush more regularly. When the toothbrush wears out it may be replaced with a model which delivers fewer brush strokes per unit of energy input. In any of these cases, electricity use increases. In principle, it is possible to examine all electricity use in this manner, noting that all energy is used in a final form such as heat, light, motion or sound, and that it is transformed from its input form to its final end use form by a "device".

Again, in principle, electricity demand can be projected by forecasting the characteristics of devices and activities. This has become known as the engineering or end use approach to demand forecasting. The most telling criticism of this method in its pure form is that it is not sensitive to changes in prices, incomes and preferences, i.e. the decision aspect of the process modelled in Stage II. This is a generally accurate criticism whose resolution requires an examination of policies affecting the decisions of the individual consuming unit. In further work for HPASC, we will be discussing this problem.

For functional forecasting purposes, an approach is emerging which seeks to overcome the inherent difficulties of both extremes of Stage II modelling methods. The econometric-end use approach (EEU) attempts to deal with electricity use at the level of the activity while recognizing that the decision to own and operate a device, i.e. to engage in an activity at some level of intensity, is inherently a problem of microeconomic choice and therefore sensitive to prices, incomes and the availability of alternatives.[3.]

In our opinion, an EEU approach is the only sensible way to forecast electricity demand and to justify a huge expenditure of public funds.

We are pleased that ISER agrees in principle with this general philosophy. The detailed work schedule circulated by ISER lays out a rather impressive plan. We anticipate problems arising because of the extensive data requirements of EEU, which will be intensified by the basic data problems of Alaska: short time-series and a small population. However, we fully support ISER's desire to cast the net widely at first, while recognizing that data, and more importantly time and financial constraints will require the net to be drawn in somewhat.

At this point we would like to comment on the allocation of resources for independent demand forecasting relative to the magnitude of potential capital investments. Given the magnitude of the stakes for a project such as Susitna, i.e. a potential investment of billions of dollars, we fell that far too little money is being spent on this crucial element of project feasibility. ISER will likely argue, and justifiably so, that data is simply not available to construct a full scale EEU model. The missing data, however, is not of the variety which is impossible to collect. With additional resources made available, it could be gathered and incorporated into the forecast model, resulting in a forecast method with which all could be reasonably comfortable.

In the following pages we will review the EEU approach to Stage II and the requirements of a Stage I model to provide requisite inputs into EEU. Our goal is two fold: first to analyze and suggest approaches to particular problems for the benefit of ISER, and secondly to lay out the logic of ISER's forecasting proposal for the benefit of all consultants involved in HPASC activities. It is our hope that this will facilitate discussion and understanding of ISER's methods and in the longer term, identify avenues for potential policy intervention.

3. THE ECONOMETRIC - END USE APPROACH

EEU begins with the simple proposition that all energy is used in capital items or devices, which perform a specific task, i.e. an end use. Each device, by virtue of its design, has a specific energy input requirement for each unit of useful output, a concept similar to "First Law Efficiency". Devices are owned or rented and operated by consuming units. However, not all consuming units own all types of devices, nor do devices operate at all times. Further, many devices may be powered by more than one fuel. The decisions to own or lease and operate a device are economic decisions made by the consuming unit in light of prices, incomes, preferences and available options. For a given period, say a year, the total energy required by a consuming unit to power a given device is by definition its hours of operation times its power requirement. If the device is electrically powered, this energy demand will contribute to an electricity demand estimate.

Any portion of the electric power consumed by the economic unit which it generates itself, does not contribute to this utility forecast.

There are, of course, many consuming units and many devices. We may translate from the device level at the consuming unit by simply summing over devices and consuming units yielding the following expression for utility electric demand over a period of one year:

$$TUD = \sum_{k=1}^{N} \sum_{j=1}^{M} [D_{kj} \cdot E_{kj} \cdot I_{kj} \cdot R_{kj} - S_{k}] \qquad (1)$$

where

TUD = total utility demand (kW.h)

D_{kj} = 1 if consuming unit k has device j
0 if otherwise

E_{kj} = 1 if device j is powered by electricity in consuming unit k
0 if otherwise

I_{kj} = intensity of use of device j by consuming unit k (hours)

R_{kj} = power requirement of device j by consuming unit k (kW)

S_{k} = amount of self supplied electricity by consuming unit k (kW.h)

N = total number of consuming units

M = number of distinct devices

This is an accounting framework for utility demand.[4] To operationalize it for forecasting purposes, each of the components must be related to known or "knowable" variables. Engineering knowledge and economic theory suggest potential relationships. Econometric or other techniques are used to estimate their direction and strength.

For operational purposes it is necessary to group consuming units into classes on the basis of predominant activity within the unit (i.e. residential, commercial, etc.), similarity in patterns of device ownership or energy requirements, or some other appropriate criterion. Clearly, there are losses in precision due to this sort of aggregation. After grouping consuming units into classes, the demand for utility electricity is obtained by the following expression:

$$TUD = \sum_{i=1}^{Q} CUD_i = \sum_{i=1}^{Q} \sum_{j=1}^{M} [N_i \, . \, PD_{ij} \, . \, PE_{ij} \, . \, I_{ij} \, . \, R_{ij} - S_i] \quad (2)$$

where

CUD_i = demand for electricity by class i (kW.h)

N_i = number of consuming units in class i

PD_{ij} = proportion of class i consumers owning device j

PE_{ij} = proportion of devices j in class i that are electrically powered

I_{ij} = average intensity of use of device j by members of class i (hours)

R_{ij} = average power requirement of device j owned by members of class i (kW)

S_i = amount of electricity self supplied by class i members (kW.h)

Q = number of consuming classes

The advantage of examining end use demand in this manner is obvious. Not only is it less data intensive than Equation (1), but also, key parameters become easier to pinpoint. For example, in an analysis of a subclass comprised of mobile homes built before 1970, space heating requirements would be rather similar.

Time, of course, is also a crucial consideration which must enter the model in a forecasting environment. The advantage of an end use model is that the factors developed above exhaust the realm of demand factors, and each will change over time. As time passes, classes of consuming units grow or decline, devices become more or less prevalent and more or less "electrical", self - supplied electricity may become more widely used, devices may be used more or less intensively, and device efficiencies will undoubtedly change. The latter is particularly important since many devices will be replaced over the forecast period and those which are not may be "retrofitted" to improve their performance.

While the passage of time is itself not the reason for change, the argument above suggests that it may prove fruitful to view demand growth in a temporal sense. At a point in time we begin with a "stock" of consuming units equipped with devices. Over the ensuing year the consuming unit may disappear, change or modify its collection of devices or means of powering them. In addition, new consuming units may be formed complete with new devices. Presumably these new devices would have energy consumption characteristics different from "old" devices. At the end of the year we witness a revised "stock" of existing consuming units and devices comprised of the previous year's units plus net increases. This may be taken a year at a time for the entire forecast period yielding electricity requirements for specific annual points and annual increments in demand.

4. THE ISER MODEL AND SUGGESTED APPROACHES AND REVISIONS

In the context of the Railbelt region, EEU makes a great deal of sense for the residential and commercial sectors which, taken together, account for about 86% of Alaska's total electricity demand. Because industrial development in Alaska is largely of the major project variety, it is best to examine these in a case by case manner. Further, with the exception of block heating in vehicles, the transportation sector currently uses an insignificant amount of electricity. Again, this is best viewed as a special case.

ISER's EEU model, Figure 1 in their "Detailed Work Plan", incorporates most of the features of an ideal EEU discussed above. It is a stock/flow model which segregates consuming units into "new" and "old" and deals with four residential subclasses, and segregates devices into six categories including an"other" category for minor appliances.

The commercial sector should be divided into at least the following groups:

1) Public/Institutional Buildings;

2) Large shopping plazas/office buildings (say larger than 100,000 or 250,000 sq.ft.);

3) Other commerical buildings.

This would be fruitful for two reasons: within each group there are similar requirements for electricity, and policies/programs may be specifically tailored, at a later date, to this particular pattern of consumption and occupancy/ownership.

Missing in ISER's proposed model is a term to account for electricity or energy supplied by the consuming unit and hence not required from a central system. This should be added to the model even though it may not greatly affect the magnitude of the final forecast. A number of considerations warrant its inclusion, not the least of which is the possibility of co-generation of electricity and steam for space heating in large commercial establishments, schools, hospitals, and the like.

The present ISER formulation allows for the scrapping of dwelling units but not for the replacement of appliances within existing units. A number of appliances ISER intends to consider have useful lives of substantially fewer years than either the forecast period or the structure. In ISER's model, this problem could be solved by adjusting the average consumption of appliances on an annual basis. It is better, however, not to confound the effiency measure with the effect of new appliance stocks.

Given these structural refinements which we consider necessary, the ISER approach to residential and commercial electricity demand forecasting is methodologically sound. Since residential and commercial consumption in the railbelt are quite important, it is necessary to examine the components of the EEU model and to suggest possible approaches to modelling each component. In this case we refer initally to our formulation of EEU above, and explicitely to these elements pertaining to Stage II.

In Equation (2), total utility demand was expressed as the sum of class demands. Class demand is a function of the number of units in the class, the proportion owning various devices, the proportion of these devices powered by electricity, the average intensity of each device's use, the average power requirements of the various devices and the amount of self-supplied electricity. The number of consuming units in each class is essentially a modified form of the output of Stage I which we discuss below. The reamining factors are however, Stage II concerns which we deal with in turn.

PD_{ij}, the proportion of class i units owning device j, is obviously a variable whose value lies between 0 and 1. For certain end uses, i.e. space heating, its value equals unity and will continue to do so over the forecast period. In other cases like clothes drying and refrigeration, its value is a matter of choice, and while perhaps initially close to unity it is variable over the forecast period. In an ideal world we would hope to estimate this proportion on the basis of income level and distribution within the Railbelt Region, bearing in mind that the decision to own a "device" also commits the owner to operating expenses over its lifetime. Hence the general price level of all competing fuels may be important.

PE_{ij}, the proportion of device j owned by class i which are electrically powered is also a variable whose value ranges between 0 and 1. Again, for certain end uses, especially refrigeration, its value is close to unity and will likely remain so over the forecast period. However, a great deal of choice exists in this area. A useful way to look at this problem has been proposed by Fuss who suggests the decision to engage in an activity with a specific fuel is essentially separable. In other words, given a decision to engage in an activity, the choice of fuel is essentially a separate question,[5] made on the basis of relative prices.

The question of the treatment of conservation arises in this instance. If conservation is factored into average energy requirements, then no more need be said. However, if we view each or any device as having a "base-line" energy requirement, then any effort to reduce it involves an explicit tradeoff of electricity for conservation. In this sense, conservation is self supply, and has an average supply price equal to the amortized annual cost of the conservation project divided by the number of kilowatt-hours displaced during a year. Marginal costs may be calculated by assuming, ideally, various levels of conservation and calculating, presumably, a step function for the fuel equivalent value of various conservation schemes. The same logic may be applied to renewable energy projects as well.

We feel it is useful to view conservation and renewables in this way when considering existing activities at a point in time. The major point is that given an existing activity, like space and water heating (the major ones) the consuming unit can choose not only to switch from one convential fuel to another but can also choose to supply a portion of its requirements with conservation. In an oil heated home, for example, the household may switch to gas, electricity, or conservation for all or part of its heating on the basis of relative prices. Considering conservation as an explicit fuel represents a useful modification of interfuel substitution analysis.

R_{ij}, the average power requirement of device j in class i, becomes basically an engineering design parameter when conservation is treated as a fuel. Consequently it is a function mainly of vintage, not confounded by retrofit. One item that should be examined is the trend in device efficiencies over time. This may well be an appropriate area for regulation.

I_{ij}, the average intensity of use of device j by class i members is also a consumer choice variable although to a limited extent in the major consumption categories. Actions like reducing inside temperatures and the like are evidence of the economizing behavior of households under this category; how much farther we can go in this area is certainly questionable. In this case, comfort and convenience bound choice from below. To the extnet that there is flexibility it is likely price and income related.

The final term in our formulation is S_i, the amount of self-supplied electricity by members of class i. In this instance we suggest that this term be kept pure in the sense that conservation not be viewed as self supply in this term. We include S_i in the model for the reasons stated above. There is a price at which self-generation or cogeneration becomes attractive whether by means of water power, wind, or conventional fuel. The model should be sensitive to this possibility.

The above relates to our formulation and also to ISER's model. The remaining terms in ISER's model relate to new household formation which we discuss below and the various "scrapping rates". Scrapping of a device involves not only physical deterioration but also economic considerations, one of which is the device's fuel requirements. Logically, the scrapping rate should increase with decreasing energy requirements for new models a particular device. This is extraordinarily difficult to measure and project over time; however, it is something to be kept in mind.

Generally speaking, we are impressed with ISER's proposed method for handling the Stage II modelling of the residential and commercial sectors. With the modifications suggested above we can wholeheartedly endorse ISER's approach and we look forward to working with ISER on further questions of approach and sensivity analysis. With respect to the ISER approach to non-residential and commercial use of electricity, we reserve judgement since the method has not yet been developed. We will, of course, comment at an appropriate time and we are confident that ISER will take a sound approach, based on their work to date.

5. STAGE I APPROACHES

We now turn to the merits of the MAP model of the Alaskan economy as a Stage I model for econometric end-use forecasting. Regional economic forecasting can take a variety of forms. Some approaches being considered in the "Detailed Work Plan" are input-output analysis, the economic base approach, Curtis Harris' locationally efficient model, and the Delphi technique. These all have strong and weak points but none is a serious contender to a moderately detailed econometric model like MAP.

What is required of the Stage I model? It must provide the number of consuming units in each class for the end use equation. That is, in the number of housing units of several types and the number of firms, employees, square footage, or business volume for commercial and institutional units. It must be sensitive to the scenarios of fast, likely, and slow growth mentioned in the "Detailed Work Plan". It must respond to changes in oil and gas pricing, energy and other major investment projects, national economic trends, and demographic realities including migration. Whiel the current MAP models incorporate most of the latter functions, the restriction of demographic projections to persons (not households or families), the introduction of housing only through the dollar volume of construction, and the lack of other physical measures of economic activity closely related to the number and type of consuming units are major deficiencies. As noted in the "Detailed Work Plan", data must be gathered and incorporated into new versions of MAP.

What regional techniques must be added? In our opinion none of the above mentioned techniques merit much effort.

Input - output analysis is appropriate when a region has a large industrial base which relies to a great extent on inter-industry sales. Alaska does not have such an economy yet, and the method's well-know data-intensity suggests that it need not be considered further. Shortcuts to true regional input-output data gathering -- such as the use of technical coefficients borrowed from other studies -- are inappropriate for an unusual state economy such as that of Alaska.

The strong points of economic base analysis -- a technique which is useful when the regional economy pivots on clearly defined basic industries -- are already contained within the MAP model. The simple economic base methods are too elementary; ISER is well beyond them already in its work. The same criticism holds for purely extrapolative methods. Just as ruler and graph paper are inappropriate for local forecasting, they are too simplistic for the economic part of econometric-end-use analysis.

Curtis C. Harris developed a regional forecasting model at the detailed industry level based on short time series changes in output by industry and state and incorporating transportation costs estimated by optimization techniques. Alaska clearly is not likely to exhibit consistent locational cost patterns of industrial development necessary to take Harris' approach.

Delphi, a technological and political forecasting technique developed first at the Rand Corporation is unlikely to yield the moderately detailed consuming unit forecasts needed here. However, it may always be considered for developing scenarios for energy projects, general ecomic growth levels, or energy policy decisions. Hence it is not a Stage I model but a source of exogenous and policy variable values for any forecasting method.

Among general methods for forecasting regional economic activity, one not yet mentioned is shift-share analysis. This method is based on statistical estimation of the contribution to a state's industrial growth of industry factors and regional factors. It is an excellent basic method which is sufficiently incorporated in a MAP-type econometric approach. While both input-output and shift-share methods are usually performed with a great deal of industry detail, such detail is not needed in our Stage I approach.

What is needed is more detail aimed at household characteristics and building stock characteristics. While data source end points for households are well-known and trusted, a region such as Alaska can have rapid and crucial post-Censal fluctuations in households and household size. As for buildings, only dwelling units are enumerated in the Census. Building stock estimates for non residential units are rare above the city level.[6] Land use surveys and Civil Defense surveys give spotty data sets, but the building stock is basically an unknown quantity for regions such as states. For the current research, increased information on the building stock is important.

As an expedient it is suggested that housing be looked at in detail (so as to allow better end use forecasts for space and water, heating, lighting, and appliance loads); that large commercial and institutional uses be examined through enumeration of structures; and that the rest be treated by the use of employment or sales estimates.

Recent efforts by others in energy forecasting suggests two approches: 1) macroeconomic econometric models such as MAP, and 2) microeconomic simulations of consuming unit responses to changes in price, income and the availability of alternatives. The former is necessary to introduce national and major regional trends. The latter is used to discover what the distributional effects of new pricing and supply levels will be.

A study commissioned by a number of New York consumer groups and carried out at Cornell University was used in testimony before the New York State Energy Master Plan Meetings in September 1979.[7] In this approach, Green, Moung, and Saltzman utilized a four-sector economic/demographic state econometric model with a partially integrated energy sub-model. The four sectors were residential, industrial, commercial and transportation. All major energy types - electricity, oil, gas and coal - were forecasted simultaneously. This Cornell model as well as another model developed with end use detail by the New York State Energy Office, predicted significantly lower electricity requirements than had previous state plans. It should be noted that while the Cornell Model is not extremely complicated (57 economic equations, 150 demographic equations) it contains <u>household formation functions</u> for each age-sex cohort. Unfortunately the Cornell Model does not give explicit place in its structure to self-supply wood space heating, or conservation.

Furthermore, in the Cornell approach, a microeconomic simulation was linked to the macro model in order to relate income and price changes and restrictions on fuel supply to consumer demand for the different fuels.[8] This, of course, requires an extensive data base of individual households studied by survey research methods. In this case a sample of 7000 households was utilized.

While such microsimulation may be beyond current possibilities in evaluating Susitna (and we are not convinced that such further study should be considered extravagant) it suggests again the need to make the energy forecasting version of MAP more oriented to consuming units, households, and to the biggest devices of all, buildings.

Looking in more detail at MAP, based on the May 31, 1979 documentation, we note that it has more than enough economic detail, but not enough demographic information because of households not appearing explicitly. Finally a housing and/or buildings component is lacking; this is a critical shortcoming.

In the "Detailed Work Plan" we support most strongly Items A 7 - 9 on electricity consumption; Item 10 on households, houses, and appliances. These are more important, in our estimation, than the refinement of the MAP economic model per se. They should receive top priority.

Regional disaggregation (Task B) is important, but less so than getting on to EEU forecasting for the Railbelt region as a whole. Thus the Items in D are crucial -- interfuel substitution plus the addition of conservation.

A general evaluation of the MAP models serves to reveal several strengths in addition to the above shortcomings. First despite the limited length of the Alaska data series, the resulting equations are adequate by conventional statistical benchmarks, at least for forecasting use. The detailed fiscal and native/non-native/military results, needed for earlier applications, are well developed, but may not be particularly helpful in the current application.

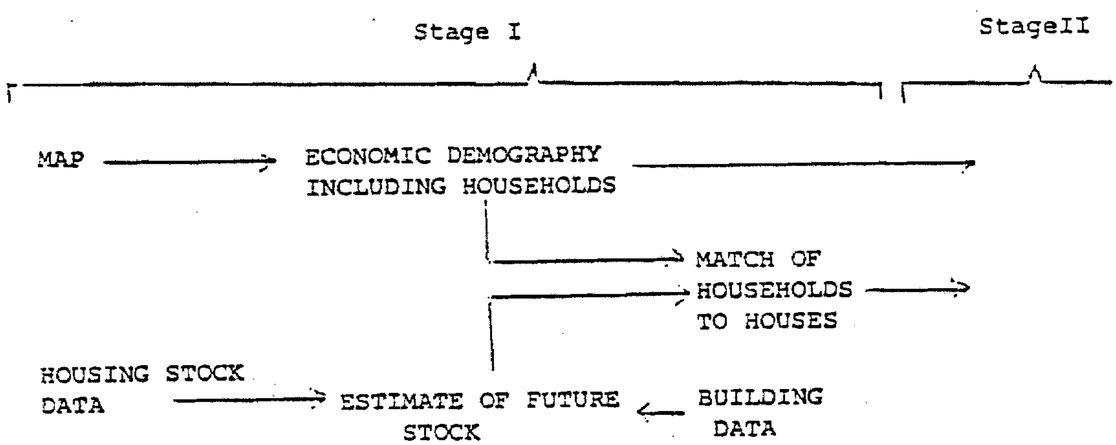
What is needed, more than any other modification, is a housing sub model. Whether the data can be gathered for such an addition remains to be seen. Lacking a formal housing model, some intermediate step is required based on the housing stock data from the decennial censuses. A brief outline of each alternative is in order.

A full-blown econometric sub model for housing would flow from the following modifications to MAP:

1) inclusion of household formation equations in the demographic sub model
2) a set of equations for the housing stock (or alternatively changes to that stock) by age and type of unit.

Some of the crucial right hand variables would be from the construction and investment functions of the economic model as well as the household formation results.

If the time series data are lacking for the housing modifications to MAP, then the available census benchmarks -- number of dwelling units by age and type -- should be combined with recent data on housing starts, mobile home sales, building permits, etc., to update the distribution of the housing stock. This results in the following structure:



6. CONCLUSIONS

Energy demand forecasting, the most crucial element of energy policy development, is difficult in the face of growing uncertainties. In order to maintain confidence in forecasting procedures, the analyst is faced with the need to develop what amount to relatively more sophisticated models and forecasts than has traditionally been the case.

Pure econometric and pure end use forecasts suffer inadequacies; hence, a blended approach combining the best elements of each is necessary. This blended EEU approach is difficult because of its data requirements and because modifications must be made to the structure of the underlying econometric and end use models on which it is based.

In the long run, an EEU forecasting system for Alaska can be developed with MAP, suitably modified, at its heart. Its data requirements are not yet attainable in a small region such as Alaska with a short data history. Therefore, in the short term, ad hoc forecasting must be carried out with the outputs of the current version of MAP. These outputs must be obtained by using a very wide range of input scenarios.

The most crucial shortcoming of the current version of MAP is the lack of a housing sector and this must be bridged by some reasonable if imperfect method of estimating Alaskan housing stock and characteristics in recent years.

7. FOOTNOTES

1. Joan Robinson, "What are the Questions?", Journal of Economic Literature 15, December, 1977, p. 1322.

2. These are an extremely expensive and sophisticated version of semi-log paper. See Herman Daly,"Energy Demand Forecasting: Prediction of Planning?", Journal of the American Institute of Planners, January 1976.

3. Robert W. Shaw Jr., "New Factors in Utility Load Forecasting", Public Utilities Fortnightly, July 19, 1979, pp. 19 - 23.

4. Much as Dr. Goldsmith's is a stock/flow approach to accounting for demand.

5. M. A. Fuss, "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs", Journal of Econometrics 5, January 1977, pp. 89 - 116.

6. B. Jones, D. Manson, J. Mulford, M. Chain, The Estimation of Building Stocks and their Characteristics in Urban Areas, Program in Urban and Regional Studies, Cornell University, 1976.

7. W. Greene, T. Mount, and S. Saltzman, "Forecast of the Demand for Major Fuels in New York State 1980 - 1994", Technical Report, September 4, 1979.

8. S. Caldwell, W. Greene, T. Mount and S. Saltzman, "Forecasting Regional Energy Demand with Linked Macro/Micro Models", Working Paper in Planning #1, Department of City and Regional Planning, Cornell University, January 1979, forthcoming in Papers of the Regional Science Association 45.

APPENDIX E

CRITIQUES OF ISER AND TUSSING REPORTS BY ALASKA UTILITY MANAGERS

- Golden Valley Electric Association (R.L. Hufman) - June 20, 1980
- Alaska Rural Electric Cooperative Association (D. Hutchens) - June 11, 1980
- Anchorage Municipal Light & Power (T.R. Stahr) - April 24, 1980

GOLDEN VALLEY ELECTRIC ASSOCIATION INC. Box 1249, Fairbanks, Alaska 99707 Phone 907-452-1151

June 20, 1980

RECEIVED

JUN 2 - 1980

ALASKA POWER AUTHORITY

Mr. Eric Yould
Executive Director
Alaska Power Authority
333 W. 4th Avenue, Suite 31
Anchorage, AK 99501

Dear Mr. Yould:

Following are comments relative to the ISER energy forecast authored by Scott Goldsmith and Lee Huskey:

1. The study estimates kWh sales only. Therefore at least a 10% upward adjustment must be made to properly forecast gross generation requirements.

2. Estimates should include the Cantwell Summit areas of the railbelt.

3. The major problem we have with the ISER forecast involves our objection to what we consider an extreme ultra-conservative approach. All studies regardless of who the authors are will, to varying degrees, reflect certain philosophical leanings of those persons participating. As I read the report, it is my opinion that the authors' philosophies tend to favor conservative approaches resulting in forecasts that reflect those tendencies. Utilities are ever mindful of the inherent dangers of grossly underestimating demand/energy projections for planning purposes. There may be some economic penalty for overbuilding for a short period of time. Most likely that penalty would be promptly wiped clean by inflationary trends. However the penalty for underbuilding may be a severe economic penalty, brownouts, blackouts, inability to serve new customers and other inconveniences all related to the above items. Those persons with responsibility to forecast only and with no utility responsibility to keep the lights on and provide service for new customers can perhaps afford to take the conservative approach. Utility planners simply cannot.

4. The study fails to adequately provide for increased usage that Susitna would encourage due to a long term stable rate base and adequate supply. With Susitna I believe electric heat for Interior Alaska would be the best buy. Deregulated oil may not even be competitive. Wood will be in short supply.

Coal in all the homes would cause intolerable pollution levels. Gas may or may not be available. Over 80% of the homes are now heated with oil most of which are hydronic baseboard systems. These are easy and economical conversions to electric boilers. If the price incentive is there, retrofitting will occur on a large scale. We know we have experienced such an occurrence for the past several years.

5. We also believe that a substantial number of electric cars will be in use by 1990; capturing 10-12% of the commuter market by 1995.

6. Further, the study anticipates substantial declines in petroleum royalties causing a severe drop in State spending. I believe that Royalty Gas revenues will pick up that slack. In addition, this Nation simply cannot allow the extreme deficit balance of trade to continue. We must produce our way out of it. Alaska has the oil and gas resources and I predict our State will be opened up to exploration such as we have never seen. There is a good chance that discoveries will be made that in combination will make the Prudhoe Bay Field seem like small potatoes.

7. One other item. It is reasonable to assume that the military plants would purchase all electrical energy from Susitna beyond that provided by their steam heat/electric plant balance point.

I admit to a rather radical philisophical departure from those that authored the ISER forecast. The main difference I suppose is that during the course of my 34 years in the electric utility business, I have had an opportunity to see and experience problems related to inadequate base load capacity and insufficent reserves.

Sincerely,

R. L. Hufman
General Manager

cc: Tom Stahr
Lee Wareham
Bob Penny
Dave Hutchens
Mike Kelly

ALASKA RURAL ELECTRIC COOPERATIVE ASSOCIATION, INC.

6000 C STREET · SUITE C · ANCHORAGE, ALASKA 99502 · (907) 276-3235

June 11, 1980

Mr. Eric Yould
Executive Director
Alaska Power Authority
333 W. 4th Ave.
Suite 31
Anchorage, Ak. 99501

Dear Eric:

Today I have read through the document prepared by ISER titled "Electric Power Consumption for the Railbelt: A Projection of Requirements." It seems obvious that the methodology used and the projections made are extremely conservative.

I will not attempt a point by point commentary on this report at this time, but a basic characteristic of this study does require comment. In the section on Major Economic Assumptions (page viii of the Executive Summary), the study assumes a high probability of a number of large construction projects in the early 1980's. However, the second item states, "In the subsequent decades, it becomes more difficult to identify specific projects or types of projects which may generate continued economic growth. There the range of economic projection widens."

To me, this says that since the preparers of this report cannot predict with certainty exactly what the components of railbelt economic growth will be after the early 1980's, they feel free to make their projections anything they wish within a wide range of what is possible. When the projections in Table A are read in this light, it is apparent that this study consistently assumes a level of economic activity in the lower portion of that range of possibility.

There is a very basic difference between an economist and a utility planner when both are looking into their crystal balls and attempting to project electric power requirements some distance into the future. The natural inclination of the economist is to be conservative in his growth projections. This is easy to understand because if he should err on the high side, he would be subject to ridicule for pulling numbers out of the air. If the economist understates the actual requirements, he can easily explain the growth in excess of his projections as the result of new economic activity which it was not safe to predict at the time of his study. For the economist to project low is to play it safe. If he is wrong on the low side, his professional reputation is carefully preserved.

A utility planner in projecting the future relies very heavily on the actual trends in load requirements contained in his experience. If he errs on the high side, the electric rates will be more than are really necessary. If he is wrong on the low side, people may freeze in the dark.

Especially in a period of rapid changes throughout the energy world, neither the economist nor the utility planner can be certain he is right. It is probable that actual power requirements will be somewhere between the projections made by these two. However, I would submit to you that the public safety requires that very great weight be given to the projection made by utility planners.

Sincerely,

Dave

David Hutchens
Executive Director

DH:ra

Comments on Tussing Susitna Review

April 24, 1980

By Thomas R. Stahr

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6 1980

ALASKA POWER AUTHORITY

Demand Studies P13-P16

I share Dr. Tussing's concern about the ISER study because an unproved methodology is being used. They are using the "end use" approach what is the latest fad in energy requirements projection techniques. Not only is this methodology unproven but even more important adequate end use data for Alaska's unique environment does not exist. At least two years of data collection and reduction would be required to obtain meaningful input data. I strongly urge a more conservative approach where principal reliance is placed on proven traditional load projection techniques. Contrary to Tussing's assertions, past load projections have proved reasonably accurate.

Negative Growth Demand Scenario P15 and 16

If the conservationist dream should come true and the State reverts toward complete wilderness, the in-state demand for energy would drop. This would also mean Alaskan contribution to Lower 48 and world energy supply would drop thus intensifying the national energy problem. Under these conditions industrial use of surplus energy would not be difficult to find. A study of dismal scenarios is not inappropriate if the broader social issues are incorporated. I would urge consideration of energy supply and demand in Alaska during the not too distant period when overall production of oil and gas enters the period of its inevitable decline.

Peak Loads, load duration curves, peak responsibility pricing and load management P16-17

Load factor, the ratio of average to peak load, expresses the relationship between annual energy and peak power demands. This relationship is quite stable and varies only slightly over large changes in total load and has changed only slightly with time. In Alaska the annual load factor is sensitive to climatic variations (i.e., warm winter vs. cold winter, etc.) but this variation can be factored out by relatively simple calculations.

It has been proposed, mainly by economists and conservationists that annual load factors can be significantly changed by pricing and load management techniques. Analysis and experience indicates that load management and peak load pricing will not have significant impact on Alaskan electric generation requirements. First it must be borne in mind that these techniques do not reduce the need for energy - they only switch around the time the energy is used. For many years ML&P has had a peak load pricing (time of day) rate which offers substantial savings for customers who transfer their energy use to off peak. At the time of our rate restructuring we found only 15 out of a possible 2,000 consumers who had done enough in this direction to yield any savings over the standard rate. Of even more importance is the fact that during extremely cold weather the night time valley in the load curve nearly disappears. Therefore, a strong effort to economically, or through load management, to force off peak usage would only result in changing the time of the peak - not eliminate it. I do not mean to say peak load pricing and load management techniques are worthless but that the potential gains are easily measurable and small.

Our main peak problem is seasonable and is due to increased lighting and heating needs in winter (irregardless of type of heat). Certainly by jacking up the winter rate high enough we could enforce extreme conservation or deprivation. Budget billing, where the customer pays a fixed amount each month would have to be prohibited to make this scheme work.

You must bear in mind that the net income that the utility receives through the year must remain the same so the limit is when the power is free in the summer and likely somewhat less than twice average in winter (assuming a two part seasonal rate with each period six months long). The net result is that the summer transient gets a free ride and the year round resident pays the amount he would have paid anyway throughout the year plus his share of the transient's use.

Even if we could eliminate the free ride problem, given our climatic conditions it is extremely questionable that we could levelize electric use throughout the year. And most importantly any decision to attempt to do so is a social matter which should be dealt with straightforwardly through the appropriate public processes.

Finally it must be understood that the value of concepts such as peak load pricing, load management and seasonal rates is more relevant to systems which have large amounts of conventional steam and nuclear generation and summer peaks. For systems such as Alaska's railbelt with a high percentage of gas turbines and winter peaks the advantages of levelizing load are not so great as the capacity of gas turbines, transmission and distribution equipment increases greatly with cold weather.

Hydro systems tend to be energy limited rather than peak load limited. The cost of hydro capacity is relatively insensitive to reasonable changes in plant design load factor or to put it another way, energy costs are not greatly dependent on load factor. Thus the economic advantage of load levelizing are not large. Backup thermal capacity needed for critical water years will be in place at the time Susitna goes on line.

Generation Alternatives P17-18

Study after study after study on generation alternatives have already been made. We are getting close to the time that construction must be started so it is too late to consider unproven resources or techniques. As previously discussed, the changes possible through pricing or load management techniques are very limited or of minor economic consequence so the proposed ACRES study is quite sufficient and appropriate for the task at hand.

Financial Feasibility P18 and 19

The Susitna project is beyond the ability of any single electric utility in the State to finance. More than likely, this would also be the case if the coal alternative were pursued. We have determined this to be the case for Anchorage Municipal Light and Power. Therefore State assistance is necessary for the construction of base load generation sources allowed by the National Energy Act (excluding of course gas or oil burning plants permitted by temporary exemptions).

Financial studies are required to determine the type and degree of direct State participation required.

In regard to binding "Hell or high water" contracts, this in essence is no different than the obligations a utility takes on when it constructs its own projects through revenue bond sales.

Marketability P20-21

Under the Fuel Use Act of 1978 the cost test is based on electric generation using imported oil. Generation units under the Act must use fuels other than gas or oil unless the cost is 1.5 times or greater than using imported oil. It is extremely unlikely that Susitna power will be more expensive than that. By the time Susitna is on line most of the generation capacity predating the Act will be too old to be used for base load generation.

Therefore even if natural gas should remain relatively inexpensive it will not be an option. The thrust of National Energy policy is clear - we must reduce our reliance on oil and gas. This will be the controlling factor, not conventional economics nor the desire of our utilities management.

I certainly hope that development of Beluga coal proves economically feasible. But if it does, it is still highly unlikely that new coal fired generation will be more attractive than Susitna.

Study Findings and Credibility P21-22

If the seismic, geological and environmental studies indicate no major unanticipated problems, Susitna is infact the best generation alternative for the railbelt. This has been established time and again.

APPENDIX F

ISSUES RAISED DURING ENERGY REQUIREMENTS FORECAST WORKSHOPS

JUNE 10 & 11, 1980

ALASKA POWER AUTHORITY

ATTACHMENT 1

Partial List of Issues Raised during Energy Requirements Forecast Workshops, June 10 &11, 1980

1. A sensitivity analysis of the forecasting model needs to be performed in order to determine the sensitive assumptions and the degree of variability in the outcome from changes in the assumptions. One particular question is how sensitive is the forecast to the set of conservation assumptions.

2. Scott Goldsmith stated that the limits of the forecast range represent 20-25% probability of exceedance; in other words, that there is a 40 to 50% chance that the actual energy requirements would fall outside the forecast range. This is a much narrower band than APA had assumed. Is it too narrow? Goldsmith should be asked to clarify the issue.

3. Do subjective probabilities have to be assigned over the forecast range to permit later risk analysis? Can it be done?

4. Consider a legislatively mandated shift away from electrical use, especially space heating.

5. There appears to be a downward bias in the econometric model due to the inability to identify discreet exogenous projects in the period after 1985 and before trending takes over in the year 2000.

6. Should a high level growth case with a mode switch toward electric (i.e., an H-E case) be added? A L-E case would not be useful since the forecast range would not be enlarged.

7. Should supply side information be fed into the forecast at some future date to somewhat define the nature and timing of the gas-electric mode split?

8. The conversion response time in the electric space heat conversion scenario may be underestimated.

Attachment 2
Bob Hufman Comments

STUDY FORECASTS SALES ONLY - NEED TO ADJUST 8 TO 10% TO COMPENSATE FOR LOSSES. LOW FIGURES ARE ACCENTUATED BY PROJECTING SALES ONLY WHEN COMPARED TO PREVIOUS REPORTS ESTIMATING GROSS GENERATION.

STUDY ASSUMES ALTERNATE ENERGY WILL BE "CHEAP" ENERGY. PHOTOVOLTAIC CELL INSTALLATION JUST ON-LINE COSTS 3 MILLION FOR 100 KW. = $30,000 per KW

STUDY FAILS TO ADDRESS THE PROBABILITY OF INCREASED USE DUE TO A STABLE RATE PROVIDED BY AMPLE HYDRO CAPACITY.

IN FAIRBANKS, DEREGULATED OIL WILL EVENTUALLY NOT BE COMPETITIVE FOR SPACE HEATING. WOOD WILL BE DEPLETED. COAL WILL CAUSE ADDITIONAL AIR QUALITY PROBLEMS. NATURAL GAS MAY OR MAY NOT BE AVAILABLE. HOWEVER, ELECTRIC HEAT WITH A STABLE RATE BASE WILL BE A TOP CONTENDER WHEN PRODUCED FROM HYDRO.

THE STUDY DECLARES THAT ELECTRIC HEAT RETROFITTING DOES NOT OCCUR. IF THE PRICE INCENTIVE IS THERE IT WILL OCCUR. GVEA CAN ATTEST TO THAT FACT. IN ADDITION, MANY OF THE SYSTEMS HAVE HYDRONIC BASEBOARD WHICH ARE EASY INEXPENSIVE CONVERSIONS TO ELECTRIC BOILERS.

THE CANTWELL SUMMIT AREA SHOULD BE INCLUDED IN THE FORECAST.

THE PROBABILITY OF SEEING A SUBSTANTIAL NUMBER OF ELECTRIC CARS BY 1990 IS GREAT. EVEN THOUGH MOST WOULD HOPEFULLY RECHARGE OFF PEAK, THE TOTAL KWHS MAY BE SUBSTANTIAL. WE MAY SEE 10%

WE EXPECT ELECTRIC HEAT CONVERSIONS TO BOTTOM OUT BY 1981. THOSE LEFT WILL STAY THERE REGARDLESS OF PRICE - PERHAPS 250 - 350 ACCOUNTS.

DECLINE OF REVENUE FROM PETROLEUM ROYALTIES WILL BE COMPENSATED FOR FROM NATURAL GAS ROYALTIES AND NEW DISCOVERIES.

WOULD PREFER TO HAVE BOB RICHARDS FROM ALASKA PACIFIC BANK DO AN ECONOMETRIC STUDY.

MILITARY PLANTS WOULD PURCHASE ENERGY FROM HYDRO BEYOND THAT DERIVED FROM A STEAM/ELECTRIC OVERALL PLANT BALANCE. WAINWRIGHT, EIELSON, CLEAR AFB, ELMENDORF, FT. RICHARDSON.

HEAT PUMPS MAY BE PRACTICAL IN SOUTHCENTRAL WITH HYDRO.

WHO IS DOING DEMAND FORECAST?

THIS HAS A MAJOR BEARING ON INSTALLED CAPACITY.

UTILTIES ARE COGNIZANT OF THE INHERENT DANGERS OF GROSSLY UNDERESTIMATING DEMAND/ENERGY PROJECTION FOR ~~PLANNIG~~ Planning PURPOSES.

IT IS QUITE EASY FOR THOSE WITH ZERO RESPONSIBILITY TO KEEP THE LIGHTS ON, TO USE THE ULTRACONSERVATIVE APPROACH MOST FAVORED BY OBSTRUCTIONISTS AND NO GROWTHERS. THERE MAY BE SOME ECONOMIC PENALTY TO OVERBUILDING BUT MOST LIKELY THE PENALTY WOULD BE WIPED CLEAN BY INFLATION WITHIN A SHORT PERIOD OF TIME. HOWEVER, THE PENALTY FOR UNDERBUILDING COULD BE A DISASTER BOTH ECONOMIC AND OTHERWISE.