Energy Probe / Enquête Energie



# an evaluation of the ISER electricity demand forecast

July 30, 1980

Robert E. Crow
James H. Mars
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een Street,
ntario, Canada,
K1A 0E4
) 233-0260

43 Queen's Park Crescent East,
Toronto, Ontario, Canada,
M5S 2C3.
(416) 978-7014

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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.

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# 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 to suggest means of making that future more desirable.

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

## 2.1 Introduction

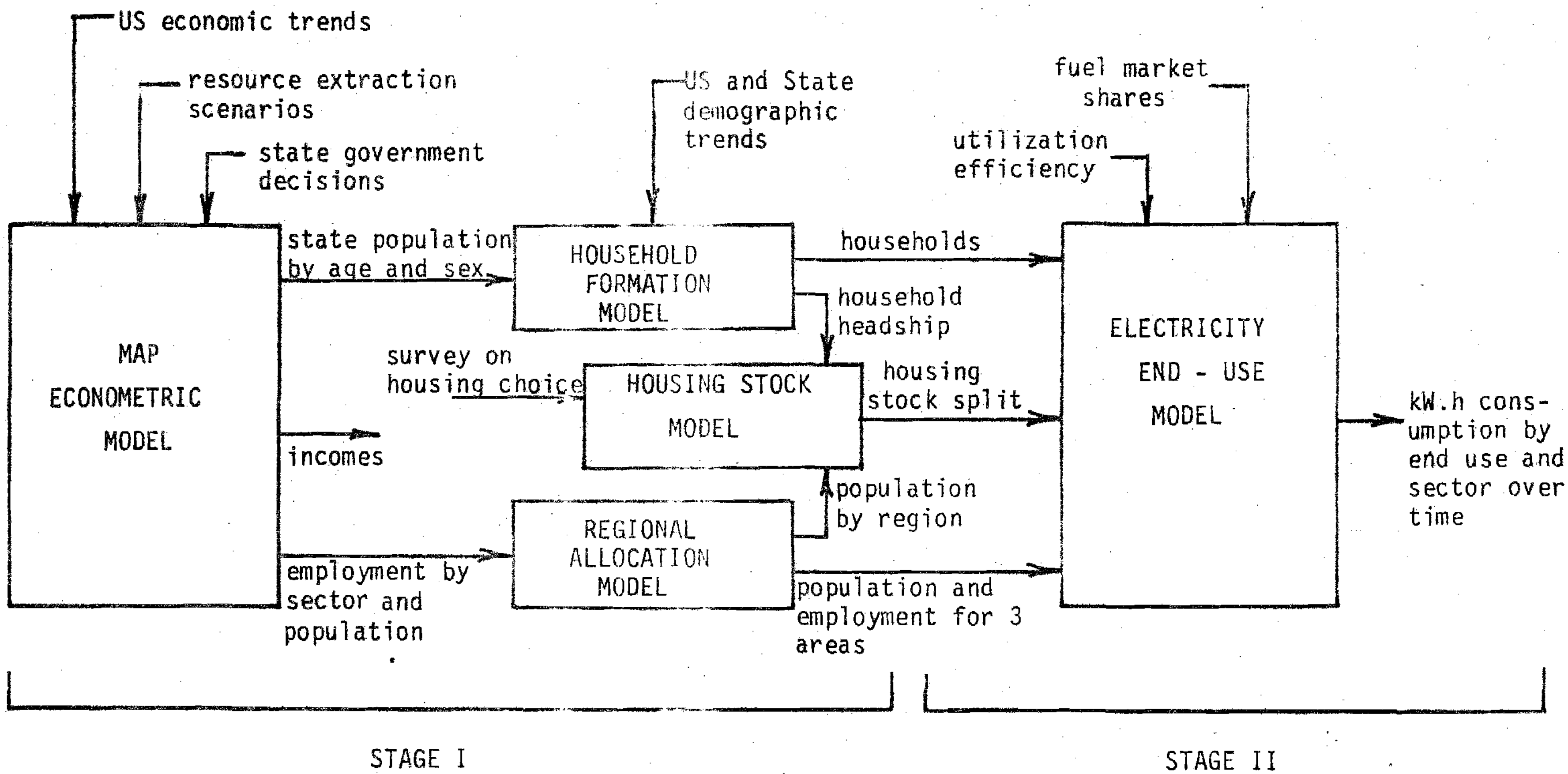
The ISER electricity demand forecasting model, while seemingly complex, has a very straightforward and logical structure and flow of information between components. The output of the model is projected values of electricity consumption for each of the three geographical areas of the Railbelt classified 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 mechanically; 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 heating plant 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 <u>dwellings</u> 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 vintage 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 service 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 information 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 sensible 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 recent energy conservation legislation offers 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 Electricty 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 |

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 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. 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 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 (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) 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 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 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 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 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 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 <u>household</u> characteristics and <u>building stock</u> 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 suggests two 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 <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 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.

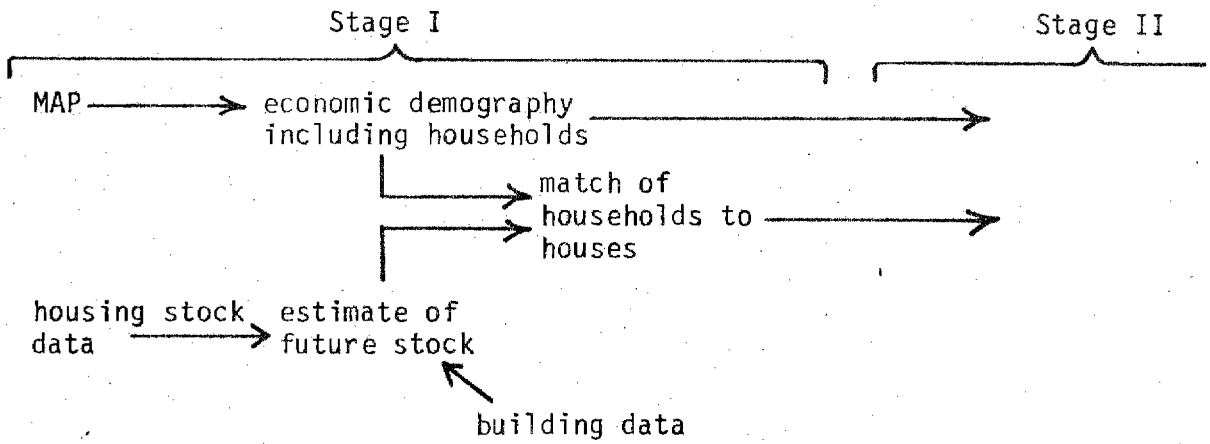
A full-blown econometric sub model for housing would flow from the following modifications to MAP:

(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 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 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.