YUKON RIVER BASIN STUDY
PROJECT REPORT: ENERGY No. 4

REVIEW OF YUKON ENERGY DEMAND STUDIES

R.A. (Tony) Hodge

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This project was completed for the Yukon River Basin Study, an intergovernmental study funded by the governments of Canada, Yukon and British Columbia.

March 31, 1983

Whitehorse, Yukon Territory

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DISCLAIMER

This report was funded by the Yukon River Basin Committee under the terms of "An Agreement Respecting Studies and Planning of Water Resources in the Yukon River Basin" between Canada, British Columbia and Yukon. The views, conclusions and recommendations are those of the author and not necessarily those of the Energy Work Group, Yukon River Basin Committee, the Government of Canada or the Government of Yukon.

This report was prepared as a background paper for the Energy Work Group. Please refer to the Final Study Report for the views of the Yukon River Basin Study Committee.

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CHAPTER ONE INTRODUCTION

Over the past fifteen years, nine different studies have been undertaken to review Yukon energy requirements. With the exception of two recently completed projects, these studies have been concerned soley with projecting electrical energy requirements for the general purpose of assisting the electrical utilities and government in financial planning related to electricity supply. A specific concern of these studies was to forecast the need for construction of Yukon hydro electric facilities.

Energy forecasting in the past, both in the Yukon and elsewhere, has almost entirely depended upon historic trends of energy use being identified and projected into the future. Application of this approach in the Yukon has caused considerable difficulty because of narrowly based and historic "boom-and-bust" nature of the Yukon's economy with the booms unpredictable and controlled by external factors such as the world price of metals and economic conditions in southern Canada and the United States.

During the past decade, the unprecedented increase in the price of non-renewable refined petroleum products has added an entirely new dimension to energy forecasting. Further, changing social values are forcing a careful review of energy sources and previously unincluded "costs" are now recognized as an integral part of the decision making process (eg. social and environmental "costs").

The result is a major change in the energy price regime. Conditions now exist which suggest that investment in technology to improve the efficiency of the present use of energy is more appropriate than investment in technology to simply produce more energy.

Historically a reasonable correlation could be made between increased economic activity and increased energy use. This correlation may no longer be valid. Now and in the future, economic growth will unlikely be paralleled by an equivalent rate of energy growth.

The impact on energy forecasting is significant. Forecasts that simply projected historic trends are no longer adequate. At the same time however, the necessity of understanding our present and future energy situation is increasingly important: it is only through developing this understanding that decoupling the economic growth/energy growth link can be accomplished in a way that maximizes benefits to society.

Energy forecasting is a heavily debated and rapidly evolving topic. While some will shrug shoulders and state that the only thing for sure about an energy forecast is that it is wrong, it is my belief that there remains significant value in projecting future energy conditions. However, that value does not necessarily lie in developing an exact prediction but rather in identifying, testing and evaluating the technical and economic conditions necessary for achieving a particular energy related goal.

This study was initiated by The Energy Work Group of The Yukon River Basin Study and completed under the auspices of The Energy Branch of The Yukon Territorial Government. The purpose of the study was to review and assess all existing Yukon energy demand studies. The following specific topics were identified for inclusion in the review of the demand studies:

1. the accuracy and completeness of base data
2. methodologies and assumptions
3. weaknesses and strengths
4. potential impact of conservation
5. unique problems in forecasting Yukon energy requirements
6. gaps in coverage with respect to the Yukon River Basin
7. recommendations on the need for further analytical work on forecasting energy requirements.

The only common link between all nine Demand Studies is that each includes a projection of future electricity uses. Only two studies, those of Hildebrandt-Young (1982) and Hodge and Ehrlich (1983) consider a variety of energy forms. Each study is dependent on widely varying methodological approaches and assumptions. As a result, a detailed comparison would be extremely complex.

Instead, in the main text of this report I have chosen to highlight only major points of comparison. A complete outline of each demand study is presented in the Appendix. Review of this Appendix will allow the reader to check and compare all detailed methods and assumptions.

Following this introduction, problems related to the existing available baseline energy data are discussed in Chapter Two. In Chapter Three some of the major methodological approaches and assumptions are reviewed. Gaps in coverage with respect to the Yukon River Basin are briefly outlined in Chapter Four and in Chapter Five, difficulties in projecting Yukon Energy requirements are outlined. A short comment is offered on the role of Yukon energy use projections in Chapter Six. Recommendations for additional work are given in Chapter Seven and the study is summarized in Chapter Eight.

CHAPTER TWO PROBLEMS RELATED TO BASELINE ENERGY DATA

Accurate historic data describing electricity use are publicly available from the utilities. All of the demand studies utilized this source. However, detailed statistics describing other forms of energy are not easily available.

The changing energy price regime has meant that forecasting energy use (electricity and other forms) must now include consideration of interfuel substitutions, the impact of conservation measures and increased efficiencies of many energy using devices. Evaluation of these factors is only possible through consideration of all forms of energy.

Further, total territorial figures for annual use of the various forms of energy are of limited value unless coupled with description of how that energy is used. Without an understanding of energy end use it is impossible to accurately estimate whether or not and to what degree more efficient energy use is possible.

Lack of a detailed database describing end use of all energy forms is the single greatest difficulty that must be overcome in projecting Yukon energy use. Some end use data are available through Federal Government Publications such as Statistics Canada's Quarterly Report or Energy Supply-Demand in Canada (Catalogue 57-003) and Lalonde et al., 1981. However, territorial statistics are so small relative to other parts of Canada that Yukon and NWT data are often grouped together, sometimes both with B.C.

An added complication characterizes some Yukon subsectors which include only a few and sometimes only one commercial establishment. In these cases, confidentiality of information can become a serious restriction.

Of the nine studies, only the work of Hodge and Ehrlich (1983) attempted to work with a comprehensive data base. A detailed set of baseline data were developed that likely represent a reasonable overall picture of existing energy end uses of all available energy forms. However, individual numbers may be in error as estimates based on secondary sources were often necessary.

Hildebrandt-Young (1981b) included projections of natural gas and petroleum products based on per capita use figures of the different forms of energy. Baseline data consisted of territorial totals for each energy form. Petroleum products were disaggregated which in itself allowed an end use categorization. However projections based on simple per capita use are vulnerable to the mixing of a variety of end uses.

The ideal data base would include energy statistics categorized by sector and subsector (see Appendix Table A-32), end use (see Appendix Table A-33) and form (see Appendix Table A-34). Petroleum products should be disaggregated as used by Hildebrandt-Young, 1981b (see Appendix Table A-22). Further, major differences in the Energy regime exist between communities in the Yukon. A detailed community or regional break down of energy conditions has never been established in the Yukon and should be an integral part of available base line data.

No system of record keeping presently exists to allow regular compilation of this detail of baseline data. However, without it, any type of comprehensive energy use projection is severely limited. Development of this baseline data gathering system is highly recommended and should be initiated as soon as possible.

Energy statistics are currently being gathered and synthesized by a variety of groups including the electrical utilities (Northern Canada Power Commission, Yukon Electrical Co. Ltd.), petroleum product supply companies (White Pass and Yukon Corporation Ltd., Gulf Canada Products, Murdoch's Fuel Service Ltd., ICG Canadian Propane Ltd.), both the Federal and Territorial governments through tax records and census data, and public interest groups (Yukon Conservation Society). Each of the groups should be involved in discussing and designing an Energy Statistics Data Bank most appropriate for understanding and projecting Yukon needs. To that end, it is recommended that a Joint Task Force be created to address this topic.

CHAPTER THREE METHODOLOGIES AND ASSUMPTIONS

Introduction

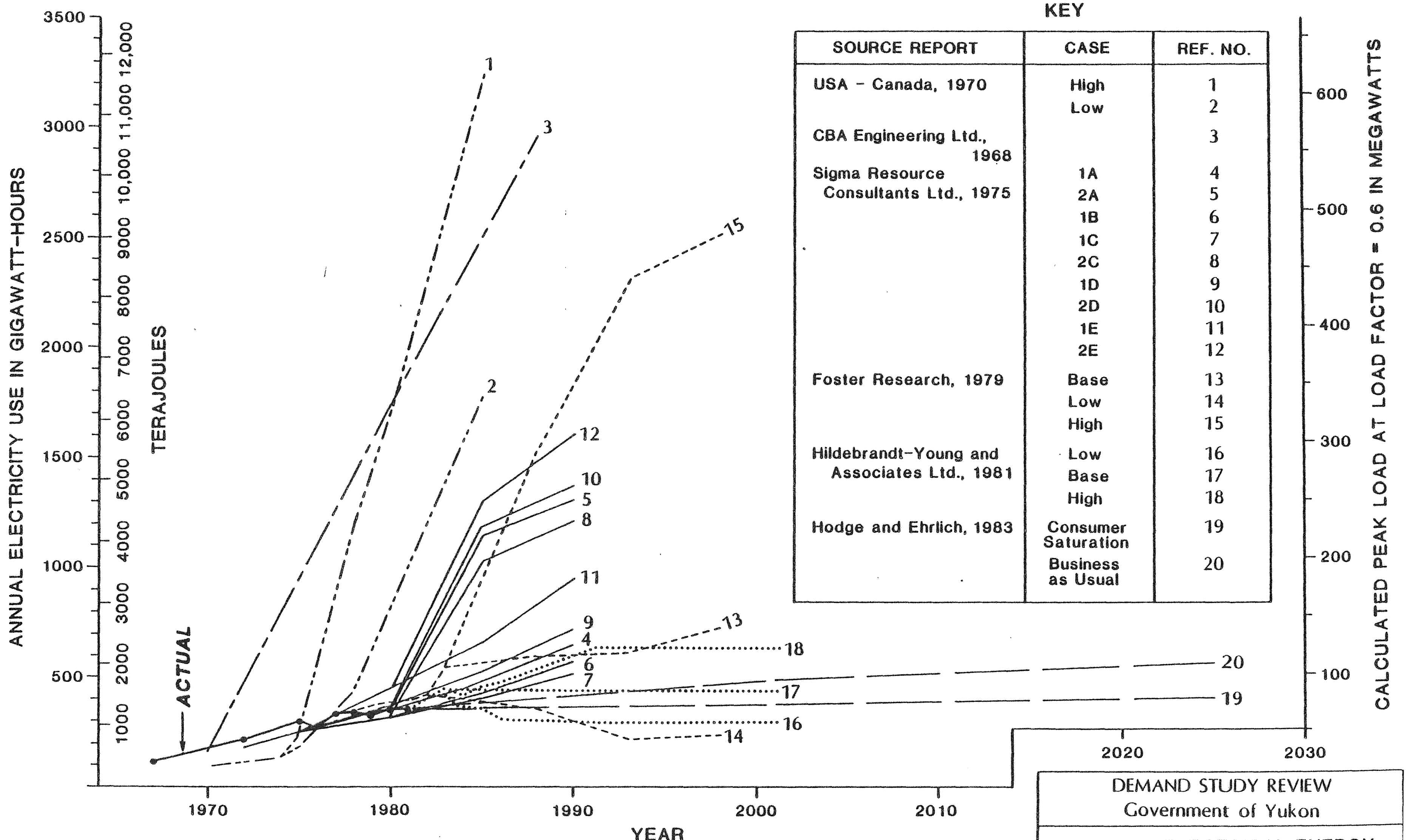
A complete description of the methodologies and assumptions utilized by each of the nine studies is given in the Appendix.

The studies can be broadly grouped into two categories: those that deal only with electricity and those that consider all forms of presently available energy. Only Hildebrandt-Young (1981b) and Hodge and Ehrlich (1983) fall into the latter category.

It is only possible to compare all nine studies in terms of their projected use of electricity. A detailed plot showing these projections is given in Figure 1. A grouping of the projections is shown on Figure 2 and a description of the categories is given below in Table 1.

The different categories identified on Figure 2 reflect more than anything, a change in attitude over time towards industrial development in the Yukon. This topic is discussed in detail in the next section.

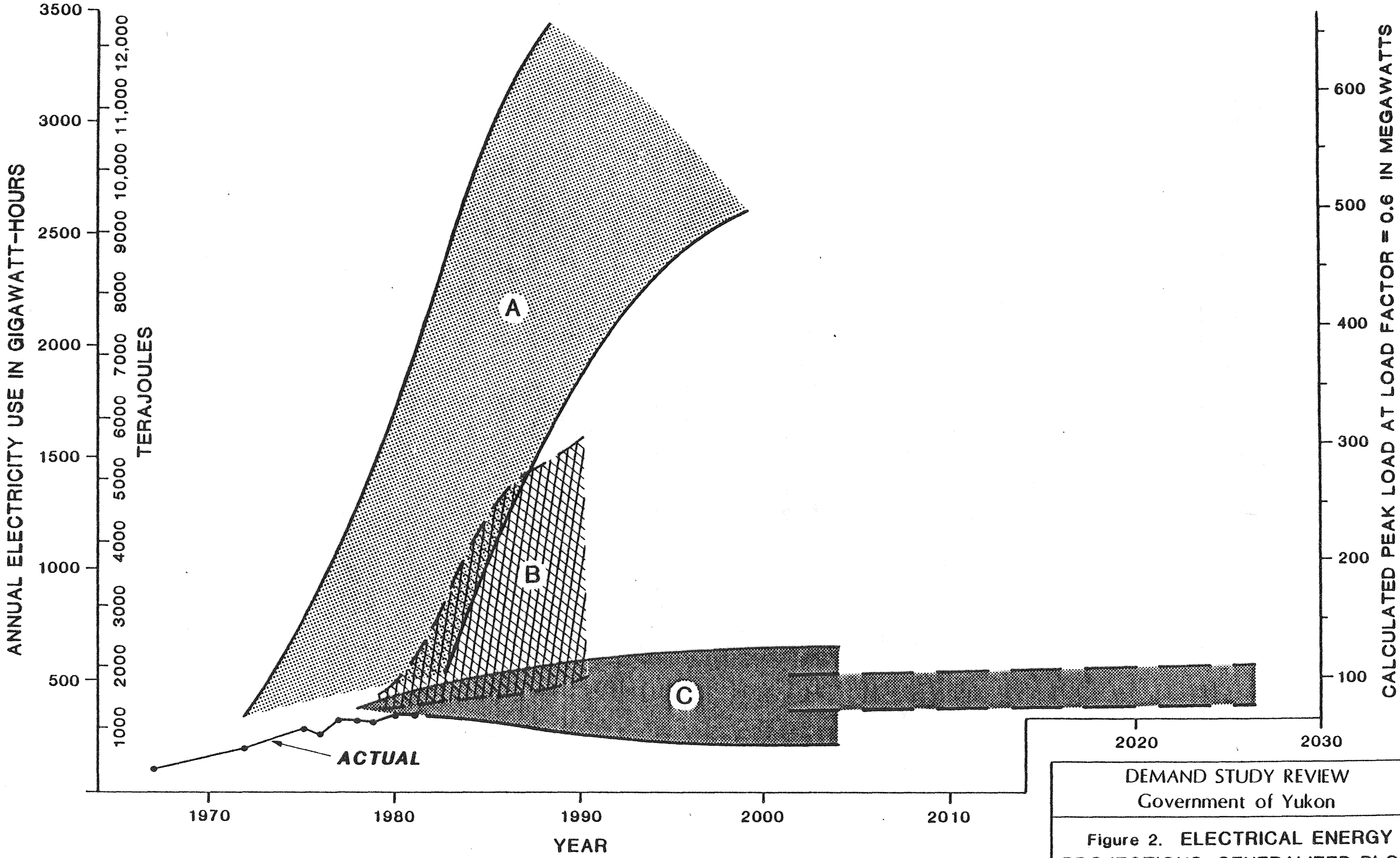
However a second observation is also worth noting: The more recent studies completed by Hildebrandt-Young (1981) and Hodge and Ehrlich (1983), come to a relatively similar conclusion regarding projected electricity requirements, for quite different reasons. Hildebrandt-Young postulate significantly reduced economic activity coupled with a drop in energy use. Hodge and Ehrlich allow for a low to moderate economic growth but conclude that electrical energy use will grow at a reduced rate because of conservation and more efficient use. Both studies allow for substitution of natural gas but the substitution assigned by Hildebrandt-Young is greater.



KEY

SOURCE REPORT	CASE	REF. NO.
USA - Canada, 1970	High	1
	Low	2
CBA Engineering Ltd., 1968		3
Sigma Resource Consultants Ltd., 1975	1A	4
	2A	5
	1B	6
	1C	7
	2C	8
	1D	9
	2D	10
	1E	11
	2E	12
Foster Research, 1979	Base	13
	Low	14
	High	15
Hildebrandt-Young and Associates Ltd., 1981	Low	16
	Base	17
	High	18
Hodge and Ehrlich, 1983	Consumer Saturation	19
	Business as Usual	20

DEMAND STUDY REVIEW Government of Yukon	
Figure 1. ELECTRICAL ENERGY PROJECTIONS: DETAILED PLOTS	
R.A. Hodge, P.Eng.	January 31, 1983



DEMAND STUDY REVIEW Government of Yukon	
Figure 2. ELECTRICAL ENERGY PROJECTIONS: GENERALIZED PLOT	
R.A. Hodge, P.Eng.	January 31, 1983

Table 1 Description of the groupings of electrical energy projections shown on Figure 2

Group A. Projections completed generally in the late sixties or early seventies that assumed massive industrialization.

- CBA Engineering Ltd. (1968)
- USA-Canada (1970)
- Foster Research (1979) High Case

Group B. Projections completed generally in the mid-seventies that assumed a range of industrialization but at levels below those projected in the earlier studies

- Sigma Resource Consultants Ltd. (1975)
- Foster Research (1979) Base Case

Group C. Projections completed generally in the last two years that projected a maximum of a low growth of electrical energy use for one of two reasons:

1. A severe slow down of industrial activity combined with some energy conservation and substitution of natural gas for electricity
   - Hildebrandt-Young (1981a and b)
   - Foster Research (1979) Low Case

2. A low to moderate growth of industrial activity combined with more extensive introduction of conservation measures and a minor amount of substitution of natural gas for electricity
   - Hodge and Ehrlich (1983)

Assumptions Regarding the Yukon's Economic Development

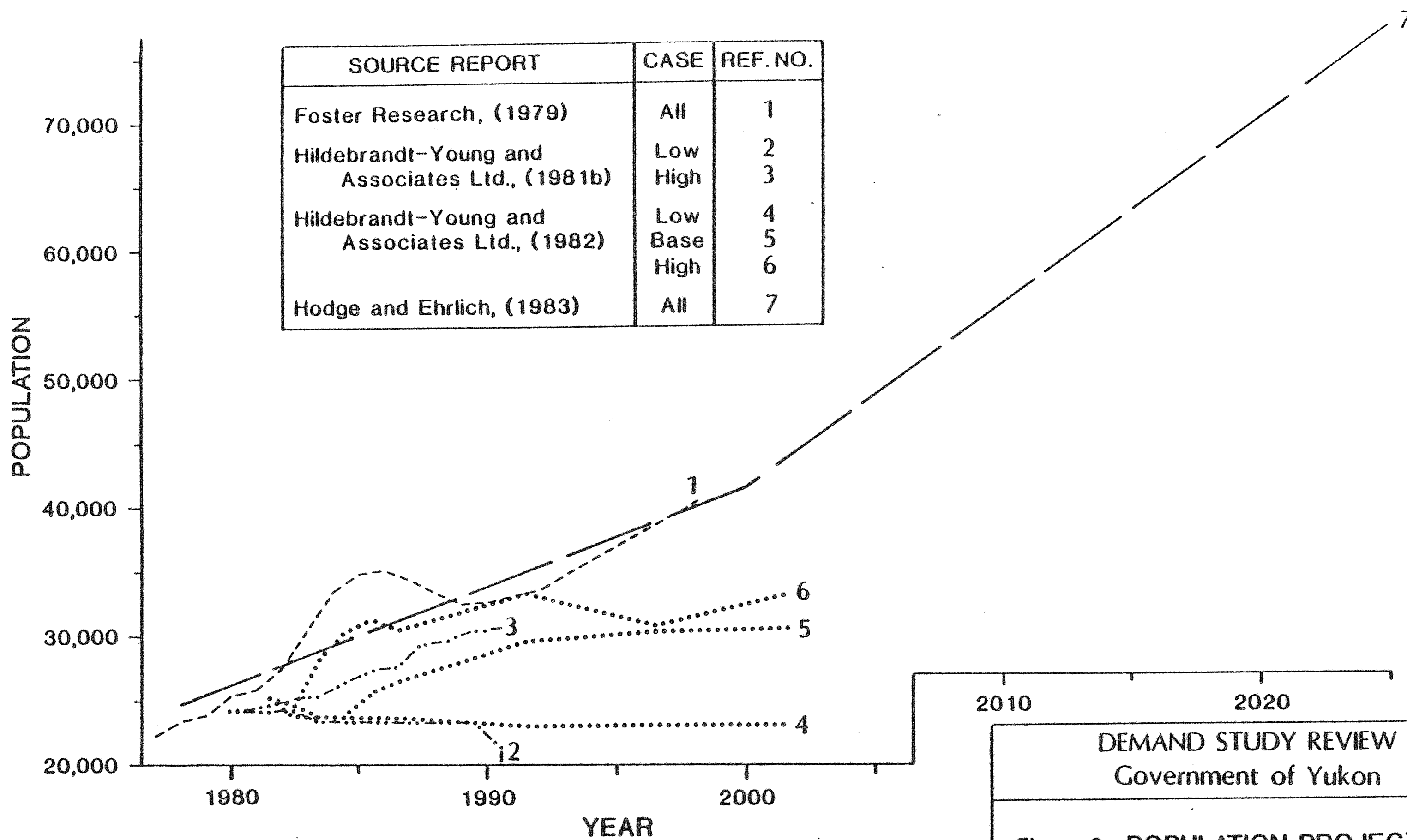
The groupings described above in Table 1 and shown on Figure 2 illustrate more than anything how attitudes towards industrial activity have changed over the past fifteen years. In the late sixties, the possibility of twenty mines, a pulp mill, a lead-zinc smelter, and an iron pellitizing operation all producing by the mid 1980's was foreseen as a real possibility (CBA Engineering, 1968). By the mid 1970's projections of mining activity had been significantly reduced. However, a number of other possibilities including an aluminum smelter, railway extension and electrification, construction and electrification of the Alaska Highway Natural Gas Pipeline and electricity exports to Alaska, B.C., and the NWT were being considered although mostly described as low probability (Sigma Resources, 1975). Also during the mid to late 1970's energy conservation was first suggested as a factor to be evaluated.

Now in the 1980's the world demand for metals is such that growth in the Yukon's mining sector is expected to be low to moderate at best and other major uses of electricity are all but discounted. Further, the price structure of energy has changed so much that in many cases either energy conservation or interfuel substitution (eg. natural gas if available) appear to be economic options that would reduce electricity consumption. (Hildebrandt-Young 1981a and b, 1982 and Hodge and Ehrlich, 1983).

The above discussion of economic development patterns combined with energy price structure changes that make energy conservation and interfuel substitutions economic alternatives lead to an important conclusion relative to projecting Yukon energy use: it is no longer appropriate to project energy use by simply adding discrete quantities of energy based on historic requirements of industrial projects.

POPULATION ASSUMPTIONS

The population projections used by Foster Research (1979), Hildebrandt-Young (1981b, 1982) and Hodge and Ehrlich (1983) are plotted on Figure 3. With the exception of the Hildebrant-Young (1982) projections which were independently developed, the projections shown on Figure 3 are tied to YTG's Economic Model. Earlier Demand Studies did either not tie their projections directly to population (USA-Canada, 1970), or did not explicitly express their population estimates (CBA Engineering, 1968).



DEMAND STUDY REVIEW Government of Yukon	
Figure 3. POPULATION PROJECTIONS	
R.A. Hodge, P.Eng.	January 31, 1983

Population projections are used in different ways by different workers. Hildebrandt-Young (1982) used per capita consumption of all energy forms as the basis for their projections thus creating a direct link with the population projections.

In developing the residential energy use projection, Hodge and Ehrlich (1983) related population to the number of households via a persons-per-household assumption. This assumption they changed with time based on another assumption that a reduction in persons-per-household would occur over time. Households were categorized as single family detached, single family attached, apartments and mobile homes. The proportion of each was also changed over time based on the assumption that there would be a reduction in the proportion of single family detached units (more people in the future would live in duplexes and apartments). However underlying this sequence of assumptions remains the population projection.

In comparing projections, the assumed population levels must be clearly understood particularly if per capita energy use is being used as the basis of projections.

Assumptions Regarding the Impact of Conservation

The first study to consider the impacts of conservation was Foster Research, 1979. In their Low Case they reduced residential and commercial energy use by 5% for the 1998 electricity use projection to allow for effects of conservation.

Hildebrandt-Young (1981b) included two conservation scenarios (one with and one without interfuel substitution). A detailed list of the energy forms affected is given in Table A-26. The approach taken by Hildebrandt-Young was to reduce per capita consumption of a given energy form (say road gasoline) by some percentage (50% for road gasoline) by the year 1990. These percentage reductions in per capita consumption were based on their best judgement. In addition a 46% reduction in the residential electrical heating load and a 40% reduction in the commercial electrical heating load was applied to 1990 projections. Conservation was not included in their 1981a and 1982 electricity forecasts.

The approach used by Hodge and Ehrlich (1983) differed significantly from that of Hildebrandt-Young (1982). Based on discussions among energy researchers from across Canada energy targets were set for each energy end use being considered. Details of all of those assumptions are given in the Appendix. A few examples will serve to illustrate.

In the residential sector the operating performance of existing energy efficient housing constructed by the Saskatchewan Research Council provided the basis for establishing energy use targets for each of the "heating and cooling" (including hot water heating) and "electricity specific" (appliances and lighting) end uses. All new houses built after 1990 were assumed to achieve this target. Assumption was also made regarding the impact of retrofitting old houses (for example a 50% improvement in the performance of pre 1978 built houses was assumed for the year 2000). As the proportion of newer energy efficient housing grew the overall residential sector moved closer to the energy target.

In the Industrial Sector the growth of energy use of each subsector was related to projected economic growth (estimated using a Long Term Simulation Model generated by Statistics Canada for the Federal Cabinet). The Base Case relationship between energy use and economic activity was modified for projected years by a factor based on energy use targets developed by the Canadian Industrial Energy Conservation Task Forces, a joint Federal Government-Industry undertaking.

In the Transportation Sector energy use targets reflecting energy conservation were also established. These targets and their origin varied from subsector to subsector. Most were handled in a manner similar to the Industrial Sector. Automobile transport was an exception with industry projections of improvements in automobile fuel consumption used as the target. For example, by the year 1990 automobiles were assumed to average 10 litres per 100 kilometres (28 miles per gallon), by the year 2000, 5 litres per 100 kilometres (53 miles per gallon) and by 2025, 3 litres per 100 kilometres (90 miles per gallon). These figures were tied to assumptions on the number of vehicles per household and distances driven per vehicle to calculate future energy requirements in the automobile subsector.

While the energy targets assumed achievable by Hodge and Ehrlich (1983) may be justifiably questioned and modified by other workers, this method of attempting to deal directly with achievable improvements in the mechanical operation of known energy end uses based on an individual industry's own projections of achievable improvements (eg. residential heating reductions possible through improvements to house thermal performance) is the only sure way of making reasonable and accurate estimates of the potential impacts of conservation. The economics of each end use in turn can be considered and conservation measures introduced as appropriate.

Assumptions Regarding Interfuel Substitutions

Only the studies of Hildebrandt-Young (1981a, b, 1982) and Hodge and Ehrlich

(1983), considered the impacts of interfuel substitutions.

Hildebrandt-Young assumed the availability of natural gas. In their 1981b report a scenario was developed in which natural gas was substituted by 1991 for:

1. space heat for all households presently using electrical space heat (1000 of 7000 units)
2. 85% of heating and stove oil use
3. 85% of electric hot water heating
4. 75% of diesel use by highway transport
5. 100% of diesel use by rail transport

As apparent from the above approach used by Hildebrandt-Young, to deal with interfuel substitutions it is again necessary to define the end uses of energy. This fact is emphasized in the work by Hodge and Ehrlich (1983) whose approach to all energy supply decisions involved the following steps:

1. project the energy requirements of a particular end use in thermal units (eg residential space heating)
2. choose the appropriate supply option based on
   a. appropriateness of supply option (e.g. liquid fuel for transportation)
   b. availability
   c. cost to the consumer
   d. quality of energy requirement (quality is a thermodynamic property relating to the amount of "useful work" that can be done)
   e. proximity of source to use
   f. where technically and economically feasible, shift to renewable energy forms
   g. where technically and economically feasible shift to Yukon produced energy forms

As a result, the work of Hodge and Ehrlich includes a complete review of all interfuel substitution possibilities. Revision of some of their decision controling assumptions (eg projected energy prices) may result in different conclusions being reached but the approach to interfuel substitutions is comprehensive and complete. Again it must be emphasized that this approach is only possible by dealing with a detailed description of energy end uses.

Assumptions Regarding Improved Fuel Use Efficiencies

A final major group of assumptions involves the projected improvements in fuel use efficiencies. It must be understood that the most fundamental concern is the amount of the energy that actually achieves its intended end use. For example a householder is primarily concerned with the amount of heat that is generated inside his house, not the amount of heat that is stored in his wood pile or his oil tank. The difference between the two is controlled by the efficiency of whatever heating device is being used. In the past decade significant effort has gone into improving the efficiency of various energy using devices. Examples include electrical appliances, wood stoves, furnaces of all types, automobiles, airplane engines (and bodies), and mine milling equipment. Further, even when the efficiency of an individual component cannot be improved, the overall system efficiency can often be dramatically improved by utilizing the reject energy that was previously wasted.

Again, only Hildebrandt-Young (1981b) and Hodge and Ehrlich (1983) considered fuel use efficiencies in their projections and only Hodge and Ehrlich (1983) allowed those efficiencies to improve with time. The efficiencies used by Hildebrandt-Young for calculating their interfuel substitutions are given in Table A-26. Their 100% efficiency assumptions for rail diesel, rail natural gas, diesel electric and natural gas electric are incorrect assumptions. For example, the maximum attainable efficiency for thermal electric generation with diesel is about 35%.

A discussion of the changes in fuel use efficiencies used by Hodge and Ehrlich (1983) is given on p A-44. For example, generation of heat from fossil fuels was projected to increase in efficiency from a Base Case (1978) figure of 60% to 80% by 2000 and 90% by 2025.

A significant amount of research and development effort in Canada and elsewhere is now going into improving the efficiency of energy use. Much of this work is being undertaken by industry and significant gains have already been made. A good example is the mining industry. At the Polaris Mining Project on Little Cornwallis Island, NWT (Cominco Ltd.) the diesel power plant has been designed as a Total Energy System achieving 93% efficiency through effective utilization of waste heat (see discussion in Hodge and Ehrlich, 1983, p 71). Future energy use projections must allow for these improvements.

Summary

Many other assumptions underlie each demand study. Studies completed in the period 1968-1975 tended to be less complicated and mainly based on requirements of potential industrial (mainly mining) projects. More recent studies have become significantly more sophisticated. In each case, energy demand projections must be carefully evaluated on the basis of the strength of underlying assumptions.

CHAPTER FOUR — GAPS IN COVERAGE WITH RESPECT TO THE YUKON RIVER BASIN

All the reports reviewed in this study include only the Yukon portion of the Yukon River Basin. The B.C. portion, particularly Atlin, lies in a completely different energy regime.

Further, with the exception of electricity projections, energy projections are made for the Yukon as a whole. In fact wide variations in energy regime exist from community to community. These variations are not identified in any energy study completed to date. A comprehensive community review of all energy use is highly recommended.

CHAPTER FIVE DIFFICULTIES IN PROJECTING YUKON ENERGY REQUIREMENTS

The following factors give rise to difficulties in preparing exact predictions of the Yukon energy requirements.

1. The narrowly based economy of the Yukon with its dependence on mining, results in vulnerability to externally controlled factors. This can give rise to erratic short term fluctuations in economic conditions and related energy use.

2. There is no complete compilation of base line energy statistics categorized by subsector, end use, form and community.

3. The energy price regime in the Yukon as well as the energy end use requirements differ significantly from southern Canada. Unfortunately the economic and technical analyses necessary to test the feasibility of conservation measures have not been completed for the Yukon and it is often necessary to draw subjectively on southern Canada experience.

In the following paragraphs each of the above points is briefly discussed.

Energy Projecting in the Yukon's Narrowly Based Economy

The vulnerability of mining to variations in world metal prices will inevitably result in future short term fluctuations in the Yukon's mining activity. In a more broadly based economy, change in a single industry would have a much smaller relative impact on overall energy requirements than in the Yukon where mining energy use amounts to 78% of the total used by the industrial sector (Hodge and Ehrlich, 1983, p. 69). Also in a more broadly based economy, energy use can more reasonably be projected to follow a smoother less erratic path.

In the Yukon, the narrowly based economy appears likely to persist. Changes in social and technological conditions now unforeseen demand that the possibility of large energy requirements not be discarded. However, the most prudent approach to energy planning at the present time is to expect a low growth in energy use (as a maximum). Also, short term fluctuations must be expected that in some cases see energy use below present levels. Given such an approach, energy use projecting no longer becomes an exercise in speculating when an economic "boom" might occur that results in a massive energy requirement. Rather, energy use projecting would concentrate on the much more achievable task of understanding and projecting energy use of the Yukon's existing economic sectors. In addition, it is important that detailed analysis be undertaken to develop an understanding of the relationship between fluctuations in economic activity and energy use. The present economic downswing provides an ideal opportunity to closely exam this sensitivity.

Base Line Energy Statistics

Very few places in the world have a well developed and complete energy data base. Here in the Yukon the size and simplicity of our economy and energy systems make this task far less formidable than in the southern industrialized provinces. However the task is complicated by the fact that some subsectors include only a few and sometimes only one, commercial establishment. In these cases, confidentiality of information becomes a serious restriction.

Energy statistics are currently being gathered and synthesized by a variety of groups including the electrical utilities, petroleum product supply companies and government. No coordination presently exists.

To provide an adequate base line for comprehensive energy use projections, statistics must be compiled that document energy end use over time by

a. form

b. subsector

c. community or geographic location

d. quality (a measure of the amount of "useful work" that can be obtained from the energy form under consideration).

Use of Southern Economic Analyses

Subjective dependence on economic analyses completed in the south needn't lead to severe errors if the southern analyses are properly understood. In time this deficiency will be overcome.

CHAPTER SIX — THE ROLE OF YUKON ENERGY USE PROJECTIONS

Energy use projections are too often thought of and depended upon as predictions of the future. Such an attitude masks the true usefulness of such projections.

Rather, it is more reasonable to consider projections as exercises in modeling future conditions. Such models should be used to identify, test and evaluate the significance of a variety of conditions that could occur in the future. Used in this way, energy use modelling can be a powerful tool in policy decision making. However, the power lies in understanding the assumptions built into such models.

It is essential that such modeling be computerized to allow for continuous review and updating of assumptions and results. Further, the development of such "Yukon Energy Model" should be closely linked with the Yukon Economic Model.

CHAPTER SEVEN RECOMMENDATIONS FOR ADDITIONAL WORK

1. Sensitivity Analysis of the Present Decrease in Energy Use

Data describing the decrease in energy use during 1982 and 1983 should be closely scrutinized and a careful evaluation made of the sensitivity of the energy regime to changing economic conditions.

2. Energy Statistics Data Bank and Related Task Force

A comprehensive Yukon Energy Statistics Data Bank should be established. Statistics should be compiled that document energy end use over time by subsector, form, and community.

3. Joint Task Force

No coordination presently exists between the various groups currently compiling energy use statistics. To overcome this deficiency it is recommended that a Joint Task Force be created to address the topic of how coordination can be best achieved and to identify each group's requirements for an Energy Statistics Data Bank.

4. Yukon Energy Model

A comprehensive and computerized Yukon Energy Model should be developed. This model should be integrated with the Yukon Economic Model and have the capability of dealing with all energy sources and forms.

5. Conservation, Interfuel Substitution, Improved Efficiencies

Work should be undertaken to review and test assumptions made in previously completed Energy Demand Studies regarding the impact of conservation, interfuel substitution, and fuel use efficiencies. Technical and economic analyses relevant to Yukon conditions should be undertaken where necessary.

CHAPTER EIGHT SUMMARY

Baseline Energy Data

No system of record keeping presently exists that allows regular compilation of the baseline data required for comprehensive energy use projections. The ideal data base would include energy statistics categorized by

1. sector and subsector
2. end use
3. form
4. community or region

Development of this baseline data gathering system is highly recommended and should be initiated as soon as possible.

Methodologies and Assumptions

The most fundamental aspect of projecting energy use relates to the expected rate of growth of Yukon economic activity. Large industrial growth in the Yukon appears unlikely and it is no longer appropriate to forecast energy requirements by simply adding discrete quantities of energy based on historic requirements of industrial projects.

In comparing projections, the assumed population levels must be clearly understood particularly if per capita energy use is the basis of projections.

The use of energy targets based on each individual industry's projections of achievable improvements in energy use, provides the most sure way of making reasonable and accurate estimates of the potential impacts of conservation.

An assessment of the potential for interfuel substitutions also requires a detailed end use analysis.

A significant amount of research and development effort in Canada is now going into improving the efficiency of energy use. Future energy use projections must allow for these improvements.

Gaps in Coverage with Respect to the Yukon River Basin

None of the existing demand studies include the B.C. portion of the Yukon River Basin and with the exception of electricity projections no comprehensive community analysis has been completed to identify regional variations in the energy regime. Such a review is highly recommended.

Difficulties in Projecting Yukon Energy Requirements

The lack of a comprehensive data base, erratic short term economic fluctuations and the lack of northern specific economic and technical analyses necessary to test the feasibility of measures to improve energy use all lead to difficulties in projecting Yukon energy requirements. However these problems are not unique to the Yukon and needn't stand in the way of completing useful energy use projections.

The Role of Yukon Energy Use Projections

Energy use projections should not be used simply as predictions of the future. Rather they should be considered as energy models and used to identify, test and evaluate the significance of variety of condition that could occur in the future. Such an approach is only possible with a Yukon Energy Model that is computerized and continuously updated. The Yukon Energy Model should be closely integrated with the Yukon Economic Model.

Recommendations for Additional Work

1. An analysis of the present decrease in energy use should be undertaken to establish the sensitivity of the energy regime to changing economic conditions.

2. A comprehensive Yukon Energy Statistics Data Bank should be established that documents energy end use over time by subsector, form, community and quality.

3. A Joint Task Force involving all interested groups should be established to establish how best to coordinate efforts and to identify each group's requirements.

4. A comprehensive and computerized Yukon Energy Model should be developed.

5. A technical and economic review should be undertaken to establish Yukon specific possibilities for reducing energy use through conservation, interfuel substitution and improved fuel use efficiencies.

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APPENDIX

Detailed Description
of
Yukon Energy Demand Studies

1968 - 1983

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TABLES

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ILLUSTRATIONS

1. INGLEDOW & ASSOCIATES LTD., 1968

HYDRO ELECTRIC RESOURCE SURVEY OF THE CENTRAL YUKON TERRITORY

TERMS OF REFERENCE

To conduct a survey of power sites and power demands in the portion of the Yukon Territory lying within a circle centred on the Town of Carmacks and having a radius of 175 miles, but excluding any sites located on the main stem of the Yukon River.

The survey consisted of:

a. A review of the future power demands in the survey area over the ten year period 1968 to 1977.

b. An analysis of all relevant hydrological, meteorological, topographical and geological data which is available

b. A field reconnaissance of the survey area

The survey report includes power site descriptions, an estimate of the hydro-electric power potential of each site, an estimate of the hydroelectric power needs of the survey area, an outline of the best method of hydro-electric power development with or without transmission lines and estimates of development costs.

GENERAL APPROACH TO DEMAND PROJECTION

Future electrical power demands were forecast using a "known" load growth obtained from the Northern Canada Power Commission and "possible" load growth estimated by adding the power requirements of industrial projects considered likely to proceed. Both a "low" and "high" load growth outlook were evaluated. Grid connected requirements were emphasized.

DETAILED ASSUMPTIONS, PROJECTIONS AND RESULTS

Table A-1 lists the system additions used by Ingledow and Associates (1968) to develop their demand projection.

Table A-1 System additions used by Ingledow and Associates to develop their electricity demand projection.

1. Projected Maximum System Demand Required by 1977 (excluding Mayo, Dawson and minor isolated systems)

	Demand (megawatts)	Consumption (Gigawatt hours)	(Terajoules)	Load Factor (%)
A. LOW LOAD GROWTH				
- NCPC Projection for Whitehorse Areas (excluding Porter and McIntyre Creek Hydro Plants)	18.0	89	320	56
- Anvil Mines (startup 1969)	8.5	54	194	72
- Pulp Mill (startup 1972)	15.0	99	356	75
Total Low Load growth	41.5	242	871	55
B. ADDITIONAL ACTIVITIES IN HIGH LOAD GROWTH				
- Kerr-Addison Mines (startup 1974)	5.0	31	112	71
- Anvil Smelter (startup 1975)	80.0	526	1894	75
Total High Load Growth	126.5	799	2876	72
2. Mayo and Dawson Requirements by 1977 (NCPC Projections)	4.4	33.3	120	86

Because the 1977 Demand projection listed above does not include the whole Yukon it is not plotted on Figure 1.

2. CBA ENGINEERING, 1968

YUKON POWER SURVEY

TERMS OF REFERENCE

To review all previous work on electrical power in the Yukon and delineate guidelines on future work. Hydro and thermal generation with gas, oil, coal and nuclear are to be included as well as a review of transmission line costs.

GENERAL APPROACH TO DEMAND PROJECTION

Mining developments provide the primary basis for estimating future loads. However, the Yukon was split into fifteen separate geographic areas and for each area an estimate was made of the growth in electrical demand expected for the industrial, residential, commercial, and community services (including street lighting) categories. Population increases were estimated based on the industrial growth.

DETAILED ASSUMPTIONS AND PROJECTIONS

Load demands assumed for mining and milling operations are shown in Table A-2 and those assumed for the residential, commercial and community services categories for different population sizes are listed in Table A-3. A four percent load growth per year per residential customer was assumed.

Table A-2. Mining Load Demands assumed by CBA Engineering, 1968 for different mine capacities.

	Total Open Pit	Total Underground
200 tons per day	800 - 1200 KW	1200 - 2000 KW
500 tons per day	1200 - 2000 KW	2000 - 3000 KW
2500 tons per day	3000 - 3500 KW	3600 - 4500 KW
5000 tons per day	4500 - 6000 KW	6000 - 7500 KW
Average Load Factor	85% - 95%	80% - 90%

Table A-3. Residential, Commercial and Community Services Load Demands used by CBA Engineering Ltd., 1968 for different population ranges

		Increased Allowance	
Population Range	Demand KVA/Residence	For Commercial Area	For Community Services, Street Lighting
50-100	2.0	15%	10%
100-500	1.8	15%	10%
500-1000	1.6	17%	8%
1000-5000	1.5	20%	7.5%
Over 5000	1.5	25%	5%

Table A-4 lists the industrial projects forecast to be in place by 1980 and 1990 as well as the associated industrial and residential load demands calculated using the above assumptions. The results are plotted on Figure 1 as #3.

Table A-4. Projected industrial developments with the associated residential/commercial loads calculated by CBA Engineering, 1968.

Area and development description	1968 Capacity in MW	Projected Capacity requirements in MW					
		1980			Possible for 1990		
		Residential/ Commercial	Industry	Total	Residential/ Commercial	Industry	Total
<u>Beaver Creek Area</u>							
500 tpd nickel-copper mine	.31	2	3	5			
<u>Burwash Landing Area</u>							
Quill Creek nickel mine	.50	2	5	7			
<u>Haines Junction Area</u>							
Copper or asbestos mine	.40	1	4	5			
<u>Whitehorse-Carcross-Tagish</u>							
New Imperial (Whitehorse Copper), Arctic (Gold), and Venus (Gold) mines	13.6	24.3	7.7	32			
<u>Teslin Area</u>							
molybdenum mines in the Wolf Lake area	.45	3.5	25	28.5			
<u>Rancheria Area</u>							
silver-lead-gold mine and camp	-	-	5	5			
<u>Watson Lake Area</u>							
Sawmill and timber preservation treatment plant (3MW) and a lead-zinc mine (5MW)	1.7	2	8	10			
<u>Frances Lake Area</u>							
silver-lead-zinc or copper mine	-	1	6	7			
<u>Canada Tungsten NWT</u>							
tungsten mine and camp	1.5	-	3	3			
<u>Ross River Area</u>							
silver-lead, barite or copper mine	.2	-	5	5			
<u>Vangorda Creek Area</u>							
Anvil Mine (12MW), other mines (12MW) smelter (68MW), population and supporting industries (20MW)	-	20	92	112			
<u>Carmacks Area</u>							
Coal mine for thermal generating plant (10MW), pulp mill (20-25MW), several mines and a population of 5000 by 1983	.40	3	37	40	-	12	52

Area and development description	1968 Capacity in MW	Projected Capacity requirements in MW					
		1980			Possible in 1990		
		Residential/ Commercial	Industry	Total	Residential/ Commercial	Industry	Total
Mayo Area							
increased mining activity	5.1	3	12	15			
Dawson Area							
gold mine (5MW), population and support industries (3.5MW)	.75	3.5	5	8.5			
Clinton Creek Area							
Asbestos mine (25MW), population and support industries (6.8MW), iron pellitizing operation after 1980 (80MW)	-	7	25	32	-	80	112
Old Crow Area							
no development	-	-	-	-	-	-	-
Snake River Area							
Crest iron mine and camp	-	-	-	-	-	140	140
MacMillan Pass Area							
zinc mine	-	-	15	15			
Totals	30.5 (1968)	75.3	254.7	330 (1980)	75.3	486.7	562 (1990)

3. UNITED STATES - CANADA, 1970

UPPER YUKON RIVER POWER MARKET POTENTIAL

TERMS OF REFERENCE

To review the characteristics of available power developments, the prospective markets for electrical energy and the contribution such projects could make to the development of the economy of the region adjacent to the Upper Yukon River Basin. Developments along the course of the Upper Yukon River were considered as well as the diversion of a portion of the river flow through the Coast Mountains to tidewater in Southeast Alaska or in Northwest British Columbia.

GENERAL APPROACH TO LOAD GROWTH ESTIMATES

Load growth estimates were made for the following regions:

1. Alaska
2. Yukon
3. British Columbia
4. Alberta
5. Pacific Northwest
6. Combined Yukon and British Columbia

In each region specific industrial developments were considered and their total requirement used as the regional estimate. A time period of 1970 to 1990 was considered.

DETAILED ASSUMPTIONS, PROJECTIONS AND RESULTS

Table A-5 lists the assumed industrial developments and their associated peak load requirements. Project numbers are keyed to the map in Figure A-1. Results are plotted on Figure 1 as #1 and #2.

Table A-5. Industrial developments and associated peak loads assumed by United States - Canada, 1970.

Project	Date Introduced	Peak Load Requirement in Megawatts	
		Minimum	Maximum
1. Copper mine north of Dawson	1980	5	10
2. Snake River Iron Mine	1985	150	200
3. MacMillan Pass lead/zinc	1975	4	6
4. lead/zinc	1975	6	8
5. smelter	1980	70	70
6. copper/molybdenum	1978	40	80
7. nickel, copper	1974	2	2
8. gold, silver, zinc	1970	2	2
9. Pulp Mill	1985	10	20
10. Whitehorse System	1985	45	55
Total		340	615

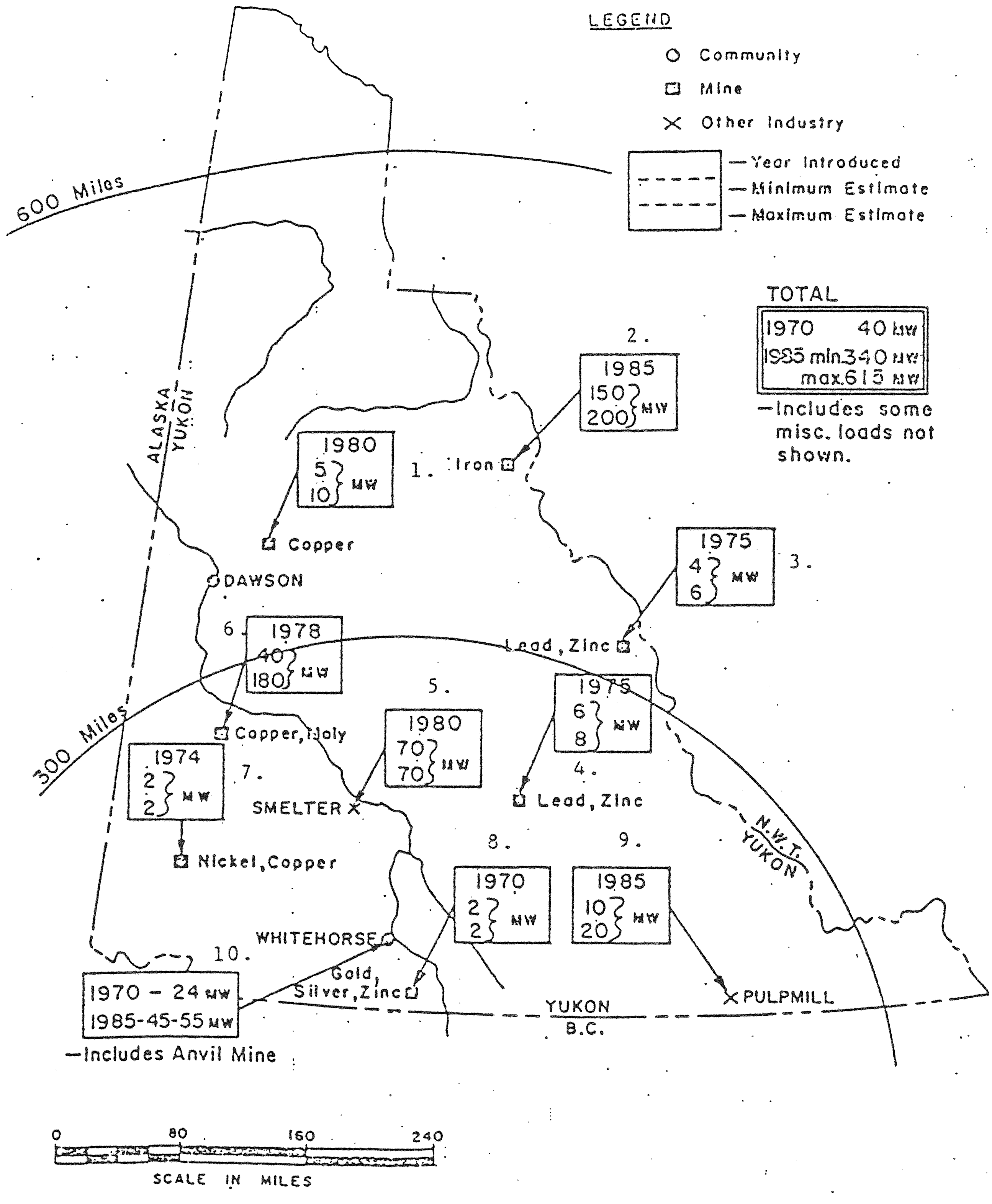


Figure A-1 Yukon forecast additional peak loads 1970-1985 after United States-Canada, 1970

4. SIGMA RESOURCES LTD. 1975

THE DEVELOPMENT OF POWER IN THE YUKON

TERMS OF REFERENCE

The main objectives of the study were to prepare:

1. a description of the existing generating plants and transmission facilities for reference purposes;

2. an inventory of all the potentially attractive hydro power sites, based on a field survey and previous studies, with consideration of alternative power sources;

3. an analysis of the growth of the demand for power with projections of the demand to 1990;

4. a comparison of the more promising power developments on the basis of cost, and the environmental and social effects;

5. a preliminary system plan, and selection of the leading schemes;

6. a systematic presentation of the criteria and methodology for evaluation of future power schemes, with particular emphasis on a decision making approach that takes account of the direct costs of power projects, the values of alternative uses of land and water resources, and the environmental and social costs.

GENERAL APPROACH TO DEMAND PROJECTIONS

The interconnected and isolated systems were considered separately. Two major cases were evaluated, one with a 100 MW smelter and one without. For each case, estimates were made of power requirements of the residential/commercial sector (exclusive of space heating) based on projected population growth and average per-capita consumption figures; electrical space heating; and projected mining loads.

DETAILED ASSUMPTIONS, PROJECTIONS AND RESULTS

Residential/Commercial

For each case a population growth and per capita usage (combined residential/commercial but exclusive of space heating) were assumed. The population estimates are listed in Table A-6. Per capita (residential/commercial) consumption in 1972 was 5300 kwh. This figure was assumed to increase to 7000 kwh per capita by 1980 and stablize at this figure through 1990. This implies that from 1980-1990, conservation measures on existing uses will offset the effects of proliferating electrical appliances.

Space Heat

In each case a percentage of new construction in the residential/commercial sector that utilized electricity for space heat was assumed. The assumption used for each case is given in Table A-6. The prevalent thinking was that more and more customers with time would be utilizing electricity for space heat.

Mining Loads

In each case a particular growth rate of new mining development was assumed. These rates are listed below in Table A-6.

Lead-Zinc Smelter

All forecasts were estimated with (Case 1) and without (Case 2) the smelter. A 75 MW average and a 100 MW peak demand were assumed for the smelter.

Table A-6. Detailed assumptions used by Sigma Resources (1975)

1990 Population	Space Heat	Mining	Projected Loads (MW) 1980 Avg	1980 Peak	1990 Avg	1990 Peak
Case 1 NO SMELTER LOAD						
A. Standard 21,000	75% of new construction electrically located	1 new mine every 5 years (2500-10,000 TPD)	39	77	74	143
B. Low Population 18,500	same as A	same as A	36	69	65	123
C. Low Population/ low space heat 18,500	75% of new construction electrically heated 1975-80; no increase 1980-90	same as A	36	69	59	106
D. High Population 24,500	same as A	same as A	42	85	81	163
E. High Population, high mining 24,500	same as A	2 new mines every 5 years (2500-10,000 TPD)	50	96	109	202
Case 2 WITH LEAD-ZINC SMELTER						
All assumptions exactly the same as CASE 1 but 75 MW average 100 MW peak smelter load added						
A. Standard			39	77	149	243
B. (Low Population case not possible)						
C. No electrical space heat after 1980			39	77	138	218
D. High population			42	85	156	263
E. High population, high mining			50	96	184	302

Other Industrial Loads

Three other types of industrial loads were considered:

- pulp mill in the Watson Lake area (15MW for 500 TPD)
- White Pass railway electrification (5 - 15 MW)
- power intensive industry such as uranium enrichment in aluminum smelting (300MW for aluminum smelter)

Either of the first two loads could be handled within the load forecast projected for the other industrial developments and therefore were not considered separately. An aluminum smelter was not included in the projections as too speculative.

RESULTS

Results are plotted on Figure 1 in the main text as #4 through #12.

5. FOSTER RESEARCH, 1979

FORECAST ELECTRIC ENERGY REQUIREMENTS IN THE YUKON TERRITORY 1979-1998

TERMS OF REFERENCE

To provide a long-range forecast of the electrical energy requirements for the Yukon with particular emphasis on the NCPC System. An annual projection was required for 1979-1983 and five year projections thereafter to 1998.

GENERAL APPROACH TO DEMAND PROJECTIONS

A Base Case industrial activity and energy use forecast was developed primarily dependent on mining activity although construction, oil and gas, forest products, tourism and government expenditures were also considered. The associated residential energy requirement was forecast through use of a population forecast (Yukon Economic Model) and assumptions on number of persons per household and per household consumption (based mainly on historic data). Commercial energy use was estimated by assuming a simple linear relationship (based on historic data also) between residential and commercial requirements. No consideration was given to supply options.

Following development of the Base Case, Low and High Cases were also developed based mainly on maximum and minimum mining activity. Other factors considered included conservation, inter-fuel substitution, use of solar heat and the heat pump, and other industrial activities such as smelters, pipelines, rail shut down, rail electrification, and electricity export to Tungsten, NWT, Cassiar, B.C., Atlin, B.C., and Skagway, Alaska.

DETAILED ASSUMPTIONS AND PROJECTIONS

Introduction

The End Use categories and System characteristics considered by Foster Research are given below in Table A-7.

Table A-7	End Use categories and System Characteristics considered by Foster Research (1979)

1. Residential
2. Commercial (general service)
3. Industrial
4. Street Lighting
5. System Losses
6. Total Annual use
7. Peak Load
8. Load Factor

In developing their forecasts, Foster Research categorized the eighteen load centres into five "Primary Systems", four in which power is generated by NCPC and one in which power is both generated and distributed by YECO. This categorization is listed below in Table A-8.

Table A-8 Primary System load centre Categorization used by Foster Research (1979)

Primary System 1:	Aishihik/Whitehorse/Faro - Whitehorse - Carmacks - Haines Junction - Ross River - Faro	(NCPC)
Primary System 2:	Mayo - Keno City - Mayo - Elsa	(NCPC)
Primary System 3:	Dawson	(NCPC)
Primary System 4:	Johnson's Crossing	(NCPC)
Primary System 5:	Other - Teslin - Destruction Bay (including Burwash Landing) - Beaver Creek - Old Crow - Stewart Crossing - Pelly Crossing - Swift River - Watson Lake (Watson Lake, airport, Upper Liard, and Lower Post)	(YECO)

For each of the above systems as well as the total Yukon, 1975-1978 historic data describing annual energy use (net generation), peak demand and load factor were compiled and reviewed to identify growth rates.

A "Base Case" forecast was then developed for each of the items listed in Table A-7. Each of these is discussed in turn in the following paragraphs.

Residential

The Yukon Economic Model was used to generate a population forecast based on the input listed in Table A-9.

Table A-9 Input used by the Yukon Economic Model to generate a population forecast for Foster Research (1979)

Mining

1. Cyprus Anvil Mill expansion on stream by 1983
2. Venus Gold Mine (Carcross) on stream by 1982
3. MacPass Tom Deposit on stream by 1985
4. MacPass Summit Lake Deposit on stream by 1995
5. MacPass MacTung Deposit on stream by 1987
6. Whitehorse Copper closed by the end of 1983
7. United Keno Hill Mine at Elsa closed by the end of 1987

Construction

8. Alaska Highway Natural Gas Pipeline started construction in 1982 and on stream by 1985
9. Major hydro dam construction starting in 1983 and on stream in 1990
10. Continuing construction of the Shakwak Highway Improvement Project through 1989

Land Claims

11. Land claims settled

Other Factors

12. 10% growth rate in Federal Government expenditures
13. 10% growth rate in YTG expenditures after 1984. Much higher rate 1978-1984
14. 16% growth rate in tourism expenditures 1978-1983, 10% thereafter
15. 14.5% annual growth in mining shipments
16. Average size of all in-migrant workers is 2.1 but only 1.5 for mainly construction oriented projects

The resulting population forecast (see Figure 3) was converted to a forecast of electrical energy customers through an assumption of persons-per-electric-energy-customer. This figure was 3.72 in 1975 and 3.28 for 1977 and 1978. Foster Research reduced the figure to 3.0 by 1983 and held it constant thereafter. The result was an increase in residential customers from 7,071 in 1978 to 13,460 in 1998.

Historic data on residential usage per customer were compiled for each of the primary system components listed in Table A-8. As no trends were apparent the 1975-1978 averages were used for developing the forecasts. These averages are listed below in Table A-10.

Table A-10 Annual Residential useage per Customer used by Foster Research (1979) and based on 1975-1978 historic averages.

	Annual Usage MWH	Annual Usage GJ
Aishihik/Whitehorse Faro System		
Whitehorse	13.5	48.6
Carmacks	8.1	29.2
Haines Junction	8.4	30.2
Ross River	7.6	27.4
Faro	13.6	49.0
Total System	13.2	47.6
Mayo System		
Keno City	3.5	12.6
Mayo	11.3	40.7
Elsa	15.0	54.0
Total System	11.4	41.0
Dawson	6.8	24.5
Johnson's Crossing	3.6	13.0
Other (YECO)	7.2	26.0
Total Yukon	12.2	44.0

Note: Figures represent historical averages 1975-1978 and were projected as constants through 1998 for Foster Research's Base Case.

Commercial

Historic data describing commercial useage were compiled for each of the primary system load centres listed in Table A-8. As no trends were apparent from the 1975-1978 data, an average figure was calculated and compared to the residential useage for the same component to obtain a ratio of commercial to residential energy use. These ratios are listed below in Table A-12. The Commercial Forecast was developed by combining the Residential Forecast with these ratios.

Table A-12 Ratios of Commercial to Residential Electrical Requirements used by Foster Research (1979) to generate the Base Case Forecast.

	Ratio
Aishihik/Whitehorse Faro System	
Whitehorse	.79
Carmacks	.94
Haines Junction	.96
Ross River	.81
Faro	.95
Total	.80
Mayo System	
Keno City	.54
Mayo	1.04
Elsa	1.00
Total	1.04
Dawson	1.04
Johnson's Crossing	1.19
Other (YECO)	1.39
Total Yukon	0.86

Note: Figures represent historical averages 1975-1978 and for Foster Research's Base Case were projected as constants through 1998.

Industrial

Table A-13 lists the Industrial subsectors considered by Foster Research.

Table A-13 Industrial subsectors considered by Foster Research

a. Mining
b. Oil and Gas
c. Forest Products
d. Construction
e. Transportation

Mining

Foster Research undertook an extensive review of the Canadian and world mining industry. Based on that review, the mining developments listed in Table A-9 were included in the Base Case. These developments with their associated energy requirements are listed below in Table A-14.

Table A-14 Foster Research's Base Case Mining Industry Developments and associated electrical requirements.

Mine	Metal	Date Onstream (shut down)	Electrical Energy Annual (GWH)	Annual (TJ)	Peak (MW)	Load Factor (%)
Cyprus Anvil	lead, zinc	1969	106	382	16.1	75
Cyprus Anvil expansion		1983	77	277	11.7	75
Elsa	silver	1914 (1988)	27.5	99	4.6	68
Venus	gold	1982	5.3	19	1.0	60
Whitehorse Copper	copper, silver	1967 (1984)	34.5	124	5.6	70
Tom Deposit	lead, zinc	1985	65.7	237	10.4	72
Howard's Pass	lead, zinc	1995	65.7	237	10.4	72
MacTung	tungsten	1987	23.5	85	3.8	70

Oil and Gas

Foster Research reviewed the possibility of electrical energy requirements for the Pointed Mountain gas processing plant (Amoco Canada Petroleum Company Ltd), Kotaneelee gas plant (Columbia Gas Development of Canada Ltd.) and potential plants in the Eagle Plains area (Aquitaine Company of Canada Ltd.). They concluded that no firm electrical energy requirements could be anticipated.

Forest Products

Expansion of the sawmill facilities in Watson Lake was forecast to cause an increase in annual energy use of 6 GWH during 1978 to 1981 with an associated increase in peak demand of 1.1 MW.

Construction

Anticipated construction projects include the Alaska Highway Natural Gas Pipeline (1982-1985), a major hydro project (1983-1990) and continuing construction of the Shakwak Highway Improvement (1978-1989). Impacts of these projects on energy requirements have been built into the residential and commercial forecasts.

Transportation

No major projects were built into the Base Case.

Street Lighting

Historic data describing street lighting requirements were compiled for each of the primary system load centres listed in Table A-8. As with the Commercial data, no trends were apparent from the 1975-1978 data and an average figure was calculated and compared to the residential useage to obtain a ratio of commercial to residential energy use. These ratios are listed below in Table A-15. The Street Lighting Forecast was developed by combining the Residential Forecast with these ratios.

Table A-15 Ratios of Street Lighting to Residential Electrical Requirements used by Foster Research (1979) to generate the Base Case Forecast.

	Ratio (%)
Aishihik/Whitehorse Faro System	
Whitehorse	2.9
Carmacks	6.3
Haines Junction	7.7
Ross River	4.6
Faro	1.3
Total	2.9
Mayo System	
Keno City	18.3
Mayo	1.7
Elsa	-
Total	2.6
Dawson	4.6
Johnson's Crossing	-
Other (YECO)	7.3
Total Yukon	3.2

Note: Figures represent historic averages 1975-1978 and for Foster Research's Base Case were projected as constants through 1998.

System Losses

Historic data describing system losses were compiled for each of the primary system load centres listed in Table A-8. For the Aishihik/Whitehorse/Faro System an increase of approximately 10 to 11% in losses was estimated as the system expands to service new and more remote mines. For the remaining components historic averages were used in the forecasts. These are listed below in Table A-16.

Table A-16 Historic averages of system losses compiled by Foster Research (1979) as a percentage of Net Generation

	losses (%)
Aishihik/Whitehorse Faro System	
Whitehorse	7.9
Carmacks	11.4
Haines Junction	17.9
Ross River	19.0
Faro	12.6
System extension (1988-1998)	12.6
Total	10.0-10.8
Mayo System	
Keno City	12.1
Mayo	4.8
Elsa	4.8
Total	4.8
Dawson	9.1
Johnson's Crossing	23.1
Other (YECO)	9.8
Total Yukon	9.5-10.7

Load Factors and Peak Demand

Historic data describing load factors and peak demand for the period 1975-1978 were compiled. An average load factor for the combined residential/commercial plus street lighting sectors was calculated for 1978 for each of the five systems and for the individual load centres. This figure was combined with projections of the industrial load factors to develop weight averaged load factors for each system. These projected load factors were combined with forecasts of net generation of calculate peak demand.

RESULTS

Base Case Forecast

The resulting Base Case forecast is shown on Figure 1 as #13. Annual electricity use increases from 336.6 GWH (1212 TJ) in 1978 to 730.4 GWH (2629 TJ) in 1998. Load factors for the total Yukon vary from 62.3 to 63.8% with various individual mine start ups and shutdowns causing yearly variations. Peak Demand increases over the forecast period from 63.5 MW in 1978 to 130.8 MW by 1998.

The High and Low Cases Developed by Foster Research (1979)

Foster Research evaluated the following factors that might cause future variation in from their Base Case:

1. the interrelated effects on electrical energy requirements of price trends, conservation and into fuel substitution
2. the probability and potential effects of utilization of solar heat and the heat pump
3. more or fewer mine developments
4. the probability and effects of a lead/zinc smelter and an aluminum smelter
5. pipeline construction and electrification
6. shutdown, extension and electrification of White Pass and Yukon Railway
7. electricity export to Alaska, B.C. and N.W.T.

The above factors were used to develop High and Low Cases. The assumptions underlying each of these cases are discussed in the following sections.

The Foster Research High Case

In addition to the electrical energy requirements of the Base Case a number of developments were included to develop the High Case Forecast. These developments are listed below in Table A-17.

Table A-17 Additional Developments included in Foster Research's High Case

Development	Date Onstream (shut down)	Electrical Energy			
		Annual (GWH)	Annual (TJ)	Peak (MW)	Load Factor (%)
Mines					
Jason Deposit, Tom Expansion (lead,zinc,silver)	1993	49.3	177	7.8	72
Howards Pass Expansion (lead,zinc,silver)	1998	49.3	177	7.8	72
Minto (copper)	1988	37.0	133	6.0	70
Soverign Metals (barite)	1988	17.5	63	4.0	50
Smelter					
lead zinc smelter	1988	827	2977	122	77.5
Pipelines					
partial natural gas pipeline electrification	1993	660	2376	84	90
Electricity Exports					
Canada, Tungsten NWT	1993	26	94	4.4	67
Cassiar, B.C.	1993	54	194	8.0	77
Skagway, Alaska	1993	7	25	1.1	73
Total		2509	9032	382	75

Results of the High Case are shown plotted on Figure 1 as #15.

The Foster Research Low Case

Several electrical energy requirements included in the Base Case were removed for the low case. Mining activity was reduced to the Cyprus Anvil Mine at Faro which was closed after 1988 and the United Keno Hill Mine at Elsa which was closed after 1983. In addition, conservation and interfuel substitution resulted in a 5% reduction in 1998 in the residential and commercial sectors energy requirements. The Low Case is plotted on Figure 1 as #14.

6. HILDEBRANDT-YOUNG 1981a

MARKET FORECAST, ELECTRICAL ENERGY REQUIREMENTS IN THE YUKON TERRITORY 1980/81 - 2000/2001

TERMS OF REFERENCE

To provide a twenty year forecast of electrical energy requirements in the Yukon.

GENERAL APPROACH TO ELECTRICITY DEMAND PROJECTIONS

Hildebrandt-Young initially develop a "Base Case" which is intended as an indication of future demand assuming no significant changes in the Yukon economy. It represents a static growth outlook and is not suggested as a probable forecast. The Base Case assumes no significant changes in Territorial population, no significant changes in per capita domestic electrical consumption, no significant change in commercial consumption, no significant change in government consumption of electricity, no change in mining/industrial activity and no new loads.

Two additional cases are then developed, a Low Case considered most probable, and a High Case. Each of these cases is developed by modifying the following factors:

1. mining activity
2. pipeline construction
3. interfuel substitution (natural gas for electricity)

DETAILED ASSUMPTIONS, PROJECTIONS AND RESULTS

Introduction

The End Use Categories and system characteristics considered by Hildebrandt-Young are given below in Table A-18. The items are essentially the same as those considered by Foster Research and listed in Table A-7 (p A-14).

Table A-18	End Use Categories and System Characteristics Considered by Hildebrandt-Young (1981a)

1. Domestic
2. Commercial
3. Industrial
4. Street Lighting
5. Total Load
6. Total Generation (including losses)
7. Peak Load
8. Load Factor

Individual forecasts were developed for the load centres listed in Table A-19.

Table A-19 Load Centres Considered by Hildebrandt-Young & Associates Ltd. (1981a)

1. Aishihik/Whitehorse/Faro System
2. Faro and Anvil Mine
3. Haines Junction
4. Ross River
5. Whitehorse
6. Carmacks
7. Johnson's Crossing
8. Mayo System
9. Elsa and Keno Mines
10. Keno City
11. Mayo Townsite
12. Total YECO-owned, non-integrated diesel systems: Beaver Creek, Destruction Bay, Old Crow, Pelly Crossing, Stewart Crossing, Swift River, Teslin, Watson Lake
13. Beaver Creek
14. Destruction Bay
15. Old Crow
16. Pelly Crossing
17. Stewart Crossing
18. Swift River
19. Teslin
20. Watson Lake
21. Dawson
22. Total Yukon

Base Case

The Base Case was calculated with two simple adjustments to the 1979/1980 historic data. Firstly, the domestic, commercial and street lighting loads were adjusted upward by 2.5% per annum for 1980/81 and 1981/82. These estimates were then held constant to 2000/2001. Secondly the industrial load was adjusted in both 1981/82 and 1982/83 for expansion of the Cyprus-Anvil operation at Faro. No other changes were made and the total forecast was held constant to 2000/2001. The Base Case is plotted on Figure 1 as #17.

Low Case Scenario

The Low Case Scenario was considered by Hildebrandt-Young as the most probable scenario. It was calculated by modifying the Base Case for a decline in mining and exploration activity, construction of a local natural gas pipeline, and substitution of natural gas for hot water heating and space heating. All changes were projected to occur on the Aishihik/Whitehorse/Faro system and all other load centres were held constant. Detailed assumptions are listed below in Table A-20. The scenario forecast was held constant beyond 1988/89 and is shown plotted on Figure 1 as #16.

Table A-20 Assumptions used by Hildebrandt-Young (1981a) to calculate the Low Case Scenario from the Base Case

ITEM	DATE	IMPACT ON ANNUAL ELECTRICITY USE	
		MWH	TJ
Stage 1 Cyprus Anvil expansion	1981/82	+26,854	+ 96.7
Stage 2 Cyprus Anvil expansion	1982/83	+27,500	+ 99.0
Whitehorse Copper terminates (includes mine and domestic loss)	1983/84	-35,500	-127.8
Decline in exploration and tourism (5% of total system sales)	1984/85	-14,907	- 53.7
Construction of local natural gas pipeline (5% of total system sales)	1984/85	+14,907	+ 53.7
End of local pipeline construction (half of previous years increase)	1985/86	- 7,454	- 26.8
Natural gas substitution for 50% of electric heat and hot water load	1985/86	-29,000	-104.4
Natural gas substitute for an additional 20% of (original) electric heat and hot water load	1986/87	-11,600	- 41.8
Natural gas substitution for an additional 15% of (original) electric heat and hot water load	1987/88	- 8,700	- 31.3
Natural gas substitute for an additional 5% of (original) electricity heat and hot water load	1988/89	- 2,900	- 10.4

High Case Scenario

The High Case Scenario was calculated by modifying the Base Case for all the activity changes in the Low Case Scenario (Table A-20) as well as increased mining activity and construction of the Alaska Highway Natural Gas pipeline. As with the Low Case, all changes were projected to occur on the Aishihik/Whitehorse/Faro system and all other load centres were held constant. Detailed assumptions in addition to those listed in Table A-20 are given in Table A-21. The High Case Scenario is plotted on Figure 1 as #18.

Table A-21 Assumptions in Addition to the Low Case Assumptions used by Hildebrandt-Young (1981a) to calculate the High Case Scenario

ITEM	DATE	IMPACT ON ANNUAL ELECTRICITY USE	
		MWH	TJ
Marbacio Resources Ltd Mine on stream	1982/83	+ 8,400	+ 30.2
Construction of Alaska Highway Natural Gas Pipeline begins -7% increase in electricity sales estimated	1983/84	+25,173	+ 90.6
Kathleen Lakes (Prism Resources) on stream	1984/85	+27,500	+ 99.0
Continued Pipeline Construction (7% increase)	1984/85	+25,173	+ 90.6
Mactung on stream	1985/86	+58,700	+211.3
End of pipeline construction	1985/86	-12,587	- 45.3
Tom Deposit comes on stream	1987/88	+95,000	+342.0
Howard's Pass comes on stream	1990/91	+82,000	+295.2

Load Factor and Peak Loads

Hildebrandt-Young forecast peak loads by using a constant load factor calculated from the 1980/81 historical data. This calculation was done for each of the load centers listed in Table A-19.

7. HILDEBRANDT-YOUNG 1981b

PROJECTED YUKON ENERGY REQUIREMENTS 1980 - 1991

TERMS OF REFERENCE

1. To review past and present energy consumption patterns in the Yukon

2. To suggest probable patterns of economic development and related patterns of energy consumption under a range of energy price possibilities.

GENERAL APPROACH TO DEMAND PROJECTIONS

The energy forms considered by Hildebrandt-Young (1981b) are listed below in Table A-22.

Table A-22 Energy Forms Considered by Hildebrandt-Young (1981b)

Gasoline:	road grade
	aviation
Aviation turbo fuel	
L.P.G. (Liquified Petroleum Gas)	
Diesel Oil:	road
	rail
	diesel generation of electricity
	heating
Electricity (hydraulic)	
Natural Gas	

A 1990 forecast of Yukon energy use was developed by projecting independently each energy form. Six cases of energy use were forecast (Table A-23). The Low and High Economic Growth projections was defined by variations in mine development activity.

Table A-23 Energy Use Cases developed by Hildebrandt-Young (1981b)

A. Low Economic Growth

- I no conservation, no interfuel substitution
- II conservation, no interfuel substitution
- III conservation, interfuel substitution

B. High Economic Growth

- I no conservation, no interfuel substitution
- II conservation, no interfuel substitution
- III conservation, interfuel substitution

In addition to the above forecasts of energy use, Hildebrandt-Young (1981b) developed three scenarios of per capita energy costs based on low, medium and high projected prices of crude oil, liquid hydrocarbon fuels, electricity and natural gas. A discussion of energy prices is beyond the scope of this report.

DETAILED ASSUMPTIONS AND PROJECTIONS

Tables A-24 and A-25 list the changes in the Yukon's mining industry that were used to define the Low and High Economic Growth cases respectively. Also listed are the associated changes in electrical energy consumption and the Yukon population.

Table A-24 Changes in the Yukon's Mining Activity, Population and Electrical Consumption Used by Hildebrandt-Young (1981b) to Define their Low Economic Growth Case.

Year	Activity	Change in electric consumption (MWH)	Population
1980/81	-	-	24,138
1981/82	expansion at Cyprus Anvil	+ 26,854	24,138
1982/83	expansion at Cyprus Anvil	+ 27,500	24,138
1983/84	closure of Whitehorse Copper	- 35,500	23,508
1990/91	closure of Cyprus Anvil	-170,000	21,348
	closure of United Keno Hill Mines at Elsa and Carcross	- 38,400	20,148

Table A-25 Changes in the Yukon's Mining Activity, Population and Electricity Consumption used by Hildebrandt-Young (1981b) to Define Their High Economic Growth Case.

Year	Activity	Change in electrical consumption (MWH)	Population
1980/81	-	-	24,138
1981/82	expansion at Cyprus Anvil	+ 26,854	24,488
1982/83	expansion at Cyprus Anvil	+ 27,500	25,053
	start up, Marbaro Resources	+ 8,400	
1983/84	closure of Whitehorse Copper	- 35,500	25,386
1984/85	start up, Prism Resources	+ 8,000	26,495
1985/86	start up MacTung	+ 58,700	27,350
1986/87	-	-	27,747
1987/88	start up Tom Deposit	+ 95,000	29,409
1988/89	-	-	29,835
1989/90	-	-	30,260
1990/91	start up Howard's Pass	+ 82,000	
	closure United Keno Hill Mines at Elsa and Carcross	- 38,400	30,706

For each of the Low and High Economic Growth projections, three cases were developed (Table A-23) depending on conservation and interfuel substitution. The detailed assumptions, underlying these cases are listed in Table A-26.

Table A-26 Detailed Assumptions Used by Hildebrandt-Young (1981b)

LOW ECONOMIC GROWTH

I NO CONSERVATION, NO INTERFUEL SUBSTITUTION

1. 1980 per capita energy use projected as constant to 1990 for all energy forms.
2. diesel generated electricity declines by 1990 to 10% of total electricity
3. changes as listed in Table A-24.

II CONSERVATION, NO INTERFUEL SUBSTITUTION

1. per capita consumption of road gasoline declines by 1990 to 50% of 1980 use
2. per capita consumption of aviation gasoline declines to historic low by 1990
3. per capita consumption of aviation turbo fuel declines by 1990 by 22.5%
4. per capita consumption of L.P.G. declines to historic low by 1990
5. per capita consumption of Diesel fuel is as follows for 1990:
   a. road: constant per capita consumption
   b. rail: constant per capita consumption
   c. electrical generation: 10% of electricity generated
   d. heating: per capita consumption declines to the lowest technically feasible.
6. electricity consumption is modified as listed in Table A-24. In addition, conservation measures are assumed to result in a 46% reduction in the 1980 residential electrical heating load and a 40% reduction in the 1980 commercial heating load.

III CONSERVATION AND INTERFUEL SUBSTITUTION

In addition to the assumptions listed in Case II above, natural gas was assumed to replace the following items:

1. 77.5% of L.P.G.'s
2. 77.5% of road diesel
3. 100% of rail diesel
4. 100% of diesel used for electrical generation
5. 85% of heating oil (diesel)

These substitutions were based on the following thermal content of fuels and energy use efficiencies:

fuel	efficiency(%)	thermal content
L.P.G.	75	110,000 BTU/gal
natural gas for space heat	75	10^6 BTU/mcf
road diesel	75	186,000 BUT/gal
road natural gas	75	10^6 BTU/mcf
rail diesel	100	186,000 BTU/gal
rail natural gas	100	10^6 BTU/mcf
diesel electric	100	186,000 BTU//gal
natural gas electric	100	10^6 BTU/mcf
heating oil	65	167,000 BTU/gal
electric hot water heat	100	3413 BTU/kW.h
natural gas hot water heat	70	10^6 BTU/mcf

HIGH ECONOMIC GROWTH

I NO CONSERVATION, NO INTERFUEL SUBSTITUTION

1. 1980 per capita energy use projected as constant to 1990 for all energy forms.

2. changes as listed in Table A-25.

II CONSERVATION, NO INTERFUEL SUBSTITUTION

Same assumptions as listed for Case II Low Economic Growth except changes to electrical consumption and population follow those listed in Table A-25.

III CONSERVATION AND INTERFUEL SUBSTITUTION

Same assumptions as listed for Case III Low Economic Growth except changes to electrical consumption and population follow those listed in Table A-25.

RESULTS

The six resulting 1990 forecasts are listed in Table A-27 in both natural units and heat equivalent units. Figures have been rounded from those contained in the Hildebrandt-Young (1981b) report.

Table A-27 Energy Use Forecasts developed by Hildebrandt-Young (1981b)

	1980 (TJ)*	1990 FORECASTS* LOW ECONOMIC GROWTH I	II	III	HIGH ECONOMIC GROWTH I	II	III
Petroleum Products							
road gasoline	2182	1755	879	879	2675	1340	1340
aviation gasoline	206	172	92	92	262	140	140
aviation turbo fuel	335	280	217	217	427	331	331
liquid petroleum gases	64	57	45	10	87	68	15
diesel fuel:							
- rail	32	25	25	-	38	38	-
- road	2686	2008	2008	453	3061	3061	691
- heating	2053	1711	886	135	2607	1350	205
- electrical generation	657	204	204	-	750	308	-
Total Petroleum Products	8215	6212	4350	1786	9907	6636	2722
Hydro Electricity Total	1176	525	354	222	1888	1843	1673
Natural Gas Total	-	-	-	2857	-	-	4372
Wood Total	266	- no projections made -					
Coal Total	454	- no projections made -					
TOTAL YUKON	10121	6737	4710	4865	11795	8479	8717
Population	24138	20148			30706		

*Note re: Units

The above table is expressed in terajoules (TJ). The heat equivalent unit of a variety of natural units. The following conversion factors apply:

Fuel Type	Natural Unit	Conversion Factor terajoules
road gasoline	megalitres	34.656
aviation gasoline	megalitres	33.518
aviation turbo fuel	megalitres	35.934
liquified petroleum gases	megalitres	27.177
diesel fuel	megalitres	38.675
electricity	gigawatt hours	3.600
natural gas	gigalitres	37.229
wood	cords x 1000	17.733
coal	tonnes x 1000	22.700

8. HILDEBRANDT-YOUNG 1982

UPDATE: MARKET FORECAST, ELECTRICAL ENERGY REQUIREMENTS IN YUKON 1981/1982 - 2001/2002

TERMS OF REFERENCE

To provide a twenty year forecast of electricity use in the NCPC portion of the Yukon electrical system.

GENERAL APPROACH TO DEMAND PROJECTIONS

A review of 1977/78 to 1980/81 historical data was initially undertaken to identify any trends in electricity use for domestic and commercial customers. Conclusions drawn from this review were then combined with various industrial development possibilities to generate three electrical energy forecasts: Low, Base and High cases. The Base Case was identified as the most likely to occur. Only the NCPC system was dealt with in this report and total Yukon figures were not generated.

DETAILED ASSUMPTIONS AND PROJECTIONS

Introduction

The End Use Categories and System Characteristics used in the report are the same as those listed in Table A-18 (p A 24).

Individual forecasts were developed for the load centres listed below in Table A-28. This list includes all the NCPC supplied centres and excludes those supplied by YECO.

Table A-28 Load Centres Considered by Hildebrandt-Young, 1982

1. Aishihik/Whitehorse/Faro System
2. Faro and Anvil Mine
3. Haines Junction
4. Ross River
5. Whitehorse (including Tagish and Carcross)
6. Carmacks
7. Johnson's Crossing
8. Mayo System
9. Elsa and Keno Mine
10. Keno City
11. Mayo Townsite
12. Dawson City
13. Total Yukon NCPC generated

For each of the load centres listed in Table A-28, a "Commuunity Information Profile" was also developed with a compilation of 1977/78 to 1980/81 historic data on population, domestic consumption per connection (government, non government, combined), commercial consumption per capita (government, non government, combined) and Total community consumption (excluding industrial).

The historic data were used to identify trends in domestic and commercial use. For domestic customers, an overall reduction per connection occurred but appeared to be levelling off in the last two years. No trends were identified in the commercial sector.

The domestic and commercial forecasts were tied directly to a population forecast. In both sectors a <u>constant per capita use</u> based on the 1980/81 figure was projected throughout the forecast period.

Hildebrandt-Young developed a population forecast for each scenario (low, base, high) dependent on mining developments, hydro construction and pipeline construction. Their population forecasts are shown on Figure 3.

Base Case Scenario

Domestic and commercial electrical use was forecast using the Base Case population forecast and per capita domestic and commercial use calculated for 1980/81.

The industrial forecast was based on the assumed activities listed in Table A-29.

Table A-29 Hildebrandt-Young (1982) assumed Base Case Industrial Activities

ITEM	DATE	IMPACT ON ANNUAL ELECTRICITY USE MWH	TJ
reduction in Whitehorse Copper activity	1982/83	- 2,352	- 8.4
new rotary drill at Cyprus Anvil	1982/83	+ 21,000	+ 75.6
reduction in United Keno Hill Mine at Elsa	1982/83	- 1,836	- 6.6
mill expansion at Cyprus Anvil	1983/84	+ 12,000	+ 43.2
Closure of Whitehorse Copper at end of 1983 (9 months operation)	1983/84	- 9,014	- 32.5
Cyprus Anvil Expansion	1984/85	+ 48,000	+ 178.8
Closure of Whitehorse Copper	1984/85	- 27,043	- 97.4
Reopen of Venus Mine	1991/92	+ 8,400	+ 30.2
Closure of Elsa Mine	1991/92	- 22,915	- 82.5
Open Kathleen Lakes Silver Mine	1991/92	+ 27,500	99.0
MacMillan Pass Mines	1998/99		
MacTung		+ 58,700	+ 211.3
Tom		+ 95,000	+ 342.0
Jason		+ 95,000	+ 342.0
Howard's Pass		+ 82,000	+ 295.2
(New Hydro Electric facility built)	Total	+330,700	+1190.5
Venus Mine closes	2001/02	- 8,400	- 30.2
Kathleen Lakes Mine Closes	2001/02	- 27,500	- 99.0

Low Case Scenario

Domestic and commercial electrical use was forecast using the Low Case population forecast and per capita domestic and commercial use calculated in 1980/81.

The industrial forecast was based on the assumed activities listed below in Table A-30.

Table A-30 Hildebrandt-Young (1982) assumed Low Case Industrial Activities

ITEM	DATE	IMPACT ON ANNUAL ELECTRICITY USE MWH	TJ
reduction in Whitehorse Copper activity	1982/83	- 2,352	- 8.4
new rotary drill at Cyprus Anvil	1982/83	+ 21,000	+ 75.6
reduction in United Keno Hill Mine at Elsa	1982/83	- 1,836	- 6.6
mill expansion at Cyprus Anvil	1983/84	+ 12,000	+ 43.2
Closure of Whitehorse Copper	1983/84	- 36,057	- 129.0
Cyprus Anvil Expansion	1984/85	+ 48,000	+ 172.8
Closure of United Keno Hill Mine at Elsa	1991/92	- 22,915	- 82.5

High Case Scenario

Domestic electrical use was forecast using the High Case population forecast and per capita domestic use calculated for 1980/81. This figure was then reduced to allow for conversion to natural gas from electricity a substitution made possible by construction of the Alaska Highway Natural Gas Pipeline. Table lists the assumed reductions.

Table A-31 Hildebrandt-Young, 1982, assumed reductions in domestic electricity use resulting from natural gas substitution High Case Scenario

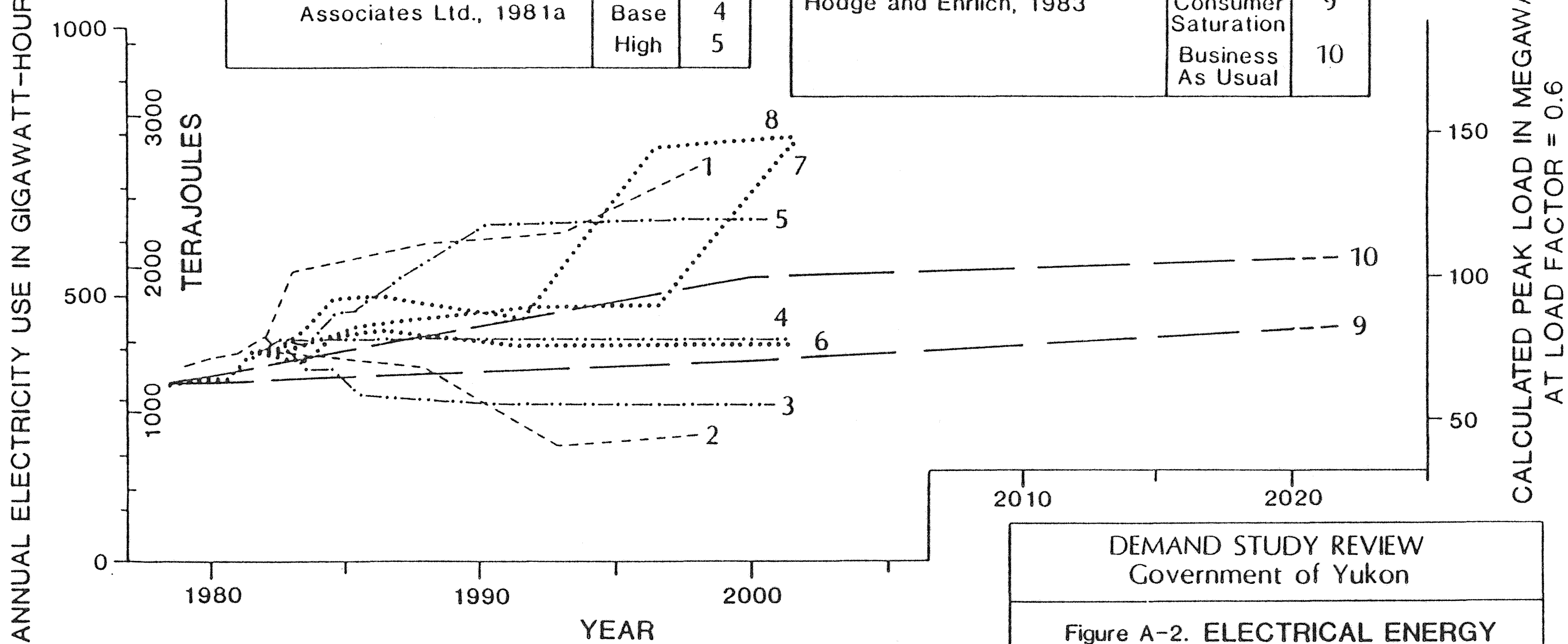
Year	Reduction % of domestic use	MWH	TJ
1988/89	50	24,000	86.4
1989/90	20	9,760	35.1
1990/91	5	2,400	8.6
1991/92	5	2,400	8.6

Commercial electrical use was forecast using the High Case population estimate and per capita commercial use calculated for 1980/81.

The High Case industrial activities were assumed to be the same as those listed in Table A-29 for the Base Case but introduction of new mines was advanced two years and in addition, construction of the Alaska Highway Natural Gas Pipeline was assumed to begin in 1983/84 and be completed by 1987/88.

RESULTS

Because Hildebrandt-Young (1982) dealt only with the NCPC system, results are not plotted on Figure 1. However, to obtain a comparison, the Hildebrandt-Young (1981) forecasts for the YECO non integrated system were added to the Hildebrandt-Young (1982) forecasts for the NCPC system. This total Yukon forecast is shown plotted on Figure A-2. Comparable data from Foster Research (1979), Hildebrandt-Young (1981a and b) and Hodge and Ehrlich (1983) have been added for comparison.



SOURCE REPORT	CASE	REF. NO.
Foster Research, 1979	Base	1
	Low	2
Hildebrandt-Young and Associates Ltd., 1981a	Low	3
	Base	4
	High	5

SOURCE REPORT	CASE	REF. NO.
Hildebrandt-Young and Associates Ltd., 1982	Low	6
	Base	7
	High	8
Hodge and Ehrlich, 1983	Consumer Saturation	9
	Business As Usual	10

DEMAND STUDY REVIEW Government of Yukon	
Figure A-2. ELECTRICAL ENERGY PROJECTIONS: RECENT STUDIES	
R.A. Hodge, P.Eng.	January 31, 1983

9. HODGE AND EHRLICH, 1983

NORTHERN ENERGY

TERMS OF REFERENCE

1. To demonstrate a cohesive and complete method for analyzing energy use.

2. To test the feasibility of a more efficient energy future, consistent with an expanded economy, that is in itself limited in growth and characterized by an emphasis on renewable, decentralized and small scale energy sources.

3. To test the feasibility of an energy future that is more dependent on Yukon (or NWT) produced energy.

GENERAL APPROACH TO DEMAND PROJECTIONS

The method used in this study does not lead to an energy forecast in the traditional sense. The projections developed are not an attempt to predict the future but rather are intended to illustrate that given certain conditions, a certain energy picture will result. The technique is sometimes called "backcasting" and is essentially a goal oriented feasibility study.

The study considers a long term time period: 1978-2025. A simplified schematic of the study methodology is shown in Figure A-3. A Long Term Simulation Model (LTSM) developed by the Federal Government was used to provide economic growth projections.

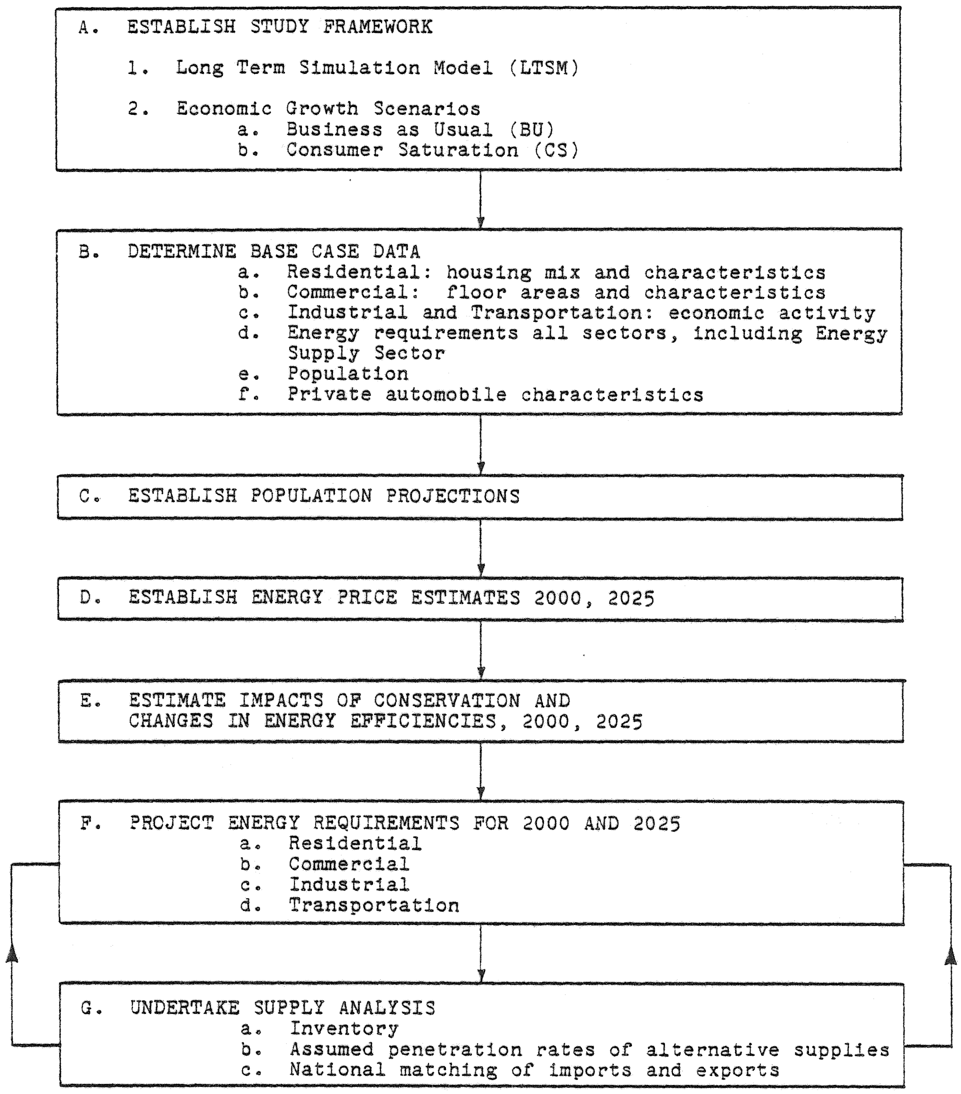


Figure A-3 Simplified schematic of method used by Hodge and Ehrlich, 1983.

Two growth scenarios were developed: Business-as-usual and Consumer Saturation. Both scenarios maintain growth rates of output, disposable income and technological development of about 4% per annum. In the Business-as-usual scenario, labour hours per year are held constant over time and added disposable income is spent mainly on services. In the Consumer Saturation Scenario, gains from technology are taken in the form of increased leisure time rather than increased expenditure on services. Thus in the Consumer Saturation scenario, labour hours per year are gradually reduced so that disposable income grows more slowly and projected output does not grow so rapidly as in the Business-as-usual scenario.

A detailed Base Case economic activity and energy demand analysis was completed first. Each of the residential, commercial, industrial, transportation and energy supply sectors was considered separately. Sectors were disaggregated into subsectors consistent with categories defined in Statistics Canada's Standard Industrial Classification (1970) and listed in Table A-32.

Table A-32
Listing of Subsectors used by
Hodge and Ehrlich, 1983

RESIDENTIAL SECTOR	COMMERCIAL SECTOR	INDUSTRIAL SECTOR
Single Family Detached (SFD)	Offices	Agriculture
Single Family Attached (SFA)	Schools/Universities	Forestry
Apartments	Hospitals	Fishing, Hunting, Trapping
Mobile Homes	Stores/Shops	Iron Mines
	Hotels/Motels/Restaurants	Other Mining
	Government (Street Lighting)	Food Processing
TRANSPORTATION SECTOR		Pulp and Paper
	ENERGY SUPPLY SECTOR	Iron and Steel
Air		Smelting and Refining
Water	Mineral Fuels	Cement
Rail	Petroleum and Biomass Refining	Chemicals
Auto		
Truck	Pipeline Transport	Other Manufacturing
Bus	Utilities	Construction

Subsector activity levels and related energy requirements were projected independently before being aggregated and synthesized to give sectoral and territorial energy requirements for the years 2000 and 2025. A key element in making these projections is the assumed degree of technically and economically feasible levels of energy conservation and improved energy use efficiencies.

For the energy analysis, the two scenarios were treated somewhat differently. In the Business-as-usual scenario, an economic fix approach was used. Nothing was incorporated that was not cost effective at a 7% discount rate and no lifestyle changes were permitted from conditions existing in 1978. For the Consumer Saturation scenario, the cost effectiveness criterion was slightly relaxed and modest lifestyle changes were allowed.

Following the demand analysis a supply analysis was undertaken. Reference energy prices were estimated, the availability of a range of energy forms confirmed, and the various energy forms matched to appropriate end uses. Matching criteria included consideration of scale, proximity of source to use, and energy quality. Energy quality is a measure of the amount of "useful work" that can be obtained from the energy form under consideration.

The result of the energy supply and demand analysis is the identification of either an energy excess available for export or an energy deficiency that must be matched by imports.

The study results in three different sets of data:

1. Base Case and projected energy end uses (Table A-33) categorized by sector (Table A-32) and form (Table A-34).

2. Primary energy sources (Table A-35) and secondary energy forms (Table A-34) identified as either Yukon produced or imported.

3. Subsector and Sector (Table A-32) Base Case and projected energy categorized by end use (Table A-33)

All data are presented in heat equivalent metric units.

Table A-33 End Use Categories used by Hodge and Ehrlich (1983)

category	description
heating and cooling	space heating, hot water heating, air conditioning, process heat below 100°C.
industrial process heat	process heat 100-260°C. process heat >260°C.
liquid fuels	transportation fuels
electricity specific	electric appliances

Table A-34 Energy Forms used by Hodge and Ehrlich, 1983

coal
natural gas
refined petroleum products
electricity
biomass solids (eg cord wood)
biomass fluids (eg alcohols)
active solar

Table A-35 Primary Energy Sources considered by Hodge and Ehrlich, 1983

coal and peat
natural gas
crude oil
hydro electricity
solar
photovoltaics (electricity)
wind (electricity)
biomass

DETAILED ASSUMPTIONS AND PROJECTIONS

Population

The population for the year 2000 was taken from the Yukon Territorial Government's Best estimate in the Yukon Economic Impact Simulation Model (1980). The projection assumes construction of the Alaska Highway Natural Gas pipeline with peak construction occurring prior to 1990. The estimate for 2000 was projected to 2025 using LTSM growth rates (See Figure 3).

Energy Demand Analysis

Residential

Number of Households

Population projections were translated into households on the basis of a figure of people per household. The Base Case figure of 3.5 was reduced to 3.2 for 2000 and 3.0 for 2025 based on a rate of change consistent with expected changes in the rest of Canada.

Housing Mix

Houses were categorized as single-family detached, single family attached, apartments and mobile homes. A decrease in the proportion of single family detached units (8%) and an increase in apartments (4%) and single family attached units (5%) was projected for the year 2000. A further decrease of 4% in single family detached units along with modest increases in the other categories was projected for 2025.

Housing Age

Housing units were divided into three age groups which identified existing units (pre 1978), units built during the transition stage (1978-1990), and units constructed after 1990 when energy efficient construction was assumed to be standard.

Residential Energy Targets

Residential energy projections were based on the requirements for the single family detached unit. For heating and cooling, the single family attached unit was assumed to use 56% of the detached unit, apartments 54%, and mobile homes 93%. Electricity specific requirements varied only slightly such that apartment units used 5% less than other units.

Table A-36 lists the energy targets of the single family detached house used as a basis for the residential energy calculations.

Table A-36 Projected and Base Case Yukon energy requirements for GJ/annum for a single family detached unit (Hodge and Ehrlich, 1983)

	Base Case	2000			2025		
		Pre 78	78-90	90+	Pre 78	78-90	90+
Heating & Cooling*	122.4	64.1	53.3	20.6	47.2	42.2	20.0
Electric Specific	18.7	16.5	14.4	10.7	14.4	12.5	9.4
Total	141.1	80.6	67.7	31.3	61.6	54.7	29.4

* includes domestic hot water

Assumed Fuel Use Efficiencies

In addition to conservation measures leading to the energy targets listed above, greater fuel use efficiencies were assumed to further reduce energy requirements. Generation of heat from fossil fuel was projected to increase in efficiency from a Base Case figure of 60% to 80% by 2000 and 90% by 2025. Generation of heat from wood was projected to increase from a Base Case figure of 55% to 62% by 2000 and 70% by 2025. Generation of heat from biomass fluids was projected to increase from 60% efficiency in 2000 to 70% in 2025.

Commercial Sector

Subsector Growth Rates

Growth rates were applied to subsector floor areas. The two subsectors "Hospitals" and "Schools and Universities" were projected to expand with population growth rates. The "Government" subsector was assumed to grow according to the annual gross territorial product growth rates of 2.5%/annum in the Business-as-usual scenario 1.4%/annum in the Consumer Saturation scenario. The remaining subsectors, Stores/Shops, Offices, and Hotel/Motel/Restaurants were projected to grow according to the overall "Commercial" sector growth rate given by the LTSM.

Building Age

Commercial buildings were divided into three age groups: pre 1978, 1978-2000 and those constructed after 2000.

Commercial Energy Targets

An energy target of 100 kW.h/m was set for all buildings constructed after 2000. The net effects of conservation on older buildings were set at 50% reduction in energy consumption per unit area by 2000 and 70% by 2025. These improvements in energy use were introduced at a rate in each subsector that depended on the characteristics of that subsector.

Over time, the heating requirement of commercial buildings was projected to greatly reduce because of improved thermal performance while the use of electrical appliances was projected to increase.

Industrial Sector

Energy use in 2000 and 2025 was projected by relating energy use to economic activity and modifying this relationship by a factor which represents the effects of conservation and energy use efficiency. This approach is expressed by the following formula which was applied to each subsector for each year being projected.

$$E_{2025} = A_{2025} \times \frac{E\ 1978}{A\ 1978} \times F$$

where

E = total consumption of energy

A = economic activity in constant $ 1980

F = factor which represents the change in energy efficiency with time between the two years in question.

Subscripts refer to the years being considered.

Table A-37 below lists the conservation factors "F".

Table A-37 Assumed industrial conservation factors used by Hodge and Ehrlich, 1983.

	Conservation Factor "F"			
Subsector	1978	1990	2000	2025
Agriculture	1.0	.80	.70	.50
Forestry	1.0	.72	.55	.27
Fishing, Hunting, Trapping	1.0	.80	.70	.50
Mineral Fuels	1.0	.86	.75	.46
Mining	1.0	.76	.64	.39
Food Processing	1.0	.79	.65	.40
Petroleum Refining	1.0	.77	.51	.35
Chemicals	1.0	.77	.51	.35
Other Manufacturing	1.0	.76	.60	.36
Construction	1.0	.78	.64	.39

Projections of economic activity varied in method with each subsector. These are discussed below. All growth rates are in constant $ 1980.

Agriculture

Projections of economic activity were assigned arbitrarily assuming a fourfold increase by 2000 and a sixteenfold increase by 2025.

Forestry

Economic activity was allowed to grow from a Base Case of $6.6 million to a ceiling of $10 million by 1990.

Fishing Hunting and Trapping

Growth rates were assumed to follow those developed by the Long Term Simulation Model (LTSM): 1.2-1.4 times increase by 2000 and 1.6-1.7 times by 2025 for the Consumer Saturation and Business-as-usual scenarios respectively.

Mining

For the Business-as-usual scenario, mining activity was projected as three times greater by 2000 and five times greater by 2025. In the Consumer Saturation scenario activity levels were assumed to be two times greater by 2000 and four times greater by 2025.

Food Processing

Growth rates were assumed to follow those given by the LTSM and resulted in double the economic activity by 2000 and tripling by 2025.

Chemicals

Growth rates were assumed to follow those given by the LTSM: 1.5-2.0 times by 2000 and 2.5-3.0 times by 2025 for the Consumer Saturation and Business-as-usual scenarios respectively.

Other Manufacturing

Growth rates were assumed to follow those given by the LTSM: 1.7-2.6 times increase by 2000 and 2.6-3.6 times increase by 2025 for the Consumer Saturation and Business-as-usual scenarios respectively.

Construction

Growth rates were assumed to follow those given by the LTSM: 1.8-2.4 times increase by 2000 and 2.7-3.3 times increase by 2025 for the Consumer Saturation and Business-as-usual scenarios respectively.

Transportation Sector

Projections of energy use in the transportation sector were undertaken exactly as in the industrial sector.

Table A-38 below lists the conservation factors "F" that are the equivalent to those for the industrial sector given in Table A-37.

Table A-38 Assumed transportation sector conservation factors used by Hodge and Ehrlich (1983)

Subsector	Conservation Factor "F"			
	1978	1990	2000	2025
Air	1.0	.80	.70	.50
Water	1.0	.80	.775	.50
Rail	1.0	.90	.80	.70
Auto	1.0	.53	.28	.16
Truck	1.0	.85	.65	.50
Bus	1.0	.85	.75	.60

Projections of economic activity varied in method with each subsector. These are discussed below.

Air

Growth rates were assumed to follow those given by the LTSM resulting in an increase of 2.5-4.0 times by 2000 and 4.2-6.2 times by 2025 for the Consumer Saturation and Business-as-usual scenarios respectively.

Water

A small amount of water transport was arbitrarily reintroduced from the year 2025.

Rail

Growth rates were assumed to follow those given by LTSM. No major rail extension was projected although an increase in activity of 1.5-2.2 times was projected for 2000 and 2.0-2.8 times by 2025 for the Consumer Saturation and Business-as-usual scenarios respectively.

Auto

Automobile use was related to population and fuel consumption was estimated using the energy targets listed below in Table A-39.

Table A-39 Assumptions used by Hodge and Ehrlich, 1983 for calculation of automobile fuel consumption

Projected fuel use is based on population growth and growth in the number of households (obtained from the residential sector analysis) and the assumptions listed below.

A. Fuel Consumption

Year	1/100km Assumed for Yukon	Miles per Gallon Assumed for Yukon	Miles per Gallon National Figure
1978	20	15	17
1990	10	28	31
2000	5	53	59
2025	3	90	100

(Assumed 10% below the rest of Canada because of more extreme climate).

B. Number of Vehicles per Household

Year	Vehicles/ Household	No. of Vehicles (Calculated)
1979	2.6	18,327 - actual registration
1990	2.6	25,000
2000	2.3	30,000
2025	1.9	50,000

The number of vehicles per household is significantly higher than the rest of Canada. This characteristic was projected to continue and for the year 2025, the figure of 1.9 vehicles/household is just over twice the national figure of .9 vehicles/household.

C. Total Annual Distance Driven Per Vehicle

Base Case levels were calculated using the fuel consumption assumptions outlined above and total fuel sales figures obtained from ERPU (1979). For projections the following assumptions were made.

a. BU Scenario: distance driven per vehicle stays constant over time.
b. CS Scenario: distance driven per vehicle is 10 reduced from Base Case levels in 2000 and 20% reduced in 2025.

Truck

Growth rates of the industry were assumed to follow the LTSM resulting in a 2.1-2.9 times increase in activity by 2000 and a 3.1-4.5 times increase by 2025 for the Consumer Saturation and Business-as-usual scenarios respectively.

Bus

Projected economic activity was arbitrarily assigned assuming a 4.0-5.0 times increase by 2000 and a 6.0-8.0 times increase by 2025.

Energy Supply Analysis

Decision making regarding supply options was based primarily on a set of Reference Energy Prices developed for the years 2000 and 2025 combined with an exercise that matched the various energy forms to appropriate end use. Matching criteria included consideration of scale, proximity of source to use and energy quality. Energy quality is the amount of "useful work" that can be obtained from the energy form under consideration.

In the following paragraphs a summary is given of the projected use of each energy form.

Non-Renewables

Coal

The small amount of coal used for industrial process heat in the Base Case was phased out for all future scenarios and no additional uses of coal were projected.

Natural Gas

Natural gas was assumed to become available with the introduction of the Alaska Highway Natural Gas Pipeline. Natural gas consumption peaked in 2000 Business-as-usual scenario in which it was projected to supply

1. 38% of residential heating
2. 52% of commercial heating
3. 7% of industrial heating and cooling

Only uses adjacent to the pipeline route were considered and because of improved combustion efficiencies, greater levels of conservation, and penetration of renewable energy forms, natural gas use was projected to decrease after 2000.

Refined Petroleum Products

Use of refined petroleum products was projected to drop off to 38%-75% of present levels in 2000 and 7%-18% of present levels in 2025 in the Consumer Saturation and Business-as-usual Scenarios respectively.

Diesel Generated Electricity

Use of Diesel generated electricity was projected to drop off from a Base Case level of 12% of the Yukon's electricity to 1.0-1.5% in 2000 and 0-1% in 2025 for the Consumer Saturation and Business-as-usual scenarios respectively.

Renewables

Electricity: Renewable

The projected penetration of renewable electrical energy is given below in Table A-40.

Table A-40 Projected penetration of electricity generated by various renewable forms for each scenario and year (Hodge and Ehrlich, 1983).

Source	% of Total Electricity Generated				
	Base Case	2000 BU	2000 CS	2025 BU	2025 CS
hydro	88	95	84	87	79
thermal generation with biomass fluids	-	2	2	2	1
wind	-	1	8	5	12
photovoltaics	-	-	5	5	8
	(1)	(2)	(3)	(4)	(5)
Total: Renewable Electricity	88	98	99	99	100

Biomass Solids (Cord Wood or Chips)

While the number of houses and commercial establishment dependent on wood were dramatically increased, the assumed improvements in the efficiency of wood burning units from a Base Case figure of 55% to 70% by 2025 limited the total use of wood to a maximum of double Base Case levels.

Biomass Fluids (Methanol, ethenol or vegetable oils)

Imported renewable biomass fluids were assumed to gradually replace refined petroleum products. The total combined use of biomass fluids and refined petroleum products was not projected to change greatly over time.

Active Solar

Active solar energy was projected to provide 1.5-2% of the total Yukon energy requirement by 2000 and 3-4% in 2025 for the Business-as-usual and Consumer Saturation Scenarios respectively. The main use was projected to be for medium temperature industrial process heat likely for remote mining operations. In all cases, active solar sources were considered seasonal.

RESULTS

Results of the work completed by Hodge and Ehrlich, 1983 are given in Figures A-4 to A-11. The territorial totals are plotted on Figure 1 as #19 and #20.

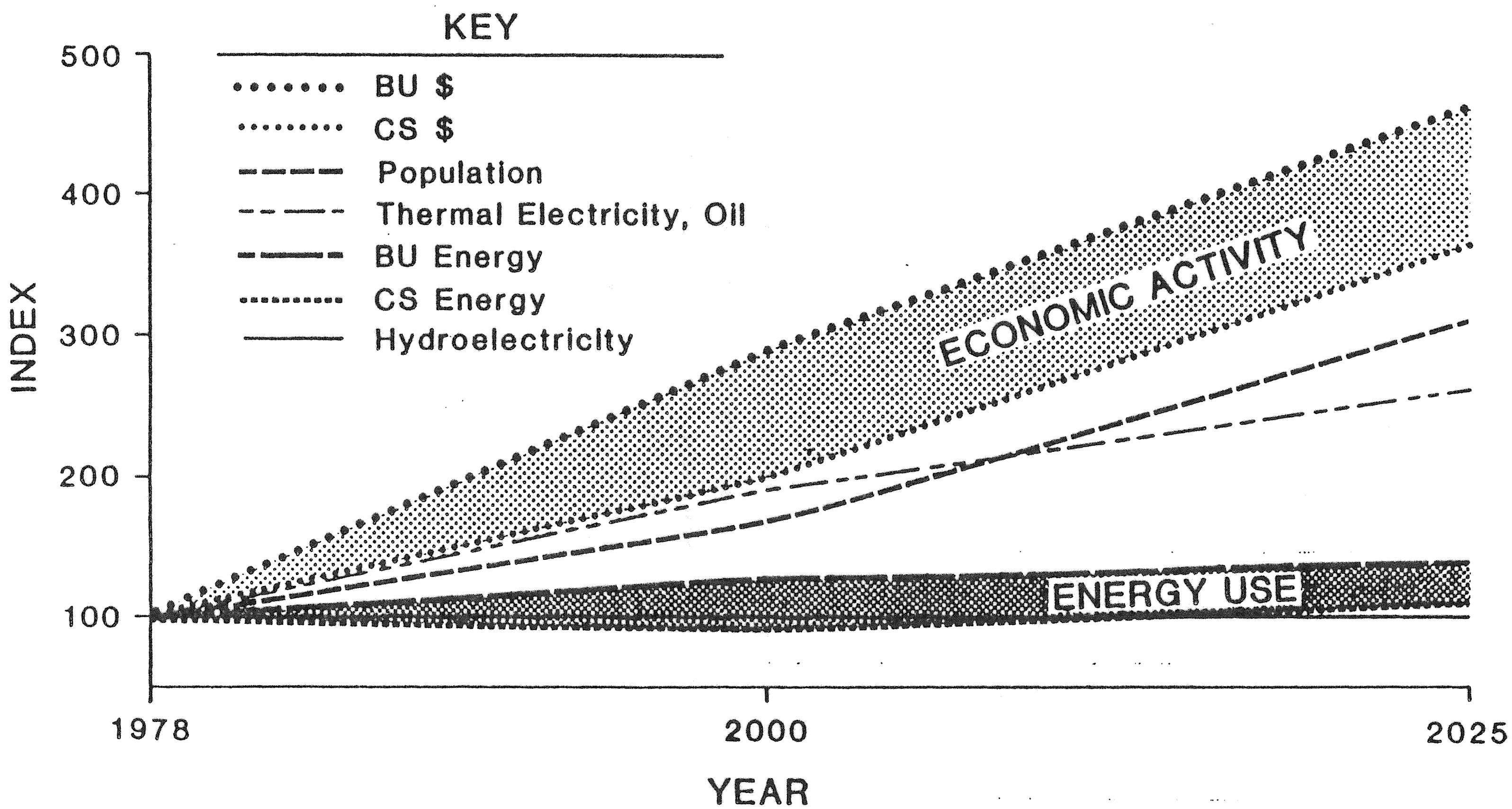


Figure A-4 Relative demographic, economic and energy projected Yukon growth. (1978=100), after Hodge and Ehrlich, 1983.

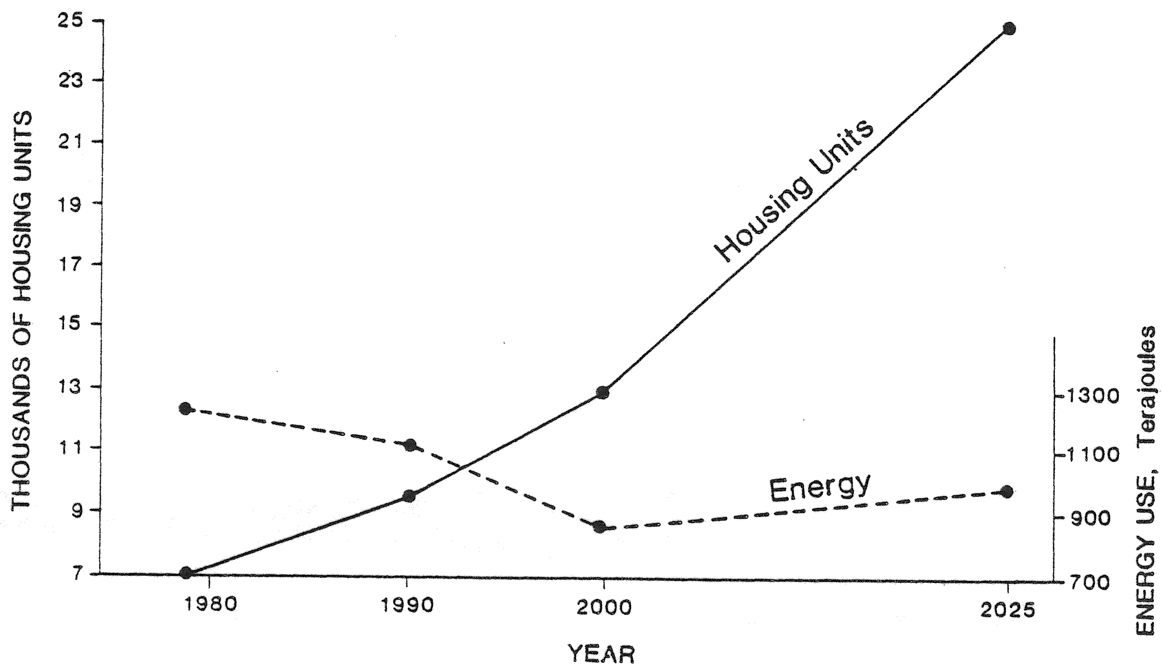


Figure A-5 Projections of Yukon residential units and energy use: 1978-2025, after Hodge and Ehrlich, 1983

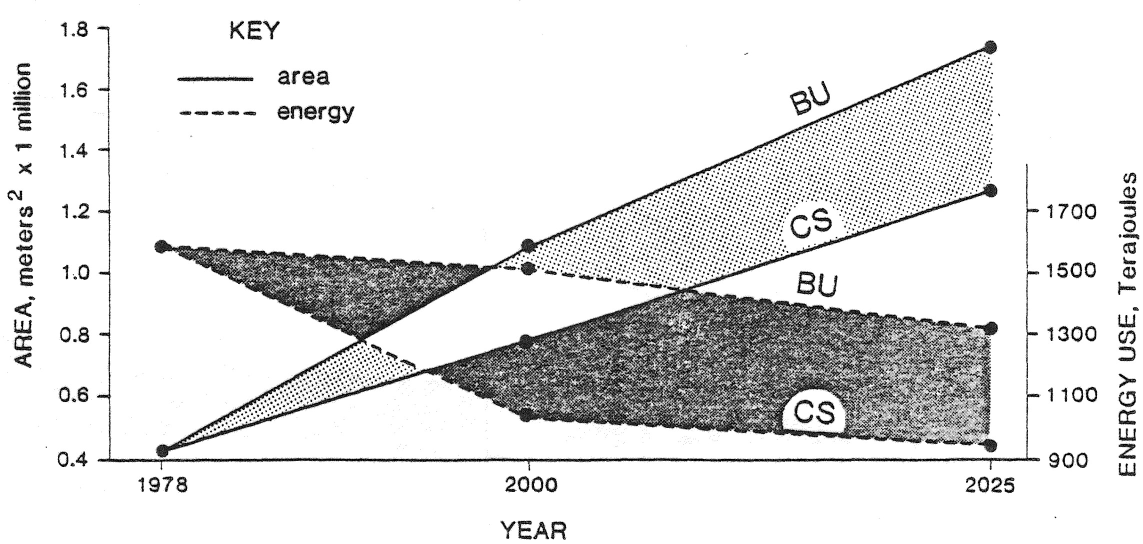


Figure A-6 Yukon Commercial sector total area and energy use projections: 1978-2025, after Hodge and Ehrlich, 1983.

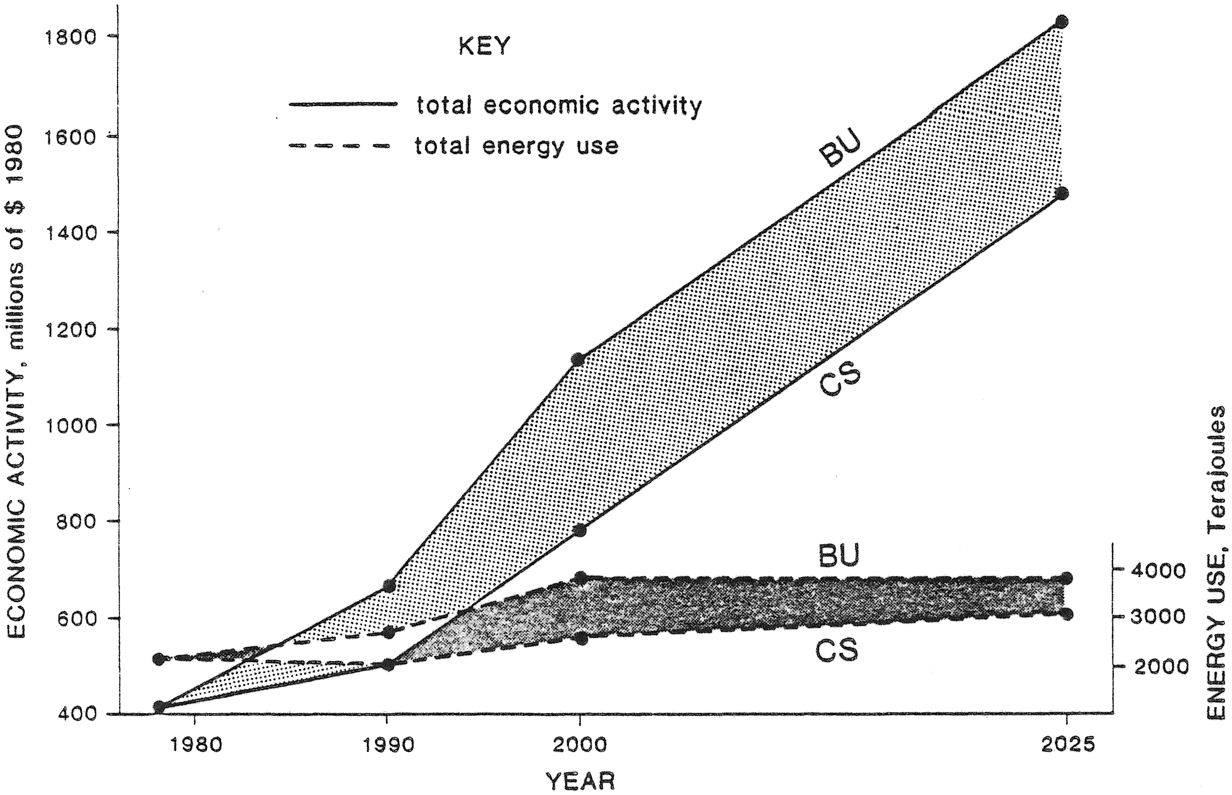


Figure A-7 Yukon industrial sector total economic activity and energy use projections: 1978-2025, after Hodge and Ehrlich, 1983

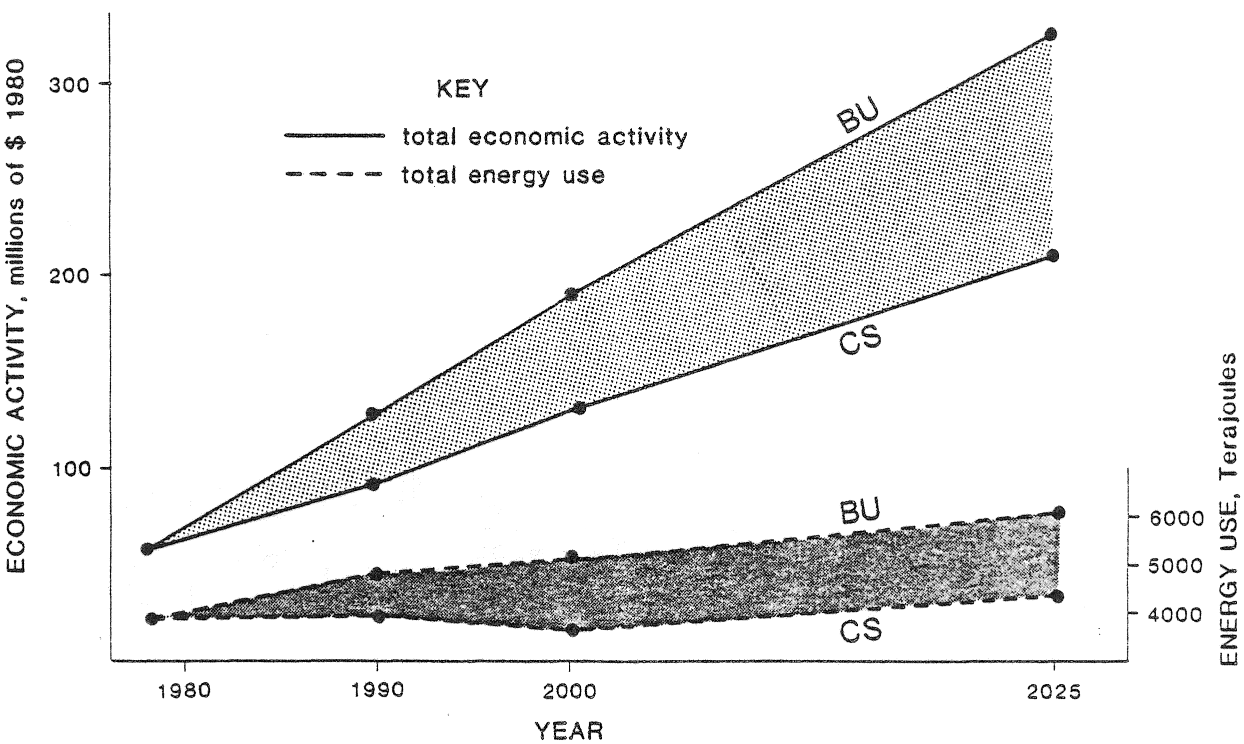


Figure A-8 Yukon transportation sector total economic activity and energy use projection: 1978-2025, after Hodge and Ehrlich, 1983.

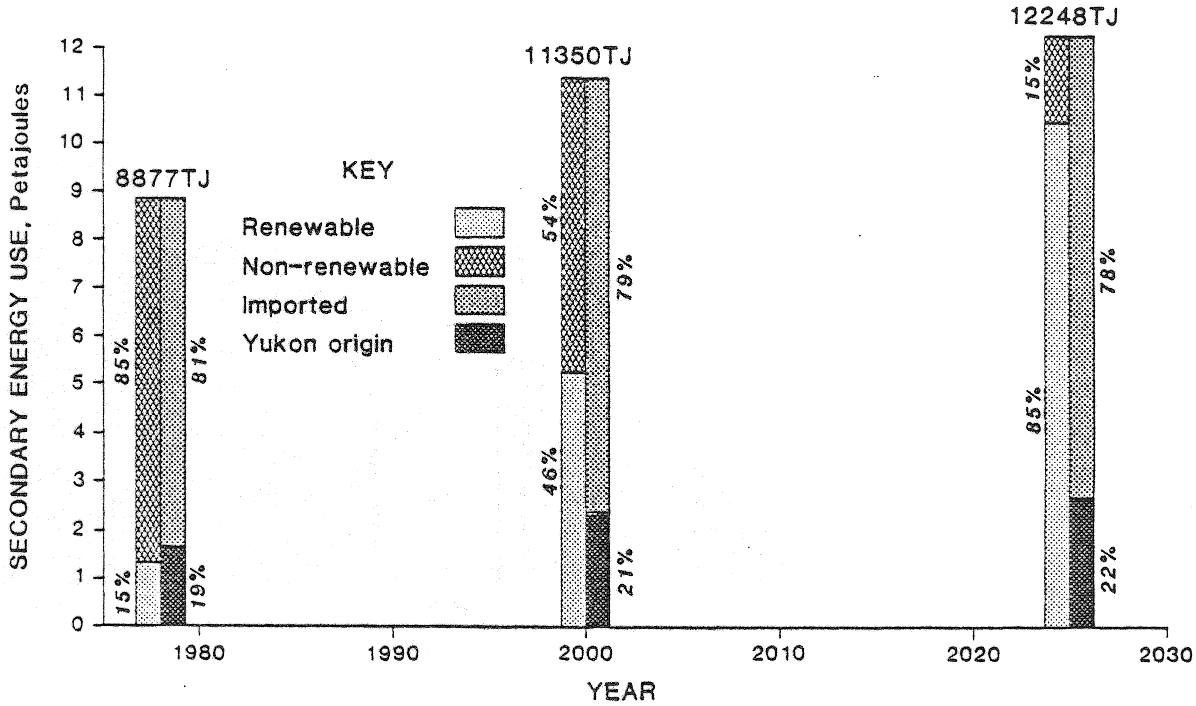


Figure A-9a Business-as-Usual Scenario

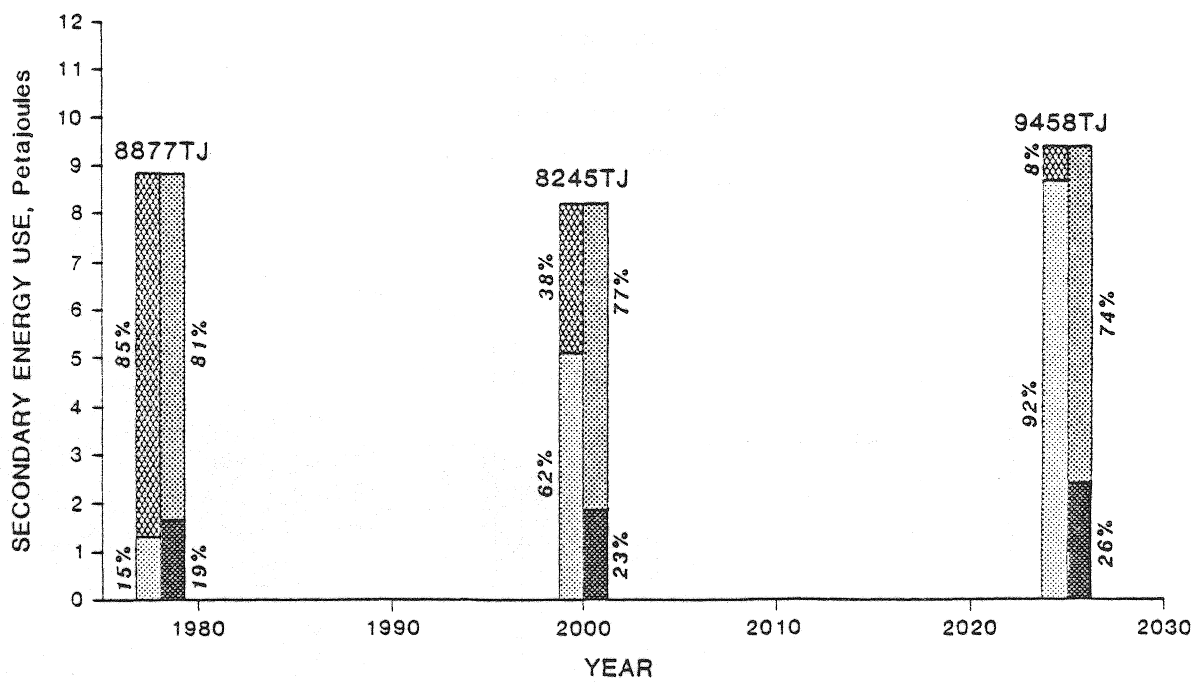


Figure A-9b Consumer Saturation Scenario.

Figure A-9 Projected changes in the proportion of Yukon-produced and renewable energy: 1978-2025, after Hodge and Ehrlich, 1983.

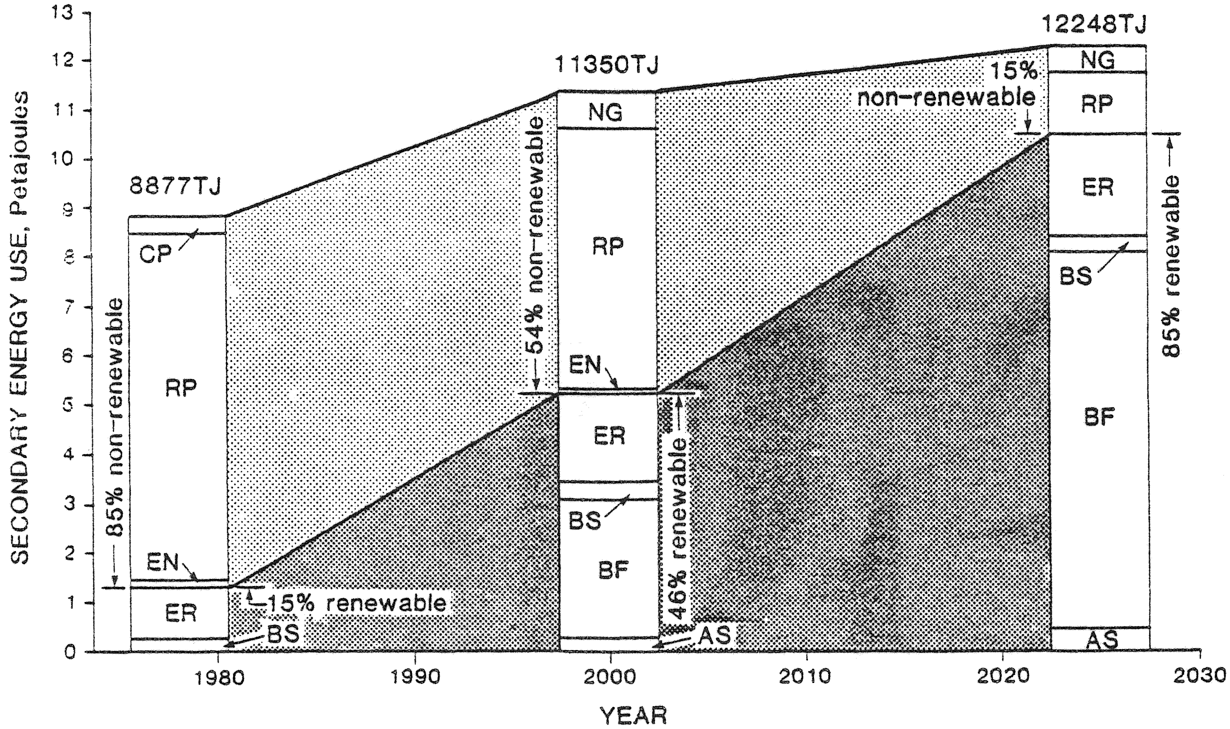


Figure A-10 Yukon Secondary Energy Use.
Business-as-Usual Scenario: 1978-2025,
after Hodge and Ehrlich, 1983

KEY

CP - coal and peat	NG - natural gas
RP - refined petroleum products	BS - biomass solids
EN - electricity non-renewable	BF - biomass fluids
ER - electricity renewable	AS - active solar

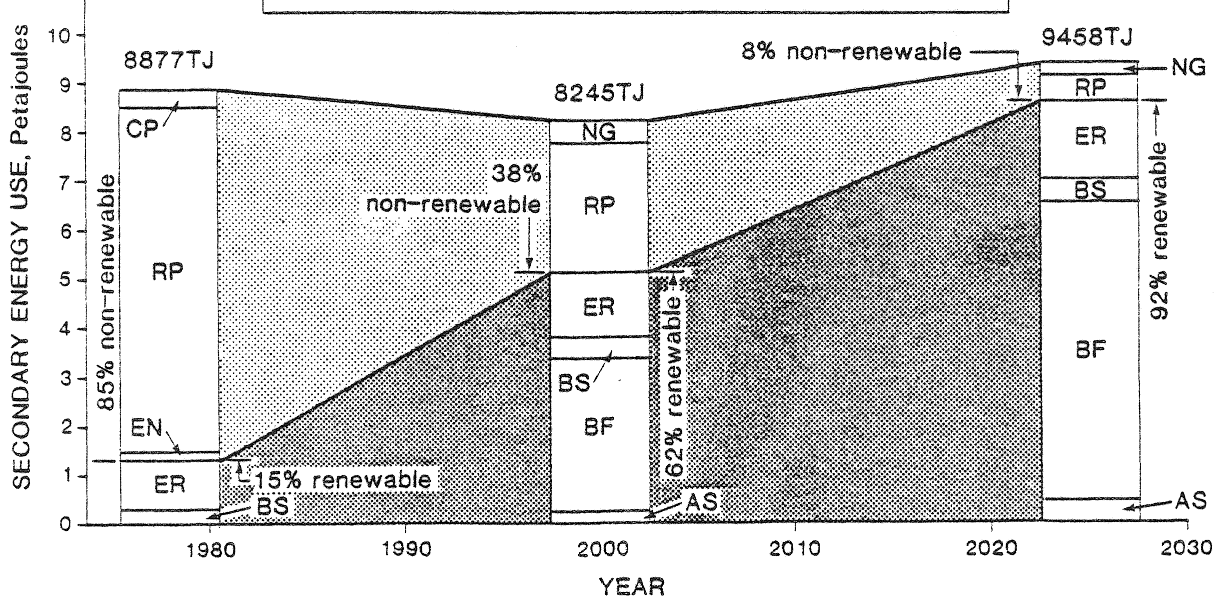


Figure A-11 Yukon Secondary Energy Use.
Consumer Saturation Scenario: 1978-2025,
after Hodge and Ehrlich, 1983.