# *Energy Demand And Supply In The Northwest Territories*
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# Energy Demand and Supply in the Northwest Territories

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# SUMMARY

## Energy Demand and Supply in the Northwest Territories

This study examines energy demand and supply patterns in the Northwest Territories (N.W.T.) as a working paper for the Federal Department of Indian Affairs and Northern Development and the N.W.T. Ministry of Energy. Conceptually, the study is similar to the soft path approach employed by David Brooks in Exploring a Soft Energy Path for the Yukon Territory. It focusses on utilizing cost effective technologies to reduce the anticipated growth of energy consumption and also to develop renewable and small-scale supply sources to meet pro jetted demands.

## Demand Analysis

The study's demand analysis utilizes an N.W.T. Science Advisory Board study, Energy in the Northwest Territories to delineate regional energy demand, by sector , for the designated base year of 1979. Regional demand is projected to )989 and 1999 assuming ten years as the maximum the period for economic developments to affect significantly the energy demand patterns.

Regional demand is pro jetted according to optimistic economic and population growth scenarios. The N.W. T. economy is described as currently being in a low growth stage created , for the most part, by the uncertainty in the mineral and oil/gas industries, the fiscal burden of a petroleum based economy, and the possibilities of government spending restraints. On the assumption that the N.W. T. economy will continue to be characterize by a large government sector, and that possibilities exist to return to a medium growth stage, it is projected that the N.W.T. gross territorial economy will, during the period 1979-1999, grow at a real annual rate of

5.3%. Continued government involvement in the territorial economy is forecast to be complemented by revenue from mining expansion, natural gas and oil development, and forest industry expansion.

Pro j ections of a buoyant economy are reflected in the choice of population forecasts. Of projected N. W.T. low and high population growth rates, the latter is used, although only a few N.W.T. communities (Yellowknife, Hay River, Pine Point, Rankin Inlet and Frobisher Bay) are likely to experience significant increases. The population and economic projections are utilized in region specific pro jection methodologies, all of them described as working papers in the Appendices.

The delineation of 1979 regional demand illustrates that the commercial and transportation sectors dominate territorial energy consumption. Regional breakdowns show that the Fort Smith and Inuvik regions account for 12 thousand tera joules or 52.6% and 22. 0% respectively of the N .W .T.'s total demand of 16 thousand tera joules. Conversion and line losses represent at least 10% of total demand.

A variety of conservation strategies and technologies can reduce territorial and regional energy demand significantly. For existing residential buildings typical conservation measures range from no cost thermostat set-back to $2000 (1981 $) retrofit investments, the latter being a cost effective investment with a pay back of less than four years. Design and demonstration models for new N.W. T. housing reveal that significant energy savings can be realized. In particular, a super-insulated, air-tight, southerly-facing glazed prototype has, in comparison to existing residences, achieved a heating load saving of 95%.

Energy consumption in existing and new commercial units (most of which are small units) can be reduced by airtight design, superinsulated building shells, and passive solar heat gain. Both conservation measures and technologies can be applied in the transportation sector. For example, cost effective devices such as radial tires and aerodynamic drag reduction devices are readily available for use by road vehicles. In the mining sector, conservation approaches in both the mining and milling stage can reduce consumption. Two important measures are peak load management and residual (waste) heat recovery.

Regional energy demand is projected to 1989 and 1999 assuming both a zero conservation and a conservation approach. Consumption projections yield 1989 and 1999 NWT zero conservation and conservation approach totals of 20.5, 13.7 petajoules and 38.1, 22.3 petajoules respectively. AS the region with the most diverse economy and the highest population, Fort Smith represents the greatest challenge to implementing conservation measures. If they were implemented as suggested, the Ebrt Smith 1999 residential energy demand could be less than in 1979. The commercial demand in 1999 could be kept to a level near that of 1979. It is suggested that a conservation approach in the Fort Smith region could result in $91 million and $164 million annual savings for diesel and heating oil in 1999 (1981$).

Implementation of suggested conservation measures would affect an actual 1979-1999 decrease in the Cambridge Bay, Inuvik, and Keewatin regions' total demand. In these regions, as well as in the Baffin region , reductions in residential and commercial demand are the main reasons for the total demand decrease.

Despite the significant demand reductions that can be achieved, totai N.W.T. energy consumption is projected to increase by 39% to 1999. This results primarily from optimistic assumptions about growth in the mining and transportation sectors and conservative assumptions for demand reduction possibilities in these sectors. The demand analysis reveals that economic growth does not have to be sacrificed because of conservation strategies.

It is recommended that energy and socio-economic data limitations be addressed as a prerequisite to further evaluation. It is also recommended that the N.W. T. government develop an economic forecasting model(s) and that it assess the various conservation options for their economic feasibility. In this context, it is suggested that real, as opposed to subsidized, energy prices be used in assessing potential conservation savings. In addition, it is suggested that the N.W.T. government take advantage of existing federal energy services and programs to foster the application of conservation measures. Finally, it is recommended that the N.W.T. government integrate the goals of community economic development and employment with housing rehabilitation and construction needs.

Supply Analysis

The study's supply analysis describes both non-renewable and renewable domestic supply sources that might alter supply patterns in a manner reducing petroleum fuels inputs to electricity and space heating requirements. Residual heat energy is selected as a supply source because it represents a fairly constant energy by-product of the N.W.T.'s mining and electricity industries. As much as 978 terajoules of energy has been identified in a Yukon/N.W.T. residual heat stream ranging in quality from radiation to 815°C.

The concept of energy cascading is introduced as a means of utilizing 100% of the residual heat stream. To date, studies and actual demonstrations indicate that "mini" - district heating using heat recovered from N.W.T. diesel-electric generating units is an achievable near term option. Combined jacket and exhaust gas heat recovery results in overall plant efficiencies of 75% and distribution temperatures appropriate to community infrastructure.

Various perspectives of actual residual heat potential are examined. At least 52% of the heating requirements for communities selected in one study can be met by district heating. Other work suggests that combined jacket and exhaust recovery is already cost effective with pay back periods of less than five years. Based on the conversion and line losses identified in the demand analysis, it is estimated that 13.4% of the N.W.T. commercial sector's demand can be met by residual heat. Finally, it is evident from mine heat reclamation efforts at Can Tung and Nanisivik that the mining sector as a whole could utilize a significant residual heat source.

Natural gas is described as potentially an assured supply source and a cost competitive alternative to conventional sources. Four factors, reserve capability, marketing, proximity of demand centres to supply, and costs have, in addition to political concerns, a bearing on potential gas utilization. Calculations suggest that less than 1% of the Mackenzie-Beaufort and mainland reserves (as estimated to 1979) would be needed to meet Fort Smith and Inuvik regional space heating demand to 1999. A perusal of natural gas well prospects revealed that some wells are as close as 26 km to existing demand centres.

Natural gas development for domestic use can be realized by utilizing export pipeline laterals or by developing site specific infrastructure. The latter option is explored for the town of Inuvik, resulting in projected delivered gas costs of $6.71/mcf for one location and $8.65/mcf for a second site (1980$). At a delivered cost of about $65,000 per residential customer it seems preferable to explore the pipeline lateral option estimated at $7957 per customer.

Natural gas can be used to meet both electricity and space heating requirements. The development of mini-district heating or total energy systems indicates that natural gas can be consumed to produce electricity and heat at a 90% 1st law conversion efficiency. In the long term, compressed natural gas might be used as a transport truck fuel.

Although coal is currently not mined in the N. W. T., the Fort Smith and Inuvik regions have several identified seams. One recent study concludes that the greatest possibilities for coal utilization are in some of the Arctic coast communities above the tree line. Coal could be used for residential and commercial heating in forced-air furnaces, stoking furnaces, and fluidized-bed combustion units. A number of environmental impacts associated with coal development are identified including the potential carcinogenity of certain types of organic matter emitted by combustion.

Hydro electricity is described as a renewable source appropriate to all N.W.T. regions. It is noted that existing load demand, primarily in the Fort Smith region could increase substantially as a result of mining and forestry development and pipeline electrification needs. Electricity supply to date is identified as 128 MW installed capacity. 'Ibis is about 3% of the identified potential hydro sources in the territory.

The extent and type of hydropower to be developed is contingent on a number of variables. The technical achievement in realizing the potential of a selected river is often limited by low terrain and site flooding. This in turn increases the costs of development. Despite certain cost advantages of large scale development, it is suggested that only small scale and micro-hydro are suitable to N.W.T. requirements.

Micro-hydro, i.e. hydro development of $\leq$ 5 MW capacity, can meet most load requirements and can also be used to divert water into existing power sites. Equipment is proven with no expected limitations from winter freeze-up. Site specific capital cost estimates vary from 39 roils to 550 roils per installed kw. It is suggested that the economic feasibility of much micro-hydro is contingent on higher production volumes of North American low and medium head turbines, near-term price escalation of conventional fuel., and accelerated depreciation of equipment. Rapid depreciation for equipment is supported by recent tax incentives from the Federal government.

Wood or forest biomass is an important untapped renewable resource in the N.W. T. To date, wood biomass accounts for about 99% of the Canadian biomass fuel supply. De spite significant information deficiencies that are only now being slowly rectified, it is possible to estimate some of the N.W.T. forest biomass potential. Forest land in the N.W.T. is confined mainly to the Inuvik and Fort Smith regions with the most productive land located on the alluvial plains of the Mackenzie River valley and basin.

To date, an annual maximum of 17.6 million $m^3$ of lumber and piles have unharvested but new development indicates a potential of 24 million $m^3$. Fuelwood production has averaged about 7000 $m^3$ annually with a maximum of 17,833 $m^3$ or 0.14 petajoules, shut 24% of the projected 1989 conservation scenario heating demand for the Inuvik and Fort Smith regions. Calculations using methodologies that encompass total biomass utilization are used to derive the total N.W.T. forest biomass energy potential. A potential of 18.7 petajoules is estimated. Factors such as commercial production and ecological constraints suggest that only a small percentage of 18.7 petajoules is actually harvestable. Nevertheless, 5% of 18.7 PJ or .93 PJ is 1.6 times the projected 1989 space heating demand (conservation) of the Fort Smith and Inuvik regions.

Combustion and gasification to meet space heating and electricity requirements appear to be the conversion technologies most appropriate to the territory. Avariety of stoves and furnaces exist that can burn wood, wood wastes, and chips. Chip burning is noted to have several technical and economic advantages but one study suggests that labour costs are still prohibitive.

Gasification is being evaluated as both a space heating and electricity supply by the federal government and a number of provincial governments. The more feasible gasification technology appears to be fluidized-bed systems.

There are a number of factors that can alleviate the development of forest biomass in the N.W.T. They include inter-governmental cost sharing, conventional fuel price increases, and tax incentives the latter being included in recent Income Tax Act revisions that allow for rapid depreciation of biomass equipment.

Despite a very small agriculture base, the N.W.T. (the Fort Smith region) has a significant area of Class 2 to Class 5 land capable of growing oats, barley and forage crops. Since a livestock industry is likely to be hampered by transportation costs and high incidence of disease, it is suggested that the land be developed for agriculture biomass production, either from the main crop or from waste, suitable to meet limited space heating requirements.

Although fuel peat is recognized by one study as a superior fuel to coal and wood, extensive date on its potential in the N.W.T. is limited . Nevertheless, the identification of peat along the Mackenzie River flood plain warrants follow-up evaluation.

Geothermal reservoirs have been identified in the Fort Smith Inuvik regions. Depending on the heat potential of the reservoirs, geothermal energy may be able to meet limited residential and commercial space heating and electricity requirements.

Continued research and development suggests that large vertical axis wind turbines (e.g., 200 kW) may, in the near-future, provide limited electricity requirements. Life-cycle cost estimates have indicated that despite high $/kw installed costs, diesel-wind systems are currently cost competitive with diesel-diesel. A recent study suggests that the most efficient linking of wind and diesel units would involve wind supplying mechanical power to the diesel generator.

Despite periods of little or no sunshine, solar energy can to some extent, be utilized in the N.W.T. In fact, passive solar design is shown to be an important component in the energy efficient prototypes described in the demand analysis. Active solar systems appear to be suitable for hot water heating. It is noted that an important factor likely to enhance the feasibility of wind and solar supply is the development of seasonal storage mediums.

It is recommended that significant effort be made to develop canprehensive inventories of all potential supply alternatives to be followed up by site specific evaluations. Within such a context, it is recommended that the NWT government continue to utilize existing renewable programs. Given the costs likely to be necessary for such endeavors, it is suggested that continued analysis focus on the question of utilizing potential hydrocrabon revenues.

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Energy and Melanie Phillips of Ottawa.

## 1.0 Introduction

The purpose of this study is to examine current and expected energy demand and supply patterns in the Northwest Territories (N. W.T. ). The report, in essence, is an information base and as such is important to N.W.T. policy development in two respects. First, energy planners need data from which to base their decisions. This report is an attempt to fill a most elementary void in such a data base, a task that must be completed before energy planning can be carried out comprehensively, i.e. to include the long-term. Second, the report provides enough of a picture to suggest some policy options to those concerned with the N.W.T.'s future. In this context, the report hopes to be a working paper for both the Department of Indian Affairs and Northern Development. (D.I.A.N.D.) and the N.W.T. Ministry of Energy.

## 2.0 Study Perspective

Conceptually, this report is similar in nature to David Brooks', Exploring a Soft Energy Path for the Yukon Territory, completed in March 1980 for D.I.A.N.D. (hereafter known as the Yukon Report). More specifically, the demand and supply components to this report attempt to encompass some of the basic elements to the "Soft Path" approach.

Demand projections include a conservation scenario based on soft path criteria encompassing the efficient use of energy. (See the Yukon Report pp. 1-4 and Appendix A.) "Efficient", in this case includes economic and thermodynamic variables as well as the objective of minimizing social and environmental consequences.

The supply component, while not as empirically comprehensive as the demand side, examines the potential of both non-renewable and renewable energy resources, the former as a transitional supply source, the latter as an ultimate supply source in a "stable" energy future. No matter what name or classification is given to the Soft

Path approach, it merely reflects the growing realization that conservation strategies and technologies and the efficient (economically/thermodynamically) application of renewable energy resources are perhaps the most realistic way to secure a stable energy future.[1]

Structurally, this study is divided into three components. Section 3 describes the N.W.T. economy. Sections 4 to 7 encompass the Demand analysis. Sections 8 to 20 encompass the Supply analysis.

## 3.0 N.W.T. Economy

As described in the Yukon Report, an understanding of the economic performance of the territory's consuming sectors (e.g., residential, commercial, mining) can serve as a basis for projecting energy demand . For example, the projected rate of energy demand of a particular sector has been directly correlated to projected economic growth. 'Ibis section, in describing some aspects of the N.W.T.'s economic sectors, does keep in mind, that:

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1 Energy, Mines and Resources Canada, The National Energy Program (Ottawa: E.M.R., 1980), pp. 65-77. The Federal government, as part of its national energy strategy not only recognizes the need for the North to reduce its dependence on oil, but in a manner that accepts the social and environmental fragility of the regions. As well as supporting various conservation and renewable energy initiatives, the report recognizes the potential of long-term soft path type forecasts in helping to determine energy futures.

See also:

Graham T. Armstrong, Director, Conservation - Conservation and Renewable Energy Branch (C.R.E.B.), E.M.R. Canada, Conservation Energy - Potential and Practice in Canada, a paper presented to the Saskatchewan Government - Office of Energy Conservation, Observation Energy Seminar Series, June 24, 1980.

Peter Hart, N.W.T. Ministry of Energy, Energy Alternatives for the Northwest Territories, a report to the Special Committee on Alternative Energy and Oil Substitution, 1980, pp. 3-6.

i) many economic trends cannot be examined to the detail prevalent in other reports; and

ii) certain features of the discussion are, where relevant, repeated in Appendices II to VI regional demand analyses.

## 3.1 N.W.T. Economy: Past, Current, and Expected Trends

Although a detailed assessment of N.W. T. economic trends is beyond the scope of this section, it is possible to highlight some of the more notable sectoral trends. Data from the recently published "Economic Accounts of the N.W .T. " illustrate economic sectoral performance for the period 1967-1977 and provide a basis for somewhat tenuous forecasts of performance.[2,3] As well, character istics of sector performance may suggest trends in energy demand .

One of the more common indicators of economic growth, the Gross Territorial Product (G. T.P. ) shows that the N.W. T. economy, during the 1967-1977 pericd, grew at a more rapid rate than Canada as a whole. This is somewhat misleading, however, because this period was characterize by a high to low growth shift. The 1967-1973/74 period was characterized by growth and development in the government, mining/o il and gas, and commercial sectors. The 1973/74 - 1977 period was characterized by:

i) a decline in oil and gas activity; "

ii) the beginning of "restraint" in government spending;

iii) the burden of oil price increases exacting a greater share of the annual N. W.T. governmental budget.

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2 Mary Pavich, Data Management Division, Northern Economic Planning Branch, D. I.A.N. D., Economic Accounts Northwest Territories (Ottawa: D. I. A. N.D.), Table 23.

3 See also: Ronald Fournier, Regional Analysis Branch, D. R.E. E. Western Region Headquarters, Economic Circumstances in the Northwest Territories (Regina: D. R. E. E., [1979] ) , p.20.

During this period the N.W.T. economy grew at a rate less than the Canadian norm.

The combination of both high and low growth periods translated into what N. W. T. economists suggested was a "medium" growth period. A perspective of some of the individual economic sectors may shed light on whether or not this growth trend will change.

The mining/oil and gas sector can influence energy demand in the following ways:

i) it has directlv been the major turbo and aviation fuels consumer (See Appendices II to VI) ;

ii) it has directly led to a variety of infrastructure development including roads, service bases, and lodging;

iii) it has directly led to exploitation of N.W. T. hydro resources;

iv) it has indirectly led to both public and private commercial sector expansion; and

v) it has indirectly led to both public and private residential expansion.

The mining/oil and gas sector continues to be the largest contributor to the Territorial G.T. P. , although its percentage share dropped from 45% to 32% over the ten year per iod. Currently, there are seven producing mines in operation (See Table 1) . Al though the extent of mineral development is a function of world prices, it is expected that a number of mines will come on stream in the next 20 years, especially to produce gold and uranium.

Oil and gas production is presently confined to the Norman Wells field (oil) and the Po inted Mountain field (gas) . Ne i ther development appears to affect energy demand to any great extent, both being pr imarily export oriented. (figure 1 illustrates that Norman Wells oil is distributed through the Inuvik region. ) In

TABLE 1

PRODUCING MINES: 1979 ENERGY DEMAND [a]

FORT SMITH REGION

| | Prod[illegible] | Capacity [illegible] | Type of Mine and Source of elec. generation | Elec. Demand MWh | TJ | Diesel elec. gal. | TJ | Diesel motive gal. | TJ | Heating Oil gal. | TJ | Gasoline gal. | TJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pine Point | Pb, Zn | 7,800-11,000 | Open Pit, NCPC Hydro & Diesel | 105,194 | 381 | 285,000[b] | 50 | 1,630,523 | 287 | 28,523 | 5 | 73,098 | 11 |
| Con-Rycon[c] | Au, Ag | 650 | Underground, NCPC Hydro and Diesel | 31,352 | 112 | 80,000 | 14 | 345,570 | 61 | 700,000 | 133 | 39,549 | 7 |
| Giant | Au,Ag | 1250 | Open Pit Underground NCPC Hydro and Diesel | 35,257 | 127 | 470,000 | 83 | 670,813 | 118 | 700,000 | 133 | 76,772 | 13 |
| Terra[d] | Cu,Ag,Bi | 200 | Underground, Terra Mining Diesel | 6,200 | 22 | 418,770 | 74 | 105,276 | 18 | 3,410 | .6 | 0 | 0 |
| Echo Bay | Cu,Ag | 120 | Underground, Eldorado Diesel | 3,800 | 14 | 256,666 | 45 | 64,524 | 11 | 2,090 | .4 | 0 | 0 |
| Can Tung[e] | W | 500-907 | Underground, Canada Tungsten Diesel | 23,000 | 83 | not available | | 124,128 | 22 | 199,268 | 35 | 20,833 | 3 |
| TOTALS | | | | 181,803 | 656 | 1,510,436 | 266 | 2,940,834 | 517 | 233,291 | 41 | 210,252 | 34 |

BAFFIN REGION

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nanisivik | Pb,Zn, Ag,Cd | 2400 | Underground Strathcona Minerals Diesel | ≤ 550 | 24 | 443,181 | 78 | 168,313 | 30 | 1,099 | .2 | 52,513 | 8 |

5

TABLE 1

Sources: 1 N.W. T. Science Advisory Board, Energy in the Northwest Territories

Notes:

a Unless otherwise indicated, the demand data was gleaned from the Science Advisory Board categories of "Comments", "Private", and "Unidentified".

b At the Pine Point mine diesel fuel is used for a variety of purposes including electricity generation, heating buildings, pumping water and lighting.

Diesel fuel used to generate electricity was derived by applying the following ratio to the Pine Point electricity demand:

$$\frac{\text{Total Pine Point (town +mine) diesel-oil input}}{\text{Total electric output.}}$$

Diesel motive demand was derived by assuming that 90% of the commercial demand could be attributed to mine consumption.

Gasoline demand was derived by assuming a 50% allocation to the mine.

c Both the Con and Giant mines have electricity supplied from tie N.C.P.C. Snare - Yellowknife System. Con generated about 25,200 MWh at its Bluefish hydro station. This electricity is fed into the N.C.P.C. system and the mine draws back a comparable amount.

Diesel - electric input was derived using ratios as illustrated above.

Diesel motive demand was distribute between Con and Giant assuming that demand would be a factor of milling (input) capacity.

e.g., Total Mine + Town Demand = 1,129,315 gal.
90% x1,129,315 = 1,016,383 gal.
Giant milling capacity = 66% Total
Con milling capacity = 34% Total

Therefore Giant diesel motive demand = 670,813 gal.
Con diesel motive demand = 345,570 gal.

Both Con and Giant used bunker oil for steam heating. A 50/50 distribution is assumed because the Con housing infrastructure is apparently as large as that of Giant. Note that the Fort Smith sub-total did not include the bunker fuel demand.

It was assumed that 5% of total community gasoline demand could be attributed to the mine. 'Ibis 5% figure results in a figure similar to that of the pine Point demand, an operation comparable in size to the Con and Giant mines combined.

d Energy demand data for the Terra and Echo Bay mines is not disaggregated and assumptions had to be made from the Port Radium data.

Energy disposition between the two mines has been allocated according to their milling capacities, Terra 62% and Echo Bay 38%

Diesel motive demand is derived by prorating from the Con mine e.g.,

$$\frac{\text{Con Mine diesel motive use}}{\text{Milling Capacity}} = \frac{\text{Terra + Echo Bay diesel use}}{\text{Milling Capacity}}$$

Diesel motive was then subtracted from total diesel with the balance adjusted to accommodate non-mine electrical demand from the community.

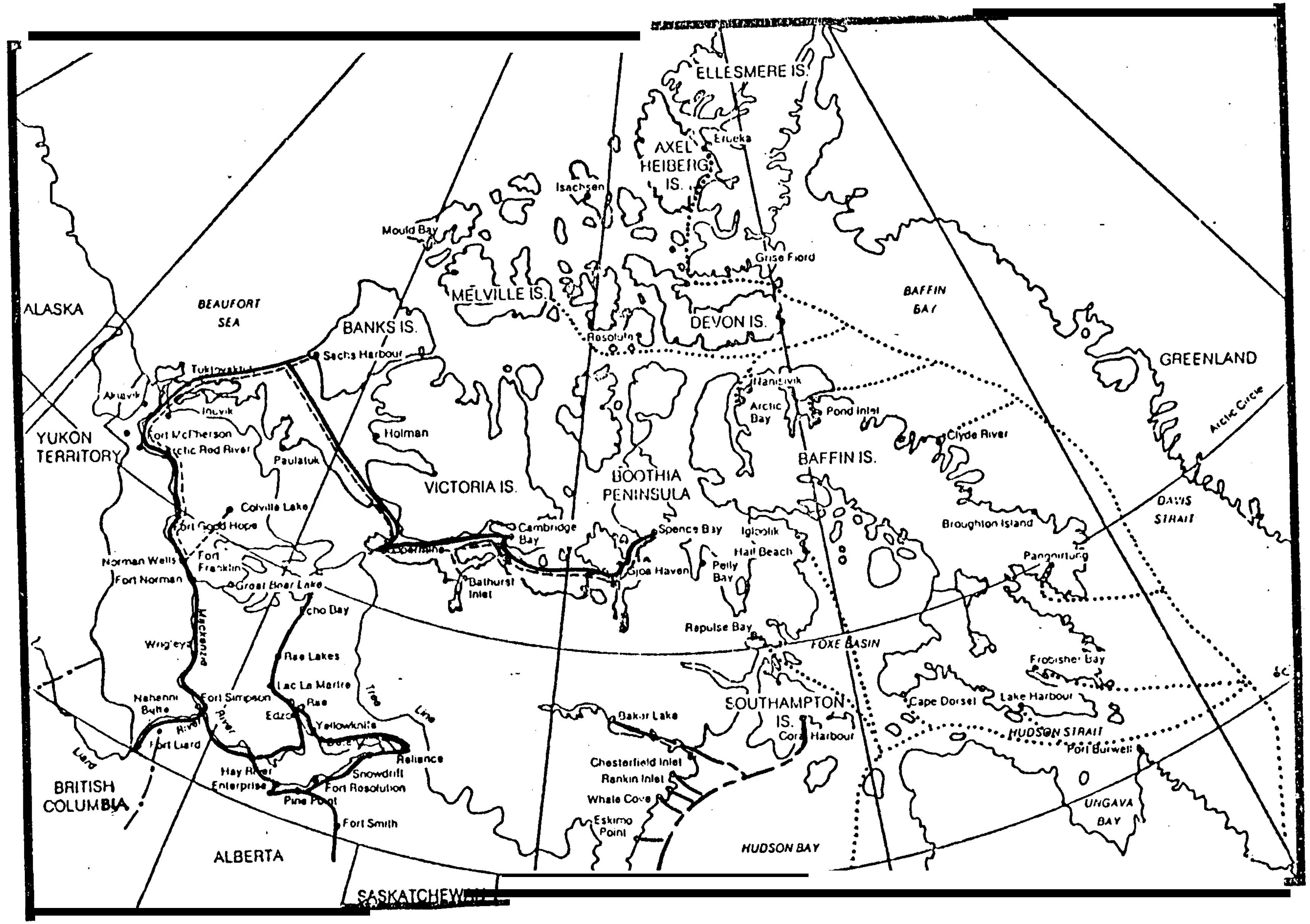
Since non-mine electrical demand was not disaggregated, it was assumed that Port Radium would have a demand comparable to a "similarly isolated" mining community, Nanisivik. The result was adjusted to account for the community's population difference.

Mine diesel - electric demand was derived by subtracting diesel motive and non-mine diesel-electric demand. Port Radium heating demand was derived using a proration method similar to the derivation for electricity demand.

e The Canada Tungsten mine, although situated in the N.W.T. is serviced by the Yukon and electricity is generated in the Yukon (see Brooks' Report, p. 48). Since there was no disaggregate heating fuel demand, Tungsten was compared to Nahanni Butte as a living environment, the latter community's demand was prorated.

It is assumed that 90% of gasoline demand can be attributed to mine use.

**FIGURE 1. DISTRIBUTION OF PETROLEUM PRODUCTS IN THE NORTHWEST TERRITORIES**




| LEGEND: | | | |
|---|---|---|---|
| ———— | From Edmonton | — - — | From Churchill |
| ……………… | From Montreal | —.—. | From Fort Nelson |
| - - - - - - - | From Norman Wells | | |

SOURCE: Government of the Northwest Territories Science Advisory Board, Energy in the Northwest Territories (Yellowknife: S.A.B., Nov. 1980), pp.7-11.

Appendix IV, it is suggested that the Norman Wells pipeline development may contribute, slightly, to the Inuvik region's residential sector demand.

Although merely conjecture at this stage, it is expected that three oil and gas developments will come on stream by 1999: the Arctic Islands, Beaufort Sea, and MacKenzie Delta fields. Even if these fields are developed, however, the ef feet on the N. W. T.'s economy and on sectoral energy demand may be minimal, especially if oil and gas are transported by tanker. Because of this uncertainty, the demand projections for the Inuvik, Cambridge Bay and Baf f in regions did not include oil and gas development assumptions.

See Appendix I for further discussion of mining development and expected energy demand.

Despite its importance to the N.W.T. economy, the mining/oil and gas sector is still an export economy, i.e. most of the market value output is exported outside the territory. Conversely, the government sector, which accounts for at least 55% of total N. W. T. wages and salaries, is a non-export sector, greatly affecting personal income and subsequently consumer goods/services and housing.4

The government sector grew steadily from 1967 to 1977 (public administration and defence grew at a real rate of 7.3% per year) and put simply, is along with the primary resource sector, the major influece on commerce, transportation and the residential sector.

Government spending is closely interwoven with the commercial sector; in fact, public administration and defence is a category of the commercial sector according to the "Economic Accounts".

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4 Dan Westman, Economic Planning Secretariat, Planning and Resources Development Division, Department of Economic Development and Tourism, The N.W.T. Economy Interim Report 1967-1977 (Yellowknife: N.W. T. Gov. , 1980).

Other than in the Ebrt Smith region, the commercial sector is, for the most part government operated. While some communities in the other regions serve as pr imary resources development staging areas, commercial development has consisted mainly of military and telecommunications servicing, and government social services infrastructure e.g. , schools, medical units, and retail goods outlets. In the Fort Smith region, commercial development has been dominated by the private sector, in the form of services and commodity distribution centres e.g. , Hay River as a marine and rail staging area.

According to the N.W .T. Economic Planning Secretariat , construction activity during the 1967 -1977 period shifted from rapid commercial development to greater activity in hewing. This shift appears to be due, in part, to an "overexpansion" of private sector commercial space combined with a greater role by the N.W. T. Housing Corporation (N. W. T.H.C. ) in the housing market. The N.W. T. H. C., established in 1974 has actively sought to provide suitable and affordable housing to all N.W. T. residents. Although the residential sector has only minimal importance on the N.W .T. economy (in terms of wages, salaries and output), the trend towards greater government involvement may have important ramifications on energy demand (See Section 6) .

Pr imary resource development and the expansion of government services are both dependent, in part, on appropriate infrastructure, a major component of which is transportation networks. For example, in the Fort Smith region, road transportation is integral to the movement of goods, passengers and mineral concentrates. As noted in Appendix II a number of road projects could "open up" untapped resource areas and thus affect future energy demand.

Forecasting economic performance over the next 20 years would be a difficult task for most economies. For the N.W.T. it is especially difficult given the susceptibility of this fragile economy to external forces e.g. , federal policy, and world metal and hydrocarbon prices. Moreover, such economic fragility would need the outlook of a myriad of scenarios, perhaps in the form of computer belling e.g. , the Yukon Economic Resource Planning Unit (E.R.P. U. ) forecasts used in the Yukon Report. Nevertheless, as described in Appendix I, certain aspects of the demand projections are based on economic forecasts.

Deriving a factor from which economic projections can be made depends on the selection of a sector or sectors of the economy that are likely to typify the expected N. W. T. perf ormance. Although mining/o il and gas is a major economic sector , it was decided to use government trends as an indicator for the economy as a whole. This is because economic trends in the government sector may more closely correspond to historical trends than the highly variable primary resource sector. Moreover, if the N.W. T. private sector experiences low growth, it is likely that government input will attempt to "stabilize" the economy.

As previously mentioned, government output under the category of public administration and defence grew at an annual real rate of 7.3%. It is assumed that this growth rate was a reflection of the previously suggested medium growth period of 1967-1977. It is further assumed that 1979 to 1999 will be a period of medium growth. More specifically, expected N.W. T. revenues from primary resource developments will be offset by increasing energy costs (at least until the late 1980's) and possible government spending restraints. Therefore, it is suggested that the historical growth rate of public administration and defence represent the government expectation of the N.W. T. economy. Rather than an annual real. rate of 7.3% (14% unadjusted - 7% inflation), it is suggested that the expected 1979-1999 medium growth rate will be 5.3% (14% unadjusted - 9% inflation).

While the medium growth forecast appears optimistic, it is not an impossible achievement. As Ronald Fournier of the Department of Regional Economic Expansion suggests, the "territorial economy can be best described as being in a temporary hold position".[5] For the economy to transcend this position, the primary resource sector must overcome the constraints of high energy costs, lack of infrastructure, lack of local markets, high transportation costs and native land claims negotiations. As well, the N.W.T. government will have to counter the trend of spending greater budget proportions on energy supply.

## 4.0 Energy Demand in the N. W. T.:

The objectives of the Demand component are to:

i) disaggregate energy consumption by N. W. T. region;

ii) illustrate energy consumption by form and sector; and

iii) project regional consumption to 1999 using zero conservation and conservation scenarios.

### 4.1 Disaggregating Energy Consumption Data

Solving energy demand and supply problems in the N.W.T. is a major challenge given such factors as: low population density, cultural differences, climatic and physiographic differences, natural resource base and income. Table 2 suggests some possible implications in applying energy strategies to two different N.W. T. regions. Figure 1 illustrates that a major factor contributing to the regional differences is the diversity of fuel supply routes, a diversity that has contributed to unequal delivered fuel costs.

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5 Ronald Fournier, Economic Circumstances in the Northwest Territories, p. 92.

TABLE 2

COMMUNITY CHARACTERISTICS THAT MAY INFLUENCE N. W. T. RESIDENTIAL CONSERVATION STRATEGIES: A YELLOWKNIFE - CAMBRIDGE BAY COMPARISON

| CHARACTERISTICS | DESCRIPTION | | POSSIBLE IMPLICATIONS FOR CONSERVATION STRATEGIES |
|---|---|---|---|
| | Yellowknife | Cambridge Bay | |
| Climate and Physiography | 8593 degree days (°C) below continuous permafrost and tree lines. | 11900 degree days (°C) above continuous permafrost and tree lines. | Extreme cold and long periods of no sunlight have necessitated long periods of indoor habitation in Cambridge Bay. Therefore per household energy demand is likely to be higher and perhaps more difficult to alter. However, retrofit options may result in more substantial savings for Cambridge Bay residents. The retrofit steps are likely to include more structural problems e.g., structural damage resulting from improper construction techniques on continuous permafrost. |
| Culture, Ethnicity and Income | 0.9% Inuit, 9.5% Indian, 89.6% Other Per capita income $8027. | 76.8% Inuit, 1.0% Indian, 22.2% Other Per capita income estimated at $3000. | Cultural and ethnic characteristics have molded particular habits and traditions regarding habitat and the environment. It is likely that Cambridge Bay residents feel differently and pursue different lives than their southern counterparts. Moreover, Cambridge Bay residents have probably a varying psyche towards household and appliance usage, i.e. their attitudes and behaviour towards energy conservation will vary from their southern neighbors. Finally, Cambridge Bay residents are caught in the squeeze of cultural adaptation to European market economies and housing, while exhibiting substantially lower incomes than their souther neighbors. |

| CHARACTERISTICS | DESCRIPTION | | POSSIBLE IMPLICATIONS FOR CONSERVATION STRATEGIES |
|---|---|---|---|
| | Yellowknife | Cambridge Bay | |
| Housing Type and Market | a mixture of single detached dwellings (37%), single attached (10%), apartments (34%), and mobile homes (17%).<br><br>Market is a mix of NWT Housing Corporation, NWT and Federal staff housing, Municipal, and private owned units. | primarily single detached.<br><br>primarily NWT Housing Corporation units. | While perhaps debatable, it is likely that the energy efficiency of residential construction is a factor of the housing ownership. Yellowknife's market is mixed. While neither private nor public controlled construction is bound by enforced building standards (theremal efficiency) it is likely that a public housing corporation such as the N.W.T.H.C. can proceed with a comprehensive policy and plan to retrofit existing homes and develop thermally efficient new homes. Cambridge Bay, with a relatively homogenous housing stock controlled primarily by the N.W.T.H.C., is perhaps an easier setting for conservation strategies. |
| Expansion of the Housing Stock | Housing development is affected by both government spending and primary resource development. | Housing development is affected by government spending. | See Description bo |

Sources:

1. N.W.T. Government Statistics Section, Population Projections Methodological Report N.W.T. 1978 to 1988 (Yellowknife: N.W.T. Gov. Statistics Section, 1979), p.31.
2. N.W.T. Government Planning and Resource Development Division, N.W.T. Statistical Profile 1980.
3. Statistics Canada, 1976 Census of Canada: Dwellings and Households.
4. Canada Mortgage and Housing Corporation and N.W.T. Housing Corporation, Housing and Northern People, 1979, pp. 99, 100.

Recognizing the diversity of its regions, the N.W.T. government has embarked on a policy of decentralizing political administration, and to a certain extent, policy formation. This decentralization process includes the possible establishment of regional energy managers to advise on both in-house and private sector energy matters.

In view of the present N.W.T. Government's political and administrative focus, it was recognized that for energy data to be useful, it had to be disaggregated according to the five N.W. T. political regions: Fort Smith, Inuvik, Keewatin, Baf f in and Cambridge Bay (the latter in the process of being recognized as a region) . In this context, one source of information for the Demand component was the N .W .T. Government's Science Advisory Board (S. A. B.) study, Energy in the Northwest Territories, released in November, 1980. The report illustrates current energy consumption by sector and form for each N. W. T. community and region. Despite its informational deficiencies (See Appendix VIII) it is an excellent attempt to overcome severe data deficiencies.

### 4.2 Energy Demand Projections: Appreach and Methodology

The data from the S. LB. report is utilized to establish 1979 as the base year for projections. It should be noted that some electricity consumption data from fiscal 1978-79 was assumed by the S.A.B. as 1979 demand. The 1979 base year illustrates energy consumption by sector and form, thereby presenting a picture of end-use demand as a basis to discussing supply alternatives.

Using 1979 as the base year, energy consumption is projected to 1989 and 1999 using two scenarios, Zero Conservation and the Conservation Approach. The choice of 1989 and 1999 as end points in the projection is based, in part, on the susceptibility of the N.W.T. economy to fluctuations in primary resource development and/or government spending. The ten year cut-off suggests that the N.W.T. economy is likely to exhibit major changes over such a period, changes that ultimately affect energy demand.

As previously noted, conservation is now recognized as a likely route in diffusing the negative impacts of a petroleum dependent economy. Conservation, as noted in the Yukon Report (p. 32) can involve such approaches as:

i) reducing inputs to get the same outputs, i.e. pure efficiency gains;

ii) changing the pattern of inputs; and

iii) changing the pattern of outputs e.g., system modifications such as transit systems.

The extent to which conservation technologies and concepts are applied depends on policy, and at this juncture is speculative in nature. Therefore energy demand to 1989 and 1999 can be presented as though little or no conservation effort will be made in any of the consuming sectors, i.e. the Zero Conservation Approach; or demand can be presented as a function of selected conservation approaches, i.e. the Observation Approach. Using these two scenarios presents a spectrum from which choices can be made.

The methodology used in the demand projections is explained in detail in Appendix I. To serve as a working paper, the Appendix describes the method, information sources and assumptions for each step of the analysis. 'Ibis format not only describes the approach, but illustrates the variables integral to each step. While Appendix I demonstrates the general methodology, each regional projection displays certain variations (see Appendices II to VI), depending on the particular economy and projections for the economy.

403 Energy Demand Projections: Units and Conversions

a. Energy consumption is illustrated in natural units e.g., gallons of fuel oil and MWh of electricity, and in the metric energy units, the petajoule and the tera joule.

1 Petajoule = 1 quadrillion ($10^{15}$) joules
1 Terajoule = 1 trillion ($10^{12}$) joules
" = 5,682 gallons of heating oil
" = 5,682 gallons of diesel oil
" = 6,369 gallons of gasoline
" = 6,1.35 gallons of turbo fuel
" = 6,579 gallons of aviation fuel
" = 278,000 kWh

b. Natural units are converted to energy units using the following conversion factors:

| | | |
|---|---|---|
| diesel oil | : | 1 gal. = 1.76 X $10^8$ joules |
| heating oil | : | 1 gal. = 1.76 X $10^8$ joules |
| gasoline | : | 1 gal. = 1.57 X $10^8$ joules |
| turbo fuel | : | 1 gal. = 1.63 X $10^8$ joules |
| aviation fuel | : | 1 gal. = 1.52 X $10^8$ joules |
| electricity | : | 1 kWh. = 3.6 X $10^6$ joules |

c. Where necessary, it has been assumed that the average diesel fuel to electricity conversion efficency is 30%.

d. Energy demand data is shown primarily as secondary energy, e.g. refined fuels, but in some cases is a mix of primary and secondary energy e.g., where electricity includes portions derived from both hydro and diesel sources.

e. The 1989 and 1999 projections assumed an annual inflation rate of 9%.

## 4.4 N.W.T. Energy Demand: 1979

Table 3 illustrates the N.W.T.'s regional and total energy consumption for 1979. The N.W. T. consumed 16,332 terajoules of energy, about 0.2% of the country's total. The major consuming sectors are, in decreasing order, the Commercial, Transportation, residential, and Mining sectors. The Commercial and Transportation sectors, in fact, consumed 7253 and 4333 terajoules respectively, about 70.9% of the N.W.T. total.

The regional perspective indicates that the Fort Smith region is, by far, the greatest energy consumer. In 1979, the Fort Smith region consumed 8589 terajoules of energy or 52.6% of the N.W.T. total. The largest energy consuming sector in the Fort Smith region is the Commercial sector which consumed 47.3% of the region's energy total and 56.1% of the total N.W.T. Commercial demand.

The Invuik and Baffin regions are the second and third largest energy consuming regions; in 1979 they consumed 3586 and 3037 terajoules respectively, about 41% of the N.W.T. total. Energy demand in these regions is also dominated by the commercial and transportation sectors. Transportation is the largest consumer in the Baffin region, 1299 terajoules or 42.8% of the regional total.

The Cambridge Bay and Keewatin regions combined, only consumed 1120 terajoules or 6.8% of the N.W.T. total. The Commercial and Residential sectors are the largest consumers in these regions.

The distribution of energy demand in the N.W.T. is perhaps a reflection of the regional differences. The significance of the Fort Smith energy demand is based, in part, on such characteristics as having the highest regional population and

TABLE 3

N.W.T. AND REGIONAL 1979 ENERGY DEMAND BY SECTOR
ALL PROJECTIONS IN TERAJOULES

| SECTOR | REGIONS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fort Smith | %T | Cambridge Bay | %T | Inuvik | %T | Keewatin | %T | Baffin | %T | N.W.T. | %T |
| RESIDENTIAL | 703 | 41.6 | 119 | 7.0 | 229 | 13.5 | 202 | 11.9 | 437 | 25.9 | 1690 | 10.3 |
| | | 8.2 | | 23.2 | | 6.1 | | 33.3 | | 14.4 | | |
| COMMERCIAL | 4066 | 56.1 | 219 | 3.0 | 1956 | 27.0 | 213 | 2.9 | 799 | 11.0 | 7253 | 44.4 |
| | | 47.3 | | 42.7 | | 52.1 | | 35.1 | | 26.3 | | |
| MINING | 1248 | 92.3 | 0 | 0 | 0 | 0 | 0 | 0 | 104 | 7.7 | 1352 | 8.3 |
| | | 14.5 | | | | | | | 3.4 | | | |
| TRANSPORTATION | 1918 | 44.3 | 73 | 1.7 | 1013 | 23.4 | 30 | 0.7 | 1299 | 30.0 | 4333 | 26.5 |
| | | 22.3 | | 14.2 | | 27.0 | | 4.9 | | 42.8 | | |
| CONVERSION and LINE LOSSES | 654 | 38.4 | 102 | 6.0 | 388 | 22.8 | 162 | 9.5 | 398 | 23.3 | 1704 | 10.4 |
| | | 7.6 | | 19.9 | | 10.3 | | 26.7 | | 13.1 | | |
| TOTAL | 8589 | 52.5 | 513 | 3.1 | 3585 | 22.0 | 607 | 3.7 | 3037 | 18.6 | 16332 | 100.0 |
| | | 100.0 | | 100.0 | | 100.0 | | 100.0 | | 100.0 | | |

Notes: There are two "% T or % Total" values for each sector.
The upper figure represents the percentage of the Total N.W.T. sector demand (horizontal totals).
The lower figure represents the percentage of the Total Regional demand (vertical totals).

being the centre of commercial and mining activity. Likewise, the muvik and Baf f in regions have the next largest populations and a certain amount of commerc ial activity. By contrast, the Cambridge Bay and Keewatin regions have the lowest regional populations and are not characterized by significant commercial activity.

An important feature highlighted by Table 3 is the energy "lost" through conversion, e.g. , diesel fuels burned to produce electricity. Conversion losses represent at least 10% of the N.W.T. total demand, i.e. 1704 terajoules, 9,682,128 gallons of diesel or light heating oil equivalents.

Using the 1979 energy distribution as a base, regional consumption is pro jetted to 1999. As previously mentioned, the projections are based, in part, on a conversion approach. The following section describes what such an approach implies.

## 5.0 Conservation Strategies and Technologies

A conservation strategy is a goal oriented approach to carrying out policy that may include the utilization of conservation technologies. A conservation technology is a technical means of reducing energy demand e.g. , insulation. The following discussion examines the possibilities for both strategy and technology application.

### 5.1 Residential Sector: Existing

As indicated in Appendix I, the residential sector energy demand is conveniently divided between existing and new units. Conservation approaches in these areas must take into account regional diversities in terms of climate, physiography, culture and the economy. For example, participants in the housing market include the federal, territorial and municipal governments as well as a mix of corporate and self -owned housing stock.

The age and type of housing stock ranges from early 1960's Northern Territorial Rental Program 26 $M^2$, 1 room, pre-fabricated homes to N. W.T. H.C. 4 bedroom, single detached, wood frame constructed units, built in Hay River to 1979 energy standards. As Table 2 notes, the varibility between regional demand centres suggests that residential conservation strategies be undertaken with an understanding of local needs.

The extent to which decentralized conservation strategies are effective depends, in part, on the managers and the participants. During the author's visit in Yellowknife, it was made clear that the policy of decentralizing N. W. T. governmental responsibilities to the five regions would be manifested, in part, by localized energy initiatives. For example, regional energy managers are expected to be hired to aid in both sectoral and in-house (government) conservation strategies. Local participation may also come from local housing associations, which are already involved in the administration of public housing.

Although localized input in energy strategy implementation may become a reality, it is clear that the N.W. T. government, in the form of the Ministry of Energy and the Housing Corporation, is undertaking much of the initiative in residential energy management. While the former department is involved in the development of regional energy initiatives, the N. W. T.H.C. has undertaken:

i) the publication and distribution of energy conservation informational booklets; and

ii) the development of user-pay schedules so that N.W.T. residents will pay an increasing share of the space heating and electrical energy costs.

N.W.T. Ministry of Energy and N.W.T.H.C. involvement in residential energy conservation strategies is expected to increase, given the indications that most of the housing expansion in the next 10 to 15 years will be government initiated.[6] Given that the implementation of conservation strategies and the application of conservation technologies entails a coordinated and well-planned effort, government involvement appears to be warranted, i.e. in an economy where private sector activity can fluctuate according to external factors, a constant institutional concern seems necessary.

Table 4 indicates that a number of conservation steps can be applied in the existing N.W.T. housing sector. The simplest steps, such as thermostat set-back, can be done at no cost. The more expensive steps such as major reinsulation, involve a financial investment. However, the rapid increase in heating fuel prices is likely to reduce the payback period. Appendix VII illustrates a simple payback scheme for a Fort Smith region house. Assuming heating oil prices that will increase in proportion to increases in conventional crude oil, it is possible that a $2000 (1981 dollars) loan can be paid back in less than four years, given the retrofit savings assumed in the regional. demand projections.

It seems likely that the effectiveness of residential energy conservation strategies will be enhanced if the N.W.T. government takes advantage of federal services. For example, the Enersave Advisory Service, a contract service of Energy, Mines and Resources Canada, offers: a free computerized questionnaire detailing retrofit possibilities for single detached homes; free technical advice through a phone-in "Heat Line" and free retrofit - related publications. To date, little use has been made of this service.

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6 Hildebrandt - Young and Associates Ltd., Market Forecasts: Electrical Energy Requirements in the Northwest Territories 1978/'79 - 1977/'98, A report prepared for the Northern Canada Power Commission, 1979, p.20.

TABLE 4

ESTIMATED ENERGY CONSERVATION POTENTIAL IN EXISTING RESIDENCES

| SOURCES OF THERMAL INEFFICIENCY | RECOMMENDATIONS | TYPICAL ENERGY SAVINGS[a] |
|---|---|---|
| 1. Insufficient insulation | RSI levels to attain[b] | |
| basement loss 14-33% | 2.1 - 5.0 | |
| walls above grade 14-30% | 3.7 - 9.0 (above grade) | |
| ceiling and attic 10-17% | 7.0 - 14.0 | 35% |
| windows and doors 15-17% | 2.0 - 3.0 (shutters), triple glazing | |
| floors 5-10% | 4.7 - 7.0 | |
| 2. Air change 35-55% | caulking; weatherstripping; sealing joints, outlets and ducting | 10% |
| 3. Oil furnace inefficiency | retrofit and replacement[c] | 3-20% |
| 4. Inefficient Hot Water System | decrease hot water use<br>fix leaky facets<br>switch to showers<br>alter washing practices<br>install insulation and heat trap<br>reduce pipe diameter<br>install heat exchanger | 30-50% |
| 5* Thermostat set too high | set back (to 20°C) | 0-20% |
| 6. Appliance inefficiency | stoves/ranges, overcirculation | 20% |
| | refridgerators, improve insulation; smiler rotors | 50% |
| | lighting (fluorescent), new design | 75% |

TABLE 4

SOURCES

1. Graham T. Armstrong, "Conservation Energy - Potential and Practice in Canada", paper presented to the Conservation Energy Series organized by the Saskatchewan Office of Energy Conservation, Regina, June 24, 1980, pp. 20, 24.

2. Canadian General Standards Board, Handbook on Insulating Homes for Energy Conservation, (Ottawa: 51-GP-42 Ml?, 1980).

3. Canadian Electrical Association, Technical Guidelines, Energy Efficient Home Program, (Montreal, 1980), p.3.

4. Bob Chill, Report on Improved Single Family Residences for the Canadian Arctic, Model No. 442-R77, (Ottawa: Department of Indian Affairs and Northern Development, 1979), p.5.

5. Energy, Mines and Resources, ENERSAVE Advisory Service, to Improve the Efficiency of Your Hot Water System, An unpublished fact sheet, 1980.

Notes:

a Typical energy savings represents: the original fuel demand X (the percentage savings subtracted from 100) . The average energy savings are cost effective, i.e. the investment payback is 6 years or less at a rate of return of 10% or better.

b Although the recommended insulation levels are for new homes, it is assumed that roving towards these levels in existing homes, to the extent that is structurally possible, will lead to the listed savings.

c As part of the 1980 Federal Energy Strategy, taxable grants of 50% of costs, up to a maximum grant of $800.00, will be applied to the upgrading or replacement of inefficient oil fired furnaces in the N.W.T.

For example, the average monthly call-ins for the Heat Line service from the N.W. T. total 2, about ●004% of total incoming calls (compared with an N. W. T./Canada population ratio of .002). Despite such obstacles as a lack of phones and the task of phoning collect, it seems possible for greater utilization of this service.

Finally, the N.W.T. will be able to take advantage of Energy, Mines and Resources Canada's "Off-Oil" program. In the N.W.T. a taxable grant of up to $800.00 will be applied to the upgrading or replacement of inefficient oil fired furnaces.

## 5.2 Residential Sector: New

In a recent address to the Saskatchewan Conservation Energy Seminar series, Dr. Graham Armstrong of the Federal Observation and Renewable Energy Branch notes that new residence construction efforts, have for the most part, failed to reach the achievable thermal efficiencies of existing low energy and cost-effective residence designs.[7] 'Ibis amounts to an understatement because the thermal efficiency of new home construction has resulted in poor performance in all regions of Canada. There are positive efforts being made in the N.W.T., however, that indicate substantial energy savings will be achieved in the near future.

Two design models typify the work being done to meet N.W.T. climate characteristics with thermally efficient housing. One is the Model No. 442-R77 prefabricated, 3 bedroom, suspended basement house. Some of its thermal efficient features include:

i) foundation, footings, and structure designed to avoid structural instability caused by damage to the ground in permafrost areas;

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7 Graham Armstrong, Conservation Energy - Potential and Practice in Canada, p. 21.

ii) insulation: walls - R.S.I. 5.0, floor - R.S.I. 4.7, roof R.S.I. 6.1;

iii) shutters placed outside sealed windows; and

iv) air tight construction.

With four prototypes recently built, performance analyses have not been completed. The design of the house suggests "a southern Canada" style that may be appropriate only to staff housing.

The other model is a prototype based on the designs of the architectural firm Allen, Drerup and White Ltd. This design's features include:

i) insulation: walls - R.S.I. 11.0, floor - R.S.I. 7.0, roof - R.S.I. 11.0; and

ii) windows, all triple glazed, sealed and facing south, except for one small bathroom window on the north side.

To date, a total of seven prototypes have been or are being built in isolated communities, primarily in the Keewatin region. A comparison of the Baker Lake model annual heating demand (3010 kWh) with the 1979 Keewatin per unit demand (1165 gallons of heating oil per year) shows that the new prototype can decrease existing demand by 95%.* Not only does the Allen/Drerup/White model suggest substantial energy savings, the design is suited to the cultural needs of native northerners and is flexible enough to allow for community by community input. If performance evaluation continues

* 1165 gallons of heating oil = $205 \times 10^9$ joules
3010 kwh of electricity = $10 \times 10^9$ joules

$$\frac{(205-11) \times 100\%}{205} = 95\%$$

to be positive, this design, incorporating passive solar design, super insulation, and air tightness could become the preferred housing type for the northern regions.[8]

The foregoing models suggest thermally efficient design possibilities for single detached housing. In the regional demand projections, the prospect of a large transition to multi-unit housing was not discussed. This is because the author had insufficient information about the social consequences of roving native northerners to multi-unit housing.

## 5.3 Commercial Sector

As previously noted, the commercial sector is the most intense energy consuming sector in the N.W.T. Despite information deficiencies concerning the sector's exact characteristics (See Appendix VIII), it is possible to suggest a number of conservation step. In fact, as Table 5 illustrates, two factors suggest significant savings.

First, most of the commercial units in the N.W.T. can be categorized as small e.g., apartment blocks, stores, schools, health facilities, law enforcement stations, and low rise office buildings. Compared to large units, existing small commercial units have a size that makes them susceptible to a more wide-ranging series of conservation steps e.g., retrofitting, revamping of the heating system and computerization.

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8 Payback calculations for these models using increased fuel prices, a $1000.00 marginal cost for the model when compared with a "conventional" house of similar area, and construction costs increasing at the rate of inflation are likely to reveal favorable payback periods.

TABLE 5

ESTIMATED ENERGY CONSERVATION POTENTIAL IN COMMERCIAL BUILDINGS WITH EXISTING TECHNOLOGY

| SOURCES OF THERMAL INEFFICIENCY | RECOMMENDATIONS | TYPICAL ENERGY SAVINGS[a] |
|---|---|---|
| | Existing Buildings (large e.g., high-rise off ice buildings) | |
| 1. inefficient office practices | thermostat set-back, design lighting, more efficient lighting | 25% |
| 2. improper control of heating, lighting and ventilation system | computerization | 30% |
| | Existing Buildings (small, e.g., schools, apartment buildings) | |
| 1. insufficient insulation | increase insulation | 30% |
| 2. insufficient heat recovery | install air-to-air heat exchangers, heat recovery chillers, heat pumps | 20% |
| 3. inefficient heating system | revamp heating system, computerization | 40% |
| 4. inefficient office practices | thermostat set-back, more efficient lighting | 25% |
| | New Buildings (large) | |
| | combine superinsulation with passive solar design; utilize lighting, machinery and employee generated heat; heat recovery systems and efficient lighting. | 80% |
| | New Buildings (small) | |
| | similar to above | 70% |

Sources: 1. David Brooks and Sean Casey, "A Guide to Soft Energy Studies," Alternatives 8 (Summer/Fall, 1979): 19

2. Graham T. Armstrong, "Conservation Energy - Potential and Practice in Canada," Tables 9, 10.

3. Federal Department of Energy, Mines and Resources Enersave Advisory Service for Industry and Commerce, "Guidebook Series for Conserving Energy," (Ottawa: Supply and Services, 1977-79).

Second, most of the commercial units in the N.W.T. are government owned and/or operated (excepting the Fort Smith region) . As noted in the residential sector discussion, government involvement seems to be necessary to ensure a comprehensive energy strategy in the N.W.T.

AS with existing and new residences, design aimed at airtight and superinsulated building shells and passive solar heat gain, can be readily applied to commercial units to produce energy savings. Although N.W.T. information is unavailable, some commercial buildings in the Yukon have been made more airtight and have had insulation levels upgraded (p.37 Yukon report). In addition, steps such as efficient lighting and waste heat recovery have helped cut peak consumption in half.[9] finally, as Table 5 indicates, the conservation potential in existing buildings is enormous.

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9 In the Yukon report, Brooks notes that payback on insulating was under 5 years at 1979 prices.

A useful document that explains conservation approaches in schools is Randy LagerWay, "Methods of Energy Conservation in Winnipeg Elementary Schools, (Winnipeg: University of Manitoba Natural Resource Institute Masters of natural *source Management Practicum, 1978) .

See Also: Conservation and Renewable Energy News, (Vol. 2, April 1979) p. 28.

This article, by Anna Olsen, describes how a passive solar community centre was designed and constructed for the Roseau River Indian reserve, about 60 miles south of Winnipeg. The design incorporates cultural features with such conservation technologies as super-insulation, solar collectors and heat recovery fans.

## 5.4 Transportation Sector

Table 3 indicates that the Transportation sector is the N. W.T.'s second largest energy consume r. Transportation energy demand is especially significant in the Ebrt Smith, Inuvik, and Baf f in regions. Transportation demand for the N. W. T. regions is described in greater detail in Tables II to VI, which accompany the "working paper" appendices. These tables reveal that the major sources of Transportation demand varies by region.

In the Fort Smith region, road transportation consumed 974 terajoules, followed closely by aviation at 776 terajoules. Although the Fort Smith region accounts for all of the N. W.T.'s rail and marine consumption, these two sources consumed only 36 and 132 terajoules respectively.

Road and aviation demand account for all of the Inuvik reg ion's consumption. Although a similar situation exists in the remaining regions , aviation clearly dominates consumption. In fact, in the Baf f in region, aviation consumed 1179 terajoules as opposed to 120 terajoules by road transportation.

Table 6 lists a variety of conservation measures currently applicable to transportation common to the N.W.T. The table reveals that the more numerous measures are applicable to road vehicles. Some of them, such as driver education workshops and reducing speeds involve a change of behaviour. Others, such as radial tires and aerodynamic drag reduction devices are technologies that are currently available.

Conservation measures for road vehicles can reduce existing consumption by 2% to 35% for each measure applied. Given that both commercial trucks and residential automobiles and trucks are, for the most part, privately owned, it is difficult to surmise how fast

TABLE 6

ESTIMATED CONSERVATION POTENTIAL IN THE TRANSPORTATION SECTOR WITH EXISTING TECHNOLOGY

| TRANSPORT SYSTEM TYPE AND DESCRIPTION | TYPE AND USE OF VEHICLES [a] | CONSERVATION POSSIBILITIES | TYPICAL SAVINGS |
|---|---|---|---|
| The existing road system is comprised of:<br>i) the MacKenzie highway, originating at Grimshaw, Alta. and branching at Enterprise to serve communities on Great Slave Lake and the Upper Mackenzie. This highway is the main route for commercial and industrial shipments as well as tourism traffic. It connects with the NTCL marine system at Hay River;<br>ii) the mining service roads;<br>iii) the old Canol road which is currently inaccessible;<br>iv) the Dempster highway linking Inuvik and Tuktoyatuk with Dawson in the Yukon; and<br>v) a series of winter roads.<br><br>Potential roads include<br>i) the Liard Valley highway, currently under construction, which will link Fort Simpson and Fort Liard with Fort Nelson, B.C.;<br>ii) the linkup from the potential " lead/zinc developments to the Arctic Ocean or south to road and/or rail line (at conceptual stage); and<br>iii) the improvement of the old Canol Road from biking trail to service capacity for new mines. | commercial diesel transport trucks carry goods to to communities and some mines | driver energy education workshops | 10% |
| | | preventive maintenance | |
| | | auxillary starting aids (larger batteries, ether or glow plugs, electric block heaters, could reduce idling time, even in cold weather) | NA |
| | | reduced speeds (90 kilometres/hr.) | 10% |
| | | radial tires | 4-9% |
| | | aerodynamic drag reduction devices | 2-6% |
| | | variable fan drives | 2-6% |
| | | engine and drive train improvements | 5% |
| | private automobiles, in the NWT many are large V8 or V6 engines | voluntary fuel efficiency standards | 10-20% |
| | | preventive maintenance | 10% |
| | | auxillary starting aids | NA |
| | | more aerodynamic body designs | 15% |
| | | radial tires | 5% |
| | Private gasoline engine trucks e.g., 1/2 ton pick-up trucks | preventive maintenance | 10% |
| | | switch to diesel/standard engines | 35% |
| | | reduced speeds | 10% |
| | | radial tires | 4-9% |
| | | engine and drive train improvements | 5% |

| TRANSPORT SYSTEM TYPE AND DESCRIPTION | TYPE AND USE OF VEHICLES a | CONSERVATION POSSIBILITIES | TYPICAL SAVINGS |
|---|---|---|---|
| The marine systems transport the greatest proportion of freight. | barge tugs | improved engine efficiency, friction reducing propellers | |
| One system uses barges to ship goods from a terminal at Hay River throughout the Mackenzie River System. | outboard motor boats | improved designs | 20% |
| The eastern and northern Arctic regions are served by ship from Montreal, including concentrate carriers from the Nanisivik mine. | Motor vessel e.g., Can Arctic's MV Arctic bulk carrier, capacity of 28 thousand tons of cargo | friction reducing paint reduce cruising speeds | |
| Transporting passengers, perishable freight and even gold concentrate, air transport is perhaps the most crucial transportation mode, especially for isolated communities. As of 1979 there were 3 inter-regional carriers and 45 local carriers. | jet aircraft, including some helicopters | increased efficiency | ) 33% |
| | turbo-prop. aircraft, including helicopters | | ) |
| | propeller - driven light aircraft | | 20% |
| Rail transport is confined to the Great Slave Lake system, a branch of the C.N.R., which connects Hay River and Pine Point with Roma Junction near the Peace River in Alberta. | d:esel - electric | improved railbed and track improved engine efficiency | 15% |

# TABLE 6

Sources:

1. Various N.W.T. maps.

2. Resources Management Consultants Ltd. , "Regional Socio-economic Impact Assessment of the Norman Wells Oilfield Development and Pipeline Project, " Report for Esso Resources Canada Ltd. as part of the Inter-provincial Pipeline N.W. Ltd. Application to the National Energy Board Vol. V, March 1980, pp. 79-81, 159-161.

3* Department of Indian Affairs and Northern Development, Economic Planning Branch, personal communication, 1980.

4. Ronald Fournier, Economic Circumstances in the N.W.T. (Regina: DREE Western Headquarters, 1979).

5. Graham T. Armstrong, "Conservation Energy - Potential and Practice in Canadar" Table 18.

6. Enersave Advisory Service for Industry and Commerce, Guidebook No. 7, Saving Money in Transportation and Delivery.

7. David Brooks, Yukon Report, P. 88.

Legend

NA - Not Available.

Notes:

a An examination of conservation potential among mining vehicles is presented within the Section 5.5.

b Alternative fuels, as one measure to reduce existing fuel demand, is discussed in the Supply component of this study.

savings can be achieved. For example, commercial trucking costs have, historically, been passed on to the consumer and are likely to continue in such a manner. Nevertheless, with vehicle registrations projected to increase (see Table 7) and new roads opening up (see Table 6), it is important to consider both the energy and cost savings from these measures.

It should be noted that the regional demand projections did not examine the conservation possibilities of a fuel transition from gasoline to diesel. It is apparent from available information e.g. EnerSave publications on conservation for trucking, that such a fuel shift is achievable.

Despite limited information, there are indications that increased engine and design efficiencies for both jet and prop driven aircraft can result in substantial savings. Again, aviation consumption is confined, for the most part, to the corporate sector, making it difficult to project the immediacy of conservation measures.

Although rail is currently confined to the Great Slave Lake system in the Fort Smith region, Table 6 shows that improved railbeds and tracks as well as improved engine efficiencies can result in savings of at least 15%. Given that both commercial trucking and rail transport is centered in the Forth Smith region, more specifically, the Mackenzie Valley, it seems worthwhile to investigate a modal shift from truck to rail. If the railway is characterized by excess capacity, such a shift might be possible without energy consumption increases and with potential savings.

5.5 Mining Sector

As described in Table 1, there are currently seven producing mines in the N.W.T. The Pine Point, Con-Rycon, and Giant mines, all in

TABLE 7

VEHICLE REGISTRATIONS IN THE N.W.T. 1969-1999

| Type | ACTUAL 1969 | ACTUAL 1979 | annual rate of increase | PROJECTED[a] 1989 | PROJECTED[a] 1999 |
|---|---|---|---|---|---|
| cars | 3253 | 5087 | 4.6% | 7976 | 12505 |
| trucks | 2243 | 8719 | 14. 6% | 17638 | 35681 |
| tractor trailers | 236 | 1668 | 21.6% | 4651 | 12973 |
| road construction equipment | 420 | 976 | 8.8% | 2268 | 5263 |
| motorcycles | 188 | 1081 | 19. 0% | 2679[b] | 6638 |

Sources: 1. Registrar of Motor Vehicles, Government of the Northwest Territories, 1980.

2* Planning and Resource Development Division, Department of Economic Development and Tourism, Government of the N.W.T., N.W.T. Statistical Profile, 1980, p.84.

Notes: a Projections of 1989, 1999 vehicle registrations assume a continuation of the 1969-1979 annual rate of increase.

b It is assumed that truck and motorcycle registrations will not continue to reflect a period of public and private sector expansion; therefore, the annual compound rate of growth is assumed to be reduced by 50% per year.

the Fort Smith region, consumed about 93% of total estimated mining demand . Most of the mining energy is consumed in the form of electricity or diesel fuel for motive purposes . The type and extent of energy consumption varies with each mine. Factors such as type of operation, e.g. open pit or underground, ore grade, and location affect energy use. As Table 8 indicates there are a number of potential mine sites expected to come-on-stream by 1999. These mines, most of which are located in the Fort Smith region, could greatly affect the territory's energy consumption.

Table 9 lists a number of conservation approaches for both mining and milling stages. For mining, two of the more important measures are peak load management and the efficient use of air valves. Peak load management could reduce the frequent power outages experienced by N.W.T. mines. Air distribution systems are a major user of electricity and must be properly maintained. At the milling stage building retrofit and steam pipe insulation appear to be achievable measures. As will be discussed in section 9, the utilization of residual or waste heat represents a significant "supply" source. The listed conservation measures can achieve from 10% to 25% savings.

## 5.6 Conservation Options for the N.W.T.

With a variety of conservation options available for each energy consuming sector what options should energy strategists pursue first? Che approach might be to attack the major consuming sectors, commercial and transportation. It is suggested, however, that despite the conservation possibilities for a commercial sector dominated by "small" units, the more readily accessible sector is the residential.

For the residential sector, conservation approaches, many involving little or no cost, are quite accessible to residential consumers.

TABLE 8

POTENTIAL MINES: 1979-1999 AND EXPECTED ENERGY DEMAND

FORT SMITH KEGION

| Mine and Location[a] | Products | Mill Capacity t.p.d. | Mine Type | Expected Life Yrs. | Electricity Demand[d] MWh | TJ |
|---|---|---|---|---|---|---|
| Cadillac Mine[b] 188 km west of Fort Simpson | Pb,Zn,Cu | 200 - 400 | underground | 6 | 10,000 | 37 |
| Lupin Contwoyto Lake | Au | 1000 | underground | | 48,234 | 173 |
| Camlaren,[c] near Yellowknife | Au | | | 2 | | |
| Bathurst/ Norsemine east of Great Bear Lake | Pb,Zn | 9000 | underground | 15+ | 70,000 | 252 |
| Canex Placer Ltd. Howard's Pass | Pb,Zn | 9000 | underground | 15i- | 70,000 | 252 |

## KEEWATIN REGION

| Mine and Location[a] | Products | Mill Capacity t.p.d. | Mine Type | Expected Life Yrs. | Electricity Demand[d] MWh | TJ |
|---|---|---|---|---|---|---|
| O'Brien Energy Resources Cullaton Lake | Au | 200 | | 3 | 9,600 | 35 |
| Pan Ocean Bisset Lake | u | | | | | |

## BAFFIN REGION

| Mine and Location[a] | Products | Mill Capacity t.p.d. | Mine Type | Expected Life Yrs. | Electricity Demand[d] MWh | TJ |
|---|---|---|---|---|---|---|
| Borealis Melville Peninsula | Fe | | | | | |
| Cominco-Polaris Little Cornwallis Island | Pb, Zn | 2050 | underground | 25 | 20,000 | 72 |

Notes:

a The possibility of mine development, type, life expectancy is based on consultation with both N.W.T. and Federal officials.

b The Cadillac, Lupin, Cullaton and Polaris mines are currently under construction.

c There are two active exploration areas in the Fort Smith region. In the Yellowknife area e.g., Camlaren, there are a number of small gold deposits of very short life expectancy, which have mine potential if gold prices continue to remain high.

In the MacMillan and Howard Pass areas along the Yukon and NWT border, there are a number of potentially viable tungsten and lead/zinc prospects.

d Expected electricity demand is based mainly on comparisons with existing mines e.g.,

Cadillac with Can Tung
Bathurst with Nanisivik

PRESENT MINE TYPES , PROBABLE SOURCES OF ENERGY INEFFICIENCY, AND CONSERVATION POTENTIAL WITH EXISTING TECHNOLOGY

| Mine | Product | Mine Type | Extent of Product ion | Fuels Used | Sources of Energy Inefficiency | Conservation Approaches | Typical Savings |
|---|---|---|---|---|---|---|---|
| Pine Point | Lead, Zinc | Open-pit | milled concentrate | diesel (electric)<br>diesel (motive)<br>gasoline<br>heating oil<br>butane | <u>mining stage:</u><br>open pit: haulage vehicles, compressed air drills<br>water pumping | use larger haulage machines, with hydro availability | |
| Nanisivik | Lead, Zinc, Silver Cadmium | Underground | milled concentrate | same as above | underground: diesel-electric vehicles, compressed air drills, | use all electric hydraulic drills, | |
| Giant Yellowknif e | Gold , Silver | Open-pit and Underground | refined | diesel (electric)<br>diesel (motive)<br>gasoline<br>bunker oil<br>propane | poor peak power control when using shaft lifts for haulage. | peak load management, also close valves when air is not needed, fix leaks on air lines | |
| Con-Rycon | Gold , Silver | Underground | refined | Same as above | | | |
| Echo Bay | Silver, Copper | Underground | milled concentrate | diesel<br>heating oil | <u>milling stage:</u><br>use of steel-lined mills, lack of control in grinding; | replace with rubber-lined mills, adjust controls to grade and size variation | 10%-25% |
| Terra | Silver, Copper, Bismuth | Underground | milled concentrate | Same as above | shaft envelope, drying plant, bunk houses poorly insulated | retrofit buildings, including insulation of steam pipes | |
| Can Tung | Tungsten | Underground | milled concentrate | diesel<br>heating oil<br>gasoline | | | |
| | | | | | <u>waste heat:</u><br>greater than 50% of heat loss is is low grade heat from heating needs. | use waste heat from shafts, machinery, and compressors. | |

Moreover, a variety of existing services and programs are readily available. Finally, the nature of this sector is such that decentralized planning and input from communities is possible.

Despite the accessibility of the residential, and even the commercial sectors, energy planners should not discount initiatives in the mining and transportation sectors. For example, without conservation initiatives, mine development might entail the necessary expansion of utility services. In addition, without conservation initiatives mining development could be curtailed by the prohibitive costs of energy supply. Such a curtailment could seriously affect the territorial economy.

## 6.0 Regional Energy Demand Projections

'Ibis section examines some of the results of the region by region demand projections. Note that Appendix I, the methodology and assumptions explanation, and II to VI inclusive, the regional Projection methodologies, have been set out as working papers thereby presenting variables that can be altered in new scenarios.

### 6.1 Fort Smith Region Forecast

The Ebrt Smith region is the source of most of the N.W.T.'s residential, commercial and mining energy demand. In particular, the region consumes all of the motive diesel fuel used for rail transport, and most of the diesel fuel used in marine and road transportation. Therefore, energy demand reductions would result in major financial savings to the region and to the territory as a whole.

As indicated in Table 10, the residential sector offers the greatest potential percentage savings. The projected savings, as explained in Appendix II, are a result of assuming the application of several

TABLE 10

PROJECTIONS OF SECONDARY ENERGY CONSUMPTION 1989, 1999 FORT SMITH REGION
ALL PROJECTIONS IN TERAJOULES ($10^{12}$ JOULES)

| ECT | NERGY SE/FORM | | | | INGS | | | % SAVINGS |
|---|---|---|---|---|---|---|---|---|
| **RESIDENTIAL** | | | | | | | | |
| Existing | Space Heating | 532 | 420 | 210 | 50.0 | 366 | 182 | 50.3 |
| | Water Heating, Lighting, Appliances, Miscellaneous | 171 | 153 | 133 | 13.1 | 137 | 120 | 12.4 |
| New | Space Heating | 0 | 265 | 132 | 50.2 | 316 | 32 | 89.9 |
| | Water Heating, Lighting | 0 | 70 | 58 | 17.1 | 84 | 69 | 17.9 |
| Sub Total | | 703 | 908 | 533 | 41.3 | 903 | 403 | 55.4 |
| **COMMERCIAL** | | | | | | | | |
| Existing | Heating (All) | 3319 | 2988 | 1529 | 48.8 | 3884 | 1989 | 48.8 |
| | Lighting, Appliances | 747 | 672 | 538 | 19.9 | 874 | 699 | 20.0 |
| New | Heating (All) | 0 | 1328 | 332 | 75.0 | 3452 | 1036 | 70.0 |
| | Lighting, Appliances | 0 | 299 | 149 | 50.2 | 777 | 388 | 50.1 |
| Sub Total | | 4066 | 5287 | 2548 | 51.8 | 8987 | 4112 | 54.2 |
| **MINING** | | | | | | | | |
| | Heat and Motive Power | 592 | 880 | 792 | 10.0 | 2319 | 1740 | 25.0 |
| | Electricity | 656 | 976 | 878 | 10.0 | 2572 | 1929 | 25.0 |
| Sub Total | | 1248 | 1856 | 1670 | 10.0 | 4891 | 3669 | 25.0 |
| **TRANSPORTATION** | | | | | | | | |
| Road | Motor Gas | 891 | 1664 | 1222 | 26.6 | 3155 | 1748 | 44.6 |
| | Diesel | 83 | 185 | 149 | 19.4 | 439 | 298 | 32.1 |
| Sub Total | | 974 | 1849 | 1371 | 25.8 | 3594 | 2046 | 43.1 |
| Air | Turbo Fuel | 587 | 984 | 886 | 9.6 | 1649 | 1154 | 30.0 |
| | Aviation Fuel | 189 | 317 | 180 | 43.2 | 531 | 254 | 52.2 |
| Sub Total | | 776 | 1301 | 1066 | 18.1 | 2180 | 1408 | 35.4 |
| Marine | Motor Gas | | | | | | | |
| | Diesel | 132 | 221 | 177 | 20.0 | 371 | 297 | 20.0 |
| Sub Total | | | | | | | | |
| Rail | Diesel | 36 | 60 | 54 | 10.0 | 101 | 91 | 10.0 |
| Sub Total | | 1918 | 3431 | 2668 | 22.2 | 6246 | 3942 | 58.4 |
| GRAND TOTAL | | 7935 | 11482 | 8485 | 26.1 | 23207 | 13534 | 41.7 |

conservation steps (See Table 3) . In particular, energy efficient new housing designs are responsible for the large projected 1989-1999 space heat demand reductions for new housing.

The extent to which conservation steps are applied in the Fort Smith residential sector appears to be dependent on such factors as:

i) the intensity of involvement in the housing market by public and private sector interests;

ii) the extent of primary resource development;

iii) the extent of inter-regional migration; and

iv) the type of housing mix established.

The foregoing factors seem to indicate that the effectiveness of residential energy conservation initiatives in the Fort Smith region is dependent on a more variable environment than is evident in other regions.

Residential sector energy demand in 1999 has the potential to be less than in I-979. In the commercial sector, energy conservation initiatives can reduce demand so that the 1999 demand is about the same as in 1979. As shown in Table 10, some of the more spectacular savings may be achievable by 1989, more specifically, those related to space heating demand reductions in new units. As with the residential sector, commercial conservation initiatives in the Fort Smith Region are dependent on a more variable environment than elsewhere.

The Fort Smith region, as noted in Table 1, has the major energy consuming mines. Table 10 shows that mining sector demand to 1999 is expected to increase substantially. Given such a substantial increase in demand, it is likely that diesel and heating fuel will have to be imported and more hydro sources tapped unless substantial energy conservation efforts are undertaken. The conservation steps assumed in the mining projections are conservative in view of the largely untapped potential of residual heat (see Section 9 of the supply analysis) .

The extent to which conservation strategies are applied could greatly effect the Fort Smith economy. At about $10,450 per TJ for heating oil and $11,818 for diesel oil, delivered, the region enjoys, except for the Inuvik region, the lowest fuel prices in the territory. On the other hand, these prices are among the highest in Canada and will increase substantially under the new federal energy policy. Assuming that, on average, an increase in crude oil price is proportionally equal to an increase in heating oil and diesel oil prices, the 1999 cost of a zero conservation energy demand might be:

i) $370 million for diesel fuel at $6.2 per gallon (1990 prices); and

ii) $307 million for light heating oil at $5.5 per gallon (1990 prices) .

Using a conservation approach, however, would result in a $91 million saving (1999 ZC vs. C Approach) in diesel oil costs and a $164 million saving in heating oil.

Obviously, the foregoing calculation is a simple analysis. The exact impact of crude oil price increases is a factor of both component increases for product cost, and a mixture of acquisition, transportation handling and storage costs, such a cost mixture being a factor of inflation which is itself affected by the national energy policy. Nevertheless, the conservation option appears to offer substantial expenditure savings. These savings will be important to:

i) mining companies who will have more finances to invest in exploration and development;

ii) commerc ial establishments that may be able to remain financially solvent;

iii) N.W.T. residents who will be able to allocate more of their finances to areas perhaps stimulative to the economy; and

iv) N.W.T. governments which may be able to cut their subsidization of energy costs to consumers.

### 6.2 Cambridge Bay Region Forecast

The Cambridge Bay region presents quite a contrast to the Fort Smith region and even the Inuvik region. It has a small and semi-isolated. population whose major economic base consists of government and primary resource commercial establishments. As such, the Cambridge Bay region energy demand is dominated by the residential and commercial sectors. Table 11 shows that conservation steps applied to these sectors can affect an absolute decrease in total regional demand from 1979 to 1999.

The possibility of an absolute decrease in energy demand is important to a region such as Cambridge Bay because it is especially affected by high fuel costs. The extent to which conservation initiatives are applied appears to be less dependent on all of the factors noted in the Fort Smith discussion. The territorial and federal governments certainly have an important role to play, especially in the residential sector.

### 6.3 Inuvik Region Forecast

Energy demand in the Inuivk region is dominated by the commercial sector. Table 12 indicates that conservation steps taken in the commercial sector could affect an absolute decrease in the region's total energy demand between 1979 and 1999.

TABLE 11

PROJECTIONS OF SECONDARY ENERGY CONSUMPTION 1989, 1999 CAMBRIDGE BAY
ALL PROJECTIONS IN TERAJOULES (10 12 JOULES)

| SECTOR | ENERGY USE/FORM | 1979 | 1989 ZC | 1989 C | INGS 1989 ZC-C | 1999 ZC | 1999 C | NGS 1999 ZC-C |
|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | |
| Existing | Space Heating | 101 | 90 | 45 | 50.0 | 80 | 40 | 50.0 |
| | Water *sting, Lighting, Appliances, Miscellaneous | 18 | 16 | 14 | 12.5 | 14 | 12 | 14.3 |
| New | Space Heating | 0 | 40 | 20 | 50.0 | 51 | 5 | 9000 |
| | Water Heating, Lighting | 0 | 7 | 5 | 28.6 | 9 | 7 | 22.2 |
| Sub Total | | 119 | 153 | 79 | 48.4 | 154 | 64 | 58.4 |
| COMMERCIAL | | | | | | | | |
| Existing | *sting (All) | 202 | 162 | 104 | 35.8 | 214 | 110 | 48.6 |
| | Lighting, Appliances | 17 | 15 | 12 | 20.0 | 20 | 16 | 20.0 |
| New | Heating (All) | 0 | 76 | 22 | 70.0 | 298 | 89 | 70.0 |
| | Lighting, Appliances | 0 | 7 | 4 | 42.8 | 19 | 10 | 47.4 |
| Sub Total | | 219 | 260 | 142 | 45.4 | 551 | 225 | 59.2 |
| MINING | | | | | | | | |
| | Heat and Motive Power | | | | | | | |
| | Electricity | | | | | | | |
| Sub Total | | | | | | | | |
| TRANSPORTATION | | | | | | | | |
| Road | Motor Gas | 21 | 39 | 28 | 28.2 | 73 | 40 | 45.2 |
| | Diesel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sub Total | | 21 | 39 | 28 | 28.2 | 73 | 40 | 45.2 |
| Air | Turbo Fuel | 16 | 27 | 24 | 11.1 | 45 | 32 | 28.9 |
| | Aviation Fuel | 36 | 60 | 58 | 3.3 | 102 | 82 | 19.6 |
| sub Total | | 52 | 87 | 82 | 5.7 | 147 | 114 | 22.4 |
| Marine | Motor Gas | | | | | | | |
| | Diesel | | | | | | | |
| Sub Total | | | | | | | | |
| Rail | Diesel | | | | | | | |
| Sub Total | | 73 | 126 | 110 | 12.7 | 192 | 154 | 19.8 |
| GRAND TOTAL | | 411 | 500 | 303 | 39.4 | 852 | 403 | 52.7 |

TABLE 12

PROJECTIONS OF SECONDARY ENERGY CONSUMPTION 1989, 1999 INUVIK REGION
ALL PROJECTIONS IN TERAJOULES ($10^{12}$ JOULES)

| SECTOR | ENERGY USE/FORM | 1979 | 1989 ZC | 1989 C | % SAVINGS 1989 ZC-C | 1999 ZC | 1999 C | % SAVINGS 1999 ZC-C |
|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | |
| Existing | Space Heating | 168 | 155 | 78 | 49.7 | 137 | 68 | 50.4 |
| | Water Heating, Lighting, Appliances, Miscellaneous | 61 | 48 | 41 | 14.6 | 42 | 37 | 11.9 |
| New | Space Heating | 0 | 84 | 42 | 50.0 | 64 | 6 | 90.0 |
| | Water Heating, Lighting | 0 | 24 | 22 | 8.3 | 18 | 15 | 16.7 |
| Sub Total | | 229 | 311 | 183 | 41.1 | 261 | 126 | 51.7 |
| COMMERCIAL | | | | | | | | |
| Existing | Heating (All) | 1234 | 1111 | 569 | 48.8 | 1296 | 664 | 48.8 |
| | Lighting, Appliances | 72 | 65 | 52 | 20.0 | 76 | 61 | 19.7 |
| New | Heating (All) | 0 | 333 | 100 | 70.0 | 691 | 207 | 70.0 |
| | Lighting, Appliances | 0 | 19 | 10 | 47.4 | 40 | 20 | 50.0 |
| Sub Total | | 1956 | 1528 | 731 | 52.2 | 2103 | 952 | 54.7 |
| MINING | | | | | | | | |
| | Heat and Motive Power | | | | | | | |
| | Electricity | | | | | | | |
| Sub Total | | | | | | | | |
| TRANSPORTATION | | | | | | | | |
| Road | Motor Gas | 306 | 568 | 414 | 27.1 | 1068 | 592 | 44.6 |
| | Diesel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sub Total | | 306 | 568 | 414 | 27.1 | 1068 | 592 | 44.6 |
| Air | Turbo Fuel | 233 | 390 | 351 | 19.2 | 654 | 458 | 30.0 |
| | Aviation Fuel | 33 | 55 | 52 | 5.4 | 93 | 74 | 20.4 |
| Sub Total | | 266 | 445 | 403 | 9.4 | 747 | 532 | 28.8 |
| Marine | Motor Gas | | | | | | | |
| | Diesel | | | | | | | |
| Sub Total | | | | | | | | |
| Rail | Diesel | | | | | | | |
| Sub Total | | 572 | 1013 | 817 | 19.3 | 1815 | 1124 | 38.1 |
| GRAND TOTAL | | 2757 | 2852 | 1731 | 39.3 | 4179 | 2202 | 47.3 |

The possibility of oil and gas development by 1999 could af feet the relative consumption by the energy consuming sectors. However, it is likely that such development would affect the commercial sector to the greatest extent, thereby leaving the potential for demand reductions.

6.4 Keewatin Region Forecast

AS with the Cambridge Bay and Inuvik regions, the absolute Keewatin region demand from 1979 to 199 can decrease with the appropriate conservation steps (see Table 13). The residential and commercial sectors dominate energy demand and offer a substantial environment for demand reductions. As in the Cambridge Bay region, government is heavily involved in the housing market. Given the performance of the Keewatin demonstration house (see section 6), it is evident that the territorial government supports initiatives aimed at residential energy demand reduction.

6.5 Baf f in Region Forecast

Unlike the other regions, the Baffin region energy demand is dominated by the transportation sector , and in particular by air travel. Table 14 indicates that demand reductions in aviation are not enough to af feet an absolute regional reduction by 1999. However, demand reductions in the residential and commercial sectors can be substantial, especially given existing governmental involvement in these sectors.

6.6 Region Forecast Summary

It is evident f rom the preceding discussions that absolute and sectoral energy demand can be significantly reduced in each region. Two factors suggest that the residential and commercial sectors are important areas to focus conservation efforts. first, it has been revealed that assumed conservation efforts in the Cambridge Bay,

TABLE 13

PROJECTIONS OF SECONDARY ENERGY CONSUMPTION 1989, 1999 KEEWATIN REGION
ALL PROJECTIONS IN TERAJOULES ($10^{12}$ JOULES)

| SECTOR | ENERGY USE/FORM | 1979 | 1989 ZC | 1989 C | 1989 ZC-C INGS | 1999 ZC | 1999 C | 1999 ZC-C NGS |
|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | |
| Existing | Space Heating | 173 | 151 | 75 | 50.3 | 132 | 66 | 50.0 |
| | Water Heating, Lighting, Appliances, Miscellaneous | 29 | 25 | 22 | 12.0 | 22 | 19 | 13.6 |
| New | Space Heating | 0 | 121 | 61 | 49.6 | 128 | 13 | 90.0 |
| | Water Heating, Lighting | 0 | 20 | 17 | 15.0 | 21 | 18 | 14.3 |
| Sub Total | | 202 | 317 | 175 | 44.8 | 303 | 106 | 65.0 |
| COMMERCIAL | | | | | | | | |
| Existing | Heating (All) | 195 | 175 | 90 | 48.6 | 335 | 171 | 49.0 |
| | Lighting, Appliances | 18 | 16 | 13 | 18.8 | 31 | 25 | 19.8 |
| New | Heating (All) | 0 | 98 | 29 | 70.4 | 197 | 59 | 70.0 |
| | Lighting, Appliances | 0 | 9 | 5 | 44.4 | 18 | 9 | 50.0 |
| Sub Total | | 213 | 288 | 137 | 52.4 | 581 | 264 | 54.6 |
| MINING | | | | | | | | |
| | Heat and Motive Power | 0 | 61 | 55 | 9.8 | | | |
| | Electricity | 0 | 35 | 31 | 11.4 | | | |
| Sub Total | | 0 | 96 | 86 | 10.4 | | | |
| TRANSPORTATION | | | | | | | | |
| Road | Motor Gas | 8 | 13 | 10 | 23.1 | 22 | 18 | 18.2 |
| | Diesel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sub Total | | 8 | 13 | 10 | 23.1 | 22 | 18 | 18.2 |
| Air | Turbo Fuel | 7 | 12 | 11 | 8.3 | 20 | 14 | 30.0 |
| | Aviation Fuel | 7 | 12 | 11 | 8.3 | 20 | 16 | 30.0 |
| Sub Total | | 14 | 24 | 22 | 8.3 | 40 | 30 | 25.0 |
| Marine | Motor Gas | 8 | 13 | 10 | 23.1 | 22 | 18 | 18.2 |
| | Diesel | | | | | | | |
| Sub Total | | | | | | | | |
| Rail | Diesel | | | | | | | |
| Sub Total | | 30 | 50 | 42 | 16.0 | 84 | 66 | 21.4 |
| GRAND TOTAL | | 445 | 751 | 440 | 41.4 | 968 | 436 | 55.0 |

## TABLE 14

### PROJECTIONS OF SECONDARY ENERGY CONSUMPTION 1989, 1999 BAFFIN REGION
### ALL PROJECTIONS IN TERAJOULES (10 12 JOULES)

| SECTOR | ENERGY USE/FORM | 1979 | 1989 ZC | 1989 C | % SAVINGS 1989 ZC-C | 1999 ZC | 1999 C | % SAVINGS 1999 ZC-C |
|---|---|---|---|---|---|---|---|---|
| **RESIDENTIAL** | | | | | | | | |
| Existing | Space Heating | 387 | 308 | 154 | 50.0 | 229 | 115 | 49.8 |
| | Water Heating, Lighting, Appliances, Miscellaneous | 50 | 40 | 35 | 12.5 | 31 | 28 | 9.7 |
| New | Space Heating | 0 | 235 | 118 | 50.0 | 251 | 25 | 90.0 |
| | Water Heating, Lighting | 0 | 30 | 25 | 16.7 | 33 | 28 | 15.1 |
| Sub Total | | 437 | 613 | 332 | 45.8 | 544 | 196 | 64.0 |
| **COMMERCIAL** | | | | | | | | |
| Existing | Heating (All) | 708 | 637 | 326 | 48.8 | 850 | 435 | 48.8 |
| | Lighting, Appliances | 91 | 82 | 66 | 19.5 | 109 | 87 | 20.2 |
| New | Heating (All) | 0 | 312 | 94 | 69.9 | 863 | 259 | 70.0 |
| | Lighting, Appliances | 0 | 40 | 20 | 50.0 | 111 | 56 | 49.5 |
| Sub Total | | 799 | 1071 | 506 | 52.7 | 1933 | 837 | 56.7 |
| **MINING** | | | | | | | | |
| | Heat and Motive Power | | | | | | | |
| | Electricity | | | | | | | |
| Sub Total | | 104 | 1091 | 982 | 10.0 | | | |
| **TRANSPORTATION** | | | | | | | | |
| Road | Motor Gas | 120 | 211 | 161 | 23.7 | 378 | 250 | 33.9 |
| | Diesel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sub Total | | 120 | 211 | 161 | 23.7 | 378 | 250 | 33.9 |
| Air | Turbo Fuel | 1098 | 1840 | 1656 | 10.0 | 3084 | 2159 | 30.0 |
| | Aviation Fuel | 81 | 136 | 129 | 5.1 | 227 | 182 | 19.8 |
| Sub Total | | 1179 | 1976 | 1795 | 9.2 | 3311 | 2341 | 29.3 |
| Marine | Motor Gas | | | | | | | |
| | Diesel | | | | | | | |
| Sub Total | | | | | | | | |
| Rail | Diesel | | | | | | | |
| Sub Total | | 1299 | 2187 | 1956 | 10.6 | 3689 | 2591 | 29.8 |
| GRAND TOTAL | | 2639 | 4962 | 3776 | 23.9 | 6166 | 3624 | 41.2 |

Inuvik and Keewatin regions would affect an actual 1979-1999 decrease in absolute demand. Second, these are regions where there is already an intense involvement by government (relative to Fort Smith), so that the environment for implementing conservation strategies appears to be less vulnerable to external forces.

Despite the appealing possibilities of energy conservation in the residential and commercial sectors, the N.W.T. summary in Table 15 reveals that the 1999 absolute demand (conservation approach) has increased by about 39% from 1979. Two factors may explain this situation. First the transportation and mining sectors, both of which are significant energy consumers, do not offer the demand reduction possibilities noted above. The energy demand of these sectors is most evident in the major N.W.T. region, Ebrt Smith. Therefore, an increase in Fort smith transportation and mining demand affects an increase in overall N.W.T. consumption. Second, this energy demand scenario has assumed significant economic and transportation development to 1999, again predominantly in the Fort Smith region, a factor affecting energy demand increases. It should be noted, however, that conservation savings for these sectors are conservative e.g., the analysis did not assume a shift from gasoline truck engines to diesel truck engines.

The development of the regional demand scenarios assumed that the extent of conservation efforts is likely to increase over time, i.e. the 1989-1.999 period is likely to experience more significant demand reductions. Table 15 illustrates this but also shows 1979-1989 to be an important transitional period. In fact, residential and commercial demand reductions during this period are close to the percentage savings achievable from 1989-1999. The table reveals, 'however, that significant conservation developments in the mining and transportation sectors are likely to take longer to be implemented.

TABLE 15

PROJECTIONS OF SECONDARY ENERGY CONSUMPTION 1989, 1999 NORTHWEST TERRITORIES
ALL PROJECTIONS IN TERAJOULES ($10^{12}$ JOULES)

| SECTOR | ENERGY USE/FORM | 1979 | 1989 ZC | 1989 C | 1989 ZC-C INGS | 1999 ZC | 1999 C | 1999 ZC-C INGS |
|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | |
| Existing | Space Heating | 1361 | 1124 | 562 | 50.0 | 944 | 471 | 50.1 |
| | Water Heating, Lighting, Appliances, Miscellaneous | 329 | 282 | 245 | 13.1 | 246 | 216 | 12.2 |
| New | Space Heating | 0 | 745 | 373 | 50.0 | 810 | 81 | 90.0 |
| | Water Heating, Lighting | 0 | 151 | 127 | 15.9 | 165 | 137 | 17.0 |
| Sub Total | | 1690 | 2232 | 1307 | 41.4 | 2165 | 905 | 58.2 |
| COMMERCIAL | | | | | | | | |
| Existing | Heating (All) | 5658 | 5073 | 2618 | 48.4 | 6579 | 3369 | 48.8 |
| | Lighting, Appliances | 945 | 850 | 681 | 19.9 | 1110 | 888 | 20 0 |
| New | Heating (All) | 0 | 2147 | 577 | 73.1 | 5501 | 1650 | 70 0 |
| | Lighting, Appliances | 0 | 374 | 188 | 49.7 | 965 | 483 | 50.0 |
| Sub Total | | 6603 | 8444 | 4064 | 51.9 | 14155 | 6390 | 54.9 |
| MINING | | | | | | | | |
| | Heat and Motive Power | 592 | 941 | 847 | 10.0 | 2319 | 1740 | 25.0 |
| | Electricity | 656 | 1011 | 909 | 10.0 | 2572 | 1929 | 25.0 |
| Sub Total* | | 1352 | 3043 | 2738 | 10.0 | 4891 | 3669 | 25.0 |
| TRANSPORTAT ON | | | | | | | | |
| Ro | Motor Gas | 1346 | 2495 | 1835 | 26.4 | 4696 | 2648 | 43.6 |
| | Diesel | 83 | 185 | 149 | 19.4 | 439 | 298 | 32.1 |
| Sub Total | | 1429 | 2680 | 1984 | 26.0 | 5135 | 2946 | 42.6 |
| Air | Turbo Fuel | 1941 | 3253 | 2928 | 10.0 | 5452 | 3817 | 30.0 |
| | Aviation Fuel | 346 | 580 | 430 | 25.9 | 973 | 608 | 37.5 |
| Sub Total | | 2287 | 3833 | 3358 | 12.4 | 6425 | 4425 | 31.1 |
| Marine | Motor Gas | 8 | 13 | 10 | 23.1 | 22 | 18 | 18.2 |
| | Diesel | 132 | 221 | 177 | 20.0 | 371 | 297 | 20.0 |
| Sub Total | | 140 | 234 | 187 | 20.0 | 393 | 315 | 19.8 |
| Rail | Diesel | 36 | 60 | 54 | 10.0 | 101 | 91 | 10.0 |
| Sub Total | | 3892 | 6807 | 5583 | 18.0 | 12054 | 7777 | 35.5 |
| GRAND TOTAL | | 13537 | 20526 | 13692 | 33.3 | 33265 | 18741 | 43.7 |

Tables 10 to 15 also suggest that economic growth does not have to be sacrificed by conservation strategies. It was assumed in this analysis that real economic growth to 1999 would be 5.3% per year. It is possible, then, for the Cambridge Bay, Inuvik and Keewatin regions to experience real economic growth and an absolute decrease in energy demand. Even for the N.W.T. as a whole, the annual rate of increase of energy demand 2.5% is less than projected economic growth. Again, the Fort Smith region is the major influence, with an energy demand increase of 3.9% per year, compared with an economic growth of 5.3% per year.

## 7.0 Recommendations

It is recommended that:

i) the information limitations listed in Appendix VIII be assessed and eliminated. More specifically, the Science Advisory Board data model should be refined, updated and extended to include regional variables and demand shifts according to economic development scenarios;

ii) the various sectoral conservation options be assessed for their economic feasibility;

iii) the N.W.T. government develop an economic forecasting model or models;

iv) the N.W.T. government assess the energy demand implications of future development projects e.g., L.N.G. terminals, pipelines;

v) the N.W.T. government devote considerable attention to energy demand reduction in the residential and commercial sectors. In this context, it is suggested that considerable use be made of existing federal services and programs such as the: "Off-Oil Program", Federal-Provincial demonstration project fund, Enersave Advisory Service and the Canadian Government Specifications Board insulation contractor certification program. Moreover, it is suggested that thermal efficient building cedes be established and enforced for new and rehabilitation construction;

vi) the N.W.T. government integrate the goals of community economic development and employment with housing rehabilitation and construction needs. More specifically, major education, training and development programs should provide support for locally based energy conservation ventures;

vii) the N.W.T. government and D.I.A.N.D. review the conservation strategies initiated in countries with similar climate and physiography e.g., Scandinavia.

viii) the N.W.T. and federal governments use real, as opposed to subsidized, energy prices in assessing potential conservation savings.

## 8.0 Energy Supply in the N.W.T.

The preceding demand analysis described current (1979) N.W.T. energy consumption by form and sector, revealing demand to be dominated by the commercial and transportation sectors. Demand projections to 1989 and 1999 showed that absolute and sectoral consumption can be reduced significantly in each region. However, if future energy supply patterns remain as they are at present, the territory is likely to continue to experience the vulnerabilities related to an economy almost solely dependent on petroleum.

Fluid petroleum derived fuels, i.e. for the most part, gasoline, diesel, and heating fuels, are mainly used for three end uses: space heating; production of electrical power; and transportation. A major task facing the N.W.T. is to alter supply in a manner that reduces fluid fuel inputs to these end uses. The following sections illustrate how this might be achieved by describing the supply potential of both non-renewable and renewable energy resources.

## 9.0 Residual (Waste) Heat Recovery

Recent studies and actual demonstration projects in the N.W.T. have demonstrated the significant potential in utilizing the waste or residual heat energy stream from existing diesel electric generating units and from mine sites. 'Ibis potential can be best understood by a brief examination of energy processes and estimated N.W.T. residual energy streams.

### 9.1 Energy End-Uses and Residual Streams

The end-uses or tasks to which energy is applied can be delineated into two categories: non-heat or work, i.e. all energy applied to transportation, lighting and mechanical drive; and process heat, i.e. energy used to heat industrial. process and to supply space heat. The common supply input for process heat is petroleum. The resultant process temperatures range as follows:

i) furnace combustion, 260°C to 815°C;

ii) boiler phase change, 100"C to 260'C; and

iii) space heating, less than 100"C.

With process temperatures ranging from 815°C to less than 100"C, it can be expected that residual heat energy will also display a wide range of quality. A recent study by Lalonde, Girouard, Letendre and Associates Ltd. (hereafter known as Lalonde et. al. ) examines the definable and usable residual heat stream in Canadian industry and identifies a range in quality from 815°C (furnace exhaust) to less than 49°C (condenser cooling and process radition.)[1] Lalonde et. al. identify two major sources of residual heat in the N. W.T. , electric power generation (base load) and mining/milling. With Yukon and N.W.T. data grouped together, the chart below illustrates the quality range of the estimated residual stream.

With total energy consumption in the territories amounting to 25.1 petajoules, it is clear that residual heat is a potentially large source of supply.

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1 Lalonde, Girouard, Letendre and Associates Ltd., A Study to Evaluate the Energy Cascading Potential in Industry, Volume I Main Report, Volume II Energy Data Base and Volume III Industrial Sector and Technical Reviews, a study prepared for the federal Conservation and Renewable Energy Branch, 1980.

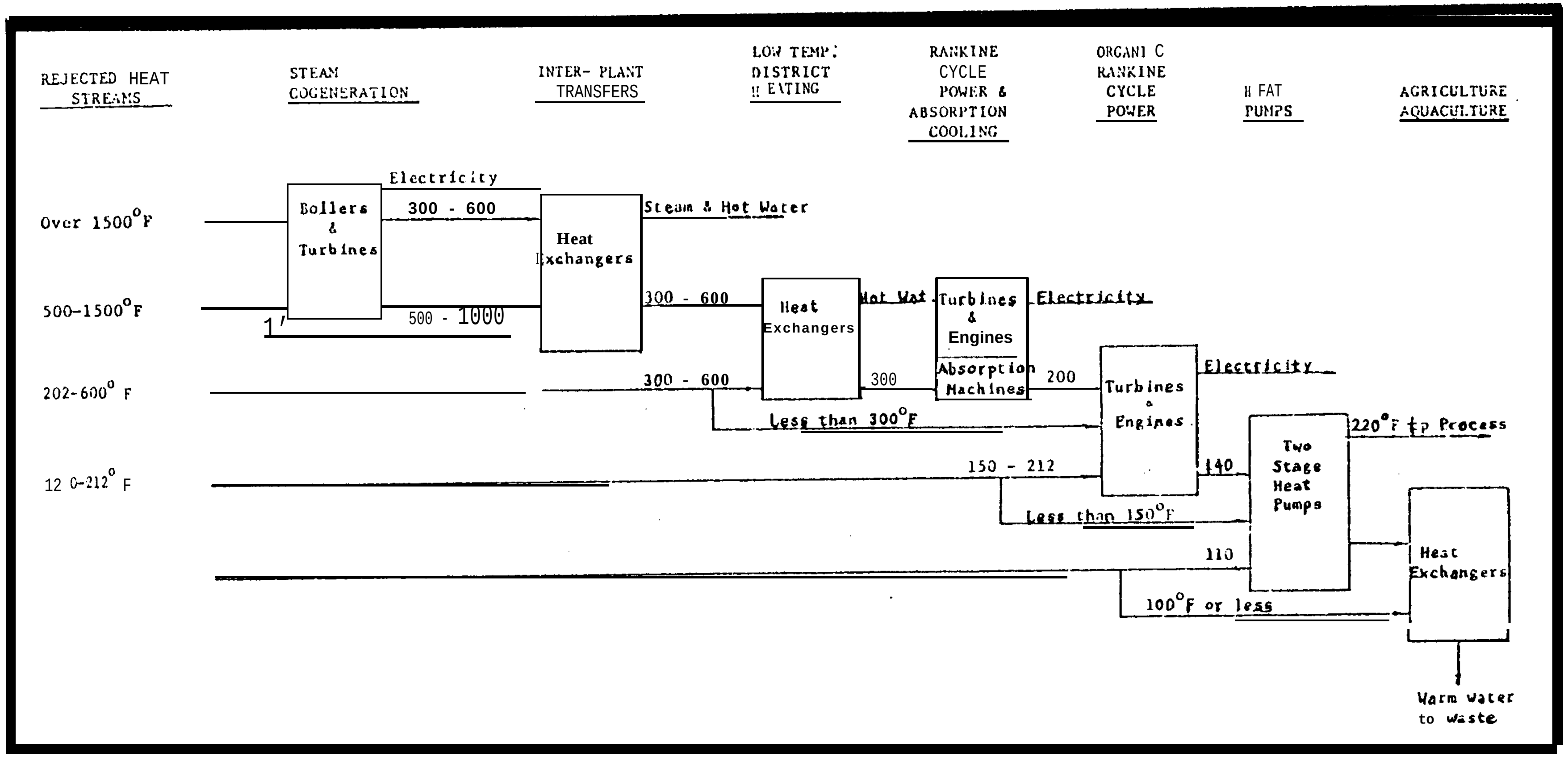
| INDUSTRY | N.W.T./YUKON RESIDUAL HEAT STREAM BY QUALITY (Energy Potential in Terajoules) TEMPERATURE RANGE 260°C to 815°C | 100″C to 260°C | 49°C to 100″C | 49°C | Radiation |
|---|---|---|---|---|---|
| Electric Power | 153 | 76 | 51 | 0 | 51 |
| Mining | 201 | 43 | 212 | 124 | 67 |

9.2 Utilizing Residual Heat Streams

If thermodynamic laws were followed, the efficient application of residual heat would entail matching the energy at a quality appropriate to the task, a process that Lalonde et. al. term energy cascading. An ideal energy cascade makes uses of all of the heat stream potential, i.e. heat is used at its highest quality e.g., for metallurgical processes and then the residual stream is matched to appropriate end-uses at each subsequent level of quality. Figure 2 describes what Lalonde et. al. terman ideal cascade. Each process such as cogeneration and district heating, uses different technologies e.g., turbines, and heat exchangers, to extract the given energy potential. Appendix IX summaries the heat recovery systems according to energy quality, applicability and cost (1979$). The more economical technologies appear to be heat exchangers, thermal storage (on a daily basis), and heat pumps (competitive when a constant temperature is available along with the end-uses appropriate to small increase in temperature and a low output temperature).[1] Cogeneration is identified as being cost competitive for consumers with existing demands greater than 0.5 MW and a steam load of 22000 kg/hr.[2]

1 Lalonde et. al., p. 111, Volume 1.
2 Ibid., p. 109, Volume 1.

FIGURE 2. GENERAL IDEAL RESIDUAL HEAT CASCADE




SOURCE: Lalonde, Girouard, Letendre and Associates Ltd., A Study to Evaluate The Energy Cascading Potenial in industry, a study prepared for the Federal Conservation and Renewable Energy Branch, E. M. R., 1980, Figure 9.2.2 Volume 1.

Table 16 describes how heat recovery systems might be applied to the estimated N. W. T./Yukon residual heat stream. A total of 916 tera joules appears to be recoverable. To date, study and demonstrations have shown that an achievable near-term heat recovery approach is the use of diesel-electric generating unit heat.

## 9.3 Residual Heat From Diesel-Electric Units

Diesel electric generating units in the N.W. T. utilize water cooling circuits in the engine block and exhaust manifolds to prevent overheating through the "removal" of residual heat. Cooling water must remove about 3 0% of the energy input. Heat also escapes in exhaust gases; about 50% to 60% of the gas total is recoverable. Recent studies and demonstration pro jects have illustrated the potential for recovering manifold (jacket) and exhaust gas heat for low temperature "mini" district heating application.[1] Jacket recovery is termed as normal temperature recovery, i.e. low grade heat at 75°C. to 90°C. Exhaust recovery systems operate at high temperature, i.e. hot water recovered at 120 °C and 130 k Pa and steam recovery at 120°C and 100 k Pa.

Although residual heat can be and is recovered separately from either jacket or exhaust gas sources, combined jacket and exhaust recovery appears to be advantageous because:

i) overall plant efficiencies (1st Law) can approach 75%; and

ii) distribution temperatures coincide with those normally used in hot water system design, resulting in smaller distribution main sizes and lower pumping rates.

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1 Ferguson, Naylor, and Simek Ltd. , An Inventory of Major Diesel Generating Systems in Canada and An Assessment of the Potential Markets for Heat Recovery, a study prepared for the Federal Conservation and Renewable Energy Branch, 1980.
and
Personal communication with the firm.

TABLE 16

RESIDUAL HEAT APPLICATIONS IN THE N.W.T. AND YUKON TERRITORIES

| RESIDUAL HEAT RECOVERY | REQUIREMENT TEMPERATURES | RECOVERABLE ENERGY TJ |
|---|---|---|
| Cogeneration | Additional fuel on site | |
| In-plant cascading | Heat exchangers | |
| Inter -plant transfers | 260°C to 815°C | 151 |
| Low-temperature district heating | 100"C to 260°C | 789 |
| Rankine Cycle power generation | 100"C to 260°C or 49°C to 100"C | 22 |
| Absorption cooling and refridgeration | 100"C to 260°C or 49°C to 100"C | .16 |
| Organic Rankine Cycle power generation | 49°C to 100"C | 6 |
| Heat Pumps | ≤ 49°C to 100"C | 8 |
| Agriculture and aquiculture | 49°C | |

Source: Yukon Report, p. 72.

The heat is recovered by a variety of heat exchanger systems and is used for in-house (plant heating) and/or commercial and residential space heating. The latter end use is based on a water or steam main distribution network. Table 17 lists the potential district heating requirements for N.W.T. communities identified by Lalonde et. al. At least 52% of the average heating requirements of the selected communities can be met by district heating.

In a study more specific to the N.W.T., Ferguson, Naylor and Simek Ltd. (hereafter known as Ferguson et. al.) assess the residual heat stream from diesel units in selected communities and calculated:

i) the gross residual heat produced;

ii) the recoverable heat, i.e. the practical amount of heat that could be extracted, accounting for losses and heat already recovered;

iii) the monthly heat supply markets;

iv) the type of distribution system needed; and

v) the pay back on community project investments.

As Table 18 illustrates, combined residual heat recovery could be feasible depending on the accepted pay back period e.g., 5 years versus 10 years. There does not appear to be a preferred region: however, the calculations for the Baffin region communities of Resolute Bay and Frobisher Bay include the most rapid pay back schemes of four and three years. As with most energy projects, the pay back will be affected by changes in capital and operating costs and the energy inflation rate.

Although the Ferguson et. al. report assessed only a few N.W.T. communities, it is possible to derive a general estimate of the readily attainable regional residual heat stream. Table 19 shows

TABLE 17

POTENTIAL DISTRICT HEATING REQUIREMENTS FOR SELECTED N.W.T. COMMUNITIES

| COMMUNITY | APPROXIMATE POPULATION | ANNUAL AVERAGE HEATING REQUIREMENTS[a] TJ | AVAILABLE ENERGY TJ |
|---|---|---|---|
| Fort Resolution | 500 | 25 | 13 |
| Yellowknife | 6100 | 316 | I-58 |
| Norman Wells | 500 | 25 | 13 |
| Aklavik | 2000 | 105 | 53 |
| Inuvik | 2670 | 139 | 139 |
| Frobisher Bay | 6000 | 316 | 105 |
| Rankin Inlet | 500 | 25 | 13 |
| Baker Lake | 500 | 25 | 13 |
| TOTAL | 18770 | 976 | 507 |

$$\frac{507}{976} \times 100\% = 52\%$$

Source: 1. Lalonde et. al. Table 9.2.2.2, p. 166, Volume 1.

Notes:

a Heating requirements were derived as follows:

(Average requirements - maximum requirements = average x 2)

TABLE 18

THE POTENTIAL FOR RESIDUAL HEAT RECLAMATION IN SELECTED N.W.T. COMMUNITIES (USING COMBINED RECOVERY)

| LOCATION | ANNUAL RECOVERABLE[a] HEAT (TERAJOULES) | ANNUAL FUEL[b] SAVINGS (GAL.) | CAPITAL INVESTMENT $ | PAYBACK (YEARS) ($1980) | SECTOR APPLICATION[c] |
|---|---|---|---|---|---|
| | | FORT SMITH REGION | | | |
| Fort Simpson | 26 | 72,394 | 804,000 | 14 | Commercial |
| Hay River | 118 | 193,286 | 1,251,000 | 6 | Commercial, residential |
| TOTAL | 144 | 265,680 | | | |
| | | INUVIK REGION | | | |
| Inuvik | 162 | 221,916 | 830,000 | 4 | Commercial, residential |
| Norman Wel is | 16 | 54,346 | 369,000 | 9 | Residential, commercial |
| TOTAL | 178 | 276,262 | | | |
| | | CAMBRIDGE BAY REGION | | | |
| Cambr idge Bay | 12[d] | 53,932 | 364,440 | 6 | Commercial, residential |
| | | KEEWATIN REGION | | | |
| Baker Lake | 16 | 69,995 | 629,000 | 9 | Commercial |
| Rank in Inlet | 22 | 48,704 | 415,000 | 8 | Commercial, residential |
| TOTAL | 38 | 118,699 | | | |
| | | BAFFIN REGION | | | |
| Resolute Bay | 27 | 23,059 | 104,000 | 4 | Commercial |
| Frobisher Bay | 97 | 239,781 | 890,000 | 3 | Commercial, residential |
| Manisivik | 37 | 19,948 | 190,000 | 8 | Industrial |
| TOTAL | 161 | 282,788 | | | |
| N.W. T. TOTAL | 533 | 997,361 | | | |

Sources: 1. Ferguson, Naylor and Simek Ltd., An Inventory of Major Diesel Generating Systems in Canada and an Assessment of the Potential Markets for Heat Recovery, A Study prepared for Energy, Mines and Resources Canada, 1980.

Notes:

a Annual recoverable heat represents the practical. amount of heat that could be extracted from the generator jacket cooling water and exhaust gases minus the amount of heat already being recovered for "in-house" use.

b Annual. fuel savings, capital investment and payback data are based on a "Viable Market" assessment, i.e. the viable market includes buildings readily accessible to the generating plant.

c Sector application represents the energy consuming sectors most readily accessible to the recoverable heat. If more than one sector is accessible, they are listed in order of potential.

d Cambridge Bay already has one heat reclamation project underway. There are five large warehouses, garages and offices heated by a hot water system which recovers waste heat from the jacket water.

the potential market utilization, assuming the residual heat supply to be appropriated by the commercial sector.[1] The Ferguson et. al. study and demonstration projects (see next subsection) suggest that the commercial sector is the most likely market for residual heat use, primarily the heating of small buildings. Table 19 shows that under a conservation scenario, the N.W.T. commercial market utilization could be 13.4%. The Keewatin and Baffin regions appear to derive the greatest potential from the district heating schemes.

## 9.4 Current N.W. T. District Heating Efforts

The foregoing discussion suggests that low-temperature district heating and inter-plant transfers offer the most applicable heat recovery scenarios. The experience of actual projects suggests that these options are being pursued. District heating projects have begun in Cambridge Bay, Rankin Inlet and Pelly Bay. Additional projects are being started in Coppermine, Lac La Martre, and Pangnirtung.

The Cambridge Bay project consists of five warehouses, garages, and offices heated by a hot water system recovering heat from the jacket cooling water. The Pangnirtung project is designed for full recovery of the residual heat stream.

To date, the major parties involved in the projects have been the N.C. P.C. , as residual heat supplier, and the N.W.T. government, as a residual heat purchaser. The N.W.T. Department of Public Works (D. P. W.) has acted as project manager, for both itself and other governmental clients. The experience has been for the N. C.P.C. and N.W. T. D. P.W. to agree on the cost recovery, i.e. N. C.P. C. appropriates a portion of every $ saved.

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1 The Table 19 notes explain the concept of market utilization.

TABLE 19

PRACTICAL N.W.T. MARKET UTILIZATION OF RESIDUAL HEAT SUPPLY

| | MARKET ON[a] | | CONSERVATION | | | CONSERVAT | | |
|---|---|---|---|---|---|---|---|---|
| | 1979 RESIDUAL Heat Supply TJ | 1979 M.U. TJ | 1989 Residual[b] Heat Supply TJ | 1989 M.U. TJ | M.U. as a % of Commercial Space Heat Demand | 1989 Residual Heat Supply TJ | 1989 M.U. TJ | M.U. as a % of Commercial Space Heat Demand |
| Fort Smith | 654 | 163 | 941 | 235 | 5.4 | 696 | 174 | 9.3 |
| Cambridge Bay | 102 | 25 | 124 | 31 | 13.0 | 75 | 19 | 15.1 |
| Inuvik | 388 | 97 | .345 | 86 | 5.9 | 215 | 54 | 8.1 |
| Keewatin | 162 | 40 | 273 | 68 | 24.9 | 160 | 40 | 33.b |
| Baffin | 398 | 99 | 749 | 187 | 19.7 | 570 | 142 | 33.8 |
| N.W.T. Total | 1704 | 424 | 2432 | 607 | 8.4 | 1716 | 429 | 13.4 |

Sources: 1. Ferguson, Naylor, and Simek Ltd., An Inventory Of Major Diesel Generating Systems in Canada and an Assessment of the Potential Markets for Heat Recovery, A study prepared for E. M. R., 1980, Volumes 1 and the Appendix to Volume 1.

2. Tables 2, 10, 11, 12, 13 and 14.

Notes:

a The study cited above, by Ferguson, Naylor, Sinek Ltd., assessed the amount of residual heat that might be utilized to meet the selected communities' space heat demand. This heat potential was analyzed according to the system's potential and according to the market potential. The ratios used were:

$$\text{System Utilization} = \frac{\text{Total Heat Currently and Potentially Used}}{\text{Total Heat Produced}}$$

$$\text{Market Utilization} = \frac{\text{Potential Market for Combined Jacket and Exhaust Gas Heat}}{\text{Total Recoverable Heat}}$$

The market utilization ratio is used for this table because it reflects actual demand sources for the residual heat supply and, as indicated in Table , offers feasible payback periods. A perusal of the study's Appendix A.3.1 "Technical Analysis" suggests that an average utilization ratio of .5 is quite approachable. Further perusal of this Appendix suggests that 60% to 70% of the communities' residual heat is recoverable. 'Ibis table assumes a conservative recovery rate of 50%.

The residual heat supply data used in this table represents the Conversion and Line Losses figures from Tables 10 to 14. Using the 1979 Ebrt Smith region as an example:

$$\text{Market Utilization} = \frac{\text{Potential Market for Combined Jacket and Exhaust Gas Heat}}{\text{Total Recoverable Heat}}$$

$$.5 = \frac{x}{654 \times 50\%}$$

$$x = 163$$

b The 1989 residual heat supply is derived from the 1979 conversion and line losses figures as follows: the 1979 conversion and line loss total for a particular region is taken as a percentage of the total regional demand (minus the conversion and line losses).

The 1979 percentage is then applied to 1989 ∠C and C. Approach total regional demand.

## 9.5 Mininq Efforts at Heat Recovery

Two N.W. T. mines, Nanisivik and Can Tung, are currently recovering residual heat. At Nanisivik, the entire complex's space heating demand is provided by diesel electric unit residual heat. As well, concentrates are dried using exhaust gas recovery. At the Can Tung mine, residual heat recovered from the jacket water and cooling lubricant is used for steam cycle cogeneration and hot water utilidor space heating.

The experienceof these mines suggests a considerable potential for mine and milling heat recovery. Communication with the Pine Point and Con-Rycon mines indicates that these large energy consumers also intend to pursue residual heat recovery. (Further discussion of recovery potential is found in the Yukon Report, p. 71) .

## 10.0 Natural Gas

In Volume II of his Mackenzie Valley natural gas pipeline assessment, Justice Thomas Berger states that "a gas pipeline in the Mackenzie Valley should provide two things for northerners, an assured energy supply and a reduction in energy costs".[1] To some extent, this statement reflects present day N.W. T. concerns, i.e. the question remains whether or not the N.W.T. will ever make use of a natural gas (N. G.) supply. This section briefly outlines some of the possibilities and limitations to N.W.T. use of N.G.

## 10.1 N.W.T. N.G. Reserves and Production

The N.W.T. contains about 68% of Canada's potential hydrocarbon producing sediments. The main geological provinces in the N.W. T.

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1 Thomas R. Berger, Northern Rontier Northern Homeland, The Report of the Mackenzie Wiley Pipeline Inquiry, Volume II (Ottawa: Supply and Services, (1977)), p. 65.

with N.G. potential are the Arctic Stable Platform, Sverdrup basin, Arctic Coastal Plain, Mackenzie - Beaufort Basin, Liard Plateau and Range, Eagle Plain, and the Interior Plans. As Table 20 shows, the N.G. reserves that have potential for N.W.T. domestic use are in the Mackenzie Delta - Beaufort Sea Basin and the Mainland Territories, primarily the Liard Plateau and Interior Plains.

N.W.T. N.G. production is confined to the Pointed Mountain Gas Field in the Liard Plateau, the south western corner of the Fort Smith region. The latest production figures (1978) show a yearly total of about 589 thousand cubic metres.[1]

10.2 <u>N.W.T. N.G. Potential For Domestic Use</u>

In addition to political concerns, four factors have a bearing on domestic N.G. utilization, reserve capability, marketing, proximity, of demand centres to supply, and costs (including environmental). The previous discussion indicates substantial N.G. reserves. The following estimate indicates the extent to which the N.W.T. might utilize such a supply.

It is assumed that N.G. will not be utilized for domestic purposes until 1989. Assuming a conservation demand scenario, the total Inuvik and Fort Smith regional space heating demands would be 90 and 342 TJ respectively. Logistics and infrastructure limitations are likely to limit utilization; therefore it is assumed that 75% and 50% of the respective Inuvik and Fort Smith demands can be matched by N.G. supply, i.e. 90 and 171 TJ respectively. From Table 20, it is assumed that 5.3 t.c.f. of the Mackenzie-Beaufort reserve is available for market in the Inuvik region. Given a constant annual

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1 Department of Indian and Northern Affairs, Oil and Gas Activities 1978 (Ottawa: D.I.N.A., 1979), p. 51.

TABLE 20

ESTIMATED N.W.T. NATURAL GAS RESERVES THAT HAVE POTENTIAL FOR DOMESTIC USE

| LOCATION | ESTIMATES OF MARKETABLE N.G.[b] T.c.f. | POTENTIAL RESERVE ADDITIONS BY YEAR 2000[c] T.c.f. | ULTIMATE POTENTIAL BY YEAR 2000[d] T.c.f. |
|---|---|---|---|
| Mackenzie Delta - Beaufort Sea | 5.3 | 15 - 23 | 39-99 |
| Mainland Territories[a] | 0.4 - 1.7 | 1 | 6-20 |
| TOTAL | 5.7 - 7.0 | 16 - 24 | 45 - 119 |

Sources: 1. Indian and Northern Affairs Canada, Oil and Gas Activities 1978 (Ottawa: Indian and Northern Affairs, 1979), p. 19.

2. National Energy Board, Canadian Natural Gas Supply and Requirements (Ottawa: N. E. B., 1979), pp. 8, 32, 33.

Notes:

a Mainland Territories includes the Yukon gas fields.

b National Energy Board estimates.

c Petroleum industry estimates.

d Geological Survey of Canada estimates.

demand of 90 TJ, a twenty year supply of N.G. would entail 90 TJ x 20 years = 1800 TJ. 'Therefore, $\frac{1.800 \text{ TJ}}{5.3 \text{ t.c. f.}}$ or $\frac{1.800 \text{ TJ}}{5,620,000 \text{ TJ}}$ = .03%.

A similar calculation for the Fort Smith region, but from an estimated 1.7 t.c. f. mainland reserve, results in about .2% of the reserve being used over twenty years. These simple calculations illustrate that extensive N.G. utilization for domestic purposes would still leave a substantial balance for export.

The marketing possibilities depend, of course, on industry and government priorities. The Mackenzie-Beaufort reserves could be distributed across the mainland by a Mackenzie Valley pipeline and/or a Dempster Highway lateral. (See Figure 3.) Such developments could possibly supply both Inuvik and Fort Smith region centres. The N.G. could come on stream anywhere after 1985 according to most estimates.[1] The other possibility is for mainland N.G. e.g., from the Pointed Mountain field, to be tapped for Fort Smith regional use.

The proximity of "potential" and "suspended" N.G. wells to demand centres was determined by a perusal of D.I.A.N.D.'s Schedule of wells 192-1980 and an assortment of their maps. The categories potential and suspended represent gas discoveries and actual well development. Table 21 indicates that, depending on the well location and demand centre, some wells are as close as 26 km to demand centres.

The costs of domestic N.G. utilization are site specific and depend on such factors as:

i) the proximity of the demand centre to the supply;

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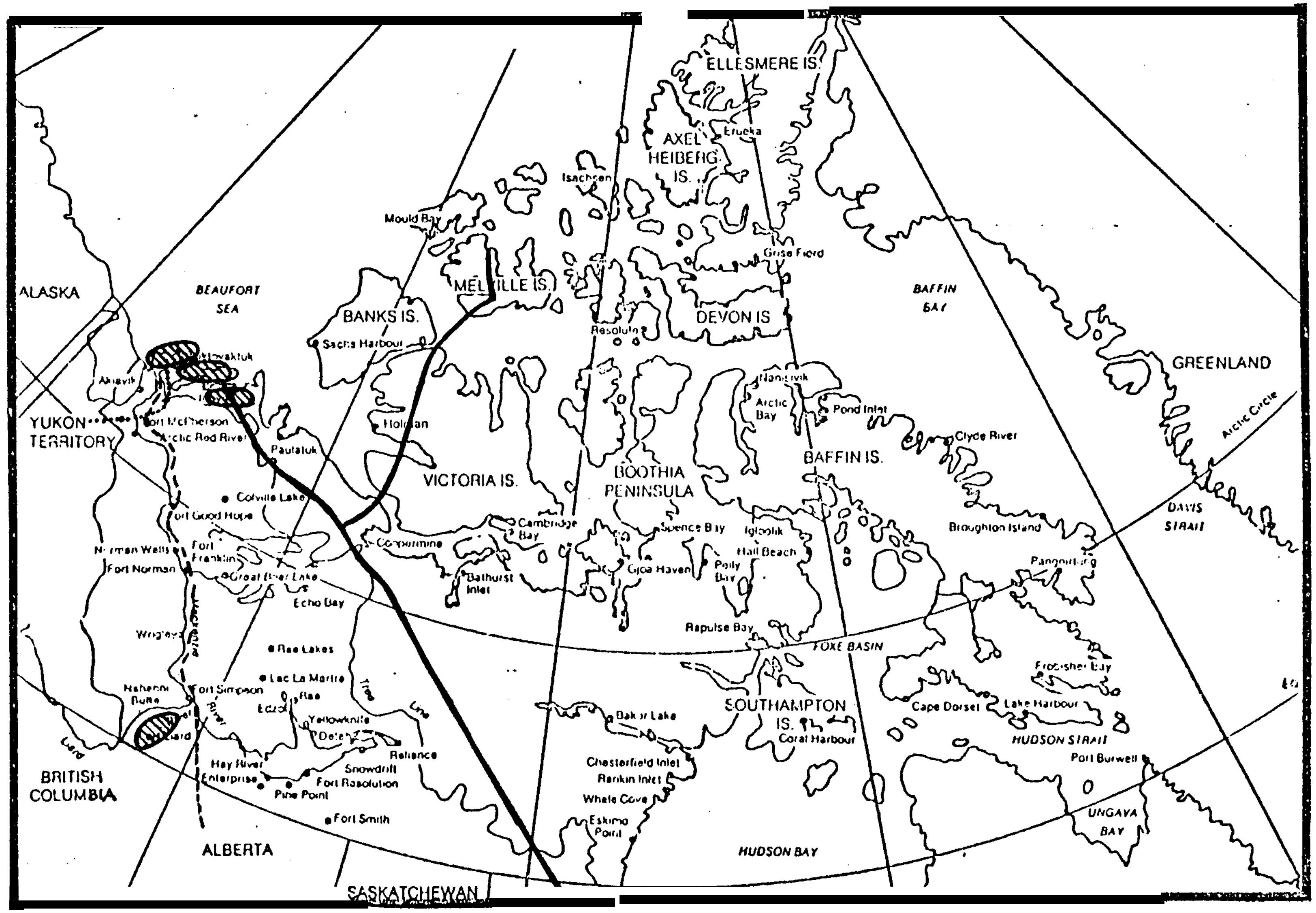
1 National Energy Board, Canadian Natural Gas Supply and Requirements 1979 (Ottawa: N.E.B., 1979), pp. 36-37.

## FIGURE 3. POTENTIAL NATURAL GAS PIPELINE ROUTES IN THE NORTHWEST TERRITORIES




| | | | |
|---|---|---|---|
| LEGEND: | ———— Polar Gas Pipeline | .......... | Dempster Extension |
| | - - - - - - - - MacKenzie Valley Pipeline | //////// | Gas Fields |

SOURCES: Department of Indian Affairs and Northern Development, Oil and Gas Activities 1978 (Ottawa: DIAND, 1979).
Personal consultations with the Government of the N.W.T.

TABLE 21

PROXIMITY OF SELECTED INUVIK AND FORT SMITH REGION DEMAND CENTRES TO NATURAL GAS WELLS[a]

| DEMAND CENTRE | WELL NUMBERS | PROXIMITY TO WELLS km | GAS FIELD LOCATION | APPROXIMATE RANGE OF WELL DEPTHS |
|---|---|---|---|---|
| | | INUVIK REGION | | |
| Inuvik | P-41, P-53, A-44, L-43 | 50-56 | Parsons | 3048 - 3962 |
| | F-36 | 90 | | |
| Tuktoyaktuk | F-40[b] | 116 | | |
| | P-41, P-53, L-43 | 65 | Parsons | 3048 - 3962 |
| | C-21, H-30, C-58, K-16 | 90 | Kumak | NA |
| | C-42, D-43, G-33 | 77 | Taglu | 3048 - 4877 |
| | | FORT SMITH REGION | | |
| Hay River | N-18 , A-05 | 129 | | 1339 - 1524 |
| Fort Liard | J-7 2 | 26 | | 3363 |
| | H-78 | 64 | | |
| Fort Providence | Briggs-Rabit | 80 | Rabbit Lake | 822 - 853 |

Sources: 1. Indian and Northern Affairs Canada, Oil and Gas Activities 1978 (Ottawa: D. I. No A., 1979), pp. 14-16.

2. Indian and Northern Affairs Canada, a selection of well location maps from the Oil and Gas Division, 1980.

3. Indian and Northern Affairs Canada, Schedule of Wells 1920-1979 (Ottawa: D.I.N.A., 1980).

Notes:

a 'lhe selection of natural gas wells that represent potential exploitation is based on two categories "potential" and "suspended" gas wells. A well may be suspended due to two factors. First, drilling might be stopped due to the end of the climatic drilling season. Second, the development f wells might be suspended because of inadequate markets, lack of capital or political/jurisdictional problems.

ii) the demand centre's pro jetted consumption;

iii) the distribution network, i.e. whether a grid will be run from a major pipeline lateral or whether a small diameter pipeline will be run from the wells directly to the community (s) ; and

iv) the costs of converting existing oil burning furnaces to N.G.

To date, cost analyses for domestic utilization are limited. Two studies have been completed for the town of Inuvik. In 1978, a study for the muvik Town Council and Chamber of Commerce examined the potential to tap one well from the Parsons Lake Field, about 48 km from the town. The study suggests that capital and operating costs would make delivered gas uncompetitive with Norman Wells' supplied oil.

A more recent study assesses the feasibility of supplying the N. C.P. C. in Inuvik from either the Parsons Lake or Ya Ya fields.[1] The N. C.P.C. is presently the major distributor of electricity to Inuvik and Tuktoyaktuk as well as utilidor heat to Inuvik. The study assumed a construction schedule and an infrastructure consisting of: two gas production/injection wells which are used alternately for gas production and excess gas re-injection; a water d isposal well; a liquid hydrocarbon disposal well; wellhead facilities; well flowlines, a gas plant to process N.G. for delivery by 13 mm pipeline; a turbine building for gas compression and propane refridgeration; heat exchangers; electricity generation facilities; and a pipeline.

The total capital cost of a Parsons Lake delivery system is $42,080,000 ($1980) with well costs of $4 million per well.[2] Annual operating and maintenance costs are estimated at $1,108,000. The total cost of delivered gas to the N. C.P.C. was calculated as

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1 Canuck Engineering Ltd. , Inuvik Gas Supply Feasibility Study, a study prepared for the town of Inuvik, 1980.

2 Ibid., Table 5.7.1.

$6.71/M.c. f. for Parsons Lake, $8.65/M.c. f. for the Ya Ya wells. This price was concluded to be currently uncompetitive with existing and foreseeable energy supply from Norman Wells (diesel oil and Bunker "C" fuel). Since calculations and time periods are not made explicit in this study, it is difficult to suggest the cost at which delivered gas prices will be competitive.

The development of a well system to serve one community appears to be an expensive supply option -- in the case of Inuvik, about $65 thousand per residential customer. Another option is to tap into an export pipeline with a lateral and distribution grid. A study by Sean Casey calculates the residential cost per customer of such a development to be $7957 (1980$ ).[1]

The Casey study shows the delivered N.G. costs to the Fort Smith region communities of Fort Simpson and Yellowknife to be higher than the Inuvik total. It appears that cheaper well drilling costs on the mainland, about $1.299 per metre versus $1457 per metre for Delta exploration, are offset by higher distribution costs.

10.3 N.G. End-Uses

If N.G. is a supply option for the Inuvik and Fort Smith regions, decisions have to be made concerning its end-use. The Canuck Engineering and Casey studies assess N.G. as a fuel for space heating/electricity and space heating respectively. Another possibility is to use N.G. solely to produce electricity. Discussions with one Inuvik Chamber of Commerce official revealed that a' study is underway to assess the feasibility of generating electricity from a plant on one of the Delta stands to be distributed to Inuvik and Tuktoyaktuk.

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1 Sean Casey, Energy Costs in the Canadian North: A Cornparison of Five Communities, a paper completed at the faculty of Environmental Studies, York University, 1979, p. 15.

N.G. electricity generation is also possible for off grid locations. If combined with a pilot liquid, it can be used as a replacement for diesel fuel.

Recent technological developments indicate that N.G. might be used in "mini" district heating or "total energ y" schemes. In particular, the Fiat Motor Company has developed a Total Energy Module (T.O .T.E.M. ) that is designed to produce heat and electric Fewer using a 127 car model engine. The T. O. T.E.M. is characterized by a 90% total energy conversion efficiency (1st Law) and small size suitable for modular arrangements, system integration, and production close to the load. With a power output of 15 KW and 140,000 kilojoules per hour this total energy system, or others like it, appears to be most applicable to apartments or small commercial buildings.

Natural gas can be used directly as a transport fuel substitute for gasoline or diesel fuel. According to Energy, Mines and Resources, compressed natural gas could be used for transport truck fleets with existing vehicle conversion costs at least $1500. [1]

## 10.4 Environmental Implications

The assessment of costs associated with natural gas utilization must take into account potential effects on the environment. Depending on the type of development e.g. , localized distribution versus export pipeline, the scope and intensity of effects will vary. Effects associated with pipeline development have been well

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1 Energy, Mines and Resources Canada, Discussion Paper on Liquid Fuel Options (Ottawa: E.M.R. Report EP-80-2E, 1980) , p. 19.

The discussion paper notes that with N.G. valued at $4/m. c. f. (Alberta border) , the cost of displacing diesel oil or gasoline in Ontario would be about $25 a barrel oil equivalent.

documented . What appears to need further assessment is the production of sulphur dioxide from compressor stations and/or electrical generating stations. Apparently, the effects of acid precipitation, to some extent caused by sulphur dioxide emissions, have been identified in a number of Arctic localities.

## 11.0 Coal

The significant volume of sediments in the N.W.T. is not only characterized by oil and natural gas, but also by scattered reserves of coal. Although coal is at present not mined, local residents along the Mackenzie Valley and the Arctic coast have used deposits for heating purposes.[1] As well, coal has been mined in the Fort Norman, Richardson Mountains (east) , and Paulotuk areas. Whether or not coal is assessed as a significant supply option depends on a number of factors including competitiveness to existing and/or alternative sources, demand, and environmental limitations.

### 11.1 Reserves and Production

Data describing coal reserve volumes in the N.W.T. are scant, and for the most part, secondary information resulting from oil and gas exploratory drilling. Nevertheless, some reports have attempted to describe existing potential seams and Table 22 summarizes their locality, nearest demand centres, and potential end-uses (Refer to Figure 4 for location) .

Data regarding coal type and quality are not clear. It appears, however', that most of the coal resources are of medium and low

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1 Arctech Services, Inuvik, Community Coal Utilization in the Northwest Territories, a report prepared for the Department of Economic Development and Tourism, Government of the Northwest Territories, I-978, pp. 4-8.

TABLE 22

KNOWN AND POTENTIAL COAL RESERVES IN THE N.W.T.

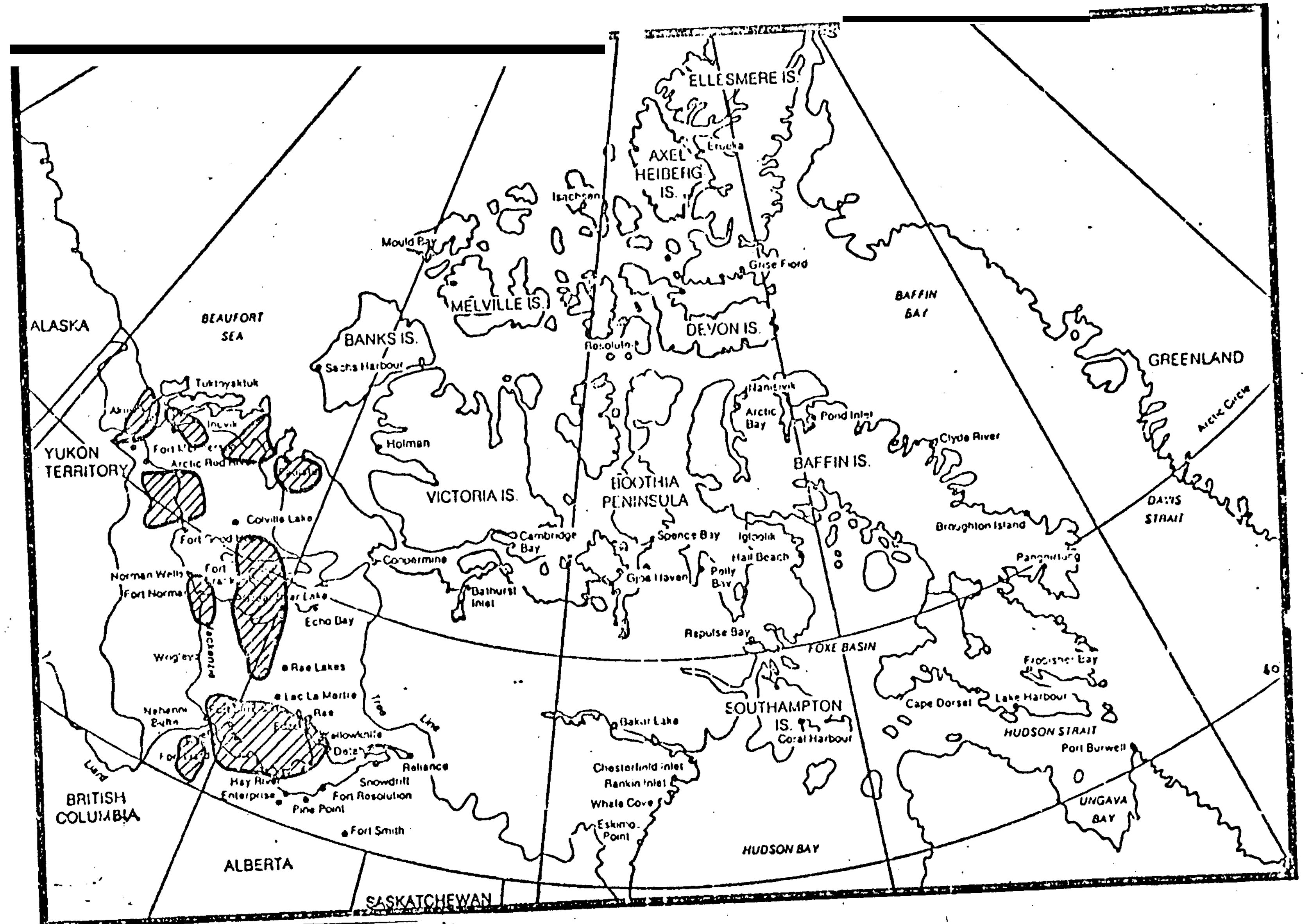
| LOCATION[a] | NEAREST COMMUNITIES | POTENTIAL END-USES |
|---|---|---|
| Peel Plateau | Fort Good Hope, Fort McPherson, Arctic Red River | Commercial/residential space heating, electrification |
| Great Bear Plain (Douglas Bay, Etacho Pt.) | Fort Franklin, 'l'errs, Echo Bay, Bathurst Mines | Commercial/residential space heating, electrification; mine heating, electrification |
| Fort Norman Basin | Fort Norman | Commercial/residential space heating, electrification |
| Sekwi | Accessible if the Canol Road opens | Mine heating, electrification |
| Richardson Mountains (east) | Aklavik, Inuvik | Commercial/residential space heating, electrification pipeline electrification |
| Franklin Bay, Darnley Bay | Paulotuk | Commercial/residential space heating, electrification |
| Banks Island | Sachs Harbour | Commercial/residential space heating, electrification |

Source: 1. Arctech Services, Community Coal Utilization in the Northwest Territories, a report prepared for the N.W.T. Department of Economic Development and Tourism, 1978.

Note:

a Refer to Figure 8.

FIGURE 4. COAL DEPOSITS IN THE NORTHWEST TERRITORIES




LEGEND: ▨ Coal Deposits

SOURCE: ARCTECH Services, Community Coal Utilization in the Northwest Territories, a report prepared for the Department of Economic Development and Tourism, Government of the Northwest Territories, April, 1978.

quality sub-bitiminous and lignite coal, although some high quality bituminous coal has been identified along the Arctic coast.[1] The gross heating value of this coal is estimated to range from 2.6 megajoules/kg (lignite) to 4.8 mega joules/kg (high quality bituminous) .

## 11.2 Coal Utilization

As Table 22 and Figure 4 indicate, most of the N.W.T. coal reserves are located in the muvik and Fort Smith regions , moreso it appears, in the former. Figure 1 indicates that most of the heating and electricity fuel input in the muvik region originates in Norman Wells. Correspondingly, delivered energy prices in the Inuvik region are the lowest in the N.W. T. The feasibility of coal utilization is therefore based, in part, on competitiveness with domestic oil. In addition, coal must be compared, on a site specific basis, with N.G. , hydro and wood (the latter two explored in upcoming sections) . In assessing fuels competitiveness, Arctech Services conclude that 'the greatest possibilities for coal utilization are in the Arctic communities where alternate sources are scarce, i.e. a location above the treeline, and where delivered fuel prices for space heating and electricity are high.[2] The communities selected for an assessment were Paulotuk, Pond Inlet, and Aklavik.

The Arctech study concludes that coal would be best utilized for N.W.T. residential and commercial space heating.[3] Technologies appropriate to this task are identified as:

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1 Ibid., p. 3.
2 Ibid., p. 13.
3 Delivered cost estimates of coal are not conclusive due to the variability of coal development cost assumptions and delivered wood prices.

i) multi-fuel forced air furnaces with oil backup for homes;

ii) fully automated stoking furnaces for multi-unit residential or small commercial units; and

iii) fluidized-bed combustion units for multi-unit residential or small commercial units.

Although coal electrification is a possibility, the absence of a suitable demand precludes such an investment. The minimum demand estimated to be economically feasible is 25 MW and as the Yukon Report indicates, some cost studies suggest coal cost competitiveness with hydro at the scale of 150 to 500 MW.[1] Installed 1979 electrical capacity in all of the Inuvik region, excluding Norman Wells, is less than 20 MW. Given conservation approaches, forecast demand is not likely to increase to a level warranting coal electrication. Moreover, due to distance, Inuvik communities would not be exploiting one coal reserve, reducing the demand per reserve even further.

Three factors could suggest exploring coal electrification. The first, oil and/or N.G. pipeline electriciation would increase the region's electricity demand if pipeline compression electrification is considered. The second factor is potential mine demand. Arctech notes that the mines east of Great Bear Lake are examining the feasibility of coal use. They point out that once a coal utilization infrastructure is in place, low cost coal could be used for community demands, both for electricity and space heating. The third factor is the technical feasibility of fluidized-bed combustion units which can produce electricity at a scale commensurate with existing Inuvik region demands.[2]

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1 Ibid., p. 17 and Yukon Report, P. 66.

2 Walter C. Patterson and Richard Griffen, Fluidized-Bed Technology: Coming to a Boil (New York: Inform, I-978).

## 11.3 Environmental Implications

MUCh has been written shut the environmental (including health) implications of coal mining and combustion. Any development of coal in the N.W.T. must take into account that underground mining (the more likely option for the territory) can be detrimental to the health of miners e.g. , "black lung" disease. The type and extent of combustion emissions depends on the coal quality and the technological measures used to reduce air emissions.

Ascription of N. W. T. coal do not indicate the sulphur content, although the Yukon Report suggests that Yukon coal has a low content.

Coal-fired electrical generating plants are one of the major sources of sulphur dioxide ( $SO_2$) which can eventually result in acid precipitation. Appendix X lists some of the toxic effects of acid precipitation, effects which may be more profound in the fragile Arctic ecology (see Figure 5) .

As previously noted, the preferred option for coal. utilization appears to be residential and commercial space heating. Recent studies by the U.S. Environmental Protection Agency (E. P.A. ) evaluate emissions from stoking furnaces burning a variety of coal types and identifies sulphur, nitrogen and carbon oxide compound emissions as well as particulate.[1] Particular emphasis is placed on evaluating polycyclic organic rotter (P. O. M.) which has potential carginogenity.

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1 R.D. Giammar, R.B. Engdahl, and R.E. Barret, P.O.M. and Reticulate Emissions Prom Small Commercial Stoker-Fired Boilers (Columbus, Ohio: Battelle Columbus Laboratories).

**FIGURE 5. ACID PRECIPITATION IN NORTH AMERICA**


LEGEND: Sensitive Lake Areas

Level of Precipitation Acidity (pH 1-6 Acidic)

SOURCE: Environment Canada

Although technologies exist that can reduce must of the combustion emissions, their ef f activeness and applicability to N.W. T. scale operations must be assessed. This uncertainty makes f luidized-bed combustion technology an attractive option. ‘Ibis technology, producing steam or hot water for space heating and electricity, reduces nitrogen oxide compound and coal ash emissions and traps at least 9@ of the existing sulphur content.

## 12.0 Non-Renewables Vs. Renewables?

The preceding sections discussed the supply potential of residual heat, natural gas and coal. Each of these sources, as assessed, are non-renewable.[1] This may not be a crucial consideration in the near-term but will be in the long term (post 1989) for at least two reasons. first, reserve reductions are likely to make continued non-renewable petroleum use very expensive. Second, decisions to utilize previously untapped non-renewable resources may tie the N.W. T. into an inflexible infrastructure, one that might prove difficult to change or reduce. One option that the N.W. T. faces is whether or not to exploit a diversity of renewable energy resources as a substitute or a complement to non-renewables. The resources examined in the following sections include hydro, wood, peat, geothermal, agriculture, wind, and solar.

## 13.0 Hydro Fewer

Although hydropower supplies about 65% of the N. W.T.'s total electricity demand, its potential as a near and long term energy supply has hardly been utilized.[2] In particular, it may be able

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1 Residual heat was assessed as a product of diesel-electric generating units.

2 Assuming a 30% diesel electric conversion efficiency, diesel fuel supplied about 710 TJ or 35% of total 1979 demand.

to provide an electricity, and possibly space heating, substitute for communities presently dependent on fuel oil. In addition, it may be able to meet power demands resulting f rom new pr imary resource developments.

## 13.1 Electricity Demand

electricity is used by three sectors: residential, commercial. and mining; the latter two consume about 48% and 34% respectively of the N.W.T. total. As summarized in Tables 10 to 15, electricity demand in the residential and commercial sectors to 1989 and 1999 can actually decrease below 1979 levels if suggested conservation strategies and technologies are implemented. As Table 8 suggests, mining development is likely to expand and Table 1.5 indicates that in spite of suggested conservation measures, mining electrical demand by 1999 could increase by a factor of five. Of course, in-house conservation efforts in the mining industry, including residual heat utilization, could reduce significantly the forecast demand.[1]

Much of the existing and potential mineral development will be in the Ebrt Smith region, which at present is the territory's major energy consumer and uses 100% of the hydro electricity produced. This region also expects to be the location of new forest industry development, as the Liard River Valley region is made accessible by road. AS is suggested in the following section, forest industry utilization of forest biomass could offset major increases in demand.

In the Inuvik region a potential source of increased electrical demand is pipeline electrification. Although actual demand depends on the type and scale of development, this is one development that

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1 As derived from Table 7 and Appendices II to VI, about 22% of mining electrical demand was self-generated. (80% of this generation was produced by Con-Rycon).

would maintain a significant demand in spite of limited conservation measures.

## 13.2 Electricity Supply

The Northern Canada Power Commission (N. C. P.C. ), which is required to supply power at cost, provides all of the N.W. T. electrical power except for about 5%, distributed by Alberta Power to the c-unities of Enterpr ise , Fort Providence and Hay River.[1] Table 23 summarizes the N. W. T. electric power capability as pro jetted to 1982. The installed 1979 capacity of 128 MW is supplied by two interconnected hydro/diesel systems, the Snare and Taltson, a bunker fuel fired plant in Inuvik, and by diesel generating units.

## 13.3 Potential Hydro Electricity Supply

For the most part, the hydro potential of the N.W.T. has not been closely evaluated. It was possible, however, to compile hydro data from most of the completed studies to date. Although it, by no means, represents 10 0% of actual potential, Table 24 illustrates that a total of 4851 MW has been identified. 'Ibis is a considerable energy potential considering that present electricity capacity represents about 3% of this total.

Data derived from Table 24 indicates that undeveloped hydro in the Fort Smith region represents shut 73% of the N.W.T. total, a potential match to new development projects in this area.

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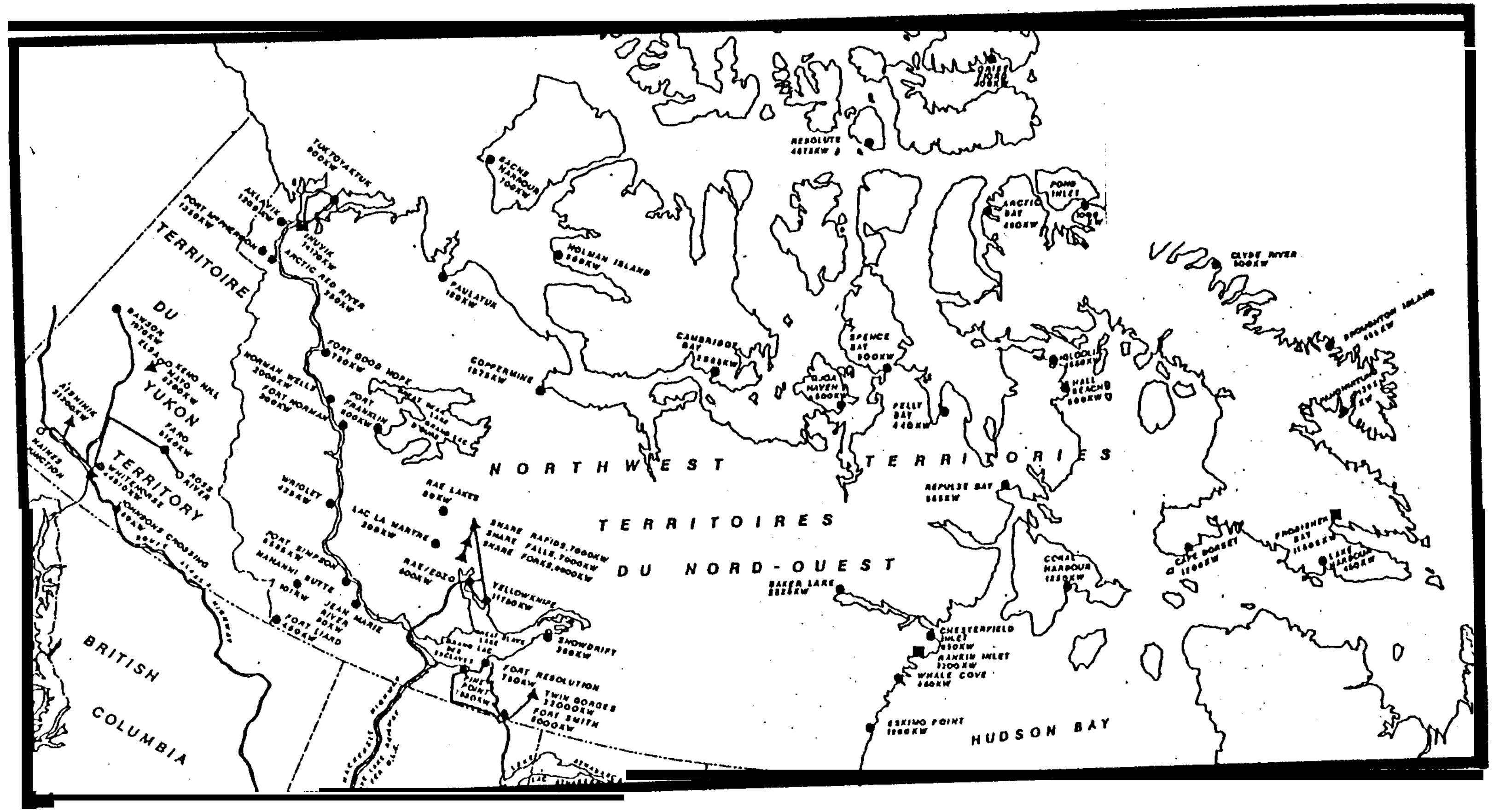
1 Ronald Fburnier, Economic Circumstances in the Northwest Territories, p. 84.

The N. C.P. C. supplies both retail and wholesale electricity, the latter to the mines and to the Plains-Western Company which supplies Ye llowknif e.

FIGURE 6. INSTALLED ELECTRICITY CAPACITY OF REMOTE COMMUNITIES (KW)




LEGEND: ● Thermal Plant ■ Utility Plant

A Hydro Plant Transmission Line

SOURCE: Northern Canada Power Corn mission

TABLE 23

ELECTRIC POWER CAPABILITY AND PEAK LOAD IN MEGAWATTS
NORTHWEST TERRITORIES, 1967 to 1982

| Year | Type of Station: Hydro | Steam | Internal Combustion | Gas Turbine | Total Installed Generating Capacity |
|---|---|---|---|---|---|
| 1967 | 35 | 1 | 10 | 1 | 47 |
| 1973 | 35 | 1 | 43 | 2 | 81 |
| 1974 | 35 | 1 | 45 | 2 | 83 |
| 1975 | 35 | 1 | 61 | 2 | 99 |
| 1976 | 35 | - | 66 | 2 | 103 |
| 1977 | 48 | - | 64 | 2 | 114 |
| 1978 | 48 | - | 75 | 5 | 128 |
| 1979 | 48 | - | 75 | 5 | 128 |
| 1980 | 48 | - | 75 | 5 | 128 |
| 1981 | 48 | - | 75 | 5 | 128 |
| 1982 | 48 | - | 75 | 5 | 128 |

Source: 1. Ronald Fournier, Economic Circumstances In the Northwest Territories (Regina: D. R. E. E., (1979)), p. 86.

TABLE 24

ESTIMATED UNDEVELOPED HYDRO-ELECTRICITY POTENTIAL in the N.W.T.[a]

| RIVER | NUMBER OF SITES | MAXIMUM INSTALLED CAPACITY MW | ESTIMATED FIRM POWER[b] MW | NEAREST EX[illegible]ING AND POTENTIAL DEMAND CENTRES |
|---|---|---|---|---|
| | | | FORT SMITH REGION | |
| Lockhart | 6 | 282 | 169 | Reliance, Snowdrift |
| Snowdrift | 1 | 10 | 6 | Reliance, Snowdrift |
| Tazin | 3 | 26 | 16 | Fort Smith |
| Tsu | 5 | 55 | 33 | Fort Smith |
| Coppermine[c] | 2 | 23 | 14 | Port Radium, Bathurst Mine |
| Petitot[d] | 1 | 50 | 30 | Fort Liard, Forestry Operations |
| Beaver[e] | 3 | 206 | 124 | Fort Liard, Forestry Operations |
| Flat | 2 | 69 | 41 | Tungsten, Mining |
| South Nahanni | 19 | 5211 | 3127 | Tungsten, Nahanni Butte, Forestry and Mining Operations Cadillac Mine, Canex Mine |
| | | | CAMBRIDGE BAY REGION | |
| Coppermine | 6 | 278 | 167 | Coppermine, Port Radium, Bathurst Mine |
| | | | INUVIK REGION | |
| Great Bear | 2 | 290 | 174 | Fort Norman, Norman Wells |
| Arctic Red | NA | 153 | 92 | Arctic Red River, Fort McPherson |
| | | | KEEWATIN REGION | |
| Kazan | 2 | 140 | 84 | Baker Lake |
| Dubawnt | 5 | 500 | 300 | None |
| Thelon | 4 | 204 | 122 | None |
| Hanbury | 2 | 303 | 182 | None |
| Tha-anne | 4 | 69 | 42 | Eskimo Point, Cullaton Lake Mine |
| Thlewiaza | 6 | 121 | 74 | Eskimo Point, Cullaton Lake Mine |
| Maguse | 5 | 65 | 40 | Eskimo Point |
| Ferguson | 4 | 30 | 17 | Whale Cove |
| GRAND TOTAL | 82 | 8085 | 4851 | |

Sources: 1. GEPAC Consultants, Power Inventory of Canada's Northern Regions, A Study prepared for D. I. A. N. D., November 1971.

2. T. Ingledow and Associates Ltd., Power Survey of the Central Mackenzie District N.W.T. Vol. I, A study prepared for D.I.A.N.D., January 1969.

3. Underwood, MacLellan and Associates, Power Site Surveys N.W.T. For the Tha-Anne, Thlewiaza, Ferguson and Maguse River, A study prepared for D.I.A.N.D., March 1980.

4* N.W.T. Ministry of Energy, personal communication, November 1980.

Notes:

a The table does not include hydro estimates for most of the Cambridge Bay and all of the Baffin regions because data were unavailable.

b Estimated firm power is assumed to average about 60% of maximum installed capacity.

c It is assumed that the upper reach portion of the Coppermine River is in the Fort Smith region while the lower reach is within the Cambridge Bay region.

d The Petitot River is in British Columbia but was assessed by GEPAC as a potential electricity source for the N.W.T.

e The Beaver River is in the Yukon.

Due to a lack of data, hydro potential for the Baffin region is not listed.

### 13.4 Development Variables

The extent and type of hydropower development is contingent upon a number of interrelated development variables. They include legalities, the environment, technology, and costs. Legal and environmental questions are, for example, tied into native land claims.

Technical and cost variables are related to the scale of hydro to be developed. In the Yukon Report, four scales of hydro development are categorized. They are:

i) microhydro, i.e. up to 5 MW potential (installed capacity);

ii) small scale, i.e. 6 MW to 50 MW;

iii) medium scale; i.e. 51 MW to 500 MW; and

iv) large scale, i.e. above 500 MW.[1]

A recent study by Underwood, MacLellan and Associates (hereafter known as UMA) describes the extent to which scales can be achieved on particular river basins.[2] Of the four Keewatin rivers they evaluate, three are in the medium scale range (installed capacity) (See Table 24). However, the capacity figures are based on achieving the rivers' ultimate potential. Two physical variables suggest that achieving such a potential is improbable.

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1 Yukon Report, p. 60.

2 Underwood, MacLellan and Associates Ltd., Power Site Survey in the Northwest Territories for the Tha-Anne, Thlewiaza, Ferguson and Maguse Rivers, a study prepared for D. I. A. N. D., 1980.

First, the development of one site can destroy, by f 100ding, the potential of another site. Second, low relief makes gradual, staged development more difficult, i.e. different sized units would be necessary as opposed to the economy of scale development of homogeneous units on high relief. Despite the difficulties in acquiring accurate cost data, it is generally acknowledged that the larger the scale, the greater liklihood for a hydro project to be cost effective. The UMA study suggests, then, that the revenue from a scaled-down hydro project would not justify the capital costs.[1]

For the most part, it appears that medium and large scale development can be avoided. As noted in the Yukon report, the latter is suited for export only. Medium scale appears to be suited to smelter, pulp and paper mill, or pipeline electr iciation development. Of the three, it is possible that pipeline electrification might be supplied by hydropower.

Small scale, and to a certain extent, micro-hydro development, if within feasible transmission distance, would be suitable to meet most communit y and mine load growth, to back out diesel generation or to meet certain demands particular to new development e.g. , large scale commercial expansion (see Section 13.6) .

13.5 Hydro Thermal Potential

Except for a few Yellowknife residences, electric heating in the N. W.T. is non-existent. This appears to be due, in part, to the associated costs of diesel powered electric heat, costs that conceivably would increase as systems were exparided to meet rising demand . No matter what the power source is, electric heating is now understood as a thermodynamically inefficient process, i.e. a high

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1 Ibid., pp. 9-1 and Figure 7-2.

T. Ingledow and Associates Ltd. (now Gepac Consultants) , Power Survey of the Central Mackenzie District N.W. T. , Volume 1, a study prepared for D. I. A.N. D. , 1969.

quality energy form, electricity, is being used to supply low quality, low grade heat. Despite such a mismatch, hydro thermal supply is being examined as a possible replacement for diesel produced space heating.

One of the conclusions of the UMA study acknowledges that hydro electric supply for the selected Keewatin region communities is still not competitive as a replacement for diesel. However, the supply of both hydro-electric and hydro thermal energy appears to be close to par with current diesel delivered costs, i.e. the annual fuel escalation rate needs only to be about 3% above the selected discount rates of 4% and 8%.[1] Although hydro thermal supply can only be assessed on a site specif ic basis , it is suggested that this form of supply, even if at present marginally uncompetitive, should be pursued as an option to reduce the vulnerability of communities to external supply problems.

## 13.6 Micro-Hydro

Recent studies evaluating electrical costs and supply in the N.W.T. recommend the evaluation and development of small scale and micro-hydro power sites.[2] Fournier suggests, in fact, that "small scale hydro-electric developments near communities could provide sufficient energy to promote community socio-economic stability through support of diverse renewable resource activities. ..3.3 The following discussion examines, in particular, micro-hydro potential in the N.W.T.

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1 UMA Report, pp. 9-10, 9-11.

2 Ronald Fournier, Economic Development Propsects in the N.W.T., p. 85.

UMA Report, p. 2.

Department of Indian Affairs and Northern Development, Report of the Task Force on Electrical Energy Costs in the North (Ottawa: D. I. A. N. D., (1976) ), P. 23.

3 Ronald Fournier, p. 85.

Figure 10 indicates that most of the N.W. T. communities currently have an installed capacity of 5 MW or less. Whether micro-hydro is categorized to a limit of 2 MW or 5 MW, it is apparent that it could meet many community electrical load demands, and possibly electrical and heating loads, depending on the community 's load management.[1]

In addition, micro-hydro sites could be used to divert water into existing power sites, thereby increasing their storage potential and the time period for which peak power can be supplied.

Micro-hydro development studies for other provinces indicate that the site feasibility is contingent on the water head and site characteristics. Table 25 summarizes both of these parameters. Note that each head category has high and low output potential. Depending on these characteristics and the pro jetted load, micro-hydro sites may have the potential to meet peak demands or they may have to be supplemented by another fuel.

Micro-hydro equipment is proven, with Europe being the major supplier of low and medium head turbines. Discussion with National Research Council (N. R.C. ) officials reveals that the workability of the turbines is apparently feasible in spite of winter freeze-up. To date, the development of standardized turbines in North America is limited to low head models and projects.[2] Although there appears to be considerable potential for medium-head development (at least in B. C.) the limited availability of turbines is likely to keep costs high in the near future.

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1 Cr ippen Consultants, Micro-Hydro Volume I, A Survey of Potential Micro-Hydro Developments for Use by Remote Communities in B.C. , a study prepared for the federal Observation and Renewable Energy Branch, 1980, p. 2.

2 Crippen Consultants, Micro-Hydro Volume 1, p. 7-2.

TABLE 25

SITE CATEGORIES AND FEATURES FOR MICRO-HYDRO DEVELOPMENT

SITE CATEGORIES

| CATEGORY | HEAD AND OUTPUT |
|---|---|
| Low head - Low output | 2 to 15 m and up to 500 kW |
| Low head - High output | 2 to 15 m and 500 to 2000 kW |
| Medium head - Low output | 15 to 200 m and up to 500 kW |
| Medium head - High output | 15 to 200 mand 500 to 2000 kW |
| High head - Low output | Over 200 mand up to 500 kW |
| High head - High output | Over 200 mand 500 to 2000 kW |

FEATURES OF SITES

| FEATURES | REMARKS |
|---|---|
| 1. Hydro power/diesel | Prime power supplied by hydraulic turbine with peaking power or stand-by provided by diesel electric. |
| 2. Grid connected | Small hydro plant connected to existing grid line for excitation and regulation. |
| 3. Existing structure | Hydro electric development utilizing an existing small structure such as a dam, irrigation drop structure, etc. |
| 4. Geographic location | Depending on the geographic location and elevation, site development can be affected by weather, snowfall, topography, etc. |
| 5. Development to be served | This feature includes industrial sites such as logging camps, mines, Indian reserves, sawmills, etc. |

Source: 1. Crippen Consultants, Micro Hydro Volume I, A Survey of Potential Micro Hydro Developments for Use By Remote Communities in B.C., A Study prepared for the Federal Conservation and Renewable Energy Branch, 1980, pp. 3-1, 3-2.

Estimates of cost feasibility vary. For example ," site specific cost estimates in B.C. reveal energy costs that range from 39 roils to 550 roils per KWh. Crippen suggests that the economic feasibility of micro-hydro is contingent on:

i) higher production volumes of North American low and medium head turbines;

ii) near-t erm real price esc.slat ion of conventional fuel; and

iii) accelerated depreciation for equipment.

The latter variable is supported by the Federal government which recently announced tax incentives that include accelerated equipment write-offs. Micro-hydro development is also being encouraged through the Provincial (Territorial) /Federal Renewable Conservation Agreements; in fact, one such project is slated for Frobisher Bay.

## 14.0 Wood Biomass

Biomass energy* is estimated to account for 4.1% and 7.4% respectively of Canada's primary and secondary energy supply.[1] Of the various biomass sources in Canada, wood and wood related wastes account for about 99% of the biomass fuel supply (1977 ).[2] Given the intent of governments toward energy self-sufficiency, it is expected that wood biomass energy will contribute even greater percentages to Canada's energy supply. In the N. W. T., wood energy

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* Biomass energy is the energy derived from living matter e.g., recently cut trees, waste material from natural processes e.g. , manure, and the waste derived from the harvesting and processing of plant and animal rotter.

1 Peter Love, Middleton Associates, Biomass Energy in Canada, Its Potential Contribution to Future Energy Supply (Ottawa: E.M.R. Report ER-80-4E), p. 16.

2 Ibid., p. 18. This biomass utilization is mainly on-site conversion of bark, pulp liquor, and hog fuel.

represents both a space heating and electricity supply source that is virtually untapped.

14.1 N.W.T. Forest Inventory and Use

The key to evaluating wood biomass energy potential is to have a comprehensive forest inventory, one that includes growth and yield data as well as impact assessments of various harvesting and silviculture approaches. To date, there is no inventory, comprehensive or otherwise, for the N.W.T. There are indications, however, that the data availability will be improving. First, D.I.A.N.D.'s forest division expects to be able to devote more resources to inventory tasks. Second, the Environment Canada Energy from Forests program (E.N.F.O.R.) expects to be initiating N.W.T. forest inventories in 1981. The E.N.F.O.R. approach to inventories includes much needed empirical formulae from which total biomass potential can be calculated.[1]

respite information deficiencies, it is possible to estimate some of the N.W.T. forest biomass potential. Figure 7, illustrating the forested and non-forested regions of Canada, shows that the N.W.T. forest land is confined primarily to the Mackenzie River valley and drainage basin, including the Liard River Valley.

The location and type of hardwood and softwood species vary according to the physiography. Balsam, poplar and white spruce are common to the alluvial flood plains, white spruce representing the major merchantable wood (at 10″ to 20″ d.b.h. ).2 As the elevation

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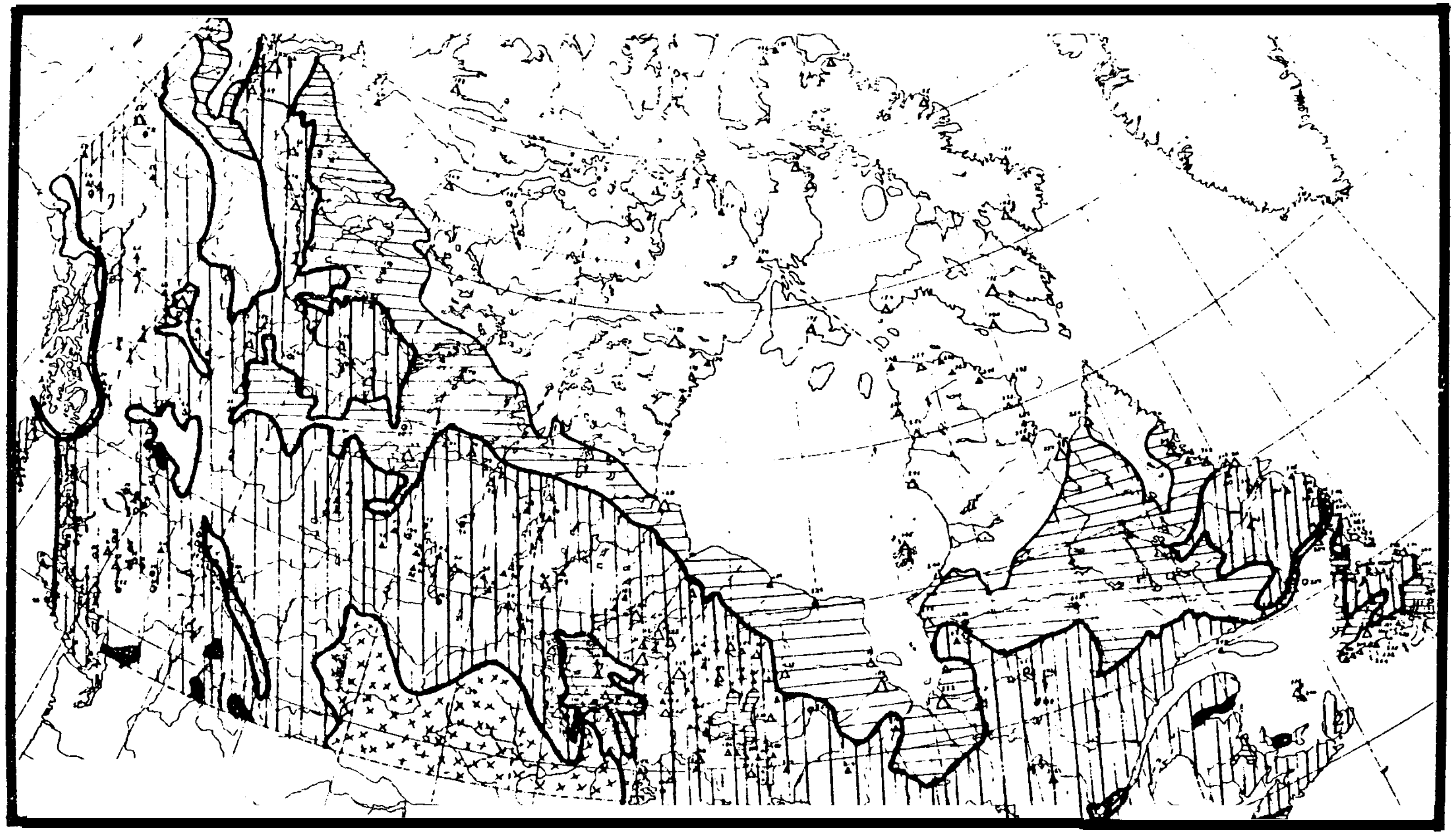
1 To date, it appears that "total" forest biomass potential is calculated from forest inventories based on merchantable boles, i.e. timber that has commercial potential for non-fuel uses. These calculations are not entirely relevant when estimating energy potential.

2 D.I.A.N.D. Forest Division.

FIGURE 7. FORESTED AND NON-FORESTED AREAS OF CANADA



LEGEND:
- Forest Land (vertical hatching)
- Wetland Forest Land, Open Lichen Woodland and Discontinuous Tundra (horizontal hatching)
- Other Non-Forest (blank)
- Agricultural and Urban (x x x)

SOURCE: TRU Techno-economic Research Unit with Victor and Burrell, Role of Renewable Sources of Energy in Remote Locations: Energy Demand Characteristics and Renewable Resource Base, Phase I Report, a study completed for the Federal Conservation Renewable Energy Branch, 1980, Map 5.5, p. 159.

increases and depending on latitude, Species such as jackpine, lodgepole pine, black spruce, aspen and birch have been identified.[1]

Timber in the N.W.T. is harvested as a source of lumber and building material, pils and fuelwood. The annual N.W.T. production of lumber, since the 1950's, has ranged from 2.35 to 14.1 million $m^3$ while annual piles production has ranged from 1.2 to 3.5 million $m^3$.[2] Estimates suggest that the projected Liard River valley development could boost total lumber and piles production to 24 million $m^3$ annually. Recent estimates from the D.I.A.N.D. Forest Resources Division indicate an annual allowable cut of 2.4 million $m^3$ of timber suggesting that:

i) **past** production figures are exaggerated;

ii) previous development has not followed appropriate forest management practices; or

iii) current estimates are a downward revision because of depleting stocks .

Commercial fuelwood production has ranged from 5.8 thousand $m^3$ in 1959 to 17.8 thousand $m^3$ in 1978. While the 1978 figure indicates a trend to increased N.W.T. fuelwood use, the 1979 total was 9071 $m^3$. In general the annual average is about 7000 $m^3$. If the

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1 Sandwell and Co. Ltd., ~~A Review of the Forest Resources and the~~ Pulp and Paper Potential of the N.W.T. and Yukon, a report prepared for D.I.A.N.D., 1967.

2 D.R.E.E., Economic Development Prospects in the N.W.T., 1979, p. 10.

1978 total is attained as an approximate annual production level, N.W.T. fuelwood supply could represent about .14 petajoules (1 x $10^{15}$ joules) of energy*. This is about 24% of the projected 1989 space heating demand (conservation approach) for the two regions encompassing the N.W. T. forest area, Inuvik and Fort Smith.[1]

The energy potential of N.W. T. forest biomass is greater than .14 PJ. Total forest utilization includes:

i) merchantable boles (10" to 20" d.b.h.) that are economically 'inaccessible, i.e. too far away from sawmills and/or pulpmills;

ii) non-merchantable species of all sizes;

iii) foliage, tops and boughs;

iv) stumps and roots; and

v) dead matter and floor cover.

In calculating the N.W.T. forest energy potential, a number of methodologies were examined. The more common approach appears to be the use of a biomass correction factor. This factor accounts for total biomass utilization arid is applied to available forest inventories, usually volumes of merchantable boles or annual allowable cut. Other methods have derived per forest area estimates of oven dried tomes of biomass potential.[2]

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1 Derived from Tables 10 and 12.

*17833 m3 (green wood) = 629505 $ft.^3$ (7406 cords) (1 cord = 85 $ft^3$ of solid wood)

7406 cords = 14811 green tons
= 29623760 lb.

. 1 lb. greenwood = 4500 b.t.u.
29623760 lb. = 1.33 x $10^{11}$ b.t.u.
= 1.4 x $10^{14}$ joules (.14 PJ)

2 TRU Techno-economic Research Unit with Victor and Burrell, Role of Renewable Sources in Remote Locations: Energy Demand Characteristics and Renewable Energy Resource Base, Phase 1 Report, a study prepared for the federal Conservation and Renewable Energy Branch, 1980, PP. 160-168, Appendix 5e. See p. 165 for methodological limitations and Peter Love aria Ralph Overend, Tree Power (Ottawa: EMR Report 78-l), pp. 7-10.

Appendix XI illustrates the method used to derive the N.W.T. forest energy potential. The result indicates a potential of 18.7 PJ in the standing biomass. Considering that the total 1979 N.W.T. energy demand amounted to 16.3 PJ, this is a significant potential.

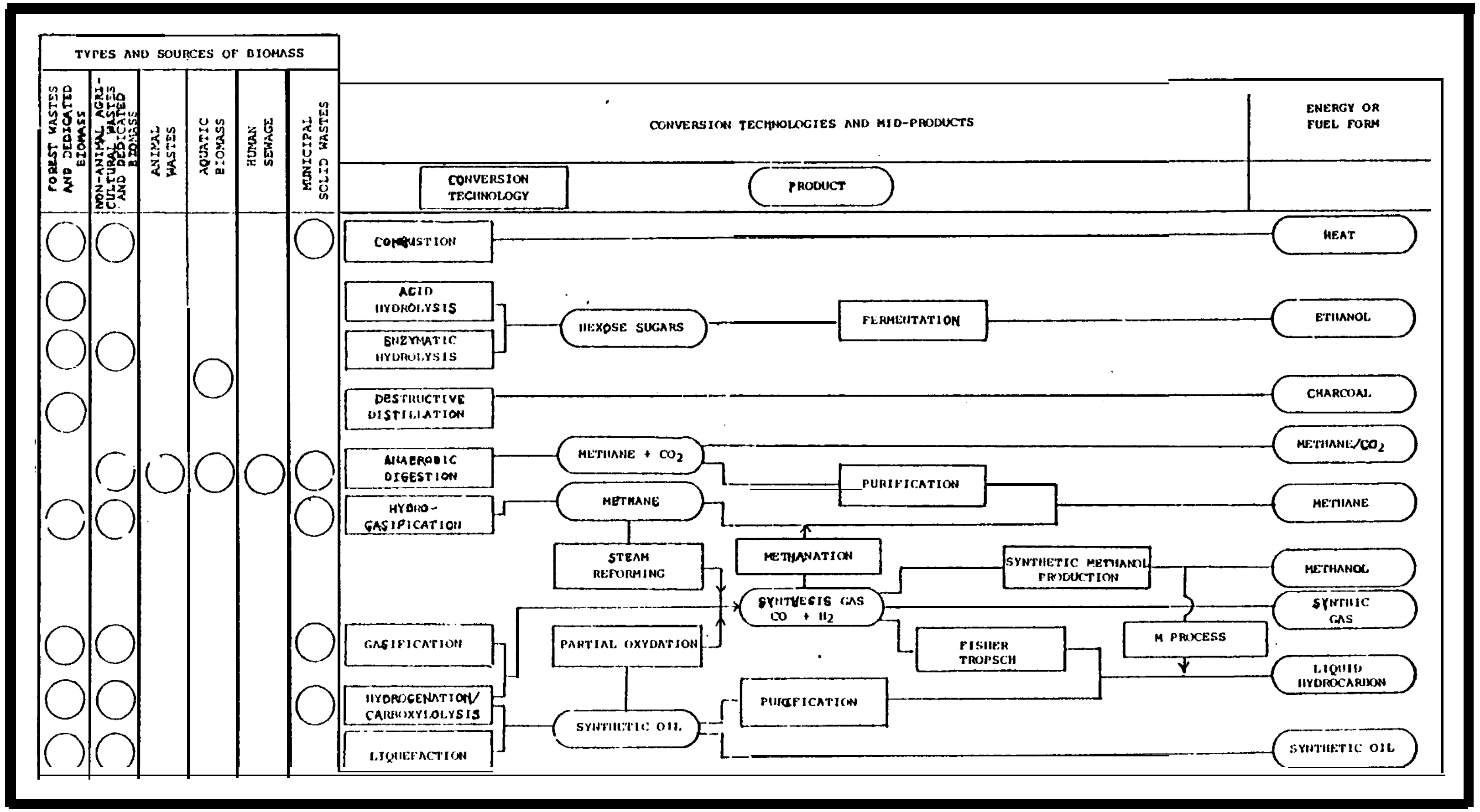
The percentage of actual biomass that can be utilized depends on a number of factors. first, a considerable portion will be harvested for commercial lumber and building materials. Second, it is likely that vast acreages are presently inaccessible. Third, the ecological fragility of the region might prohibit a practice of total biomass utilization, a practice which could result in irreversible organic matter depletion. These factors suggest that actual forest energy potential will be less than 18.7 PJ. The potential is significant if one considers that 5% utilization or .93 PJ is 1.6 times the projected 1989 space heating demand (conservation approach) for the Inuvik and Fort Smith regions.

14.2 <u>Forest Energy Conservation Technologies</u>

Amajor variable affecting the utilization of forest biomass energy is the type and feasibility of energy conversion technologies. The schematic diagram illustrated in Figure 8 shows that forest related biomass can be converted to usable energy by direct combustion, acid hydrolysis, enzymatic hydrolysis, destructive distillation, hydro-gasification, gasification, hydrogenation, and liquefaction. Of these processes, combustion and gasification appear to be the most applicable to the Inuvik and Ebrt Smith Regions.

AS noted previously, wood continues to be a space heating fuel along the Mackenzie Valley, especially in native communities. A conversion technology still being used is the oil drum stove. Although it has a low conversion efficiency, less than 25%, it is simple to make, relatively maintenance free, and safe. The popularity of this stove has acted as a buffer to the market penetration of newer and more fuel efficient "radiant" and "circulating" stoves.

**FIGURE 8. TECHNOLOGIES FOR THE CONVERSION OF RENEWABLE BIOMASS TO ALTERNATIVE ENERGY FORMS**




SOURCE: Peter Love, Middleton Associates, Biomass Energy in Canada, its Potential Contribution to Future Energy Supply, EMR Report ER80-4e, Figure 2, p.5.

Fuel efficient wood furnaces are available for both commercial and industrial space heating purposes. There are many types that burn a variety of fuel combinations e.g., wood waste and household waste.[1] Special furnaces are now on the market that can burn wood chips efficiently. The technical and economic advantages to chip burning include:

i) reliable and convenient operation;

ii) minimum handling from forest to furnace;

iii) utilization of previously unused forest biomass;

iv) efficient combustion process.[2]

A reCent study evaluated the feasibility of burning wood chips in a wood-oil furnace for a proposed commercial complex in Rae.[3] Despite its technical feasibility the project was concluded to be uncompetitive with conventional heating, due primarily to high labour costs. The study revealed some of the cost factors likely to affect most site-specific projects in the region including cost of harvesting, transportation, storage, and conventional fuels backup. Two factors suggest that the study results are misleading. First, alternate labour uses were not examined for comparison. Second, if proper maintenance is applied to efficient wood furnaces, backup needs would be minimal.

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1 Michael Glover, Renewable Energy in Remote Communities: The State of the Art Background Paper (Ottawa: C.M.H.C., 1977), p. 35.

2 Ibid., p. 33.

3 Peat, MarWick, and Associates, Assessment of the Potential for Using Wood as a Source of Energy in the N.W.T., a study prepared for the Economic Development Department, N.W.T. government, 1979.

An example in applying wood space heating to a particular demand centre is found in the Yukon Report.[1] The acreage demand necessary to heat Whitehorse was calculated for a variety of heating assumptions. The ultimate acreage necessary to meet a particular demand was found to be contingent on yield, rotation time, and extent of biomass harvest e.g. , use of total tree.

Heat from a wood biomass stove or furnace can be used to power a Stirling engine, i.e. an engine that converts heat to mechanical or electrical energy. The Department of National Defence is examining the feasibility of a Canadian made engine for Arctic application.[2]

Gasification by partial oxidation is fast becoming a suggested option for both space heating and electrical supply. Wood gasifiers are under varying stages of development and demonstration projects have been initiated inmost regions of Canada. For example, the N.W. T. government, under the auspices of the Federal/Territorial Conservation Agreement intends to evaluate the feasibility of a gas powered 1.20 KW modified diesel generator. A review of projects and research suggests that fluidized-bed gasifiers may represent the best gasification technology.[3] Fluidized-bed gasifiers are characterized by a high throughput; high energy potential, i.e. among the high range of produce gas energy content, 58 KJ/m$^3$; good gas quality, and low capital cost. The Saskatchewan Power Company is, in fact, experimenting with fluidized-bed combustion of various biomass fuels including wood, chips, sawdust, and straw. At least two studies suggest that wood gasification is cost competitive with conventional fuels options.[4]

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1 Yukon Report, p. 69.
2 Canadian Renewable Energy News, 2 (May, September 1979): 28 and 30:
3 Ralph Overend, Wood Gasification (Ottawa: EMR, 1979) . Canadian Renewable Energy News, 3 (Nov. 30).
4 Ralph Cverend, Wood Gasification, p. 46 and Michael Glover, Renewable Energy in Remote Communities, p. 26.

If the Liard Valley road construction succeeds in fostering sawmill operations, energy demand in the Fort Smith region could experience a considerable increase. Experience across the country reveals, however, that a variety of technologies are appropriate to making sawmill operations virtually energy self -reliant. These technologies include pile burning furnaces, packaged boilers, suspension burners, fluidized-bed combustion, and co-generation.[1]

## 14.3 Implementing Forest Biomass Conversion Technologies

It is still too early in the design and development of forest biomass conversion technologies to make definitive conclusions about feasibility. Nevertheless, it appears that some reoccurring factors such as high labour costs and costs of stand-by electricity and heating may serve to offset the attractiveness of the technologies. To alleviate the uncertainty associated with such factors, the following options have been suggested:

i) federal, territorial, and community cost sharing;

ii) conventional fuel price increases; and

iii) tax incentives.

To date, a variety. of measures and programs exist to assist in biomass energy development. They include:

i) the Federal/Territorial Conservation Agreement;

ii) the revision of Section 34 of the Income Tax Act to allow for rapid depreciation of biomass conversion equipment; and

iii) the federal biomass energy programs providing monies for demonstration projects. (See Appndix XII for a more detailed. description.)

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1 Peter Love, Biomass Energy in Canada, p. 3.

## 14.4 Environmental Implications

Despite its attractiveness as a renewable energy source, forest biomass conversion is not without potentially detrimental effects on the environment. Appendix XIII lists some of the major effects from wood stoves, boilers, and gasifiers, including particulate matter, toxics, and CO and SO compound emissions.

# 15.0 Energy From Agriculture

Agriculture generates straw, crop residues, animal manure, and processing residues, all of which can be converted to usable energy. Although it has been estimated that at least 513 PJ of agriculture derived energy is available in Canada, it does not seem a likely option for remote communities.[1] The N.W.T., in fact, does not have much of an agriculture base due to such circumstances as climatic limitations, high costs, limited markets, and lack of infrastructure. Nevertheless, it appears that some agriculture biomass energy potential exists.

## 15.1 N.W.T. Agriculture

With the exception of fruit trees, practically anything grown in southern Canada can be grown in parts of the N.W.T. As of 3.976, the territory, more specifically the Fort Smith region, had a total of 1891 ha of farm land. About 421 ha were cultivated, mainly with hay and other fodder crops. While this does not represent a significant agriculture base, a recent Saskatchewan Institute of Pedology study indicates four regions where there is such potential.

1 TRU Techno Economic Research Unit, Role of Renewable Sources of Energy in Remote Locations, p. 169.

As Figure 9 illustrates, there are four areas of agriculture potential (the Hay river valley is identified as part of the Mackenzie area). The Slave River area has about 100 000 ha of well drained soils (Class 5 or better) plus about 350 000 of poorly drained soils still suitable for forage crops.

The Upper Mackenzie area has about 671000 ha of Class 3 or 4 land and about 342 000 haof Class 5. The Hay River valley has shut 24 000 ha of Class 3or 4 land and about 109 000 haof Class 5. The Hay River valley has about 24 000 ha of Class 3 or 4 land and about 109 000 ha of Class 5. Finally the Liard area has about 441000 ha of Class 3 or 4, 22 000 ha of Class 2 and 500 000 ha of Class 5. The survey suggests that a considerable acreage of forage crops could be grown. In fact, Class 3 or 4 land has produced 70 bu./acre and 45 bu./acre respectively of oats and barley.[1]

Although the survey suggests the potential of an expanded livestock industry, such as expansion faces major obstacles in transportation costs and the high incidence of insect-related disease. Therefore, it is suggested that alternative development of the land could foster a source of biomass energy.

## 15.2 Conversion Technologies

As indicated in Figure 8, agriculture biomass can be converted to usable energy by combustion, enzymatic hydrolysis, anaerobic digestion, gasification, hydrogeneration, and liquefaction. Direct combustion burners are now available capable of generating high grade heat (about 1200°C) for steam electricity and eventually for space heating. Agriculture biomass can also be burned with wood biomass in burners and fluidized-bed systems.

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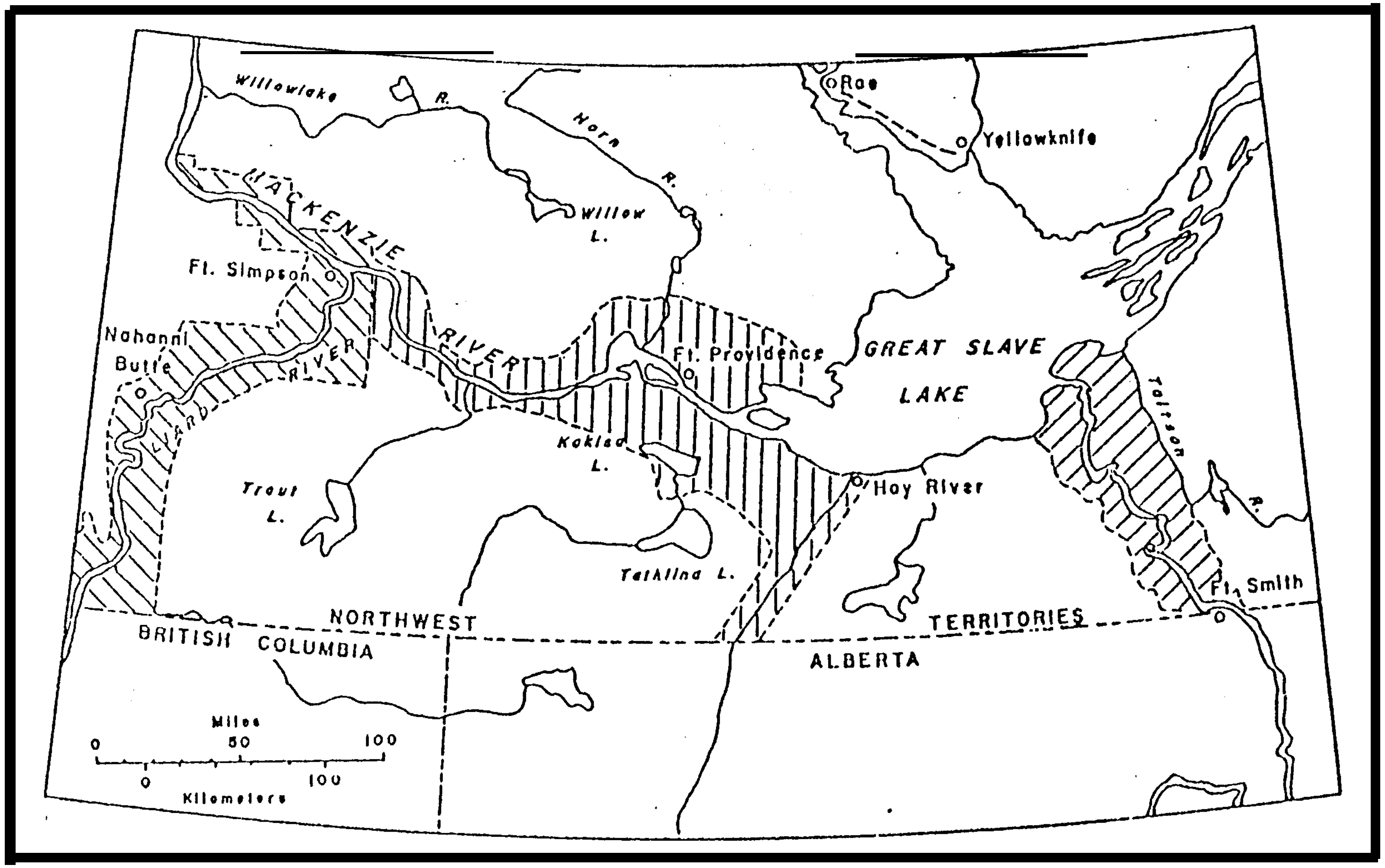
1 Ronald Fournier, Economic Circumstances in the N. W. T., p. 62.

**FIGURE 9. AGRICULTURAL AREAS OF THE NORTHWEST TERRITORIES**




LEGEND:
- Liard and MacKenzie River Area
- Upper MacKenzie River Area
- Slave River Lowland Area

SOURCE: Ronald Fournier, Economic Circumstances in the N.W.T. (Regina: DREE Western Headquarters, 1979).

## 16.0 Peat Energy

Fuel peat is recognized as a superior fuel to coal., wood, and other biomass because:

i) it has a low sulphur content;

ii) it has a high heating value; and

iii) it is a superior feedstock for gasifiers, due to its low moisture content and a high heating value.[1]

Although accurate inventories for the N.W.T. are unavailable, a recent study by the Montreal Engineering co suggests that peat potential exists along the Mackenzie River floodplain. (See Figure 10) .

## 17.0 Geothermal Energy

Despite the scarcity of data, it appears that geothermal energy potential exists in the N.W. T. mainland sedimentary basins. Geothermal energy, i.e. heat from the earth's interior, has the potential to be used for both space heating and steam electrical generation. The energy potential of a particular geothermal reservoir is dependent on the following characteristics: dry steam, hot water, or warm water.

Information from a recent study indicates that the Inuvik and Fort Smith regions are characterized by hot water and warm water geothermal reservoirs.[2] If the region has a high incidence of hot water reservoirs, characterized by temperatures of 200°C to 259°C, the resource could provide residential (multi-unit) and commercial heating and low pressure steam turbine power generation.

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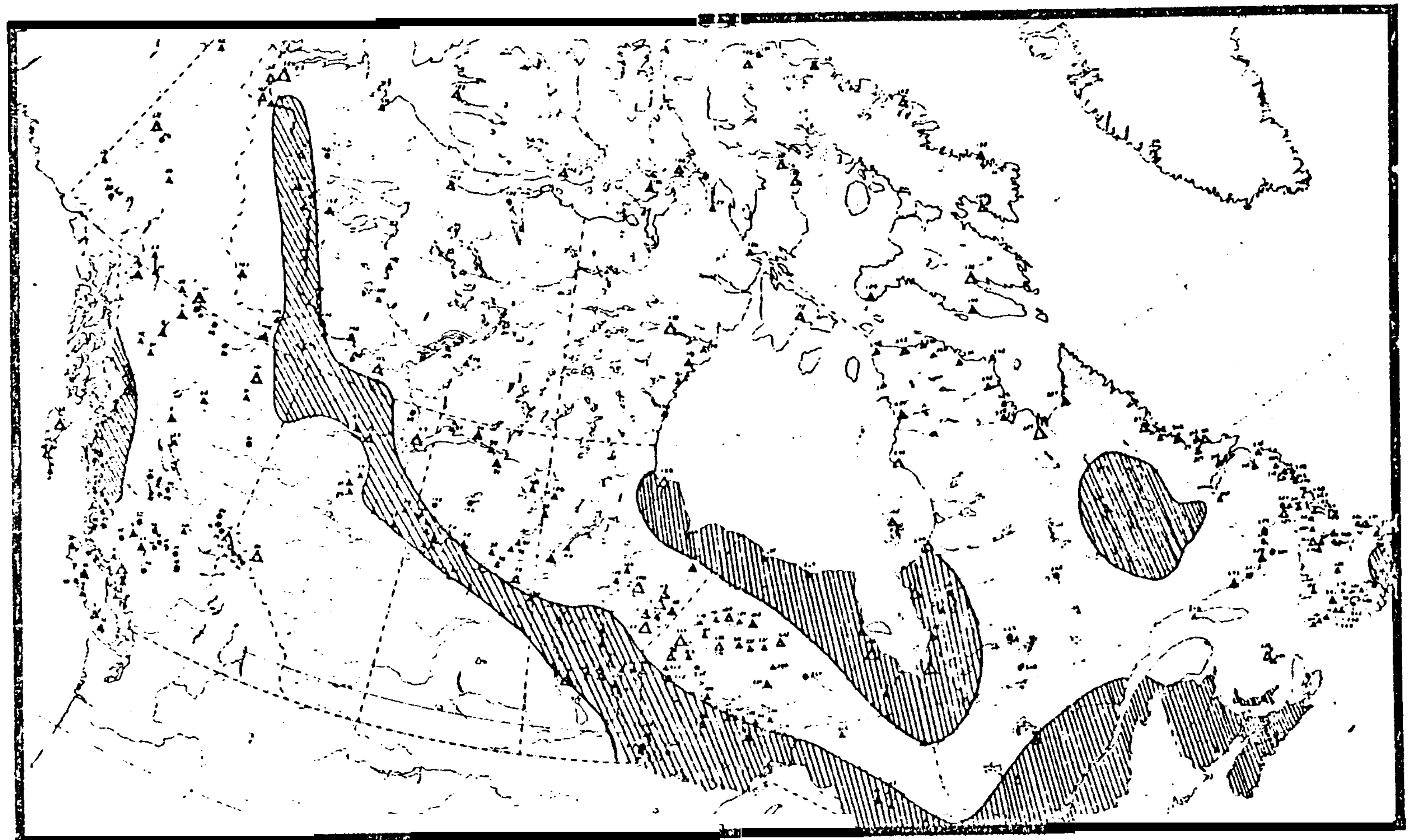
1 TRU Techno Economic Research Unit, p. 147.
2 Ibid., p. 148.

## FIGURE 10. PEAT DEPOSITS IN THE NORTHWEST TERRITORIES



LEGEND: Peat Deposits

SOURCE: TRU Techno-economic Research Unit with Victor and Burrell, Role of Renewable Sources of Energy in Remote Locations: Energy Demand Characteristics and Renewable Resource Base, Phase I Report, a study completed for the Federal Conservation and Renewable Energy Branch, 1980, Map 5.3, p. 149.

To date, N.W.T. geothermal data has been a secondary result of hydorcarbon exploration. What is needed, are more site specific evaluations.

## 18.0 Wind Energy

The application of wind kinetic energy in northern communities is, through research and demonstration, becoming a plausible energy source for:

i) navigation aids;

ii) telecommunications and geophysical apparati;

iii) diesel electric backup in remote communities;

iv) electricity supply to isolated dwellings;

v) pumped storage supply for micro-hydro units;

vi) space heating to prevent sewage and water pipes from freezing.[1]

Experience to date suggests that wind power has been suitably demonstrated as an appropriate energy source for the first two categories in the foregoing list. For example, Bristol Aerospace is manufacturing 50 KW vertical axis wind turbines (V.A.W.T.) that are self-starting and used to charge batteries.[2]

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1 R.S. Rangi, Recent Canadian Activities in Wind Power (Ottawa: N.R.C., 1975). Christian Betlignies, "The Utilization of Wind Power in the Arctic", a paper presented at the Solar Energy Society of Canada seminar The Potential of Solar Energy in Canada Ottawa, June 1975. and Canadian Renewable Energy News 3 (Oct. 1980): 17.

2 Canadian Renewable Energy News 2 (Jan. 1980): 8.

## 18.1 Wind Electricity

To be a suitable diesel electric backup, wind systems must generate more electricity than the 50 kW V.A.W. T. currently being used to charge batteries. The National Research Council (N. R.C. ) is attempting to meet such power needs through the demonstration of large V. A.W.T. 's. To date, the N.R.C. has constructed V. A. W.T.'s in the Magdalen Islands, Churchill, and Swift Current. Preliminary evaluations have not been made available, however, it has been indicated that the N.R. C. foresees 200 KW wind units (Magdalen Islands' unit) as either an independent power source or one interconnected to a grid.[1] The Magdalen Islands and Churchill projects are of particular relevance to the N. W.T. because of their location in high energy wind regimes, regions comparable to an area encompassing several Keewatin region communities.

V. A. W.T.'s have been demonstrated in the N.W.T. by both the N.R.C. and the N. C.P. C. Although demonstration projects in Frobisher Bay and Cambridge Bay have been discontinued, the N.W.T. government is evaluating the appropriateness of several wind systems to be demonstrated through the Federal/Territorial Conservation Agreement.

As with other renewable energy sources, technical and economic feasibility, especially the latter, cannot be assessed without more detailed data bases and site specific evaluations. Nevertheless, life cycle cost assessments suggest that despite high $/KW installed costs, diesel-wind electrical systems are cost competitive with diesel-d iesel.[2]

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1 An interview with an American wind system designer suggests several V.A. W. T. design limitations. See Canadian Renewable Energy News 3 (June, 1980) : 7.

2 Christian Bettignies, "The Utilization of Wind Power in the Arctic. "

As a diesel backup, wind systeins have been commonly evaluated as an electricity source. A recent study suggests that the most efficient linking of wind and diesel units would involve wind mechanical power turning the diesel generator rather than generating electricity.[1]

## 18.2 Energy Storage

Energy storage is a factor which would enhance the feasibility of northern wind system. A storage unit can store excess power and rechannel it as electricity or low grade heat when needed.

At present, a variety of batteries are being used to store energy and charge electrical systems. The ef f activeness of batteries is related to such variables as type, voltage, amp-hour storage capacity , and the operating environment.

Although lead-acid batteries are currently used in most number, they are not the ideal. type for northern wind energy storage needs, i.e. long storage and deep discharge capability. A recent development by the National Aeronautic and Space ministration is a REDOX battery capable of extensive storage capacity.[2] It has also been suggested that wind energy could be stored as thermal energy. Re sistance heaters would accommodate the expected variable input by being staged and could potentially provide space and/or steam heat.

Re search and development is also being initiated for the application of fuel cells as wind energy storage units. Excess direct current charges from a wind generator can be used to dissociate water into hydrogen and oxygen, and when power is needed the fuel cell can combine the two constituents to produce electricity.[3]

1 TRU Techno-economic Research Associates, p. 127.
2 Consultations at the National Research Council.
3 Michael Gilover, Renewable Energy in Remote Communities, p. 21.

## 1.9.0 Solar Energy Applications

The application of solar energy can be divided into three categories: passive solar, active solar, and photovoltaic systems. While all three categories offer some potential to N.W.T. energy demands, they are limited by the winter periods of little or no sunlight, periods of high demand when solar utilization may offer scant supply.

### 19.1 Passive Solar

Passive solar systems are heating systems where energy flow occurs mainly by the natural modes of radiation, conduction, and convection without external power requirements.[1] As a means of supplying low grade heat (20°C to 30°C), passive systems, incorporating design components such as super insulation, and air tightness, are presently cost competitive with conventional systems. For example, Gough notes that without achieving ultimate thermal standards, passive systems may afford savings estimated to exceed the additional monthly amortized cost of the building by a factor greater than three.[2] Moreover, as noted in section 6.2, housing prototypes are being designed for N.W. T. communities that can decrease existing demand by 95%.

### 19.2 Active Solar

An active solar system is a heating system whose energy is collected and transported by a continuously pumped fluid medium requiring external power input.[3] A recent study suggests that active

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1 Bruce Gough, Passive Solar Heating in Canada, a study prepared for the Federal Conservation and Renewable Energy Branch, 1979, p. 116.
2 Ibid., p. 24.
3 Ibid., p. 116.

residential solar hot water applications may soon be cost competitive with existing northern diesel electric systems.[1] Further evaluation is necessary because a review of the art for both space and water heating suggests that there is little agreement among experts with regard to the exact nature of technological improvements in the near to long-tern, a factor likely to affect the systems's ultimate cost competitiveness.

## 19.3 Photovoltaic Systems

Photovoltaic or solar cell systems convert solar insolation to electricity. The seasonal nature of N.W.T. insolation makes photovoltaic systems more costly per average watt when compared to existing power sources.[2] Nevertheless photovolatic systems appear to be an appropriate energy source for meteorological equipment, navigation buoys, and remote telecommunications sites.[3]

## 19.4 Factors Important to Solar Implementation

As noted previously, there are long winter periods of little or no sunshine in the N.W.T. Certain factors make the utilization of yearly insolation more plausible. First, passive solar potential might be enhanced with effective thermal storage. Thermal storage mediums researched and used to date include water, glycol, and glauber salts. Second, active solar hot water systems cannot be depended upon during zero or scant sunlight periods. Therefore,

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1 Bureau of Management Consulting, Federal Department of Supply and Services, Long-Term Outlook for Direct Use of Solar Energy in Canada, a study prepared for the Conservation and Renewable Energy Branch, Ottawa, 1980, p. 27.

2 ibid., p. 89

3 Middleton Associates, Near-Term Markets for Photovoltaic Power Systems in Canada, a study prepared for the National Research Council Solar Program, 1980.

they may be most applicable as backup systems. Since hot water is necessary on a year round basis, during periods of increased and high insolation, solar systems could act as primary supply. Storage systems would also enhance active system potential.

## 20.0 N.W.T. Energy supply: 1979 - ?

The preferred soft path approach to matching demand with supply is to derive a future demand scenario for each consuming sector and then to backcast supply alternatives, i.e. to retch supply sources, preferably renewable, to the assumed cut-off year demand. This study has not derived a preferred demand scenario, rather it has merely projected demand patterns existant in 1979. The foregoing sections have described supply options that may be able to match projected demand with domestic sources while decreasing the territory's dependence of petroleum for electricity and heating. It is clear that this approach is limited by absence of a detailed energy quality retch, i.e. a pro jetted match of demand and supply according to temperatures needed. Nevertheless, the N. W.T. consumption patterns are s imply delineated into transportation, electricity and, for the most part, low grade heating (≤ 49°C) requirements.

Table 26 summarizes the domestic supply options for each consuming sector. The supply sources are listed according to regional use, end-use, and expected periods of implantation and/or termination. What becomes immediately evident is that the greatest number of supply options are located in the two most intense consuming regions, Fort Smith and Inuvik. This suggests that extra-territorial dependence on energy supply can be greatly diminished.

TABLE 26

POTENTIAL N.W.T. DOMESTIC ENERGY SUPPLY SOURCES BY SECTOR

ELECTRICITY SOURCES

| TIME PERIOD DURING WHICH SUPPLY SOURCES COME ON-STREAM | RESIDENTIAL BUILDINGS | | COMMERCIAL BUILDINGS | | MINING | | TRANSPORTATION |
|---|---|---|---|---|---|---|---|
| | Existing | New | Existing | New | Existing | New | |
| 1979-7, supply source has capability for immediate use | hydro | hydro | hydro | hydro | hydro | hydro | |
| | | hydro potential includes micro and small scale | | | | | |
| | wind | wind | wind | wind | | | |
| | | wind turbines as a diesel back-up or complement | | | | | |
| | forest biomass | forest biomass | forest biomass | forest biomass, applicable only to the Fort Smith and Inuvik regions | | | |
| | | coal- fuidized bed | | coal fuidized bed | coal | coal applicable only to the Fort Smith and Inuvik regions | |
| phased out by 1999 | petroleum | petroleum | petroleum | petroleum | petroleum | petroleum | |
| 1989-?, supply source can come on stream any time after 1989 | natural gas | natural gas | natural gas | natural gas, applicable only to the Fort Smith and Inuvik regions | | | |
| | | geothermal | | geothermal | | geothermal | |

TABLE 26

POTENTIAL N.W.T. DOMESTIC ENERGY SUPPLY SOURCES BY SECTOR

HEATING SOURCES

| TIME PERIOD DURING WHICH SUPPLY SOURCES COME ON-STREAM | RESIDENTIAL BUILDINGS | | COMMERCIAL BUILDINGS | | MINING | | TRANSPORTATION |
|---|---|---|---|---|---|---|---|
| | Existing | New | Existing | New | Existing | New | |
| 1979-? | residual heat | residual heat | residual heat | residual heat | residual heat | residual heat | |
| | | coal - fluidized bed | | coal - fuidized bed | coal | coal | |
| | | hydro (micro or small scale) | | hydro | | | |
| | forest biomass | forest biomass | forest biomass | forest biomass, applicable only to the Fort Smith and Inuvik regions | | | |
| | solar - passive | passive<br>active | passive | passive<br>active | | | |
| phased out by 1999 | pet roleum | petroleum | petroleum | petroleum | petroleum | petroleum | |
| 1989- ? | | natural gas | natural gas | natural gas | | natural gas applicable only to the Fort Smith and Inuvik regions - ? | |
| | | geothermal | | geothermal | | geothermal applicable only to the Fort Smith and Inuvik regions | |
| | peat | peat | peat | peat, applicable only to the Fort Smith and Inuvik regions | | | |
| | agriculture biomass | | agriculture biomass | agriculture biomass applicable only to the Fort smith region | | | |
| | | FLUID FUELS | | | | | |
| | | | | | | | Natural Gas |

20.1 Table 26: Discussion

As indicated in Table 26, domestic petroleum use might be phased out by 1989. This is likely to happen only if some of the following variables occur. First, cost competitive non-renewable (e. g., natural gas ) or renewable altermtives must be found. Cost competitiveness must include costs of retrofit and conversion as well as the mitigation of environmental impacts. Second, if suitable supply options exist, it would be benef icial to the territory to receive some type of economic return on domestic oil being diverted f rom territorial use to export markets. Such a return would enhance the financing of alternative supply sources.

It is assumed that natural gas, as both an electricity and heating supply source, will not come on stream until I-989. Although both site specif ic and pipeline lateral options are discussed, the latter appears to be potentially cost competitive with existing supply. Coal is suggested as a near-term electricity and/or heating supply for the Fort Smith and Inuvik regions. If environmental and health impacts of mining the coal can be overcome, the more immediate uses seem to be electricity and heating for new commercial buildings (by fluidized-bed systems) and for both existing and new mines (if accessible) .

Table 26 indicates that residual heat could be immediately available as a supply source in the N.W. T. As a by-product of combustion, residual heat would appear to be available indefinitely, either from utility electricity generation or from mine processes. The attractiveness of residual heat is enhanced by its applicability to all of the consuming sector, except transportation.

Natural gas and coal are non-renewable options. The soft path approach aims for these sources to be transitional, i.e. they are useful sources until renewable sources can meet all of the projected demand. It is suggested that coal might be a suitable transition source. The uncertainty of 100% renewable dependence suggests that a long-term source like natural gas be exploited as a complement to renewable.

Hydro development, primarily small-scale and micro has potential in all of the regions. Development is possible in the next ten years and, as an electricity source, appears suitable to all non-transportation sectors. As a heating source, it is suggested that near-term application would be confined pr imarily to new residential and commercial buildings.

Along with hydro, forest biomass potential represents the major renewable opt ion. It is suggested that within the next ten years, combustion and gasification systems could supply heating and electricity requirements for both existing and new residential and commerc ial buildings. Agriculture biomass, if stressed as a supply alternative, could meet limited Fort Smith heating requirements after 1989.

Geothermal energy, if evaluated as a feasible option, could meet both electricity and heating requirements for existing and new residential and commercial buildings. Development is assumed to occur after 1989 and would be confined to the Fort Smith and Inuvik regions.

Peat in the Fort Smith and Inuvik regions could meet limited heating requirements in the next ten years. Wind and solar represent supply options for all regions. Wind systems, as an electricity source, could be developed in the next ten years, primarily as a petroleum or gas generator backup/compliment. Passive solar design in the next ten years has the potential to reduce building space heating demand significantly. Active solar seems most appropriate to new commercial and residential hot water requirements. Wind and solar feasibility could be enhanced by the development of seasonal storage units.

Although the ultimate application depends on location and mine type, it appears that the mining sector could best utilize three supply sources: residual. heat, hydro, and coal. There are no foreseeable transportation options. However, compressed natural gas might become a feasible vehicle supply source after 1989.

## 20.2 Recommendations

Given the generalities of the supply analysis, recommendations concerning specific supply options seem inappropriate. Rather, it is suggested that maximum effort be made to develop comprehensive inventories of all potential supply alternatives. This would then be followed up by site specific evaluations. A complementary approach to resource evaluation would be for the N.W.T. government to continue to utilize existing renewable programs and to explore possibilities for additional support.

Although it is suggested that assessment should precede energy strategies, it is likely that exploring a wide range of supply alternatives is cost prohibitive in the near-term. For example, site specific hydro assessments are very costly and monies diverted to such tasks can preclude investigation into other renewable options. Nevertheless, the diverse supply oPtions in the Mackenzie Valley regions offer the potential for a significant improvement in domestic energy self-reliance. Wood biomass, agriculture biomass, peat, and geothermal energy should not be discounted because of perceived initial expense. In this context, the question of territorial revenue associated with oil and gas development is integral to the energy strategies mapped out for the N.W.T.

# APPENDIX I

## METHODOLOGY, INFORMATION SOURCES AND ASSUMPTIONS

For each region, the general approach to projecting energy demand is as follows.

### A. RESIDENTIAL SECTOR: EXISTING

Method: Glean available data.

Sources: Canada Mortgage and Housing Corporation (C. M.H.C. ) and the N.W. T. I-busing Corporation (N. W. T.H. C. ) , Housing and Northern People; Report of the Joint Task Force on Northern Housing Policy, Sept. I-97 9. hereafter known as Housing and Northern people.

A source that aided in the determination of active housing stock is:

> Hildebrandt - Young and Associates Ltd. , @ate: Market Ebrecast, Electr ic Energy Requirements in the Northwest Territories 1979/'80 - 1999/2000 (Winnipeg: A study prepared for the Northern Canada Fewer Commission, 1980) , PP. 25-109.

Assumptions:

1. Cambridge Bay, Keewatin and Baf f in regions' housing stock were assumed to be single detached. This assumption is based, in part, on the part, on the data from Statistics Canada 1976 Census Publication 93-802, Dwellings and Households , Table 8 "Occupied Dwelling by Tenure and Structural Type for Municipalities of 1000 population and over - N. W.T. ".

   A perusal of this table indicates that Fort Smith, Fort Simpson, Hay River, Pine Point and Rae-Edzo, all in the Fort Smith region and Inuvik and Frobisher Bay, in the Inuvik and Baf f in regions respectively, account for approximately 85% and 96% of total N.W.T. single attached and apartment units respectively. Therefore, it is assumed that the balance of single detached dwellings can be accounted for in scattered demand centres, such as in the Cambridge Bay, Keewatin and Baffin regions. (Reasons why Baffin housing stock is assumed to be 100% single detached are discussed in Appendix C.)

<u>Method</u>: Derive per unit heating oil demand. Where there is no doubt concerning housing stock type and heating fuel demand in 1979, per unit demand is derived by:

$$\frac{\text{1979 Heating oil demand}}{\text{1979 Housing stock.}}$$ Where i represents the regional housing stock .

<u>Assumptions</u>:

1. Data concerning regional housing stocks and residential fuel demand is sometimes less than complete. For example, for the Fort Smith region, the heating oil total is low. At the same time the housing stock characteristics vary, i.e. they include single detached apartment, single attached, and duplex units. To derive a per unit heating demand, all housing types are converted to single detached units. Consultation with the federal department of Energy, Mines and Resources indicates how non-single detached unit energy demand corresponds to that of single detached dwellings (see Appendix II for an example).

2. Single attached units generally consume about 50% of the per unit demand by single detached units;

Apartment units generally consume about 25% of single detached unit heating demand.

Duplex and mobile home units consume about 75% of single detached unit heating demand.

Method: Project Housing Stock to 1989 and 1999. Multiply 1979 housing stock by the selected attrition rate.

Source: Housing and Northern People.

Method : Reject heating fuel demand, *zero* conservation approach. Multiply 1989 and 1999 housing stock (either single detached units or single detached equivalents) by the 1979 per unit heating oil demand .

Project heating fuel demand assuming a conservation approach, i.e. the selected conservation savings.

Source: Table 4.

Assumptions: From Table 4 it is assumed that conversation measures would reduce heating oil cumulatively using the following steps:

| | |
|---|---|
| insulation upgrading | 35% savings |
| reduction of air change | 10% savings |
| furnace retrofit | 10% savings |
| thermostat set-back | 5% savings |

Method: Derive per unit electricity demand. Divide the total 1979 residential electricity demand by the housing stock.

Project electricity demand, zero conservation. Multiply 1989 and 1999 housing stock by the 1979 per unit electricity demand.

Project electricity demand using the conservation approach. Multiply the 1989 and 1999 zero conservation demand totals by (100 - energy savings) .

Sou rces:


1. David Brooks and Sean Casey , "A Guide to Soft Energy Paths" , Alternatives 8 (Summer/Fall, 1979) : 17-19.

2. Yvonne Penning and Lewis McCall, "Manitoba: Sof t Energy Path", Alternatives 9 (Winter , 1980): 27-36.

3. University of Saskatchewan, Dept. of Mechanical Eng ineer ing , Energy Efficient I-busing - A Prairie Appreach, published by the Alberta Conservation Board and the Sask. Office of Energy Conservation, 1980.


As sumptions:

1. A perusal of the literature and allowances for N.W .T. ethnic and community characteristics suggests on electricity demand distribution of:

| | |
|---|---|
| water heating | 40% of total demand |
| lighting | 10% of total demand |
| appliances | 20% of total demand |
| blink heater and other winter vehicle accessories | 30% of total demand |

2. From Table 4, it is assumed that energy demand would be reduced by the following steps:

| | |
|---|---|
| water heating | 30% savings |
| lighting | 5% savings |

3. The utilization of more energy efficient appliances is assumed to be offset by increasing appliance saturation.

## B. RESIDENTIAL SECTOR: NEW

Method: Determine the region's rate of population growth and project population to 1989 and 1999. The most up-to-date series of population projections for the N.W.T. are from:

N.W. T. Government Statistics Section, Population Projections Northwest Territories 1978 to 1988, 1979 Methodological Report.

This report attempts to simulate real life population change by portraying fertility, mortality and migration as probabilities of occurence. These probabilities are derived from historical trends (19 71-19 78) . Therefore, the population projections are, in part, a reflection of economic conditions. The report used two projections, Projection A is basically a low growth zero migration scenario that, in part, reflects recent negative (out-migration) statistics. Projection B assumed net-migration as a factor input. The results suggested that only four communities, populations Yellowknife, Pine Point, Frobisher Bay and Rankin Inlet are likely to be affected by economic development.

The Projection B data were utilized for this study to reflect the view that a number of development projects are likely to reduce and perhaps reverse out-migration patterns.

For any of the following demand projections based on population forecasts, it should be noted that the following factors could affect population trends in each N.W.T. region:

i) government expansion;

ii) primary resource development (modest population increases may be experienced followed by a small natural rate of growth); and

iii) rural to urban migration.

Method: Determine the 1989 and 1999 housing needs.

1989 housing need = [1989 population - (1989 housing stock x 1989 average household size)] ÷ average household size.

1999 housing need = [1999 population - (1999 housing stock, a sum of 1979 + 1989 remaining stock) X 1999 average household size)] ÷ average household size.

Assumptions: The Hildrebrandt - Young Market Forecast study for the N.C.P.C. (1979 draft) came up with an average per unit household rate of 4.5. The report (pp. 16, 17) suggests that occupancy rate or household rate data should reflect cultural differences, occupancy patterns for a variety of housing, and occupancy patterns for rural/urban variations.

Method: Project heating fuel demand, zero conservation approach. Multiply the 1989 and 1999 new dwelling units by the 1.979 per unit demand.

Project heating fuel demand, conservation approach, by multiplying the 1.989 and 1999 demand totals by the assumed conservation reduction.

Assumptions: It is assumed that housing similar in efficiency to the Allen Drerup, White prototype models (section 5) will have penetrated the N.W.T. market to the extent that 1989 savings will be about 50% of the 1989 Z.C. demand. In addition, it is assumed that by 1999 the implementation of energy efficient housing will ensure a 90% reduction of the 1999 Z.C. heating demand.

Method: Project electricity demand, zero conservation approach. Multiply the 1989 and 1999 new dwelling units by the 1979 per unit electricity demand.

Pro ject electricity demand, conservation approach by multiplying the 1989 and 1999 demand totals by the conservation savings.

Assumptions:

1. From Table 3, it is assumed that electrical demand for 1989 and 1999 would be reduced by the following steps:

   improve the hot water system 40% savings
   improve lighting 5% savings.

2. It is assumed that there is no attrition rate for housing built after 1989.

   **Note:** An important general assumption to this analysis assumes that there will be no shifts to multi-unit housing in the next 20 years.

C. COMMERCIAL SECTOR

Commercial sector energy demand projections in the Yukon Report are based on population projections and economic forecasts from the Yukon Economic Research and Planning Unit (E. R.P.U. ) . Although N. W.T. projections cannot benef it from forecasts similar to the E. R.P. U. models, an assumed rate of economic growth can be derived, as explained in section 3.1 of the main text. Given the variability of the 5.3% per year economic growth assumption, it seems reasonable to limit its use in this analysis, i.e. to use it in sector pro jections where no alternative factors could be used, such as the mining and transportation sectors. Since population projections are based, in part, on historical trends in the economy, it was decided to use this factor in the commercial sector projections. As a background to the use of population projections the following relationships are noted:

1. Most commerc ial and service enterprises are government operated.

2. Commercial activity in many of the northern communities is linked to hydrocarbon and mineral supply and staging centres, military and government telecommunication centres and social service units.

3. Commercial activity in the larger urbanized centres is linked to both government and primary resource sector development.

   In 1977, the mining/oil and gas sector accounted for shut 20% of the wage and salary total.

4. The mining sector is likely to experience the start-up of a number of mines while exploration is expected to continue to grow, especially in the gold and uranium areas.

5. The Arctic Island natural gas and Beaufort Sea oil and gas deposits are likely to come on stream by 1999 with only minimal effects on the N. W. T. economy, assuming the use of tanker traffic to ship the products.

Method: Project commercial unit stock to 1999. Given the absence of physical variables for the size of the sector, index numbers, (1979 = 100) are used, i.e. x for the public sector and 100 - x for the' private sector.

e.g. , public expansion = index number x $\frac{\text{1989 population}}{\text{1979 population}}$

Project commercial heating demand, zero conservation approach. Take the 1979 total heating demand and divide by 100 to get the per unit demand index. Multiply the 1989 and 1999 totals by the per unit demand.

Project commercial heating demand, conservation approach. Multiply by the assumed savings.

Assumptions: From table 5 the following conservation steps can be assumed to be applied cumulatively to existing buildings:

| | |
|---|---|
| increase insulation | 20% savings |
| use heat recovery devices | 20% savings |
| revamp heating system | 20% savings |

From Table 5, conservation measures for new buildings assume a potential 70% saving.

Method: Project commercial electricity demand zero conservation to 1999 on the same basis of heating as 1979 and 1989. The per unit 1979 demand is derived and is used to multiply the 1989 and 1999 commercial units.

Project commercial electricity demand, conservation approach.

Assumptions: From Table 5 it is assumed that improving office practices in existing buildings would reduce demand 20%. It is also assumed that electricity demand in new buildings would be reduced by 50%. ,

D. TRANSPORTATION SECTOR: ROAD

Introduction: AS noted in Table 6, road transportation is integral. to the movement of goods, passengers and mineral concentrates. While most of the current traffic is confined to the lower Mackenzie Wiley, it is likely that volumes in the Inuvik region will increase in relation to improvements on the Dempster highway. There is also the possibility that mining development may result in new road infrastructures, e.g. , the Contwoyto Lake properties.

While most of the road gasoline demand projections are based on estimated vehicle registration growth, it is important to note that all facets of transportation will be influenced by primary resource development and tourist growth. The latter factor, tourism, could become a major fuel consumer depending on infrastructure development. Unfortunately, data that might aid in predicting growth is virtually nil, according to the N.W.T. Department of Tourism. What little data was available shows, not surprisingly, that the Mackenzie Valley is the major tourist region and consequently, fuel consumer. Discussions with tourist officials suggest, however, that other regions are beginning to attract some of the tourist flow from the Mackenzie.

| Region | % Total 1979 Tourist Visitation | Mode of Transport |
|---|---|---|
| Mackenzie Valley | 75 | road, air |
| Keewatin | 5 | air |
| Baffin | 10 | air |
| Delta | 10 | road, air |

Method: Project 1989 and 1999 road gasoline demand zero conservation by deriving a ratio:

$$\frac{\text{Regional gasoline consumption}}{\text{N. W. T. gasoline consumption}} = k$$

and multiplying the ratio by the selected vehicle totals from Table 7.

Assumptions:

1. Automobiles and light trucks are assumed to be of equal energy demand equivalent.

2. Motorcycles are assumed to consume about 25% of automobile/truck demand.

Method: Project 1989 and 1999 gasoline demand, conservation approach.

Assumptions:

1. From Table 6 it is assumed that by 1989 the following conservation steps will be affecting energy demand from automobiles and light trucks, cumulatively:

| | |
|---|---|
| voluntary fuel efficiency | 10% savings |
| preventive maintenance | 10% savings |
| radial tires | 10% savings |

2. By 1999, the following steps will be in effect for the 1989 Z.C. demand:

| | |
|---|---|
| voluntary fuel efficiency | 20% savings |
| preventive maintenance | 10% savings |
| aerodynamic design | 10% savings |
| radials | 10% savings |
| engine and drive train improvements | 5% savings |

3. From Table 6, it is assumed that improvements in snowmobile rotor and track efficiencies will result in 20% savings from 1989 on.

Method: Project diesel motive demand. Projections of trailer truck diesel consumption can be made from:

i) trailer truck registration forcasts;

ii) economic growth forecasts; and

iii) projected concentrate shipments.

Given the data limitations for the latter approach, an average forecast is used (in some cases) , based on truck registrations and economic growth. The latter is based on the historical growth (1967-197 7) of the public administration sector, 14.3% per year. At a predicted inflation rate of 9% per year, it is assumed that the Gross Territorial Product will grow at 5.3% per year.

Method: Project diesel motive demand, conservation approach.

Assumptions:

1. From Table 6, it is assumed that the following conservation measures will apply in 1989 , cumulatively:

| | |
|---|---|
| driver education and preventive maintenance | 10% savings |
| reduced speeds | 5% savings |
| drag reduction devices | 2% savings |
| radial tires | 4% savings. |

2. From Table 6, it is assumed that the following steps will be 'n effect on the 1989 Z .C. demand, cumulatively:

| | |
|---|---|
| driver education and preventive maintenance | 10% savings . |
| reduced speeds | 6% savings |
| drag reduction devices | 6% savings |
| radial tires | 5% savings |
| auxillary starting aids | 5% savings |
| variable fan drives | 6% savings |
| engine and drive train improvements | 53 savings |

E. TRANSPORTATION: NON-ROAD

Introduction: For the most part, the usage of aviation and turbo fuels is dependent on private industrial activity, primarily the mining/oil and gas sector. In the Yukon Report aviation energy demand projections are based on forecast G.T.P. (p. 88). However, this may not be a completely accurate approach for the N.W.T. because mining/oil and gas share of the total N.W. T. - G. T.P. dropped from 45% to 32% during the period 1967-1977.

Assumptions:

1. It is assumed that aviation demand can be pro jetted using a 5.3% per year real rate of growth. (See previous section)

2. It is assumed that mining/oil and gas' share of the G. T.P. will again move towards 40-50%.

Method: Aviation, rail and marine energy demands are all projected using an annual real growth rate of 5.3% per year.

Assumptions:

1. From Table 6, it is assumed that turbo fuel demand can be reduced 10% by 1989 and 3 0% by 1999 (over 1.989 Z .C. levels) . From Table 6, it is assumed that aviation fuel demand is reduced 5% by 1989 and 20% by 1999.

2. That 10% savings can be achieved in rail energy demand by 1989.

3. That 20% savings can be achieved in marine energy demand by 1989.

F. MINING: SEE THE FORT SMITH REGIONAL ANALYSIS IN APPENDIX II

# APPENDIX II

## FORT SMITH REGION DEMAND PROJECTIONS

### A. RESIDENTIAL SECTOR: EXISTING

#### A.1 Size of Housing Stock

According to the N. W. T.H. C. , the 1979 housing stock in the Fort Smith region includes 4270 units. Two factors indicate that this figure may be too low. First, the Statistics Canada publication, 1976 Census Dwellings and Households indicates that Fort Smith communities of over 1000 people, representing about 86% of the region's population, live in 4910 housing units. Second, when the total Fort Smith region is divided by the average household size of 4.5, 5288 units is the result. This study assumes that there are 5288 active housing units in the region.

#### A.2 Unit Consumption of Heating Oil

Table II indicates that the Fort Smith residential sector consumed 1,483,000 gal. of heating oil in 1979. When this total is divided by the number of housing units, a per unit consumption of 280 gal. results. Allowing for the varying energy demands of apartment and attached housing units, a figure of 280 gal. per unit is quite low for N.W. T. housing. The discrepancy is due primarily to the understating of heating oil consumption in the N.W. T. Science Advisory Board report. The S .A.B. report does indicate, however, that about 340 TJ of propane were used in the Fort Smith region. Assuming that 8 0% of this total was used for residential heating purposes, the resultant heating oil equivalent is about 2,727,273 gal. or 532 TJ. To derive the unit consumption of heating fuel it is necessary to convert all of the Fort Smith housing stock to single detached equivalents.

TABLE II ENERGY CONSUMPTION BY FORM AND SECTOR: FORT SMITH REGION, 1979

| SECTOR | ELECTRICITY MWh | ELECTRICITY TJ | DIESEL (ELECTRIC) 000 GAL. | DIESEL (ELECTRIC) TJ | DIESEL (NON-ELEC.) 000 GAL. | DIESEL (NON-ELEC.) TJ | HEATING OIL 000 GAL. | HEATING OIL TJ | GASOLINE 000 GAL. | GASOLINE TJ | TURBO FUEL 000 GAL. | TURBO FUEL TJ | AVIATION FUEL 000 GAL | AVIATION FUEL TJ | TOTAL TJ | TOTAL % T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | | | | | | | | | |
| Government | 9550 | 34 | | | | | 491 | 86 | | | | | | | 120 | |
| Private | 38023 | 137 | | | | | 992 | 174 | | | | | | | 311 | |
| Sub Total | 47573 | 171 | | | | | 1483 f | 260 | | | | | | | 431 | 5.6 |
| COMMERCIAL | | | | | | | | | | | | | | | | |
| Government | 27456 | 99 | | | 385 | 68 | 3658 | 644 | | | | | | | 811 | |
| Private | 182345 | 648 | | | 11320 ° | 2000 | 3449 | 607 | | | | | | | 3255 | |
| Sub Total | 209801 | 747 | | | 11705 | 2068 | 7107 d | 1251 | | | | | | | 4066 | 53.0 |
| Street Lighting | 1546 | 5 | | | | | | | | | | | | | 5 | .06 |
| MINING | 181803 | 656 | 1510 | 266 | 2941 | 517 | 233 | 41 | 210 | 34 | | | | | 1248 | 16.3 |
| TRANSPORTATION | | | | | | | | | | | | | | | | |
| ROAD | | | | | | | | | | | | | | | | |
| Private | | | | | | | | | 5029 | 790 | | | | | 790 | |
| Gov. | | | | | | | | | 576 | 101 | | | | | 101 | |
| Other | | | | | 474 a | 83 | | | | | | | | | 83 | |
| Sub Total | | | | | 474 | 83 | | | 5605 | 891 | | | | | 974 | 25.0 |
| AIR | | | | | | | | | | | | | | | | |
| Gov. | | | | | | | | | | | 294 | 46 | 89 | 13 | 59 | |
| Private | | | | | | | | | | | 3324 | 541 | 1157 | 176 | 717 | |
| Sub Total | | | | | | | | | | | 3618 | 587 | 1246 | 189 | 776 | |
| RAIL[b] | | | | | 203 | 36 | | | | | | | | | 36 | |
| NE | | | | | 750 | 132 | | | | | | | | | 132 | |
| UTILITY | | | 3843 | 669 | | | | | | | | | | | | |
| TOTAL | 440723 | 1579 | 5350 | 935 c | 16073 | 2836 | 8823 | 1552 | 5815 | 925 | 3618 | 587 | 1246 | 189 | 7668 | 100.0 |

Housing stock energy demand tends to vary according to the housing stock type e.g. , single detached, spar-t, duplex units. Using data supplied by Energy, Mines and Resources Canada, all of the Fort Smith housing stock is converted to single detached equivalents (as the most intense energy consumer, assumed to be equal to a 100% conversion) in the Table below.

| Housing Type | Conversion Rate % (A) | Number of Units in the Ebrt Smith region (B) | Single Detached Equivalents (A) x (B) |
|---|---|---|---|
| Single Detached | 100 | 2688 | 2688 |
| Single Attached | 50 | 420 | 210 |
| Apartments | 25 | 1240 | 310 |
| Duplexes | 75 | 55 | 41 |
| Mobiles | 75 | 885 | 664 |
| Total | | 5288 | 3913 |

Dividing 2,727,273 gal. of heating fuel by 3913 single detached equivalents results in a per unit demand of 697 gal.

A. 3 Housing Stock Projections

Given that appropriate housing stock attrition rate data is unavailable for the total regional stock, a rate similar to Cambridge Bay, i.e. , 1.1% per year compounded, is used. It is also assumed that the apartment stock will remain constant to 1999.

| Year | Non-Apartment Housing Stock |
|---|---|
| 1979 | 5288 -1240 = 4048 |
| 1989 | 4740 - 1240 = 3500 |
| 1999 | 4249 - 1240 = 3009 |

The 1979 housing stock, as a percentage of total non-apartment units, is: single-detached 66.4%; single attached 10.4%; duplex 1.4%; and mobile 2.1.9%. Applying this distribution to the 1989 and 1999 data, the following housing stock projections result.

| Housing Type | Conversion Rate | 1989 Actual Units | 1989 Single Detached Equivalents | 1999 Actual Units | 1999 Single Detached Equivalents |
|---|---|---|---|---|---|
| Single Detached | 100 | 2324 | 2324 | I-997 | 1997 |
| Single Attached | 50 | 364 | 182 | 313 | 156 |
| Apartments | 25 | 1240 | 310 | 1240 | 310 |
| Duplexes | 75 | 49 | 37 | 42 | 32 |
| Mobiles | 75 | 766 | 575 | 659 | 494 |
| Total | | 4740 | 3428 | 4249 | 2989 |

A.4 Projected Heating Fuel Demand: Zero Conservation

1989 ZC Demand = 3428 SD Equivalents x 697 gal./unit
= 2,389,316 gal. or 420 TJ

1999 ZC Demand = 2989 SD Equivalents x 697 gal./unit
= 2,083,333 gal. or 366 TJ

A.5 Projected Heating Fuel Demand: Observation Appreach

1989 C Demand = 210 TJ

1999 C Demand = 182 TJ

See Appendix 1 and Section 5 of the text for the conservation assumptions used in the regional analysis.

A.6 Unit Consumption of Electricity

In 1979, 5288 residential units consumed 47,573 MWh or 8996 KWh per unit.

A.7 Projected Electricity Demand: Zero Conservation

1989 ZC Demand = 4740 units x 8996 KWh per unit
= 42,641 MWh or 153 TJ

1999 ZC Demand = 4249 units x 8996 KWh per unit
= 38,224 MWh or 137 TJ

A.8 Projected Electricity Demand: Conservation Approach

The 1989 and 1999 conservation demands assume water heating savings of 3 0% and lighting savings of 5%.

1989 C Demand = 133 TJ

1999 C Demand = 120 TJ

B. RESIDENTIAL SECTOR: NEW

B. 1 Housing Stock Needs

N.W .T. population projections indicate an annual growth rate of 2.7% per year compounded, yielding a 1989 population of 31,062 and 1999 population of 10,368. Accordingly, the number of new dwelling units required will be:

1989 Housing Demand = [31.,062 - (4749 units x 4=5 persons per household)] ÷ 4.5
= 2163 units

1999 Housing Demand = [40,544 - (4249 + 2163) x 4.5] ÷ 4.5
= 2598 units

B.2 Projected Heating Fuel Demand: Zero Conservation

1989 ZC -d = 2163 units x 697 gal./unit
= 1,507,611 gal. or 265 TJ

1999 ZC -d = 2598 units x 697 gal./unit
= 1,810,806 gal. or 316 TJ

B.3 Projected Heating Fuel Demand: Conservation Approach

The 1989 conservation demand assumes a space heating saving of 50%.

1989 C Demand = 132 TJ

The 1999 conservation demand assumes a space heating saving of 9 0%.

1999 C Demand = 32 TJ

B.4 Projected Electricity Demand: Zero Conservation

1989 ZC Demand = 2163 units (all assumed to be connected)
x 8996 KWh/unit
= 19,458 MWh or 70 TJ

1999 ZC Demand = 2598 units x 8996 KWh/unit
= 23,372 MWh or 84 TJ

B.5 Projected Electricity Demand: Conservation Appreach

The 1989 and 1999 conservation demands assume hot water savings of 40% and improved lighting savings of 5%.

1989 C Demand = 58 TJ

1999 C Demand = 69 TJ

## C. COMMERCIAL SECTOR

### C.1 Index Numbers

Based on existing data, the public and private categories account for 2 0% and 8 0% respectively of the commercial sector's energy demand . Given the absence of any physical variables for the size of the sector, index numbers (1.979 = 100) are used, i.e. "20" for public and 80 for private.

### C. 2 1989 Heating Fuel Demand: Zero Conservation

The 1989 Zero conservation demand for heating fuel is derived as follows :

$$\text{Public Sector Expansion} = \text{Index No.} \times \frac{\text{1989 Population}}{\text{1979 Population}}$$

$$= 20 \times \frac{31{,}062}{23{,}797} = 26$$

$$\text{Private Sector Expansion} = 80 \times \frac{31{,}062}{23{,}797}$$

$$= 104$$

Total Expansion = 104 + 26 = 130

Ne t Expansion = 130 - 100 = 30

Given an assumed 10% attrition rate for existing structures, this results in 90 remaining and 40 new units. The 1979 total commercial demand for heating fuel (both diesel and heating oil) is 3319 TJ. 'Ibis results in a per unit consumption of 33.2 TJ. Therefore,

1989 ZC Demand = 130 units x 33.2 TJ
= 4316 TJ, 24,431,818 gal of fuel

C.3 1989 Heating Fuel Demand: Conservation Appreach

The 1989 conservation demand for heating fuel is derived as follows:

1989 ZC Demand for Existing Buildings = 90 units x 33.2 TJ/unit
= 2988 TJ

1.989 C Demand for Existing Buildings = 1529 TJ

1989 ZC Demand for New Buildings = 4316 - 2988
= 1328 TJ

Assuming 7 0% savings,

1989 C Demand for New Buildings = 332

Total 1989 C Demand = 1861 TJ

c. 4 1999 Heating Fuel Demand: Zero Conservation

The 1999 zero conservation demand for heating fuel is derived as follows:

$$\text{Public Sector Expansion} = 26 \times \frac{40,544}{23,797} = 44$$

$$\text{Private Sector Expansion} = 104 \times \frac{40,544}{23,797} ' 177$$

Total Expansion = 177 + 44 = 221

Net Expansion = 221 - 130 = 91

Given an assumed attrition rate for existing structures, this results in 117 remaining and 104 new units. Recalling that the 1979 per unit consumption is 33.2 TJ,

1999 ZC Demand = 223. units x 33.2 TJ/unit
= 7337 TJ or 41,477,272 gal.

C.5 1999 Heating Fuel Demand: Conservation Approach

The 1999 conservation demand for heating fuel is derived as follows:

1999 ZC Demand for Existing Buildings = 117 units x 33.2 TJ
=3884 TJ

1999 C Demand for Existing Buildings = 1989 TJ

1999 ZC Demand for New buildings = 104 units x 33.2 TJ/unit
= 3452 TJ

1999 C Demand for New Buildings = 1036 TJ

Total 1999 C Demand = 3025 TJ

C.6 1989 Electricity Demand: Zero Conservation

1979 Demand = 747 TJ or 7.47 TJ/unit

1989 ZC Demand = 130 x 7.47 TJ/unit
= 971 TJ

C. 7 1989 Electricity Demand: Conservation Approach

The 1989 conservation demand for electricity is derived as follows:

1989 ZC Demand for Existing Buildings = 90 units x 7.47 TJ/unit
=672 TJ

1989 C Demand for Existing Buildings = 538 TJ

1989 ZC Demand for New Buildings = 971 - 672 = 299 TJ

Assuming a 50% reduction for new buildings,

1989 C Demand for New Buildings = 149 TJ

Total 1989 conservation demand = 687 TJ

C.8 1999 Electricity Demand: Zero Conservation

1979 Demand = 7.47 TJ/unit

1999 ZC Demand =221 units x 7.47 TJ/unit
= 1651 TJ

C.9 1999 Electricity Demand: Conservation Appreach

The 1999 conservation demand for electricity is derived as follows:

1999 ZC Demand for Existing Buildings = 117 units x 7.47 TJ/unit
=874 TJ

1999 C Demand for Existing Buildings = 699 TJ

1999 zc Demand for New Buildings = 1651 - 874
=777 TJ

Assuming a 50% reduction for new buildings,

1999 c Demand for new buildings = 388 TJ

Total 1999 conservation demand = 1087 TJ

D. TRANSPORTATION SECTOR: ROAD

D.1 Current Gasoline Demand

As the region with most of the N. W.T.'s road system, Fort Smith consumed 891 TJ of gasoline and about 83 TJ of non-mine motive diesel oil.

## D.2 Assumptions

Pro jections for 1989 and 1999 gasoline demand assume that:

i) the main gasoline users are cars, light trucks , motorcycles and snowmobiles;

ii) the tourist sector is likely to af fect future gasoline demand;

iii) the number of vehicles register< in the Fort Smith region is a factor of the ratio:

$$\frac{\text{Regional Gasoline Consumption}}{\text{N.W. T. Total Gasoline Consumption}} = k$$

iv) the ratio k remains constant in the projections; and

v) the vehicular distribution remains constant.

## D.3 Projected 1989 Gasoline Demand: Zero Conservation

The value of k for the Fort Smith region is:

$$k = \frac{5,605,000 \text{ gal.}}{8,800,000 \text{ gal.}} = .6369$$

Given that breakdowns of snowmobile registrations were unavailable, it is assumed that the balance of vehicles e.g. , cars, light trucks and, motorcycles account for 10 0% of the gasoline demand. Using Table 5, the derived number of cars, trucks, and motorcycles is:

| Vehicle Type | 1979 | 1989 | 1999 |
|---|---|---|---|
| Cars | 3240 (36%) | 5080 | 7964 |
| Tr ucks | 5553 (62% ) | 11234 | 22725 |
| Motorcycles | 688 (2%) | 1706 | 4228 |

Assuming that cars and light trucks have equal energy demands and that motorcycles consume about one quarter the energy of cars/light trucks, the 1989 ZC Demand is derived as follows:

1989 ZC Demand (as a factor of registrations)

$$\frac{16,740}{8,965} \times 891 \text{ TJ} = 1664 \text{ TJ}$$

1664 TJ can be distributed as 599 TJ cars,

1032 TJ trucks and 33 TJ moto rcyles.

1989 C Demand assumes that motorcycle fuel efficiency remains constant but that car/light truck demand can be reduced with the following options:

| | |
|---|---|
| voluntary fuel efficiency | 10% savings |
| preventive maintenance | 10% savings |
| radial tires | 10% savings |

1989 C Demand = 1222 TJ

D.4 Projected 1999 Gasoline Demand: Conservation Approach

Although the 1989 demand projections are based on vehicular registrations, itself a function of historical growth rates, it is likely that a variety of development projects will affect the gasoline demand to 1999. The development can be categorized as primary resource development, tourism and road development.

Primary resource development: Table 8 lists some of the mining developments likely to be on stream in the region by 1999. All of thin, with possible exception to the Howard's Pass (transport to the

Yukon) , the Camlaren (near existing routes) and the Cullaton Lake (air transport) are likely to entail road expansion to connecting demand centres. For example, estimated fuel energy demand necessary to move the Contwoyto Iake concentrates is between 2 million and 9 million ga3-ions of diesel fuel.

Road Construction: AS listed in Table 6, a number of road construction projects are likely to be completed by 1999. Of these the Liard Valley highway project appears to have the most possible impact on transportation demand.

Tourism: The combination of expansion in the mining field and road network is likely to establish an infrastructure conducive for significant tourism expansion. Despite the possibilities in the foregoing sectors, it is virtually impossible to attempt gasoline demand projections without more accurate information. Therefore, the 1999 gasoline demand projections will also depend on vehicle registration projections.

1999 ZC Demand (as a factor of registrations) =

$$\frac{31,746}{8,965} \times 891 \text{ TJ} = 3155 \text{ TJ}$$

3155 TJ can be districted as 1136 TJ (cars);

1956 TJ (trucks); and 63 TJ (motorcycles)

1999 C Demand assumes the following options:

| | |
|---|---|
| voluntary fuel efficiency | 20% savings |
| preventive maintenance | 10% savings |

aerodynamic design 10% savings
radials 10% savings
engine and drive train improvements 5% savings

1999 C Demand = 1748 TJ

D.5 Current Diesel (Road) Demand

Table II illustrates that the Fort Smith region consumed 474,000 gallons of diesel fuel (83 TJ) in 1979. In fact, this total represents 100% of the N.W.T. demand as noted in the S.A.B. report.

D. 6 Projection Alternatives

Projections of road diesel demand, assumed to be confined to trailer truck consumption can be made from:

i) trailer truck registration projections (Table 7) ;

ii) economic growth projections; and

iii) mining concentrate shipment projections.

While there is not a wealth of data for any of these approaches, the third option appears to be the least desirable. This is because a large percentage of concentrates are shipped by marine, rail, air and truck through the Yukon. Therefore, diesel fuel demand is taken as an average of vehicle registration and economic growth projections.

D.7 Projected 1989 Diesel Demand: Zero Conservation

1979 Demand = 83TJ

1989 ZC Demand = $\frac{4651}{1668}$ X 83 TJ = 231 TJ

Assuming a real rate of economic growth of 5.3% per year.

1989 ZC Demand = $(1.053)^{10}$ X 83 = 139 TJ

Actual 1989 ZC Demand = $\frac{(139 + 231)}{2}$ = I-85 TJ

D.8 Projected 1999 Diesel Demand: Zero Conservation

1989 ZC Demand = $\frac{12,973}{1668}$ X 83 = 645 TJ

or

$(1.053)^{20}$ x 83 = 233

Actual 1999 ZC Demand = $\frac{(645 + 233)}{2}$ = 439 TJ

D.9 Projected 1989 Diesel Demand: Conservation Appreach

1989 C Demand assumes:

| | |
|---|---|
| . driver education and preventive maintenance | 10% savings |
| reduced speeds | 5% savings |
| drag reduction devices | 2% savings |
| radial tires | 4% savings |

1989 C Demand = 149 TJ

D.10 Projected 1999 Diesel Demand: Conservation Approach

1999 C Demand assumes:

| | |
|---|---|
| driver education and presentive maintenance | 10% savings |
| reduced speeds | 5% savings |
| drag reduction devices | 6% savings |
| radial. tires | 5% savings |
| auxillary starting aids | 5% savings |
| variable fan drives | 6% savings |
| engine and drive train improvements | 5% savings |

1999 C Demand = 298 TJ

E. TRANSPORTATION SECTOR: AIR

E.1 Current Fuel Demand

1979 Turbo Fuel Demand = 587 TJ

1979 Aviation Fuel Demand = 189 TJ

E. 2 Projected Fuel Demand: Zero Conservation

The 1989 and 1999 zero conservation demands assume a 5.3% real annual rate of economic growth:

1989 Turbo Fuel ZC Demand = 587 TJ X $(1.053)^{10}$
= 984 TJ

1989 Aviation Fuel ZC Demand = 189 TJ x $(1.053)^{10}$
= 317 TJ

1999 Turbo Fuel ZC Demand = 587 TJ x $(1.053)^{20}$
= 1649 TJ

1999 Aviation Fuel ZC Demand = 189 TJ x $(1.053)^{20}$
= 531 TJ

E.3 Projected Fuel Demand: Conservation Approach

1989 Turbo Fuel C Demand = 886 TJ

1989 Aviation Fuel C Demand = 180 TJ

1999 Turbo Fuel C Demand = 1154 TJ

1999 Aviation Fuel C Demand = 254 TJ

## F. TRANSPORTATION SECTOR: RAIL

### F. 1 Projection Alternatives

The Fort Smith region is the source of 100% of the N. W.T.'s rail energy demand. Given that the present rail system serves the commerc ial centre of Hay River and the Pine Point mine , rail energy demand projections can be related to both general economic activity and mine development. However, the prospect of mining expansion to the year 1999 is not likely to result in significant rail expansion , due' primarily to cost barriers. Therefore, rail energy demand projections will be based on economic growth forecasts.

F. 2 Projected Fuel Demand: Zero Conservation

1979 Rail Diesel Demand = 36 TJ

1989 ZC Demand = 36 TJx $(1.053)^{10}$ = 60 TJ

1999 ZC Demand = 36 TJx $(1.053)^{20}$ = 101 TJ

F.3 Projected Fuel Demand: Observation Appreach

A10% saving in fuel efficiency is assumed for 1989 and 1999:

1.989 Rail Diesel C Demand = 54 TJ

1999 Rail Diesel C Demand = 91 TJ

Note: This analysis did not explore the potential fuel savings that might be encountered by a transfer from truck to rail shipment. It appears to be necessary to examine such possibilities over different time scenarios.

G. TRANSPORTATION: MARINE

G.1 Projection Alternatives

It is assumed that 100% of the marine diesel fuel consumed in the N.W.T. in 1979 can be attributed to the Fort Smith region. While the eastern Arctic is serviced by the marine sector, the transport ships do not refuel in the N.W.T. It appears that marine demand in the Fort Smith region is distributed among barge tugs and commercial/sport boats. Since marine commerce appears to be related to general economic activity, the demand projections are based on economic growth forecasts.

G. 2 Projected Fuel Demand: Zero Conservation

I-979 Marine Diesel Demand = 132 TJ

1989 ZC Demand = 132 TJ X $(1.053)^{10}$
= 221 TJ

1999 ZC Demand = 132 X $(1.053)^{20}$
= 371 TJ

G.3 Projected Fuel Demand: Conservation Appr each

Rom Table 6, a 20% increase in the marine sector fuel efficiency is assumed.

1989 C Demand = 177 TJ

1999 C Demand = 297 TJ

H. MINING SECTOR

H.1 Mines and Energy Demand

Table 1 lists the operating mines in the Fort Smith region and their estimated energy demand. The extent and form of energy used varies according to the mine type. For example, open-pit mines may consume diesel oil to operate water pumps, air drills and haulage vehicles. Underground mines may use diesel oil to operate ventilation and hoisting equipment (which according to N. C. P. C., is the major contributor to peak demand). In addition, both open-pit and underground mines have mill operations that require energy for pumping, transport and drying.

As Table 9 illustrates there are a number of sources of inefficiency in the use of energy in mining. The conservation options are used in projecting mine demand to 1989 and 1999.

## H.2 Projected Fuel Demand: Zero Conservation

ZC Demand to 1999 is projected on the basis that certain mines will have come on stream and that 1979 aggregate energy demand remains constant, unless otherwise indicated.

By 1989, it is assumed that the Terra and Echo Bay tines will have ceased operation, leaving a 1979 aggregate energy demand of 1248 TJ -66 TJ= 1182 TJ. Table 8 suggests that two news mines will be in operation by 1989, the Cadillac and Lupin operations .The projected energy demand of these mines is prorated using the Con-Rycon mine as a base:

Con-Rycon utilized 313 TJ energy to produce 650 tons per day of ore

$$\frac{313}{650} = \frac{x}{1400}$$

x = 674 TJ

1989 ZC Demand = 1182 TJ (remaining mines)
+ 674 TJ (new mines) = 1856 TJ

By 1999 it is assumed that three mines, Can Tung, Cadillac and Lupin, will have ceased operation. This results in an aggregate demand of 1856 TJ - 817 TJ = 1039 TJ.

Table 8 suggests that three new mines will be in operation by 1999, Camlaren, Bathurst Norsemine and Canex.

The energy demand for the new mines have also been prorated using the Con-Rycon mine as a base:

$$\frac{313\,TJ}{650} = \frac{x}{8000}$$

$$x = 3852\ TJ$$

1999 ZC Demand = 1039 TJ + 3852 TJ = 4891 TJ

## H.3 Projected Fuel Demand: Conservation Appreach

From Table 9, it is assumed that an energy saving of 10% is assumed possible to achieve by 1989.

1989 C Demand = 1670 TJ

The 1999 C Demand is based on the assumption that by 1995, mining could equal the target for all industry of 25% per unit of output projected by the federal government for all industry, (p. 92 Yukon Report) .

1999 C Demand = 3669 TJ

**Notes:**

a All of the non-mine, non-heavy equipment native diesel demand is allocated to the Fort Smith regions.

b All of the rail and marine demand is allocated to the Fort Smith region.

c Diesel-electric consumption is not included in the total.

d The figures for commercial heating oil demand do not include mine consumption.

e Pr ivate commercial diesel (non-electric) demand was adjusted to account for the separate classification of mining and transportation consumption, the latter category including rail and marine.

f The residential heating oil demand is understated. See Appendix I for the adjustment methodology.

TABLE III ENERGY CONSUMPTION BY FORM AND SECTOR: CAMBRIDGE BAY REGION, 1979

| SECTOR | ELECTRICITY MWh | ELECTRICITY TJ | DIESEL 000 GAL. | (ELECTRIC) TJ | DIESEL 000 GAL. | (NON-ELEC.) TJ | HEATING OIL 000 GAL. | HEATING OIL TJ | GASOLINE 000 GAL. | GASOLINE TJ | TURBO FUEL 000 GAL. | TURBO FUEL TJ | AVIATION FUEL 000 GAL | AVIATION FUEL TJ | TOTAL TJ | TOTAL % T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | | | | | | | | | |
| Government | 4726 | 17 | | | | | 566 | 100 | | | | | | | 117 | |
| Private | 306 | 1 | | | | | 6 | 1 | | | | | | | 2 | |
| Sub Total | 5032 | 10 | | | | | 572 | 101 | | | | | | | 119 | 28.3 |
| COMMERCIAL | | | | | | | | | | | | | | | | |
| Government | 3629 | 13 | | | 54 | 13 | 711 | 125 | | | | | | | 151 | |
| Private | 1071 | 4 | | | 72 | 9 | 313 | 55 | | | | | | | 68 | |
| Sub Total | 4700 | 17 | | | 126 | 2 2 | 1024 | 150 | | | | | | | 219 | 52.0 |
| Street Lighting | 78 | 0.3 | | | | | | | | | | | | | 0.3 | |
| MINING | | | | | | | | | | | | | | | | |
| TRANSPORTATION | | | | | | | | | | | | | | | | |
| ROAD | | | | | | | | | | | | | | | | |
| Comm. | | | | | | | | | 54 | 8 | | | | | 8 | |
| Government | | | | | | | | | 85 | 13 | | | | | 13 | |
| Other | | | | | | | | | | | | | | | | |
| Sub Total | | | | | | | | | 139 | 21 | | | | | 21 | 17.4 |
| AIR | | | | | | | | | | | | | | | | |
| Government | | | | | | | | | | | 31 | 5 | 2 | 0.3 | 5.3 | |
| Private | | | | | | | | | | | 69 | 11 | 240 | 36 | 47 | |
| Sub Total | | | | | | | | | | | 100 | 16 | 242 | 36.3 | 52.3 | |
| UTILITY | | | 777 | 137 | | | | | | | | | | | 9 | 2.1 |
| TOTAL | 9810 | 35.3 | 777 | 137 a | 126 | 22 | 1650 | 290 | 139 | 21 | 100 | 16 | 242 | 36.3 | 420.6 | 100.0 |

# APPENDIX III

## CAMBRIDGE BAY REGION DEMAND PROJECTIONS

### A. RESIDENTIAL SECTOR: EXISTING

#### A.1 Size of Housing Stock

According to thge N.W.T.H.C. , the 1979 housing stock in the Cambridge Bay region includes 736 units.

#### A.2 Unit Consumption of Heating Oil

Table III indicates that the Cambridge Bay residential sector consumed 572,000 gal. of heating oil in 1979. When this total is divided by the number of housing units, a per unit consumption of 777 gal. results. Given that most of the units in the Cambridge Bay region are assumed to be single detached, 777 gal. seems like a reasonable figure to use in the analysis.

#### A.3 Housing Stock Projections

N. W. T.H.C. data indicate an attrition rate of about 1.1% per year. Given that over 8 0% of the region's stock is N.W. T.H.C. control-led, the attrition rate can be assumed to pertain to the entire region. This results in 656 housing units remaining in 1989 and 585 in 1999.

#### A.4, Projected Heating Fuel Demand: Zero Conservation

1989 ZC Demand = 656 units x 777 gal./unit
= 509,712 gal. or 90 TJ

1999 ZC Demand = 585 units x 777 gal. /unit
= 454,545 gal. or 80 TJ

A.5 Projected Heating Fuel Demand: Conservation Approach

1989 C Demand = 45 TJ

1999 C Demand = 40 TJ

A.6 Unit Consumption of Electricity

In 1989, 736 residential units consumed 5032 MWh or 6837 KWh per unit.

A. 7 Projected Electr icity Demand: Zero Conservation

1989 ZC Demand = 656 units x 6837 KWh/unit
= 4485 mWh or 16 TJ

1999 ZC Demand = 585 units x 6837 KWh/unit
= 3999 MWh or 14 TJ

A.8 Projected Electricity Demand: Conservation Approach

The 1989 and 1999 conservation demands assume water heating savings of 3 0% and lighting savings of 5%.

1989 C Demand = 14 TJ

1999 C Demand = 12 TJ

B. RESIDENTIAL SECTOR: NEW

B.1 Housing Stock Needs

N.W.T. population projections indicate an annual growth rate of 2.8% per year compounded, yielding a 1989 population of 4311 and 1999 population of 5682. Accordingly, the number of new dwelling units required will be:

1989 Housing Demand = [4,311 - (656 units x 4.5 persons/unit)] ÷ 4.5 = 302 units

1999 Housing Demand = [5682 - [(585 + 302) x 4.5] ] ÷ 4.5 = 376 units

B.2 Projected Heating Fuel Demand: Zero Conservation

1989 ZC Demand = 302 units x 777 gal./unit = 40 TJ

1999 ZC Demand = 376 units x777 gal./unit = 51 TJ

B.3 Projected Heating Fuel Demand: Conservation Appreach

The 1989 conservation demand assumes a space heating saving of 50%.

1989 C Demand = 20 TJ

The 1999 conservation demand assumes a space heating saving of 90%.

1999 C Demand = 5 TJ

B.4 Rejected Electricity Demand: Zero Conservation

1989 ZC Demand = 302 units (all assumed to be connected) x 6837 KWh = 2065 MWh or 7 TJ

1999 ZC Demand = 376 units x 6837 KWh per unit = 2570 MWh or 9 TJ

B.5 Projected Electricity Demand: Conservation Appreach

The 1989 and 1999 conservation demands assume hot water savings of 40% and improved lighting savings of 5%.

1989 ZC Demand = 5 TJ

1999 ZC Demand = 7 TJ

## C. COMMERCIAL SECTOR

### C.1 index Numbers

Based on existing (1979( data, the public and private categories account for 65% and 35% respectively of the commercial sector's energy demand. Given the absence of any physical variables for the size of the sector, index numbers (I-979 = 100) are used, i.e., "65" for public and "35" for private.

### C.2 1989 Heating Fuel Demand: Zero Conservation

The 1989 zero conservation demand for heating fuel is derived as follows :

Public Sector Expansion = Index No. x $\frac{1989 \text{ population}}{1979 \text{ population}}$

$= 65 \times \frac{4311}{3271} = 86$

Private Sector Expansion = $35 \times \frac{4311}{3271} = 46$

Total expansion = 86 + 46 = 132

Net expansion (from 1979) = 132 - 100 = 32

Given as assumed 10% attrition rate for existing structures, this results in 90 remaining and 42 new units in 1989. The 1979 total commercial demand for heating fuel is 1,050,000 gal. or 185 TJ. This results in a per unit consumption (1979) of 1.8 TJ. Therefore,

1989 ZC Demand = 132 units x 1.8 TJ/unit
= 238 TJ

C.3 1989 Heating Fuel Demand: Conservation Appreach

The 1989 conservation demand for heating fuel is derived as follows:

1989 ZC Demand for Existing Building = 90 units
x 1.8 TJ/unit = 162 TJ

1989 C Demand for Existing Buildings = 104 TJ

1989 ZC Demand for New Buildings =
42 units x 1.8 TJ/unit = 76 TJ

Assuming a 70% reduction,
1989 C Demand for New Buildings = 22 TJ

Total 1989 C Demand = 126 TJ

C.4 1999 Heating Fuel Demand: Zero Conservation

The 1999 zero conservation demand for heating fuel is derived as follows:

Public Sector Expansion = $86 \times \frac{5682}{3271} = 149$

Private Sector Expansion = $46 \times \frac{5682}{3271} = 80$

Net Expansion (from 1989) = 229 - 132 = 97

Given an assumed 10% attrition rate for existing structures, this results in 119 remaining and 110 new units. Recalling that the 1979 per unit consumption is 1.8 TJ/unit,

1999 ZC Demand = 229 units x 1.8 TJ/unit = 412 TJ

C. 5 1999 Heating Fuel Demand: Conservation Approach

The 1999 conservation demand for heating fuel is derived as follows:

1.999 ZC Demand for Existing Buildings = 119 units x 1.8 TJ/unit
= 214 TJ

1999 C Demand for Existing Buildings = 110 TJ

1999 ZC Demand for New Buildings = 412 - 211
= 298 TJ

1999 C Demand for New Buildings = 89 TJ

Total 1999 C Demand = 199 TJ

C.6 1989 Electricity Demand: Zero Conservation

1979 Demand = 4700 MWh or .17 TJ per unit

1989 ZC -d = 132 units x .17 TJ/unit
= 6204 MWh or 22 TJ

C.7 1989 Electricity Demand: Conservation Approach

The 1989 conservation demand for electricity is derived as follows:

1989 ZC Demand for Existing Buildings = 90 units x .17 TJ/unit
= 15 TJ

1989 C Demand for Existing Buildings = 12 TJ

1989 ZC Demand for New Buildings = 22 - 15
= 7 TJ

Assuming a 50% reduction for new buildings,

1989 C Demand for New Buildings = 3.5 TJ

Total 1989 C Demand = 16 TJ

C.8 1999 Electricity Demand: Zero Conservation

1979 Demand = .17 TJ/Unit

1999 ZC Demand = 229 units x .17 TJ/unit
= 39 TJ

C.9 1999 Electricity Demand: Conservation Appreach

The 1999 conservation demand for electricity is derived as follows:

1999 ZC Demand for Existing Buildings = 119 units x .17 TJ/unit
= 20

1999 C Demand for Existing Buildings = 16 TJ

1999 ZC Demand for New Buildings = 39 - 20
= 19 TJ

1999 C Demand for New Buildings = 10 TJ

Total 1999 C Demand = 26 TJ

## D. TRANSPORTATION SECTOR: ROAD

### D. 1 Current Gasoline Demand

Table III indicates that 1979 fuel consumption attributable to road transport includes 126,000 gal. (22 TJ) of diesel fuel and 139,000 gal. (21 TJ) of gasoline.

### D.2 Assumptions

Projections for 1989 and 1999 assume that:

i) the main gasoline users are cars, light trucks, motorcycles and snowmobiles;

ii) the main diesel users are road construction vehicles;

iii) the tourist sector has no influence on vehicular usage;

iv) the number of vehicles registered in the Cambridge Bay region is a factor of the ratio:

$$\frac{\text{Regional Fuel Consumption}}{\text{N.W.T. Total Fuel Consumption}} = k$$

v) the ratio k remains constant in the projections; and

vi) the vehicular distribution remains constant in the projections except for projection changes as noted in Table 5.

### D.3 Projected Gasoine Demand: Zero Conservation

The value of "k" for the Cambridge Bay region is:

$$k = \frac{139{,}000 \text{ gal.}}{8{,}800{,}000 \text{ gal.}} = .0158$$

Using Table 5, the derived number of cars and trucks (where all are assumed to be light trucks) is:

| Vehicle Type | 1979 | 1989 | 1999 |
|---|---|---|---|
| Cars | 80 | 126 | 198 |
| Trucks | 138 | 279 | 564 |
| Total | 218 | 405 | 762 |

1989 ZC Demand (as a factor of registrations)

$$= \frac{405}{218} \times 21 \text{ TJ} = 39 \text{ TJ}$$

$$1999 \text{ ZC Demand} = \frac{762}{218} \times 21 \text{ TJ} = 73 \text{ TJ}$$

## D.4 Projected Gasoline Demand: Conservation Appreach

1989 C Demand = 28 TJ

1999 C Demand = 40 TJ

## E. TRANSPORTATION SECTOR: AIR

### E. 1 Current Fuel Demand

1979 Turbo Fuel Demand = 16 TJ

1979 Aviation Fuel Demand = 36 TJ

## E.2 Projected Fuel Demand: Zero Conservation

The 1989 and 1999 zero conservation demands assume a 5.3% real annual rate of economic growth:

$$1989 \text{ Turbo Fuel ZC Demand} = 16 \text{ TJ} \times (1.053)^{10} = 27 \text{ TJ}$$

$$1989 \text{ Aviation Fuel ZC Demand} = 36 \text{ TJ} \times (1.053)^{10} = 60 \text{ TJ}$$

$$1999 \text{ Turbo Fuel ZC Demand} = 16 \text{ TJ} \times (1.053)^{20} = 102 \text{ TJ}$$

## E.3 Projected Fuel Demand: Conservation Approach

1989 Turbo Fuel C Demand = 24 TJ
1989 Aviation Fuel C Demand = 58 TJ
1999 Turbo Fuel C Demand = 32 TJ
1999 Aviation Fuel C Demand = 82 TJ

Notes:

a Not included in the total

TABLE IV ENERGY CONSUMPTION BY FORM AND SECTOR: INUVIK REGION, 1979

| SECTOR | ELECTRICITY MWh | ELECTRICITY TJ | DIESEL 000 GAL. | (ELECTRIC) TJ | DIESEL 000 GAL. | (NON-ELEC.) TJ | HEATING OIL 000 GAL. | HEATING OIL TJ | GASOLINE 000 GAL. | GASOLINE TJ | TURBO FUEL 000 GAL. | TURBO FUEL TJ | AVIATION FUEL 000 GAL | AVIATION FUEL TJ | TOTAL TJ | TOTAL % T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | | | | | | | | | |
| Government | 13000 | 47 | | | | | 729 [a] | 128 | | | | | | | 175 | |
| Private | 4000 | 14 | | | | | 47 | 8 | | | | | | | 22 | |
| Sub Total | 17000 | 61 | | | | | 776 | 136 | | | | | | | 197 | 9.5 |
| COMMERCIAL | | | | | | | | | | | | | | | | |
| Government | 12000 | 43 | | | 314 | 55 | 3674 | 651 | | | | | | | 749 | |
| Private | 8000 | 29 | | | 1213 | 211 | 1810 | 317 | | | | | | | 557 | |
| Sub Total | 20000 | 72 | | | 1527 | 266 | 5484 | 968 | | | | | | | 1306 | 63.0 |
| Street Lighting | 395 | 1 | | | | | | | | | | | | | 1 | |
| MINING | | | | | | | | | | | | | | | | |
| TRANSPORTATION | | | | | | | | | | | | | | | | |
| ROAD | | | | | | | | | | | | | | | | |
| Private | | | | | | | | | 1133 | 172 | | | | | | |
| Government | | | | | | | | | 054 | 133 | | | | | | |
| Other | | | | | | | | | | | | | | | | |
| Sub Total | | | | | | | | | 1907 | 306 | | | | | 306 | |
| | | | | | | | | | | | | | | | | 27.5 |
| AIR | | | | | | | | | | | | | | | | |
| Government | | | | | | | | | | | 226 | 37 | 7 | 1 | 30 | |
| Private | | | | | | | | | | | 1180 | 196 | 200 | 32 | 228 | |
| Sub Total | | | | | | | | | | | 1414 | 233 | 215 | 33 | 266 | |
| UTILITY | | | 2965 | 522 | | | | | | | | | | | | |
| TOTAL | 37395 | 134 | 2965 | 522 [b] | 1527 | 266 | 6260 | 1104 | 1987 | 306 | 1414 | 233 | 215 | 33 | 2076 | 100.0 |

# APPENDIX IV

## INUVIK REGION DEMAND PROJECTIONS

### A. RESIDENTIAL SECTOR: EXISTING

#### A.1 Size of Housing Stock

According to the N. W. T. H. C., the 1979 housing stock in the Inuvik region includes 2005 units. Two factors indicate that this figure may be too high, i.e. , while there may be 2005 units, it appears doubtful that all are being used. First, the Hildebrandt-Young Market Forecast Update notes that there are shut 1470 electrical domestic connections. Second, the average household size assumed by this study (4. 5 persons per household) suggests that 1677 housing units are being used. Since it is doubtful that the occupany rate for this region is 3.6, as suggested by a housing stock of 2005, this study assumes that there are 1677 active housing units in the Inuvik region.

#### A. 2 Unit Consumption of Heating Oil

Table IV indicates that the Inuvik residential sector consumed 776,000 gal. of heating oil in 1979. When this total is divided by the number of housing units, a per unit consumption of 465 gal. results. Given that there are only shut 600 to 700 multiple attached units in the region, a figure of 465 gal. is low. Like the Fort Smith region, an understanding of heating oil demand makes an accurate projection cliff icult. Given that the Inuvik region falls somewhere between the Fort Smith and Cambridge Bay regions in terms of degree day figures, it is assumed that the per unit heating oil demand for Inuvik is:

(Cambridge Bay per unit demand of 777 gal. +) - 2 = 737 gal./unit
(Fort Smith per unit demand of 697 gal. )

## A.3 Description of the Housing Stock and Conversion to Single Detached Equivalents

A complete and disaggregate description of the region's housing stock does not exist. However, Statistics Canada does have data pertaining to housing types in the largest population centre, Inuvik. For smaller population centres (less than 1000),. reference is made to the Cambridge Bay and Fort Smith experiences, which suggest that communities of this size are likely to be composed of single detached units. As in the Fort Smith analysis, the Inuvik region housing stock data are converted to single detached equivalents.

| musing Type | Conversion Rate % (A) | Number of Town of muvik | Units Region of Inuvik (B) | Single Detached Equivalents (A) X (B) |
|---|---|---|---|---|
| Single Detached | 100 | 58[a] | 1082 | 1082 |
| Single Attached | 50 | 330 | 330 | 115 |
| Apartments | 25 | 190 | 190 | 47 |
| Duplexes | 75 | 15 | 15 | 10 |
| Mobiles | 75 | 60 | 60 | 45 |
| Total | | 653 | 1677 | 1299 |

Notes:

a According to Statistics Canada data this figure is understated. However, given the assumed occupancy rate, the single detached total would have to be 58. It is likely that the single detached unit total for the balance of the communities offsets this understatement.

A. 4 Current Heating Fuel Demand for the Inuvik Region

1979 - d = 737 gal./unit x 1299 J.D. Equivalents
= 957,363 gal. or 168 TJ

A.5 Housing Stock Projections

If N. W. T.H.C. housing stock attrition data are used for all of the Inuvik region, it would indicate an attrition rate of less than 1%. N.W.T.H.C. stock represents only 36% of the total stock, thereby understating the regional attrition rate. As in the Cambridge Bay and Fort Smith regions, a rate of 1.1% per year compounded is used, assuming that the spar-nt stock will remain constant to I-999.

| Year | Non-Apartment Housing Stock |
|---|---|
| 1979 | 1677 -190 = 1487 |
| 1989 | 1503 -190 = 1313 |
| 1999 | 1347 -190 = 1157 |

The 1979 housing stock distribution, as a percentage of total non-apartment units, is: single-detached 73%; single attached 22%; duplex 1%; and mobile 4%. Applying this distribution to the 1989 and 1999 data, the following pro j ections result:

| Housing Type | Conversion Rate % | 1989 Actual Units | 1989 Single Detached Equivalents | 1999 Actual Units | 1999 Single Detached Equivalents |
|---|---|---|---|---|---|
| Single Detached | 100 | 958 | 958 | 845 | 845 |
| Single Attached | 50 | 289 | 144 | 254 | 127 |
| Apartments | 25 | 190 | 47 | 190 | 47 |
| Duplexes | 75 | 13 | 10 | 12 | 8 |
| Mobiles | 75 | 52 | 39 | 46 | 34 |
| Total | | 1313 | 1198 | 1157 | 1061 |

A. 6 Projected Heating Fuel Demand: Zero Conservation

1989 ZC Demand = 1198 JD Equivalents x 737 gal./unit
= 882,926 gal. or 155 TJ

1999 ZC Demand = 1061 JD Equivalents x 737 gal./unit
= 781,957 gal. or 137 TJ

A. 7 Projected Heating Fuel Demand: Conservation Approach

1989 C Demand = 78 TJ

1999 C Demand = 68 TJ

A. 8 Unit Consumption of Electricity

In 1979, 1677 residential units consumed 17,000 MWh or 10,137 KWh per unit. However, 10,137 KWh per unit appears to be high so the projections may be somewhat overstated.

A.9 Pro jetted Electricity Demand: Zero Conservation

1.989 ZC Demand = 1313 units x 10, I37 KWh/unit
= 13,309 MWh or 48 TJ

1999 ZC Demand = 1157 units x 10,137 KWh/unit
= 11,728 MWh or 42 TJ

A.10 Pro jetted Electricity Demand: Conservation Approach

The 1989 and 1999 conservation deinands assume water heating savings of 30% and lighting savings of 5%.

1989 C Demand = 41 TJ

I-999 C Demand = 37 TJ

B. RESIDENTIAL SECTOR: NEW

B.1 Housing Stock Needs

N.W.T. population projections indicate an annual growth rate of 1.6% year tort'pounded, yielding a 1989 population of 8,846 and 1.999 population of 10,368. Accordingly, the number of new dwelling units required will be:

1989 Housing Demand = [8,846 - (1313 units x 4.5 persons per unit)] ÷ 4.5 = 653 units

1999 Housing Demand = [10,368 - (1157 + 653) x 4.5] ÷ 4.5
= 494 units

B.2 Projected Heating Fuel Demand: Zero Conservation

1989 ZC Demand = 653 units x 737 gal./unit
= 481,261 gal.. or 84 TJ

1.999 ZC Demand = 494 units x 737 gal./unit
= 364,078 gal. or 64 TJ

B.3 Projected Heating Fuel Demand: Conservation Approach

The 1989 conservation demand assumes a space heating saving of 50%.

1989 C Demand = 42 TJ

The 1999 conservation demand assumes a space heating saving of 90%.

1999 C Demand = 6 TJ

B.4 Projected Electricity Demand: Zero Conservation

1989 ZC Demand = 653 units (all assumed to be connected) x
10,1.37 KWh/unit
= 6619 MWh or 24 TJ

1999 ZC remand = 494 units x 10,137 KWh/unit
= 5,008 MWh or 18 TJ

B .5 Pro jected Electricity Demand: Conversation Approach

The 1.989 and 1999 conservation demands assume hot water savings of 40% and improved lighting savings of 5%.

1989 C Demand = 22 TJ

1999 C Demand = 15 TJ

### B.6 Additional Variables

A variable which might be considered in revised housing energy demand projections is the Norman Wells Oilf ield development project. Resources Management Consultants (Alberta Ltd. ) estimate a need for about 50 new housing units (permanent) in Normal Wells. [See: E.Sources Management Consultants (Alberta, Ltd. ) , "Regional Socio-economic Impact Assessment of the Norman Wells Oilfield Development and Pipeline Project", a report for Esso Resources Canada Ltd., as part of the Inerprovincial Pipeline N.W. Ltd.'s application to the National Energy Board, Vol. V, March 1980.1

## C. COMMERCIAL SECTOR

### C. 1 Index Numbers

Based on existing (1979) data, the public and private categories account for 57% and 43% respectively of the commercial sector's energy demand. Given the absence of any physical variables for the size of the sector, index numbers (I-979 = 100) are used, i.e. , "57" for public and "43" for private.

### C.2 I-989 Heating Fuel Demand: Zero Conservation

The 1989 zero conservation demand for heating fuel is derived as follows :

$$\text{Public Sector Expansion} = \text{Index No.} \times \frac{\text{1989 Population}}{\text{1979 Copulation}}$$

$$= 57 \times \frac{8846}{7548} = 67$$

$$\text{Private Sector Expansion} = 43 \times \frac{8846}{7548} = 50$$

Total Expansion = 67 + 50 = 117

Net Expansion (from 1979 ( = 117 - 100 = 17

Given an assured 10% attrition rate for existing structures, this results in go remaining and 27 new units. Given the public/private distribution noted above, the 117 units can be broken down as 67 public and 50 private.

The 1979 total commercial demand for heating fuel (both diesel and heating oil) is 1234 TJ 266 diesel and 968 heating oil) . This results in a per unit consumption (1979) of 12.34 TJ. Therefore,

).989 ZC Demand = 117 units x 12.34 TJ/unit
= 1444 TJ (311 diesel, 1133 heating oil)

C.3 1989 Heating Fuel Demand: Conservation Appreach

The 1989 conservation demand for heating fuel is derived as follows:

1989 ZC Demand for Existing Buildings = 90 units x 12.34 TJ/unit
= 1111 TJ

1989 C Demand for Existing Buildings = 569 TJ

1989 ZC Demand for New Building's = 1444 - 1111
= 333 TJ

Assuming a 70% reduction,

1989 C Demand for New Buildings = 100 TJ

Total 1989 C Demand = 669 TJ

## C. 4 1999 Heating Fuel Demand: Zero Conservation

The 1999 zero conservation demand for heating fuel is derived as follows :

$$\text{Public Sector Expansion} = 67 \times \frac{10,368}{7,548} = 92$$

$$\text{Private Sector Expansion} = 50 \times \frac{10,368}{7,548} = 69$$

Total Expansion = 92 + 69 = 161

Net Expansion (from 1989) = 161 - 117 = 44

Given an assumed 10% attrition rate for existing structures, this results in 105 remaining and 56 new units. Recalling that the 1979 per unit consumption is 12.34 TJ,

1999 ZC Demand = 161 units x 12.34 TJ/unit
= 1987 TJ

## C.5 1999 Heating Fuel Demand: Conservation Appreach

The 1999 conservation demand for heating fuel is derived as follows:

1999 ZC Demand for Existing Buildings = 105 units x 12.34 TJ/unit
= 1296 TJ

1999 C Demand for Existing Building's = 664 TJ

1999 ZC Demand for New Buildings = 1987 - 1296
= 691 TJ

1999 C Demand for New Building's = 207 TJ

Total 1999 C Demand = 871 TJ

C. 6 1989 Electricity Demand: Zero Conservation

I-979 Demand = 72 TJ or .72 TJ/unit

1989 ZC Demand = 117 units x .72 TJ/unit
= 84 TJ

C. 7 1989 Electricity Demand: Conservation Appreach

The 1989 conservation demand for electricity is derived as follows:

1989 ZC Demand for Existing Buildings = 90 units x .72 TJ/unit
= 65 TJ

1989 C Demand for Existing Buildings = 52 TJ

1989 ZC Demand for New Buildings = 84 TJ - 65 TJ
= 19 TJ

Assuming a 50% reduction for new buildings,

1.989 C Demand for New Buildings = 10 TJ

Total I-989 C Demand = 62 TJ

C.8 1999 Electricity Demand: Zero Conservation

1979 Demand = .72 TJ/unit

1999 ZC Demand = 161 units x .72 TJ/unit
= 116 TJ

C.9 1999 Electricity Demand: Conservation Approach

The 1999 conservation demand for electricity is derived as follows:

1999 ZC Demand for Existing Buildings = 105 units x .72 TJ/unit
= 76 TJ

1999 C Demand for Existing Buildings = 61 TJ

1999 ZC Demand for New Buildings = 116 - 76
=40 TJ

Assuming a 50% reduction for new buildings,

1999 C Demand for New Buildings = 20 TJ

Total 1999 C Demand = 81 TJ

D. TRANSPORTATION SECTOR: ROAD

D.1 Current Gasoline Demand

Although the Inuvik region does not have an extensive road system, 1,987,000 gal. of gasoline were consumed in 1979. There is a strong possibility that road fuel demand will increase substantially hen one considers the following factors:

i) Dempster Highway Improvement - It is expected that by 1989 this highway will be in such a condition as to allow a steady seasonal stream of commercial and tourist traffic. The highway will be extended to Tuktoyaktuk;

ii) Canol Road - If the Canol Road is upgraded to a level allowable for vehicular usage, there could be an increase in commercial and industrial traffic; and

iii) If Inuvik and Tuktoyaktuk become staging and administrative centres for possible Beaufort Sea and Mackenzie Valley hydrocarbon developments, it is likely that fuel demand will be affected.

D.2 Assumptions

Projections for 1989 and 1999 road gasoline demand assume that:

i) the main users are cars and light trucks ;

ii) the number of vehicles registered in the Inuvik region is a factor of the ratio:

$$\frac{\text{Regional Gasoline Consumption}}{\text{N.W.T. Total Gasoline Consumption}} = k$$

iii) the ratio k remains constant in the projections; and

iv) the vehicular distribution remains constant.

D.3 Projected Gasoline Demand: Zero Conservation

The Value of "k" for the Inuvik region is:

$$k = \frac{1{,}987{,}000 \text{ gal.}}{8{,}800{,}000 \text{ gal.}} = .2258$$

Using Table 7, the derived number of cars and trucks is:

| Vehicle Type | 1979 | 1989 | 1999 |
|---|---|---|---|
| cars | 1149 (37%) | 18 01 | 2824 |
| Trucks | 1969 (63%) | 3983 | 8057 |
| Total | 313.8 | 5784 | 10881 |

1989 ZC Demand (as a factor of registrations) = $\frac{5784}{3118}$ x 306 TJ = 568 TJ

568 TJ can be distributed as 210 TJ cars and 358 TJ trucks.

$$1999 \text{ ZC Demand} = \frac{10881}{3118} \times 306 \text{ TJ}$$
$$= 1.068 \text{ TJ}$$

D .4 Projected Gasoline Demand: Conservation Appreach

1989 C Demand = 414 TJ

1999 C Demand = 592 TJ

E. TRANSPORTATION SECTOR: AIR

E. 1 Current Fuel Demand

1979 Turbo Fuel Demand = 233 TJ

1979 Aviation Fuel Demand = 33 TJ

E. 2 Projected Fuel Demand: Zero Conservation

The 1989 and 1999 zero conservation demands assume a 5.3% real annual rate of economic growth:

$$1989 \text{ Turbo Fuel ZC Demand} = 233 \text{ TJ} \times (1.053)^{10}$$
$$= 390 \text{ TJ}$$

$$1989 \text{ Aviation Fuel ZC Demand} = 33 \times (1.053)^{10}$$
$$= 55 \text{ TJ}$$

$$1999 \text{ Turbo Fuel ZC Demand} = 233 \text{ TJ} \times (1.053)^{20}$$
$$= 654 \text{ TJ}$$

$$1999 \text{ Aviation Fuel ZC Demand} = 33 \times (1.053)^{20}$$
$$= 93 \text{ TJ}$$

E. 3 Projected Fuel Demand: Conservation Approach

1989 Turbo Fuel C Demand = 351 TJ

1989 Aviation Fuel C Demand = 52 TJ

1999 Turbo Fuel C Demand = 458 TJ

1999 Aviation Fuel C Demand = 74 TJ

Notes:

a Not included in the total

b Understated total; see Inuvik region discussion for derived 1979 demand .

TABLE V ENERGY CONSUMPTION BY FORM AND SECTOR: KEEWATIN REGION, 1979

| SECTOR | ELECTRICITY MWh | TU | DIESEL 000 GAL. | (ELECTRIC) TU | DIESEL 000 GAL. | (NON-ELEC.) TU | HEATING OIL 000 GAL. | TU | GASOLINE 000 GAL. | TU | TURBO 000 GAL. | FUEL TU | AVIATION FUEL 000 GAL | TU | TOTAL TU | % T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | | | | | | | | | |
| Government | 7000 | 25 | | | | | 974 | 170 | | | | | | | 195 | |
| Private | 1000 | 4 | | | | | 20 | 3 | | | | | | | 7 | |
| Sub Total | 8000 | 29 | | | | | 994 | 173 | | | | | | | 202 | 45 |
| COMMERCIAL | | | | | | | | | | | | | | | | |
| Gov. | 4000 | 14 | | | 94 | 16 | 607 | 120 | | | | | | | 150 | |
| Private | 1000 | 4 | | | 54 | 9 | 281 | 50 | | | | | | | 63 | |
| Sub Total | 5000 | 18 | | | 14a | 25 | 960 | 170 | | | | | | | 213 | 48 |
| Street Lighting | 242 | | | | | | | | | | | | | | | |
| MINING | | | | | | | | | | | | | | | | |
| TRANSPORTATION | | | | | | | | | | | | | | | | |
| ROAD | | | | | | | | | | | | | | | | |
| Private | | | | | | | | | 18 | 3 | | | | | 3 | |
| Government | | | | | | | | | 79 | 12 | | | | | 12 | |
| other | | | | | | | | | | | | | | | | |
| Sub Total | | | | | | | | | 97 | 15 [a] | | | | | 15 | 7 |
| AIR | | | | | | | | | | | | | | | | |
| Government | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | |
| Private | | | | | | | | | | | 45 | 7 | 41 | 7 | 14 | |
| Sub Total | | | | | | | | | | | 45 | 7 | 41 | 7 | 14 | |
| UTILITY | | | 1189 | 209 | | | | | | | | | | | | |
| TOTAL | 13242 | 47 | 1189 | 209 | 140 | 25 | 1962 | 343 | 97 | 15 | 45 | 7 | 41 | 7 | 444 | 10D .0 |

# APPENDIX V

## KEEWATIN REGION DEMAND PROJECTIONS

## A. RESIDENTIAL SECTOR: EXISTING

### A.1 Size of Housing Stock and Unit Consumption of Heating Oil

According to the N. W. T. H. C., the 1979 housing stock in the Keewatin region included 853 units. However, the Science Advisory Board Statistics suggest that this figure is too low. As Table V indicates, 994,000 gal of heating oil were consumed in 1979 or 1,165 gal. per unit. For the most part, degree day data suggests that the Keewatin region has a comparable climate to the Inuvik region, which was assumed to have a per unit consumption of 737 gal. In making the Keewatin projection; the choice then is to assume a per unit figure other than 1,165 gal or to use this figure, assuming a part icular hidden reason for the higher consumption. Given that this region has not experienced any significant housing booms, the figure of 1,165 gal. per unit (based on 853 units) is used. Finally, it is assumed that all of the housing units are single detached.

### A.2 Housing Stock Projections

N. W. T.H. C. data indicates an attrition rate of 1.4% per year. lherefore,

1989 Housing stock = 742 units

1999 Housing stock = 646 units

A.3 Projected Heating Fuel Demand: Zero Conservation

1989 ZC Demand = 742 units x 1165 gal./unit
= 864,430 gal. or 151 TJ

1999 ZC Demand = 646 units x 1165 gal./unit
= 752,590 gal. or 132 TJ

A.4 Projected Heating Fuel Demand: Conservation Approach

1989 C Demand = 75 TJ

1999 C Demand = 66 TJ

A.5 Unit Consumption of Electricity

In 1979, 853 residential units consumed 8,000 MWh or 9379 KWh per unit.

A.6 Projected Electricity Demand: Zero Conservation

1989 ZC Demand = 742 units x 9379 KWh/unit
= 6,959 MWh or 25 TJ

1999 ZC Demand = 646 units x 9379 KWh/unit
= 6,059 MWh or 22 TJ

A.7 Projected Electricity Demand: Conservation Approach

1989 C Demand = 22 TJ

1999 C Demand = 19 TJ

## B. RESIDENTIAL SECTOR: NEW

### B.1 Housing Stock Needs

According to the N.W.T. government population projections, the Keewatin region population is projected to increase at a rate of 3.4% per year compounded, yielding a 1989 populationof 5988 and a 1999 populationof 8365. Accordingly, the number of new dwellings required will be:

1989 Housing Demand = [5988 - (742x 4.5)] ÷ 4.5
= 589 units

1999 Housing Demand = [8365 - (646 +589) X 4.5] ÷ 4.5
=624 units

### B .2 Projected Heating Fuel Demand: Zero Conservation

1989 ZC Demand = 589 units x 1165 gal./unit
= 686,185 gal. or 121 TJ

1999 ZC Demand = 624 units x 1165 gal./unit
=726,960 gal. or 128 TJ

### B.3 Projected Heating Fuel Demand: Conservation Appreach

The 1989 conservation demand assuines a space heating saving of 50%.

1989 C Demand = 61 TJ

The 1999 conservation demand assumes a space heating saving of 90%

1999 C Demand = 13 TJ

B.4 Projected Electricity Demand: Zero Conservation

1989 ZC Demand = 589 units x 9379 KWh/unit
= 5524 MWh or 20 TJ

1999 ZC Demand = 624 units x 9379 KWh/unit
= 5852 MWh or 21 TJ

B. 5 Projected Electricity Demand: Conservation Approach

The 1989 and 1999 conservation demands assume hot water savings of 40% and improved lighting savings at 5%.

1989 C Demand = 17 TJ

1.999 C Demand = 18 TJ

C. COMMERCIAL SECTOR

C.1 Index Numbers

Based on 1979 energy demand, the public and private categories account for 7 0% and 3 0% respectively of the commercial sector's energy demand. Given the absence of any physical variables for the size of the sector, index numbers (1979 = 100) are used, i.e. , "70" for public and "30" for private.

C.2 1989 Heating Fuel Demand: Zero Conservation

The 1989 zero conservation demand for heating fuel is derived as follows:

$$\text{Public Sector Expansion} = \text{Index No.} \times \frac{\text{1989 Population}}{\text{1979 Population}}$$

$$= 70 \times \frac{5988}{4286} = 98$$

Private Sector Expansion = 30 x 5988 = 42
4286

Total Expansion = 98 + 42 = 140

Net Expansion (from 1979( = 140 -100 = 40

Given an assumed 10% attrition rate for existing structures, this results in go remaining and so new units in 1989. The 1979 total commercial demand for heating fuel is 195 TJ (25 diesel and 170 heating oil). 'Ibis results ina per unit consumption (1979) of 1.95 TJ. **Therefore,**

1989 ZC Demand = 140 units x 1.95 TJ/unit
= 273 TJ (238 heating oil, 35 diesel)

C.3 1989 Heating Fuel Demand: Conservation Appreach

The 1989 conservation demand for heating fuel is derived as follows:

I-989 ZC Demand for existing Buildings = 90 units x 1.95 TJ/unit
= 175 TJ

1989 C Demand for Existing Buildings = 90 TJ

1989 ZC Demand for New Buildings = 50 units x 1.95 TJ/unit
= 98 TJ

Assuming a 70% reduction,

1989 C Demand for New Buildings = 29 TJ

Total 1989 C Demand = 119 TJ

## C.4 1999 Heating Fuel Demand: Zero Conservation

The )999 zero conservation demand for heating fuel is derived as follows:

Public Sector Expansion = 98 x $\frac{8365}{4286}$ = 191

Private Sector Expansion = 42 x $\frac{8365}{4286}$ = 82

Total Expansion = 191 + 82 = 273

Net Expansion (from 1989) = 273 - 140 = 133

Given an assumed 10% attrition rate for existing structures, this results in 172 remaining and 101 new units. Recalling that the 1979 per unit consumption is 1.95 TJ/unit,

1999 ZC Demand = 273x 1.95 TJ/unit
= 532 TJ (464 heating oil, 68 diesel)

## C.5 1999 Heating Fuel demand: Conservation Approach

The 1999 conservation demand for heating fuel is derived as follows:

1999 ZC Demand for Existing Buildings = 172 units x 1.95 TJ/unit
=335 TJ

1999 C Demand for Existing Buildings = 171 TJ

1999 ZC Demand for New Buildings = 101 x 1.95 TJ/unit
= 197 TJ

Assuming a 7 0% reduction,

I-999 C Demand for New Buildings = 59 TJ

Total 1999 CDemand=230TJ

C.6 <u>1989 Electricity Demand: Zero Conservation</u>

1979 Demand = 5000 MWh, 18 TJ or .18 TJ/unit

1989 ZC Demand = 140 units x .18 TJ/unit
= 25 TJ

C.7 <u>1989 Electricity Demand: Conservation Appreach</u>

The 1989 conservation demand for electricity is derived as follows:

1989 ZC Demand for Existing Buildings = 90 unts x .18 TJ/unit
= 16 TJ

1989 C Demand for Existing Buildings = 13 TJ

1989 ZC Demand for New Buildings = 50 x .18 TJ/unit
=9TJ

Assuming a 50% reduction for new buildings,

1989 C Demand for *w Buildings = 5 TJ

Total 1989 C Demand = 18 TJ

C.8 <u>1999 Electricity Demand: Zero Conservation</u>

1979 Demand = .18 TJ/unit

1.999 ZC Demand = 273 units x .18 TJ/unit
= 49 TJ

C.9 1999 Electricity Demand: Conservation Approach

The 1999 conservation demand for electricity is derived as follows:

1999 ZC Demand for Existing Buildings = 172 units x .18 TJ/unit
= 31 TJ

1999 C Demand for Existing Buildings = 25 TJ

1999 ZC Demand for New Buildings = 101 units x .18 TJ/unit
= 18 TJ

Assuming a 50% reduction for new buildings,

1999 C Demand for New Buildings = 9 TJ

Total 1999 C Demand = 34 TJ

D. TRANSPORTATION SECTOR: ROAD

D. 1 Current Gasoline Demand and Assumptions

Although the Keewatin region has virtually no roads, it still consumed 97,000 gal. of gasoline. The nature of the coastal communities suggests the use of outboard motor boats. Therefore, it is assumed that 50% of the gasoline demand can be allocated to the marine transportation sector. In addition, 100% of the road sector consumption is attributed to snowmobiles. Since no specific data on N.W.T. snowmobile registrations exist, projections are based on G.T. P. forecasts.

D.2 Projected Gasoline Demand: Zero Conservation

1989 ZC Demand = 8 TJ (1979 Snowmobile Demand) x $(1.053)^{10}$
13 TJ

1999 ZC Demand = 8 TJ $(1.053)^{20}$
22 TJ

D.3 Projected Gasoline Demand: Conservation Approach

From Table 6, it is assumed that snowmobile rotor and track efficiency can be improved by 20%. Therefore,

1989 C Demand = 10 TJ

1999 C Demand = 18 TJ

E. TRANSPORTATION SECTOR: MARINE

E.1 Assumptions

It is assumed that outboard motor boats consumed 8 TJ of gasoline in 1979. Projections are based on G.T.P. forecasts.

E.2 projected Gasoline Demand: Zero Conservation .

1989 ZC Demand = 13 TJ

1999 ZC Demand = 22 TJ

E.3 Projected Gasoline Demand: Conservation Approach

From Table 5, it is assumed that outboard rotor boat efficiency can be improved by 20%. Therefore,

1989 C Demand = 10 TJ

1999 C Demand = 18 TJ

## F. TRANSPORTATION SECTOR: AIR

### F.1 Current Fuel Demand

1979 Turbo Fuel Demand = 7 TJ

1979 Aviation Fuel Demand = 7 TJ

### F.2 Projected Fuel Demand: Zero Observation

1989 Turbo Fuel ZC Demand $= 7\ TJ \times (1.053)^{10}$
$= 12\ TJ$

1989 Aviation Fuel ZC Demand $= 7\ TJ \times (1.053)^{10}$
$= 12\ TJ$

1999 Turbo Fuel ZC Demand $= 7\ TJ \times (1.053)^{20}$
$= 20\ TJ$

1999 Aviation Fuel ZC Demand $= 7\ TJ \times (1.053)^{20}$
$= 20\ TJ$

F.3 Projected Fuel Demand: Conservation Appreach

I-989 Turbo Fuel C Demand = 11 TJ

1989 Aviation Fuel C Demand = 11 TJ

1999 Turbo Fuel C Demand = 14 TJ

1999 Aviation Fuel C Demand = 16 TJ

## G. MINING

### G.1 Current and Future Prospects

Although there are presently no operating mines in the Keewatin region, it is expected that at least one and perhaps two mines will. be on stream by 1989. Table 8 lists one mine currently under construction plus a potential uranium development. While the identified uranium development may never materialize, it is expected that at least one such mine will open by 1989. Statistics reveal that the Keewatin region is the area of heaviest exploration (primarily uranium and gold) in the N.W.T.

### G.2 Energy Demand: Zero Conservation and Conservation Appreach

From Table 8, the new mine assumed to be on stream by 1989 is the cullation Lake development. The energy demand is prorated from the Con-Rycon mine. In producing 650 t.p. d. of mill. capacity, con consumes 313 TJ, 36% electricity, 19% diesel motive, 42% heating oil and 3% gasoline. Using ratios:

$$\frac{313\ TJ}{650\ t.p.d.} = \frac{x}{200\ t.p.d.} \qquad \therefore x = 96\ TJ$$

1989 ZC Demand = 96 TJ

1989 C Demand = 86 TJ

By 1999, it is assumed that the Cullaton Lake operation will have terminated. While it is expected that at least one uranium mine will be in existence, the dearth of data precludes reasonable projections.

Notes:

a A percentage of gasoline consumption is attributed to the marine sector. See the text for the method of adjustment.

TABLE VI ENERGY CONSUMPTION BY FORM AND SECTOR: BAFFIN REGION, 1979

| SECTOR | ELECTRICITY MWh | ELECTRICITY TJ | DIESEL 000 GAL. | (ELECTRIC) TJ | DIESEL 000 GAL. | (NON-ELEC.) TJ | HEATING OIL 000 GAL. | HEATING OIL TJ | GASOLINE 000 GAL. | GASOLINE TJ | TURBO 000 GAL. | FUEL TJ | AVIATION FUEL 000 GAL | AVIATION FUEL TJ | TOTAL TJ | TOTAL % T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RESIDENTIAL | | | | | | | | | | | | | | | | |
| Government | 12083 | 43 | | | | | 17% | 313 | | | | | | | 356 | |
| Private | 1956 | 7 | | | | | 421 | 74 | | | | | | | 81 | |
| Sub Total | 14039 | 50 | | | | | 2217 | 387 | | | | | | | 437 | 16.8 |
| COMMERCIAL | | | | | | | | | | | | | | | | |
| Government | 12588 | 45 | | | 642 | 112 | 1151 | 203 | | | | | | | 360 | |
| Private | 12843 | 46 | | | 1413 | 246 | 034 | 147 | | | | | | | 439 | |
| Sub Total | 25431 | 91 | | | 2055 | 358 | 1985 | 350 | | | | | | | 799 | 30.0 |
| Street Lighting | 473 | | | | | | | | | | | | | | | |
| MINING | 6550 | 24 | 443 a | 78 | 168 | 30 | 1 | .2 | 53 | 8 | | | | | 62 | 2.4 |
| TRANSPORTATION | | | | | | | | | | | | | | | | |
| ROAD | | | | | | | | | | | | | | | | |
| Private | | | | | | | | | 218 | 34 | | | | | 34 | |
| Government | | | | | | | | | 549 | 86 | | | | | 06 | |
| Other | | | | | | | | | | | | | | | | |
| Sub Total | | | | | | | | | 767 | 120 | | | | | 120 | 50.0 |
| AIR | | | | | | | | | | | | | | | | |
| Government | | | | | | | | | | | 337 | 55 | 48 | 7 | 62 | |
| Private | | | | | | | | | | | 6408 | 1043 | 486 | 74 | 1117 | |
| Sub Total | | | | | | | | | | | 6745 | 1098 | 534 | 81 | 1179 | |
| UTILITY | | | 2718 | 475 | | | | | | | | | | | | |
| TOTAL | 46493 | 165 | 3161 b | 563 | 2223 | 308 | 4203 | 737 | 820 | 120 | 6745 | 1098 | 534 | 81 | 2597 | 100.0 |

# APPENDIX VI

## BAFFIN REGION: DEMAND PROJECTIONS

### A. RESIDENTIAL SECTOR: EXISTING

#### A.1 Size of Housing Stock

According to the N.W.T. H.C., the 1979 housing stock in the Baffin region includes 1851 units. Given a 1979 population of 8617, this suggests a household size of about 4.7. Given that an average household size of 4.5 has been previously adopted for other regions, it does not appear unreasonable to use the housing stock figure of 1.851, i.e., it is likely that if there is a discrepency in household sizes, the Baffin region would probably be higher, rather than lower than the average. All of the Baffin housing stock is assumed to be single detached.

#### A. 2 Unit Consumption of Heating Oil

Table VI indicates that the Baffin residential sector consumed 2,217,000 gal. of heating oil in 1979, for a per unit demand of 1198 gal. Although this figure appears high in comparison to other N.W.T. regions, it is probably appropriate for this analysis, given that the Baffin region exhibits the highest degree day figure among N.W.T. regions.

#### A.3 Housing Stock Projections

N. W. T.H.C. data suggests a housing stock attrition rate of 2.4% per year compounded. Therefore, 1989 and 1999 projections are 1460 and 1152 units, respectively.

A.4 Projected Heating Fuel Demand: Zero Conservation

1.989 ZC Demand = 1460 units x 11.98 gal./unit
= 1,749,080 gal. or 308 TJ

I-999 ZC Demand = 1152 units x 1198 gal./unit
= 1,380,096 gal. or 229 TJ

A.5 Projected Heating Fuel Demand: Conservation Appreach

1989 C Demand = 154 TJ

1999 C Demand = 115 TJ

A. 6 Unit Consumptiuon of Electricity

In 1.979, 1851 residential units consumed 14039 MWh or 7584 KWh per unit.

A. 7 Pro jetted Electr icity Demand: Zero Conservation

1989 ZC Demand = 1460 units x 7584 KWh/unit
= 11073 MWh or 40 TJ

1999 ZC Demand = 1152 units x 7584 KWh/unit
= 8737 MWh or 31 TJ

A.8 Projected Electricity Demand: Conservation Approach

The 1989 and 1999 conservation deinands assume water heating savings of 3 0% and lighting savings of 5%.

1989 C Demand = 35 TJ

1999 C Demand = 28 TJ

## B. RESIDENTIAL SECTOR: NEW

### B.1 Housing Stock Needs

N.W.T. population projections indicate an annual growth rate of 3.0% per year compounded, yielding a 1989 population of 11,580 and 1999 population of 15,563. Accordingly, the number of new dwelling units required will be:

1989 Housing Demand = [11,580 - (1460x 4.5 persons per unit)] ÷ 4.5 = 1113 units

1999 Housing Demand = [15,563 - (1152 + 1113) x 4.5] ÷ 4.5 = 1193 units

### B.2 Projected Heating Fuel Demand: Zero Conservation

1989 ZC Demand = 1113 units x 1198 gal./unit = 1,333,374 gal. or 235 TJ

1999 ZC Demand = 1193 units x 1198 gal./unit = 1,429,214 gal. or 251 TJ

### B. 3 Projected Heating Fuel Demand: Conservation Appreach

The 1989 conservation demand assumes a space heating saving of 50%.

1989 C Demand = 118 TJ

The 1999 conservation demand assumes a space heating saving of 90%.

1999 C Demand = 25 TJ

B.4 Projected Electricity Demand: Zero Conservation

1989 ZC Demand = 113 units x 7584 KWh/unit
= 8,440 MWh or 30 TJ

1999 ZC Demand = 1193 units x 7584 KWh/unit
= 9,048 MWh or 33 TJ

B.5 Projected Electricity Demand: Observation Approach

The 1989 and 1999 conservation demands assume hot water savings of 40% and improved lighting savings of 5%.

1989 C Demand = 25 TJ

1999 C Demand = 28 TJ

B.6 Additional Variables

There are a number of variables which must be considered in revised housing energy demand projections in the Baffin region. They include:

i) the present construction of the Polaris lead-zinc mine on Little Cornwallis Island;

ii) the possibility of future development of the Borealis iron deposit on Melville Peninsula; and

iii) the development of the natural gas field in the Parry Islands area, including the construction of an L. N. G. terminal..

C. COMMERCIAL SECTOR

C. 1 Index Numbers

Based on existing (1979) data, the public and private categories account for 45% and 55% respectively of the commercial sector's energy demand. Given the absence of any physical variables for the size of the sector, index numbers (1979 = 100) are used, i.e. "45" for public and "55" for private.

C. 2 1989 Heating Fuel Demand: Zero Conservation

The 1989 zero conservation demand for heating fuel is derived as follows :

$$\text{Public Sector Expansion} = \text{Index No.} \times \frac{\text{1989 Population}}{\text{1979 Population}}$$

$$= 45 \times \frac{11,580}{8,617} = 60$$

$$\text{Private Sector Expansion} = 55 \times \frac{11,580}{8,617} = 74$$

Total Expansion = 60 + 74 = 134

Net Expansion = 134 - 100 = 34

Given an assumed 10% attrition rate for existing structures, this results in 90 remaining and 44 new units.

The 1979 total commercial demand for heating fuel (both diesel and heating oil) is 708 TJ (358 diesel and 350 heating oil). This results in a per unit consumption (1979) of 7.08 TJ. 'lherefore:

,1989 ZC Demand = 134 units x 7.08 TJ/unit
= 949 TJ

## C. 3 1989 Heating Fuel Demand: Conservation Approach

The 1989 conservation demand for heating fuel is derived as follows:

1989 ZC Demand for Existing Buildings =
90 units x 7.08 TJ/units = 637 TJ

1989 C Demand for Existing Buildings = 326 TJ

1989 ZC Demand for New Buildings = 312 TJ

Assuming a 70% reduction

1989 C Demand for New Buildings = 94 TJ

Total 1989 C Demand = 420 TJ

## C.4 1999 Heating Fuel Demand: Zero Conservation

The 1999 zero conservation demand for heating fuel is derived as follows :

Public Sector Expansion = $60 \times \frac{15,563}{8,617} = 108$

Private Sector Expansion = $74 \times \frac{15,563}{8,617} = 334$

Total Expansion = 242

Net Expansion = 242 - 134 = 108

Given an assumed attrition rate of 10% for existing structures, this results in 120 remaining and 122 new units. Recalling that the 1979 per unit consumption is 7.08 TJ/unit,

1999 ZC Demand = 242 x 7.08 TJ/unit
= 1713 TJ

C.5 1999 Heating Fuel Demand: Conservation Appreach

The 1999 conservation demand for heating fuel is derived as follows:

1999 ZC Demand for Existing Buildings =
120 units x 7.08 TJ/unit = 850 TJ

1999 C Demand for Existing Buildings = 435 TJ

1999 ZC Demand for New Buildings = 1713 - 850
=863 TJ

1999 C Demand for New Buildings = 259 TJ

Total 1999 C Demand = 694 TJ

C.6 1989 Electricity Demand: Zero Conservation

1979 Demand = 91 TJor .91 TJ/unit

1989 Z.C. Demand = 135 units x .91 TJ/unit
= 122 TJ

C.7 1989 Electricity Demand: Conservation Appreach

1989 Z.C. Demand for Existing Buildings =
90 units x .91 TJ/unit = 82 TJ

1989 C. Demand for Existing Building = 66 TJ

1989 Z.C. Demand for New Buildings = 122 - 82
= 40 TJ

Assuming a 50% reduction for new buildings,
1989 C. Demand for New Buildings = 20 TJ

Total 1989 C. Demand = 86 TJ

C.8 1999 Electricity Demand: Zero Conservation

1979 Demand = .91 TJ/unit

1999 ZC Demand = 242 units x .91 TJ/unit
= 220 TJ

C.9 1999 Electricity Demand: Conservation Approach

The 1999 conservation for electricity is derived as follows:

1999 ZC Demand for Existing Buildings =
120 units x .91 TJ/unit = 109 TJ

1999 C Demand for Existing Buildings = 87 TJ

1999 ZC Demand for New Buildings = 111 TJ

Assuming a 50% reduction for new buildings,

1999 C Demand for New Buildings = 56 TJ

Total 1999 C Demand = 143 TJ

## D. TRANSPORTATION SECTOR: ROAD

### D.1 Current Gasoline Demand

Although the Baffin region has no road system, 767,000 gal. of gasoline (non-mine) were consumed in 1979. Despite the possibility of future development projects mentioned previously, it is not likely that road systems will be constructed.

### D.2 Assumptions

Projections for 1989 and 1999 assume that 50% of the gasoline demand can be attributed to snowmobiles, and 50% to cars/light trucks (confined to Frobisher Bay) .

### D.3 Projected Gasoline ( Snowmobile) Demand: Zero Conservation

1989 ZC Demand = 60 TJx $(1.053)^{10}$
= 101 TJ

1999 ZC Demand = 60 TJx $(1.053)^{20}$
= 168 TJ

### D.4 Projected Gasoline (Snowmobile) Demand: Conservation Appreach

From Table 5 it is assumed that snowmobile motor and track efficiency can be improved by 20%.

,1989 C Demand = 81 TJ

1999 C Demand = 134 TJ

D.5 Assumptions Pertaining to Cars & Light Trucks

Projections for 1989 and 1999 road gasoline demand assume that:

i) the number of vehicles registered in the Baffin region is a factor of the ratio:

$$\frac{\text{Regional Gasoline Consumption}}{\text{N.W.T. Total Gasoline Consumption}} = k$$

ii) The ratio k remains constant in the projections.

D.6 Projected Gasoline (Cars & Trucks) Demand: Zero Conservation

$$\text{Gasoline ratio } k = \frac{383,500 \text{ gal.}}{8,800,000 \text{ gal.}} = .0435$$

Using Table 5, the derived number of cars and trucks is:

| Vehicle Type | 1979 | 1989 | 1999 |
|---|---|---|---|
| Cars | 221 | 347 | 546 |
| Trucks | 379 | 755 | 1552 |
| Total | 600 | **1102** | 2098 |

1989 ZC Demand (as a ratio of "registrations) =

$$\frac{1102}{600} \times 60 \text{ TJ} = 110 \text{ TJ}$$

$$\text{1999 ZC Demand} = \frac{2098}{600} \times 60 \text{ TJ} = 210 \text{ TJ}$$

D.7 Projected Gasoline (Cars & Trucks) Demand: Conservation Approach

1989 C Demand = 80 TJ

1999 C Demand = 116 TJ

## E. TRANSPORTATION SECTOR: AIR

### E.1 Current Fuel Demand

1979 Turbo Fuel Demand = 1098 TJ

1979 Aviation Fuel Demand = 81 TJ

### E.2 Projected Fuel Demand: Zero Conservation

1989 Turbo Fuel ZC Demand = 1098 TJ X $(1.052)^{10}$
= 1840 TJ

1989 Aviation Fuel ZC Demand = 81 TJ z (1.053)10
= 136 TJ

1999 Turbo Fuel ZC Demand = 1098 TJ X $(1.053)^{20}$
= 3084 TJ

1999 Aviation Fuel ZC Demand = 81 TJ x (1.053)20
= 227 TJ

### E.3 Pro jetted Fuel Demand: Conservation Appreach

1989 Turbo Fuel C Demand = 1656 TJ

1989 Aviation Fuel C Demand = 129 TJ

1999 Turbo Fuel C Demand = 2159 TJ

1999 Aviation Fuel C Demand = 182 TJ

## F. MINING

### F. 1 Current Mine Demand

The 1979 secondary energy demand is represented as one secondary energy aggregate. The one producing mine in the Baf f in region, at Nanisivik, consumed 62 TJ.

### F. 2 Pro jetted Mine Demand: Zero Conservation

Mine demand in 1989 is assumed to be a combination of projected existing mine demand plus new mine demand.

Existing mine demand $= 62\ TJ \times (1.053)^{10}$
$= 104\ TJ$

Table 8 lists one mine, the Polaris development, currently under construction. It's aggregate 1989 energy demand is derived using the Con-Rycon mine consumption in a ratio:

$$\frac{313}{650} = \frac{x}{2050} \quad \therefore\ x = 987\ TJ$$

1989 ZC Demand = 1091 TJ

1989 C Demand = 982 TJ

Due to a lack of specific data there are no 1999 mining projections.

Notes:

a The mining sector's diesel electric demand has been noted as an addition *for* utility demand, an approach similar to the Fort Smith region's sector analysis.

b This total has not been included in the grand total.

# APPENDIX VII

## POTENTIAL RETROFIT SAVINGS FOR A FORT SMITH HOME

### *CRUDE* OIL PRICES

| Year | Crude Oil Price Per Barrel[a] ($) | Percent Increase Over Previous Year |
|---|---|---|
| 1980 | 16.75 | 0 |
| 1981 | 18.75 | 11.9 |
| 1982 | 20.75 | 10.7 |
| 1983 | 22.75 | 9.6 |
| 1984 | 27.25 | 19.8 |
| 1985 | 31.75 | 16.5 |

### HEATING OIL PRICES

| Year | Percentage Rise in Crude Price | Home Heat Oil Price per Gallon[b] |
|---|---|---|
| 1980 | | 1.84 |
| 1981. | 11.9 | 2.06 |
| 1982 | 10.7 | 2.28 |
| 1983 | 9.6 | 2.50 |
| 1984 | 19.8 | 2.95 |
| 1985 | 16.5 | 3.44 |

### COSTS IF YOU DON'T INSULATE

| Year | Oil Price per Gallon ($) | Annual *sting Costs (697 gal. /year) ($) |
|---|---|---|
| 1980 | 1.84 | 1.282 |
| 19a | 2.06 | 1436 |
| 1982 | 2.28 | 1589 |
| 1983 | 2.50 | 1742 |
| 1984 | 2.95 | 2056 |
| 1985 | 3.44 | 2398 |

## APPENDIX VII (cent'd)

### SAVINGS IF YOU DO INSULATE

| Year | Uninsulated ($) | Insulated ($) | savings Per Year ($) |
|---|---|---|---|
| 1980 | 1282 | Did not insulate | |
| 1981 | 1436 | 718 | 718 |
| 1982 | I-589 | 794 | 794 |
| 1983 | 1742 | 871 | 871 |
| 1984 | 2056 | 1028 | 1028 |
| 1985 | 2398 | 1199 | 1199 |

### THE COST OF MONEY

| Year | Loan ($)[d] | Interest at 18% ($) | Total ($) | savings ($) | Balance ($) |
|---|---|---|---|---|---|
| 1981 | 2000 | 360 | 2360 | 718 | 1642 |
| 1982 | 1642 | 296 | 1938 | 794 | 1143 |
| 1983 | 1143 | 206 | I-349 | 871 | 478 |
| 1984 | 478 | 86 | 564 | 1028 | -464 |

Notes:

a Crude oil prices are assumed to correspond to the national energy strategy quotes.

b Heating oil price increases are assumed to increase in proportion to crude price increases.

c Heating oil demand is assumed to be for a typical Fort Smith region unit. See Appendix II.

d The complete insulation costs is assumed to be $2,500 (1981 dollars). Assuming that the home-owner has made use of a $500 Canadian Home Insulating Program (C.H.I.P.) grant, the loan would be for $2000.

# APPENDIX VIII

## INFORMATIONAL LIMITATIONS

The informational limitations to this study are listed according to two categories. first, there are limitations related to the methodology. Second, there limitations inherent in the N.W.T. Science Advisory Board Report, Energy in the Northwest Territories.

1. With respect to the methodology (Appendix I) , there is insufficient and incomplete data pertaining to:

   housing stink number by region
   housing stock type and age by region
   housing stock attrition by region
   household size by region
   number of electrical connections per region
   electrical end-use by region
   appliance activation by region
   residential movement to multi-dwelling units
   energy demand by structural housing type
   heating fuel demand by region
   number of commercial units by region
   commercial unit attrition rate by region
   energy demand by mine
   more detailed break-down of commercial energy demand
   vehicle registration and type by region
   economic sectoral forecasts

2. The S .A.B. report does not:

   i) explain how fiscal year data e.g. , 1978/79 data was adjusted to form the 1979 calendar baseline year;

   ii) detail L.P. G. distribution by region;

   iii) include heavy equipment, mining or drill ship fuel demand in the transportation category;

iv) provide sufficient heating fuel data;

v) delineate what commercial (private) diesel fuel represents;

vi) provide sufficient data for mining communities such as Tungsten and Naninvik;

vii) present data in a consistent and clear manner e.g., shifting from GWh to MWh.

## APPENDIX IX

### A SUMMARY OF HEAT RECOVERY SYSTEMS

| SYSTEM | ENERGY INPUT Type | ENERGY INPUT Temperature °C | ENERGY OUTPUT Power % | ENERGY OUTPUT Heat % | ENERGY OUTPUT Temperature °C | ENERGY OUTPUT Capacity MW | COMMERCIAL AVAILABILITY |
|---|---|---|---|---|---|---|---|
| Cogeneration | | | | | | | |
| Steam Cycle | Any fossil, nuclear refuse | 550 | 10-20 | 60-70 | 100-250[a] | .5-500[b] | Widely available |
| Gas Turbine | Gas fuel oil | 700-1000 | 20-35 | 40-60 | 100-250[a] | .5-75[b] | Available |
| Diesel | Fuel Oil | High | 36 | 23-28 | 100-180[a] | .5-25[b] | Widely available |
| District Heating | Any | 95-150 | 0 | 90 | 60-140 | 10-2000 | In Europe |
| Heat Pump | Waste heat | -20 to +100 | o | 200-600 | 120 | 10 | Limited production |
| Power Recovery | | | | | | | |
| Steam | Waste heat | 200 | 6-20 | 0 | NA | .38 | Available |
| Organic Rankine | Waste Heat | 65-280 | 6-20 | 0 | NA | 3.7 | Limited production |
| Heat Exchangers | Heat | 600 | 0 | 80 | 600 | Any | Widely available |
| Storage | Heat | 500 | 0 | 75-95 | 500 | Any | Components widely available |

**Notes:**

a Temperature of saturated steam

b Electrical capacity

Cogeneration; two high quality tasks from high quality energy

Bottoming cycle; a high quality task using low quality energy

District heating; selling the energy to someone who needs it

Heat pumps; raising the temperature or energy until it is suitable for another task

Storage; keeping it until it is needed

Heat exchangers; transferring heat from matter which no longer requires it to matter that does require it

Absorption cooling and refrigeration; to provide building or process cooling

Agriculture and aquaculture; utilizing rejected energy for food production.

Source: Lalonde et. al., 1979.

## SIMPLIFIED ECONOMIC ANALYSIS

| SYSTEM | ENERGY INPUT | | ENERGY OUTPUT | | INSTALLED COST[a] | CAPITAL CHARGE[b] | TOTAL COST[c] |
|---|---|---|---|---|---|---|---|
| | TYPE | ASSUMED COST ¢/kWh | POWER $kW_e$ | HEAT $kW_t$ | $/$kW_t$ | ¢/kWh | ¢/kWh |
| Cogeneration | | | | | | | |
| Steam | Residual Oil | 1 | .15 | .65 | 160 | .78 | 1.07 |
| Gas Turbine | Fuel Oil | 1.5 | .25 | .45 | 263 | 1.29 | 3.87 |
| Diesel | Fuel Oil | 1.5 | .36 | .25 | 347 | 1.7 | 6.62 |
| District Heating | Power plant Waste heat at 100″C | .375 | 0 | .90 | 336 | 1.64 | 2.05 |
| Heat Pump | Electricity | 3 | 0 | 3 | 167 | .82 | 1.82 |
| Power Recovery (organic Rankine) | Waste Heat at 200″C | 0 | .15 | 0 | 1265 -3800/$kW_e$ | 6.2-18 | 5.75-17.6/$kWh_e$ |
| Heat Exchanger Gas-Liquid | Waste Heat at 350°C | 0 | 0 | .8 | 56 | .27 | .2-1 |
| Liquid-Liquid | Waste heat at 130°C | 0 | 0 | .8 | 34 | .1? | .17 |
| Storage | Waste heat at 100″C | 0 | 0 | .9 | NA | .48[d] | .48 |
| Oil Furnace | Oil | 1.5 | 0 | .8 | 56 | .27 | 2.4 |

**Notes:**

a installed cost = Quoted cost x 1.1 (inflation factor) x (1979 - quote date) x 1.15 (US to Cdn. conversion) = Cost per kW of heat.

b Capital charge = Installed cost per kWt - (8760 hrs/year x .35 utilization factor) x .15 $/$ invested.

c Total heat cost = (Energy input cost/heat produced + Capital charge - Value of power produced.

d Storage cost = $5/kWh x 128 uses/year.

# APPENDIX X

## ENVIRONMENTAL EFFECTS OF ACID PRECIPITATION

1. Lowering pH levels.

2. Acceleration of calcium and magnesium (important nutrients) leaching.

3. Decreasing soil fertility.

4. Promotion of toxic heavy metal deposition.

5* Reduction of plant reproductive potential.

6. Inhibition of microbial decomposition.

7. Inhibition of lichens' nitrogen fixation potential.

8. Deterioration of freshwater ecosystems located on non-calcareous bedrock.

9. Reduction of lake microbial decomposition.

10. Reduction of fish reproductive potential.

Source: 1. Harvey Babich, Devera Lee Davis and Guenther Stotzky, "Acid Precipitation Causes and Consequences", Environment 22 (May, )980) : 9-11.

# APPENDIX XI

## N.W.T. FOREST ENERGY POTENTIAL

### METHOD I

1. The estimated NWT sustained yield or annual allowable cut is 2.4 million $m^3$ per year.[1]

2. The conversion of sustained yeild volume to weight of biomass is $2.4 \times 10^6 m^3 \times 0.37$ oven dried tonnes (ODt) per $m^3$ = $8.9 \times 10^5$ ODt[2]

3. $8.9 \times 10^5$ ODt of biomass is converted to total biomass potential using a correction factor of 230% or 2.3 .
$8.9 \times 10^5$ ODt $\times 2.3 = 17.8 \times$ ODt $\times 10^5$

4. 17.8 ODt $\times 10^5$ ODt = $17.8 \times 10^8$ kg.

5. $17.8 \times 10^8$ kg $\times$ 10.5 MJ/kg green wood[3] =
$186.9 \times 10^8$ MJ or $1.87 \times 10^{16}$
10.5 MJ $\times 10^{1}$' or $1.05 \times 10^{18}$ joule

6. $1.87 \times 10^{16}$ = 18.7 petajoules (PJ)

Sources: 1. D. I. A.N.D. Forest Management Unit

2* Peter Love and Ralph Overend, Tree power, p. 7.

3. Love and Overend, p. 35.

# APPENDIX XII

## FEDERAL FOREST BIOMASS ENERGY PROGRAMS

Program: Energy from Forests (ENFOR)

Budget: $29.9 Million for the total period

Time Frame: 6 years - FY 78-79 FY 83-84

Objective:

To carry out research, development and demonstration projects to provide a technological basis for the substitution of fossil fuel suppliers by biomass to the extent of 8% of Canada's primary energy demand by 1985; and to develop technological know how to go much further than 8% (with respect to liquid fuels for transportation purposes) .

Mandate:

To provide funding for R & D to the private sector and provincial governments to meet the above objective.

Co-ordinators:

ENFOR Secretariat
Canadian Forestry Service
Environment Canada
Place Vincent Massey
19th Floor
Hull, Quebec
K1A 0E7

Contact:

a) Dr. T. S. McKnight, Director (819) 99701683
b) Dr. R.C. Dobbs, Biomass Production Coordinator
c) Mr. R.J. Neale, Biomass Conversion Co-ordinator (819) 997-1682
d) Mr. L.G. Defore, Program Secretary (819) 997-3407

staff : Total of 15 person years devoted to the program.

Current Projects:

45 projects are currently being funded with four special demonstration projects done under the umbrella of ENFOR. The total funding for the 45 projects is $2.95 million and the funding for the four special projects totals $1.27 million.

Information on Projects:

All projects are conducted on a fully funded contract basis. Contracts have been made through RFP's from DDS and by open solicitation by ENROF.

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Source: 1. Peter Love, Biomass Energy in Canada (Ottawa: EMR Report ER-80-4E).

| | |
|---|---|
| Program: Forest Industry Renewable Energy (FIRE) | Budget: $103 Million for the *total* period<br>$8 M-FY 79-80 $28 M-FY 82-83<br>$11 M-FY 80-81 $37 M-FY 83-84<br>$19 M-FY 81-82<br><br>Time frame: FY 78-79 FY 83-84 |

**Objective:**

The objective of the FIRE program is to provide an incentive for industry to utilize waste forest biomass as a source of energy, thus reducing the dependence on traditional non-renewable resources.

**Mandate:**

To approve and provide funding to meet the above objective.

**Co-ordinators:**

Conservation & Renewable
Energy Branch
EMR
580 Booth St., 6th Floor
Ottawa, K1A 0E4
(613) 995-1801

Contact:

Subash Juneja
Head FIRE Program

Current Projects:

65 applications have been made to the FIRE program. 45 have received formal approval, the rest are being processed. *

Information on Projects:

To respond to the need for a program to stimulate the use of forest biomass residue as fuel, the FIRE program was established and announced in July, 1978.

To be eligible for FIRE assistance, a project must involve an installation of capital facilities to be used for one or more of the following purposes:

1. Direct combustion or gasification of forest biomass, such as hog fuel, sawdust, slash, etc. , to produce energy that will be used in the applicant's manufacturing operations or in an associated community, or both.

2. Conversion of forest biomass into prepared fuels having enhanced heating value, transportability or storage properties.

3. Incineration and recovery of pulp mill spent liquor, to produce a net energy surplus which will be used in the applicant's manufacturing o-rations, or in an associated community, or both.

*Up to day information is available from the FIRE secretariat.

| | |
|---|---|
| Program: Biomass Energy Loan Guarantees (BELG) | Budget: $150 Million<br>Time Frame: July 1978 to March 1984 |

**Objective:**

The objective of the loan guarantee program are to help reduce. Canada's dependence on petroleum through the substitution of forest residues or municipal wastes, and to encourage the efficient use of energy through cogeneration of heat and electricity.

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**Co-ordinators:**

FIRE Secretariat
Conservation & Renewable
Energ y Branch
EMR
580 Booth St., 6th Floor
Ottawa, K1A 0E4
(613) 995-1801

**Contact:**

Subhash Juneja
Co-ordinator
(613) 995-1801

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**Current Projects:**

No loans have been approved to date due to the newness of the program.

Information on Projects:

An important role in achieving the above objectives can be played by biomass-based mult i-client energy systems - local utilities or their equivalents - which can take advantage of the subst itution and conservation opportunities occasioned by the integration of industrial and residential energy demands. Extending federal guarantees to loands made to such organizations, or to special -purpose loans made by utilities, industries, municipalities, or those of their joint subsidiaries have appropriate borrowing powers, will lower cost of capital and attract new lenders.

The total cumulative guarantee ceiling will be $150 million with a maximum guarantee of $30 million available to any single project.

Eligible pro jects are biomass-based utility generation facilities, or mult i-client energy systems dedicated to an industrial complex and possibly its associated settlements.

# APPENDIX XIII

## MAJOR ENVIRONMENTAL EFFECTS OF FOREST BIOMASS CONVERSION TECHNOLOGIES

| Technology | Major Effects |
|---|---|
| Wood Stoves | Particulate air pollution, expecially polycyclic organic rotter which is potentially care incgenic. |
| Wood Boilers | High particulate emissions, high $CO_x$ and $SO_x$ missions |
| Biomass Gasif iers | Occupational Hazards from toxics in raw gas e.g., $NH_3$, $H_2S$, $CN_2$. Water pollution from oxygenated hydro-carbons. |

Source: 1. Steven E. Plotkin, "Energy From Biomass", Environment Vol. 22 (Nov. 80) : 6-14.