LEGISLATIVE ASSEMBLY OF THE NORTHWEST TERRITORIES

9TH ASSEMBLY, 6TH SESSION

TABLED DOCUMENT NO. 10-81(3)

TABLED ON NOVEMBER 30, 1981

Tabled Document No. 10-81 (3)
Tabled Nov. 30, 1981

Northwest Territories Minister of Renewable Resources

NOV 10 1981

MEMBERS
LEGISLATIVE ASSEMBLY

I am pleased to provide you a copy of this report on the Energy Supply Alternatives for the N.W.T.

The report summarizes on a community-by-community basis, what is currently known about energy supply alternatives in the N.W.T. The technology currently available to utilize each energy form is discussed. Recommendations are made for further assessment or pilot projects where appropriate.

The report is important in that it indicates fairly clearly what alternative energy sources could be utilized in each region of the N.W.T. It describes what we do not know, and therefore indicates the direction for future studies.

There are a few notable omissions in the report and other aspects that may be questionable. However, there is much useful information here, and I believe you will be interested in reviewing the situation in your constituency. Attached is a brief summary of the report.

Richard Nerysoo,
Minister.

Attach.

Summary of Findings

Community Specific Energy Supply

Adelaar and Associates

August 1981

1. Natural Gas

Natural gas discoveries have been made in close proximity to some upper Mackenzie and Delta communities. This gas could be used for space heating and electrical generation.

Technological/economic limits in supplying natural gas at a community scale appear to make it unfeasible in the very near term (5 years). However, rapidly increasing petroleum costs make it advisable to study the feasibility of a delivery infrastructure for total energy system application.

It should be noted that the consultant has not adequately reviewed Parsons Lake/YaYa Gas as an option for Tuktoyaktuk and Inuvik. Preliminary forecasts by Dome Petroleum indicate that it would be feasible to combine the new energy needs of industry with the towns requirements. Further, they have indicated that gas from the named sources could provide energy at a considerably lower price. Other studies of the situation have been incomplete or inconclusive. E.M.R., the Town of Inuvik and the G.N.W.T. are now collaborating in the preparation of a study proposal to review the matter.

2. Coal

Coal deposits, primarily low grade lignite, lie within proximity of 11 communities in the lower Mackenzie and Baffin areas.

Recent research and application indicate that coal gasification may be an appropriate conversion technology, with the possibility of providing energy for space heating and electrical generation. Wood gasification technology can be applied to coal.

The economics of a total energy system using coal gas in a territorial community, is still open to question. Further work must be done to assess this possibility.

.../2

3. Nuclear

Discussion in the report revolves around the use of A.E.C.L.'s SLOWPOKE III (Safe Low Power Critical Experiment) nuclear reactors. R.W. Spence of Giant Yellowknife Mines recommended the widespread use of these reactors to the House of Commons Sub-Committee on N.C.P.C. He suggested that this would significantly reduce power costs. The report disagrees with Mr. Spence's analysis, concluding that nuclear power will remain more expensive than diesel generation. Moreover, the complex issues associated with nuclear power development have prompted numerous suggestions for a close review on further development until all of the issues have been reviewed with full public input. The report recommended that no consideration be given to SLOWPOKE applications in the Territories until all issues are addressed in an appropriate medium.

4. Hydro

Large scale hydro development possibilities have been identified in proximity to 14 N.W.T. communities. No studies have been undertaken to assess the economics of small, or community-scale generation.

Community-sized generators are becoming increasingly common in the south. Many of these units are pre-packaged to reduce installation costs.

Major northern limitations are:

- stream flow seasonal variations, requiring larger storage reservoirs than otherwise, with adverse environmental and capital cost effects.

- ice protection measures.

There are no easy "rules of thumb" that can be applied to assess the cost worthiness of an installation. The proper type of equipment, the need for water storage, the operating output and the costs, all depend upon the nature of the site.

Sites that will not likely be grid connected in the foreseeable future should be studied, to determine if hydro is practicable, thereafter to proceed with engineering studies of promising locations.

5. Wood

Wood can be used to an increased extent in the Western N.W.T., either through direct combustion in stoves/furnaces, gasification, or as boiler fuel. However, community supply data is non-existent. To evaluate the sustainable yield, surveys are required to determine the available standing wood, the productivity and accessibility.

Provided that a community's resource is deemed sufficient, the report recommends a wood supply infrastructure should be supported. The extension of wood gasification technology should be examined.

.../3

6. <u>Wind</u>

The Keewatin and some Arctic Island areas have greater potential wind energy than anywhere else in North America. Other regions of Canada have established wind energy pilot projects.

The report recommends a wind/diesel hybrid system (wind as a supplement to diesel) is used for testing. Problems may be encountered with lubrication and component failure in the use of machines primarily designed for the south.

Northwest Territories Minister of Renewable Resources

NOV 10 1981

ᒪᓕᒐᓕᐅᖅᑎᓄᑦ

ᖁᓈᐊᓯᒃ ᐳᕐᓚ ᐆᒥᖕᓚ ᐅᓂᒃ ᑳᓕᐊᕐᔪᐊᒥᒃ ᐱᒃ ᔪᑎᖃᖅᑐᒥᒃ ᐆᒻᒪᖅᑯᑕᐅᔪᓐᓇᕐᒥᔪᓂᒃ ᓄᓇᑦᓯᐊᕐᒥ ᑐᓂᓯᔪᓐᓇᕋᒪ ᐃᓕᕐᓯᕐᓄᑦ.

ᐅᓂᒃ ᑳᓕᐅᖅᓯᒪᔾᔪᖅ ᓄᓈᑦ ᒪᓕᒃ ᔪᒥᑦ, ᐆᒻᒪᖅᑯᑎᓄᑦ ᐊᑐᖅᑕᐅᔪᓐᓇᖁᔾᔪᕐᒥᔪᓂᒃ ᓄᓇᑦᓯᐊᕐᒥ. ᒫᓇ ᐊᖅᑐᑕᐅᔪᓐᓇᖁᔭᖅᑐᑦ ᐆᒻᒪᖅᑯᑎᖃᕐᓂᕐᒧᑦ ᐅᖃᐅᓯᐅᔾᔪᖅ. ᑕᒪᓐᓇ ᖃᐅᔨᓴᖅᑕᐅᒃ ᑲᓂ-ᖁᔭᐅᔾᔪᑦ ᐊᑐᖅᑕᐅᓗᓂᓗ ᐊᔪᕐᓇᖏᑉᐸᑦ.

ᑖᓐᓇ ᐅᓂᒃ ᑳᓕᐅᕐᔪᓯᒪᔾᔪᖅ ᐊᑐᕐ ᓂᖃᒻᒪᑎᒃ ᐳᖅ ᐅᖃᐅᓯᖃᕐᓂᓪᓗᑦ ᖃᓄᖅ ᐆᒻᒪᖅᑯᑎᖃᕐᓂᕐᒧᑦ ᐊᑐᒃ ᑲᓐᓂᕈᓐᓇᖁᔾᔪᕐᒪᓕᑦ ᐊᐱᒃ ᑐᖅᓯᒪᓂᕐᖓᓂ ᓄᓇᑦᓯᐊᕐ. ᐅᖃᐅᓯᖃᕐᒪᑦ ᖃᐅᔨᒪᕐᒥᑕᑦ ᑎᓐᓂᒃ, ᑕᐃᒪᓗ ᖃᓄᖅ ᓯᐳᓂᕐᑎᕐᓂ ᖃᐅᔨᓴᕈᓐᓇᕐᒪᓕᑕ ᖃᐅᔨᒪᓇᖅᑎᑦᓯᕐᒪ.

ᑕᐃᒪ ᐊᒥᓲᓐᓂᕐᑦ ᑑᓚᓗᐊᑦ ᐅᖃᐅᓯᐅᕐᓂᓪᓚᑕ ᐅᓂᒃ ᑳᓕᐊᕐᔪᓯᒪᔪᒥ ᐊᒻᒪᓗ ᐊᐱᖅᑯᑕᐅᔪᓐᓇᖅᑎᓪᓗᑎᒃ ᐊᒥᕐᕿᑦ. ᕿᓯᕙᓂ; ᑖᓐᓇ ᑐᑭᓯᒃ ᑲᓐᓂᕈᓕᕙᔪᓐᓇᕐᒪᑦ, ᐊᒻᒪᓗ ᑖᓐᓇ ᖃᐅᔨᓴᕐᕕᒋᒪᓂᐊᖅᑕᕆᓴᕐᑎᑲ-ᕐᓯᐅᒃ ᓄᓇᖁᑎᕐᓯᕐᓂ. ᑕᐃᒪ ᐃᓕᓯᓯᒪᔾᔪᑦ ᐅᓂᒃ ᑳᒥᒃ.

ᑎᑦᓯᑦ ᓂᑎᓯ,
ᒥᓂᔅᑕ.

ᐃᓕᖃᖅᑐᓂ

ᐅᓂᒃ ᑳᖅ ᖃᐅᔨᓴᐅᓯᒪᔪᓂᒃ

ᓄᓇᓕᖕᓂ ᐆᒪᖅᑯᑎᓄᑦ ᐊᑐᖅᑕᐅᔪᒃᓴᑦ

Adelaar and Associates

ᐋᒡ ᒍᓯ 1981

1. ᐅᖅᓯᐊᓗᒃ ᓴᖅ

Mackenzie ᐊᒻᒪ Delta ᓄᓇᓕᖏᑦᑕ ᖃᓂᒋᔭᖏᓐᓂ ᐅᖅᓯᐊᓕᖕᓂᒃ ᓇᓂᓯᓯᒪᔪᑦ. ᑖᓐᓇ ᐅᖅᓯᐊᓗᒃ ᓴᖅ ᐊᑐᖅᑕᐅᔪᓐᓇᖅᐳᖅ ᐅᖅᑰᓴᐅᑕᐅᓗᓂ ᐊᒻᒪ ᖃᐅᒪᐅᑕᐅᓗᓂ.

ᓄᓇᓕᖕᓂ ᐅᖅᓯᐊᓗᒃ ᓴᖅᑎᑦᓯᓂᖅ ᐊᔪᕐ ᓇᕐ ᓂᐊᖅᑐᔫᖅᐳᖅ ᐊᕐ ᕿᒍᓂ ᑕᑦᑕᒪᓂ. ᑭᓯᐊᓂ, ᐅᖅᓯᐊᓗᐃᑦ ᐊᑭᑦ ᑐᖅᐸᑦᑕᐊᒻᒪᑎᑦ ᓂᖏᓐᓄᑦ ᖃᐅᔨᓴᕐᒍᔨᓇᔭᖅᐳᒍᑦ ᐊᔪᕐ ᓇᕋᔭᙱᓪᓚᖏᑦ ᐆᒪᖅᑯᑎᖃᕐ ᓂᕐ ᒧᑦ ᐋᖅᑭᒃ ᓯᐅᓐᓇᕐ ᓂᕐ ᒥᒃ.

ᖃᐅᔨᒪᔭᐅᔭᑎᐊᖅᑲᖅᐳᖅ ᖃᐅᔨᓴᓚᐅᖅᑐᖅ ᖃᐅᔨᓴᑦ ᓯᐊᓚᐅᓐᖏᓚᑦ Parsons Lake/YaYa Gas ᐊᑐᖅᑕᐅᔪᓐᓇᕋᔭᕐᒪᖔᑦ ᑐᒃ ᑑᔭᖅᑐᕐᒥᐅᓄᑦ ᐊᒻᒪ ᐃᓅᕕᖕᒥᐅᓄᑦ. Dome Petroleum-ᑯᑦ ᐅᖃᓚᐅᖅᐳᖅ ᐊᔪᕐ ᓇᕋᔭᙱᓐᓂᖓᓂᒃ ᑲᑎᑕᐅᓂᖕᓂᒃ Dome petroleum-ᑯᑦ ᓴᓇᕝᕕᖓᑕ ᐊᒻᒪ ᓄᓇᓖᑦ ᐱᕆᑎᐊᖃᖅᑕᕆᐊᖕᓂᒃ. ᐊᒻᒪ, ᐅᖃᓚᐅᑎᒋᔪᑦ ᖃᐅᔨᒪᔭᐅᔪᓂᑦ ᓴᓇᕝᕕᐅᔪᓂᑦ ᐅᖅᓯᐊ-ᓗᒃ ᑖᒃᑯᓇᖓᑦ ᑕᕋᔭᕐᒪᑕ ᐊᑭᑐᓗᐊᕈᑦᑐᒥᒃ. ᐊᓯᕈᑦ ᖃᐅᔨᓴᖅᑕᐅᓯᒪᔪᑦ ᑕᒪᑐᒪ ᒥᒃ ᓵᓄᑦ ᐱᔭᕇᖅᑕᐅᓚᐅᕈᒪᑕ. ᐃᓅᕕᒻᒥᐅᑕᐃᑦ ᓗ ᓄᓇᓯᐊᑦ ᒪᕆᒪᒃ ᑯᕈᑦᓗ ᒫᓐᓇᐅᔪᖅ ᐱᓕᕆᐊᖃᕐᕕᓕᖅᐳᑦ ᐋᖅᑭᒃ ᓯᐋᓯᒃ ᓗᑎᒃ ᖃᐅᔨᓴᕈᑎᒋᓪᓚᕆᒃᓴᒥᓂᒃ ᑕᒪᑐᒪ ᒥᒃ ᓵᓄᑦ.

2. ᐊᕐᔭᒃ ᓵᓄᑦ

Mackenzie-ᒥ ᐊᒻᒪ ᕿᑭᖅᑖᓗᒻᒥ 11-ᓂ ᓄᓇᓕᖕᓂ ᖃᓂᒋᔭᖏᓐᓂ ᓇᓂᓯᓕᐅᑎᕗᑦ ᐊᕐᔮᒃᓴᓂᒃ.

ᖃᐅᔨᓴᕈᑕᐅᓚᐅᖅᑐᑦ ᐊᒻᒪ ᐊᑐᖅᑕᐅᓚᐅᖅᑐᑦ ᖃᐅᔨᒪᓂᖅᑎᑦᓯᕗᑦ ᐊᕐᔭᒃ ᓵᓄᑦ ᐆᒪᖅᑯᑎᒃᑯᕈᓐᓇᕋᔭ-ᕐᒪᑖ ᐅᖅᑰᓴᐅᑎᓄᑦ ᐊᒻᒪ ᖃᐅᒪᐅᑎᓄᑦ ᐊᑐᖅᑕᐅᓇᔭᖅᑐᓂᒃ. ᕿᔪᒻ ᓄᑦ ᐆᒪᖅᑯᑎᒃ ᓴᐃᑦ ᐊᑐᖅᑕᐅᔪᓐᓇᑎᕗᑦ ᐊᕐᔭᒃ ᓴᑎᑐᑦ.

ᓄᓇᑦ ᓯᐊᕐ ᓄᓇᓕᖕᓂ ᐆᒪᖅᑯᑎᒃᑯᓚᑎᑦ ᓂᖅ ᐊᕐᔭᒃ ᓴᐃᑦ ᐊᑐᕐ ᓗᒥᑦ ᓯᓚ ᐊᐱᖅᑯᑕᐅᔪᓐᓇᖅᐳᑦ. ᓯᓚ ᖃᐅᔨᓴᒃ ᑲᓐ ᓂᑎᐊᖃᕐᒪᑕ ᐊᔪᕐᓇᕋᕐᒪᖔᑦ.

3. ᖁᖅᑖᔪᓄᑦ

ᐅᓂᒃ ᑳᓚᐊᑎᔭᐅᓯᒪᔪᖅ ᐅᖃᐅᓯᖃᓗᐊᖅᐳᖅ ᖁᖅᑖᔪᓄᑦ ᐆᒪᖅᑯᑎᑦ ᐊᑐᖅᑕᐅᓂᖕᓂᒃ A.E.C.L. SLOWPOKE III -ᓂᑦ. R.W. Spence Giant Yellowknife Mines-ᒥᐅᑕᖅ. ᐊᑐᕐᒍᔨᓚᐅᖅᐳᖅ ᖁᖅᑖᔪᓄᑦ ᐆᒪᖅᑯᑎᓂᒃ ᑲᓇᑕᐅᑉ ᒐᕙᒪᒃ ᑯᖕᑕ N.C.P.C.-ᑯᓐᓄᑦ ᐊᐅᓚᑦ ᓯᔨᖕᓂᒃ. ᐅᖃᖅᓗᓂ ᐊᑭᑐᓗᐊᖕᓂᖅᓴᐅᓇᔭᕐᒪᑦ ᖃᐅᒪᐅᑎᓄᑦ.

ᐅᓂᒃ ᑳᓕᐊᕐᔪᒻᒪᕙᑦ ᐊᓯᖃᑎᒃᑲᓚᐅᖕᖏᑉᐳᖅ Mr. Spence ᐅᖃᐅᓯᑎᔪᖕᓂᒃ, ᐃᓱᒪᓪᓗᑎᒃ ᖁᖅᑕᕿᓅᑦ ᖃᐅᒪᐅᑎᑦ ᓯᓚ ᐊᑭᑦᑐᒪᑎᓂᐊᕐᒪᑕ. ᐊᒻᒪᓗ ᐊᒥᓯᓂᑦ ᐊᔾᔭᕐᓇᕐᓂᖏ ᖁᖅᑕᕿᓅᑦ ᐆᒻᒪᖅᑯᑎᖃᕐᓂᐅᑉ ᐱᓕᕆᐊᑎᔪᐅᒃ ᑲᓐᓂᕐᖁᔪᐅᕗᑦ ᖃᐅᔨᖅᑕᐅᒃ ᑲᓐᓂᕐᓗᓂ ᓄᓇᑦᓯᐊᕐᒥᐅᑕᐃᑦ ᐃᓕᐅᑎᑕᐅᓗᑎᒃ. ᑕᐃᒪᓕ ᐊᑐᓕᕈᔪᐅᓯᒪᕗᖅ SLOWPOKE-ᑯᑦ ᑐᒃ ᓯᖁᕈᑎᒥᔪᖏᑦ ᐃᓱᒪᒥ-ᔪᐅᕐᖁᔪᐅᖕᖏᖅᓗᓂ ᑭᓯᐊᓂ ᖃᐅᔨᒪᔪᐅᑦᓯᐊᓕᖅᐸᑕ.

4. ᐃᒪᕐᒧᑦ

14-ᓂᒃ ᓄᓇᓕᑦᓂ ᓄᓇᑦᓯᐊᕐᒥ ᐃᒪᕐᒧᑦ ᐆᒻᒪᖅᑯᑎᖃᕈᓐᓇᖁᓯᒥᔪᐅᕗᖅ. ᖃᐅᔨᓴᓚᐅᖕᖏᑦᑐᑦ ᓯᓚ ᓄᓇᓕᑦᓂ ᐅᑉᐸᑯᓐᓃᑦ ᒥᑭᔪᓂ ᐊᐅᓚᑕᐅᕙᓐᓇᕐᒪᖁᑦ.

ᓄᓇᓕᑦᓄᑦ ᒥᑭᔫᑦ ᐆᒻᒪᖅᑯᑎᖃᕐᐹᑦ (ᐃᑯᒪᓕᕐᑎᕐᐹᑦ) ᐊᑐᖅᑕᐅᓚᖁᑦ ᓂᖅᓴᐅᓯᓕᐊᓕᖅᐳᑦ ᖃᑦᑐᓈᑦ ᓄᓇᖏᓐᓂ. ᐊᒥᓯᑦ ᑕᒪᒃ ᑯᐊ ᐃᑯᒪᓕᕐᑎᕐᐹᑦ ᓴᓇᔪᐅᓚᒥᖅᓯᒪᖃᑦᑕᖅᐳᑦ ᐊᑭᑐᓗᐊᕐᖁᖕᖏᓗᑦ.

ᐅᑭᐅᖅᑕᖅᑐᒥ ᐊᔾᔭᕐᓇᕈᑕᐅᓗᐊᖃᑦᑕᖅᐳᑦ:

- ᒎᒃᓂᐅᑉ ᐊᒃᐱᓖᕐᖃᑦᑕᕐᓂᖏ ᐅᑭᐅᒥ ᐅᐱᕐᖏᒥ ᐊᐅᔪᒥ ᐅᑭᐊᒃᓵᒥ, ᐊᕐᓂᖅᓴᒥ ᐊᐅᓚᕝᕙᑎᐊᖃᕐᓂᖏᓄᑦ ᑕᒫᓐᓇ ᐊᑭᑐᔪᐊᓗᐊᖃᑦᑕᕐᒪᑦ.
- ᓯᒎᑉ ᓴᐳᒃᔪᐅᓂᖏᓄᑦ ᒪᓕᒐᖏᑦ

ᐊᑐᐊᓚᖅᑕᖃᑦᑎᐊᕆᓪᓚᑦ ᖃᐅᔨᓴᕐᓂᕐᒧᑦ ᐊᑭᑐᓂᖕᓂᒃ ᓴᓇᓂᕐᒧᑦ. ᐱᕐᑯᑎᒥᔪᐅᓂᐊᖅᑐᑦ ᐊᑐᖅᑕᐅᔪ-ᑎᐊᓖᑦ, ᐃᒪᖃᑎᐊᖃᕐᓂᖅ, ᐊᐅᓚᑦᓯᓂᐅᕙᑦ ᐊᒻᒪᓗ ᐊᑭᒥᔪᐅᕙᑦ, ᐊᒃᐱᓖᖕᓇᔪᖅᐳᑦ ᒪᓕᒃ ᑐᒥᑦ ᓇᒦᖕᓂᑎᔪᖏᑦ.

ᐃᑯᒪᓕᕐᑎᐹᑦ ᓇᑐᓇᐃᖅᑕᐅᓯᒪᓂᐊᖅᑑᔫᖕᖏᑦᑐᑦ ᓯᕗᓂᑦ ᑎᓐᓂ ᖃᐅᔨᓴᖅᑕᐅᔪᑎᐊᖃᕐᓂᐊᖅᐳᑦ, ᐃᒪᕐᒧᑦ ᖃᐅᒪᐅᑎᓕᐅᕈᓐᓇᕐᒪᖁᑦ, ᐊᒻᒪᓗ ᑭᒡᓗᓂᐊᒎᑦ ᐃᓂᒃ ᓴᑎᔪᖏᑦ ᐋᖅᑭᒃᓯᖅᑕᐅᕙᓕᐊᓕᕐᓗᑎᒃ.

5. ᕿᔪᒃᓄᑦ

ᓄᓇᑦᓯᐊᑉ ᐅᐊᓕᓂᖓᓂ ᕿᔪᒃᓂᒃ ᐊᑐᕈᓐᓇᖅᐳᑦ, ᐅᖅᑰᓴᐅᑎᒥᓗᒥᑦ. ᑭᓯᐊᓂ, ᖃᐅᔨᒪᓇᖏᓪᒪᑦ ᖁᓄᖅ ᕿᔪᖅᑲᖅᑎᒥᓂᐊᕐᒪᖁᑦ. ᕿᔪᐃᑦ ᐊᑐᖅᑕᐅᔪᓐᓇᖅᑐᑦ ᖃᐅᔨᒥᐊᕐᓂᐊᕐᓗᒥᑦ, ᖃᐅᔨᓴᖅᑕᐅᔪᑎᐊᖃᖅᐳᑦ ᖁᓄᖅ ᕿᔪᖅᑲᖅᑎᒥᒃ ᒪᖁᑦ ᒫᓐᓇ, ᐊᑐᖅᑕᐅᔪᓐᓇᕐᒪᖁᑦ ᐊᒻᒪᓗ ᐱᔪᐅᔪᓐᓇᕐᒪᖑᑦ.

ᓄᓇᓕᐅᑉ ᐊᑐᑎᐊᖃᖅᑕᕆᑦ ᓈᒻᒪᒃᐸᑕ, ᕿᔪᐃᑦ ᑲᑎᖅᓱᖅᑕᐅᕙᓪᓕᐊᔪᑎᐊᖃᖅᐳᑦ ᓯᕗᓂᕐᒥ ᐊᑐᖅᑐᒃᓴᐅᓂᐊᕐᓗᑎᒃ ᕿᔪᐃᑦ ᐊᑐᖅᑕᐅᕙᓪᓕᐊᓂᖏᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᑎᐊᖃᖅᐳᑦ.

6. ᐊᓄᑎᒧᑦ

ᑭᐸᓪᓕᕐᒥ ᐊᒻᒪᓗ ᐅᑭᐅᖅᑕᖅᑑᑉ ᐃᓚᖏᓐᓂ ᐊᓄᑎᑐᓗᐊᕐᓂᖅᓴᐅᓖᑦᔪᒃᒪᑦ ᑲᓇᑕᐅᑉ ᐃᓚᖏᓐᓂᑦ. ᑲᓇᑕᐅᑉ ᐃᓚᖏᓐᓃᑦ ᑕᐅᖅ ᐊᓄᑎᓕᐅᖅᓗᑎᒃ ᖃᐅᒪᐅᑎᓕᐅᖃᑦᑕᖅᑐᑦ.

ᑕᐃᒪ ᖃᐅᔨᓴᕈᑕᐅᕐᖁᔪᐅᕆᕗᖅ ᐃᑯᒪᓄᑦ ᐊᒻᒪᓗ ᐊᓄᑎᒧᑦ ᑲᑎᑦᓗᒥᑦ ᖃᐅᒪᐅᑎᓕᐅᕈᓐᓇᕐᒪᖁᑦ. ᐊᑲᐅᖕᖏᑦᓕᐅᕈᑎᖃᕐᓂᐊᖅᑐᒃᓴᐅᔪᖅ ᐃᑯᒪᓂᒃ ᐊᑐᕐᓂᐊᕐᓗᑎᒃ ᑐᕌᖓᓗᐊᖅᑐᓄᑦ ᖃᑦᑐᓈᑦ ᓄᓇᖏᓄᑦ.

COMMUNITY SPECIFIC ENERGY SUPPLY
IN THE YUKON AND NORTHWEST TERRITORIES

ADELAAR & ASSOCIATES

176 Bronson Avenue

Ottawa, Ontario

Martin Adelaar

with

COMMUNITECH and ASSOCIATES

Box 4036

Station E, Ottawa

Stephen Graham

Prepared for the Department of

Indian Affairs and Northern Development

Contract No. 81-117

August 1981

ADELAAR & ASSOCIATES
176 Bronson Avenue
Ottawa, Ontario
K1R 6H4
(613) 235-5187

August 7, 1981

Department of Indian Affairs and Northern Development,
Northern Resources and Economic Planning Branch,
Les Terrasses de la Chaudiere,
10 Wellington Street,
Hull, Quebec

Attention: Mr. P.D. Broadhead

Dear Sir:

RE: Community Specific Energy Supply in the Yukon and Northwest Territories
F.C. 36111-3-102-136-00-6017-0001-1552
File No.: A1632-81-117

We are pleased to submit our report for an assessment of community specific energy supply in the Yukon and Northwest Territories. The objectives of the study have been to identify, and where possible, evaluate selected Territorial energy resources both in terms of inventory and technologies necessary to bring the resource on-stream.

The results of the study indicate, first of all, that pre-feasibility studies and follow-up demonstration projects are necessary in deciding the actual community-specific feasibility of one energy source over another. As is indicated, some regions of the Territories have only one option, e.g., wind in the northwestern Arctic and therefore, immediate efforts can be made to assess its potential.

The study, in discussing the commercial availability and performance of energy conversion technologies, should be perceived as a transitional stage to site selection studies. However, as is stressed in Sections 1 and 2, inventory and technology assessment are only two components in evaluating Territorial energy resource development, socio-economic and environmental considerations should be included as well.

Finally, we would like to reiterate the importance of energy conservation strategies and steps as a crucial component to a Territorial energy strategy. Application of comprehensive and innovative conservation measures would, to some extent, aid the development of Territorial energy resources.

Yours sincerely,

Martin Adelaar

ADELAAR & ASSOCIATES
Martin Adelaar

TABLE OF CONTENTS

TABLE OF CONTENTS Cont'd

TABLE OF CONTENTS Cont'd

Page

SECTION

TABLE OF CONTENTS Cont'd

APPENDICES

TABLES

MAPS

Page

MAP

FIGURES

Page

FIGURE

COMMUNITY SPECIFIC ENERGY SUPPLY IN THE YUKON AND NORTHWEST TERRITORIES

1. INTRODUCTION AND STUDY APPROACH

Two recent studies completed by Energy Probe Ottawa, (hereafter known as the N.W.T. and Yukon Reports), assess future Territorial energy demand and suggest a mix of non-renewable and renewable resources as an appropriate energy supply.[1,2] The studies were initial components in a process designed by the Territorial governments and the Department of Indian Affairs and Northern Development (D.I.A.N.D.) to achieve a Northern Energy Strategy in 1981.[3] As such, the studies were limited by their terms of reference in exploring energy supply options to a greater depth and range.

The Territories' geographical diversity and a concomitant need for information that would facilitate the selection of energy supply feasibility projects suggested further community specific assessment. This report, in meeting the terms of reference designed by D.I.A.N.D., is then, an assessment of community specific energy supply in the Territories.

1.1 Study Objectives

The objectives of the study are to:

i) further compile Territorial energy supply inventories;

ii) list data contacts and references;

iii) describe government programs relevant to the development of Territorial energy resources;

iv) comment, according to relevant literature and personal communications, on the technical and economic feasibility in developing identified energy resources;

v) develop a matrix that will match identified Territorial energy resources to community needs; and

vi) identify data limitations and recommend follow-up work.

An interim report submitted by Adelaar & Associates was designed primarily to meet the first three objectives. Data additions, however, have entailed some modifications in the presentation of the interim report. Therefore, in integrating the interim report, the final report attempts to meet all of the study objectives.

1.2 Study Approach

Initial discussions with D.I.A.N.D. indicated the need to develop a matrix that would illustrate energy supply options for each Territorial community, e.g., page 32 of the interim report, with particular emphasis on off-grid communities. It was also suggested that information was needed describing energy extraction and conversion technologies that could be applied at the Territorial community scale. The emphasis of the study then, is mainly on two of the many factors that will indicate the feasibility and practicality of bringing identified energy supply resources on-stream, supply inventory and technologies.

Given the emphasis of the study, it was decided to structure the report as follows. Tables are presented that describe both the current and potential energy situation for each Territorial community. The tables and accompanying discussions (presented in Section 2) are essentially a summary of sections 4 to 10 which detail each of the selected energy supply options and their appropriate technologies.

The table presentations are a useful means in illustrating potential energy end-uses and the present stage of maturity of suggested technologies. Their format draws, in part, on the approach employed in two relevant technology assessment summaries.

In 1980, the Alaskan Council on Science and Technology (A.C.S.T.) presented a report based on the results of an A.C.S.T. Energy Committee Workshop held in 1980.[4] The report identifies the major issues in Alaskan energy research and in describing priorities and recommendations includes a rough assessment of the maturity of solar, wind, and geothermal technologies (see Appendix A).

Also in 1980, the Energy Project Office of the National Research Council published a review of the N.R.C.'s bioenergy research and development activities. In the report, Ralph Overend presents a "techno-economic" assessment of bioenergy conversion processes that also includes a table describing technical maturity.[5]

In recognition of the severe information problems pertaining to energy inventories and technologies appropriate to the Territories, sections 4 to 10 each include a listing of data limitations and all relevant contacts and references. Finally, in recognizing the complexities of technology assessment, section 3 describes the general considerations that should be taken into account in developing some indication of the technologies' feasibility.

1.3 Choosing Territorial Energy Supply Options: Criteria for Selection

As noted previously, the Yukon and N.W.T. Reports identify a number of Territorial energy resources that might meet projected demands. Tables 1 to 3 summarize the results of the reports' supply recommendations. The supply options are suggested, in part, on the basis of criteria that include: energy resource inventory; cost and technical factors in marketing the supply options; environmental implications; and institutional factors integral to development. While this report intends to consider some of these criteria, not all of the previously identified supply options will be assessed. Energy resources to be examined are listed below.

ENERGY RESOURCE	REASON FOR SELECTION
• HYDRO POWER	• considerable potential has already been identified. • resource is renewable. • technologies are available for immediate utilization.
• FOREST BIOMASS	• considerable potential has been identified. • resource is potentially renewable. • technologies exist for harvesting and conversion. • community scale application.
• WIND	• wind regimes sufficient to meet Territorial community power needs have been identified. • resource is renewable. • possibly the only "off-oil" resource available for many communities.

TABLE 1 **Possible Domestic Sources of Energy for the Yukon, by Sector of Use**

	Existing building	New building	Transportation	Anvil district	Isolated Mines	Smelter*	Agriculture
Electricity							
Hydropower							
Micro (-5MW)	X	X			(X)		
Small (6 to 50MW)		X	(X)				
Medium (51 to 500 MW)				(X)			
Coal				(X)		(X)	
Wind	/	/			/		
Wood	X	X			X		
Municipal Wastes	/	/					
Natural Gas** (assuming pipeline)	(X)	(X)					
Heat							
Coal				X			
Solar (Passive)		/					X
Wood	(X)	(X)			X		X
Geothermal	/	/					/
Heat Reclamation	(X)	(X)		(X)	(X)	(X)	(X)
Natural Gas (assuming pipeline)	(X)	(X)					
Fluid Fuels							
None Foreseen							

LEGEND:

/ = possible but small
X = good match
(X) = best possibilities

* = or any other large, new land
** = total energy systems

Source: The Yukon report, p.58

TABLE 2

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-?, 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	

SOURCE: N.W.T. REPORT, p. 117

TABLE 3

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	passive	passive			
	-	active		active			
phased out by 1999	petroleum	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

SOURCE: N.W.T. REPORT, p. 118

• PEAT	• resource has been identified in the N.W.T. • harvesting and conversion technologies have been developed in Finland under similar climatic conditions. • community scale application.
• COAL	• considerable potential has been identified. • conversion technologies exist that can minimize environmental impact.
• NATURAL GAS	• considerable potential has been identified. • appropriate space heat and electricity fuel.
• NUCLEAR POWER	• potential for low cost source of space heat.

The reasons why previously identified supply options were not idenfified are as follows:

• AGRICULTURE BIOMASS	• preliminary inventory does not indicate an adequate resource
• WASTE HEAT RECOVERY	• refuse conversion and waste heat recovery should be pursued as part of energy demand management studies.
• PASSIVE SOLAR	• should be pursued as an energy demand management concern.
• ACTIVE SOLAR	• seasonal insolation and storage limitations.
• GEOTHERMAL	• necessary inventory unavailable.

1.4 Study Limitations

In order to view this report in the proper perspective, it is necessary to identify two major limitations. First, the report does not examine the options available to utilize electrical generating unit waste heat, primarily from diesel units, as a community energy supply. As noted in the N.W.T. Report, recent studies and actual Territorial applications have demonstrated the potential for recovering both diesel manifold and exhaust gas heat for low temperature "mini" district heating applications. Waste heat utilization, as noted in Sections 4 to 10 should be considered in the context of total energy system development. For the purposes of this report, however, waste heat utilization is assumed to be a demand management option.

Second and more importantly, the study does not examine the nature and range of social and environmental impacts likely to arise as a result of community specific energy development. Using Section 5's discussion of small scale nuclear technology as an example, it is clear why the tabulated results as developed for this study are incomplete. Since it is now mandatory for most government funded energy projects to be accompanied by socio-economic and environmental impact statements and hearings, it is suggested that the study results be viewed with those considerations in mind.

1.5 References

1. Adelaar, Martin. Energy Demand and Supply in the Northwest Territories. A Study prepared for D.I.A.N.D. and the N.W.T. Ministry of Energy, 1981.

2. Brooks, David B. Exploring a Soft Energy Path for the Yukon Territories. A study prepared for the Department of Indian Affairs and Northern Development (D.I.A.N.D.), 1980.

3. D.I.A.N.D., Economic Analysis Branch. An Energy Strategy for Northerners. A discussion paper presented at the Intergovernmental Task Force meeting Wednesday, January 21, 1981.

4. Alaska Council on Science and Technology. Alaskan Energy, Research Priorities and Recommendations. A special report based upon the results of the A.C.S.T. Energy Committee Workshop held in February 1980, Anchorage Alaska, March 1980.

5. Overend, Ralph. "Conversion Technologies - The Prospects" in Bioenergy Research and Development A Summary of the Program to March 1980, ed. B.A. Summers (Ottawa: NRC, 1980).

2. COMMUNITY SPECIFIC ENERGY SUPPLY OPTIONS: A SUMMARY

2.1 Discussion of the Summary Tables

Sections 4 to 10, in focussing on the elements of supply inventory and conversion technology, assess the community specific energy potential for a series of selected energy resources. Tables 4 to 6 represent a summary of those sections; it is suggested that the reader refer to the appropriate energy section to get a better understanding of each option's potential.

Table 4 is a summary of the energy situation faced by Territorial communities. The table indicates that most of the communities are off-grid and depend heavily on fluid petroleum products for both space heating and electricity. Peak electricity demand, as based on 1979 data, reveals that most communities have loads of less than 1 MW (electricity).

Table 4 lists population and population growth estimates as a variable that may affect energy demand. While only a few Territorial communities are expected to undergo substantial population increases, positive growth rates suggest that energy demand may increase unless appropriate conservation strategies and techniques are employed.* As noted in the N.W.T. Report, energy demand can be reduced substantially without a concomitant loss of growth in the economy.

Using Table 4 as a background, Table 5 matches Territorial communities with suggested indigenous energy supply options. The development limitations listed in Table 5 are based, in part, on the summary of conversion technologies in Table 6. Based on Tables 5 and 6, the following observations can be made:

i) Communities in the western and northwestern Arctic, especially in the N.W.T.'s Baffin region, have mainly one indigenious energy option, wind-power. Table 5 suggests that wind energy potential ranges from marginal to good depending on the location. It is precisely the variability

* Where up-to-date population data were unavailable communities were not listed.

TABLE 4 - TERRITORIAL COMMUNITIES AND THEIR ENERGY SITUATION

Community	1978 Population	1975-1978[a] Annual Population Growth Rate %/Yr.	Current Transportation Links	Off-Grid	Energy Consumption: Heating Fuel gal.	Energy Consumption: Non-Electric Diesel Fuel gal.	Energy Consumption: Diesel Electric Fuel gal.	Total Energy Consumption kWh (000)	1979 Peak Load kW
BAFFIN REGION									
Arctic Bay	403	3.0	air, water	yes	158,370	6,511	81,304	909	320
Broughton Island	329	3.0	air, water	yes	168,412	24,803	66,668	778	200
Cape Dorset	693	2.9	air, water	yes	361,429	171,296	160,210	2,037	380
Clyde River	411	2.9	air, water	yes	173,843	23,893	83,111	1,304	260
Frobisher Bay	2693	3.4	air, water	yes	1,109,037	42,228	1,217,223	17,396	3,700
Hall Beach	396	3.1	air, water	yes	144,331	9,318	65,061	722	190
Igloolik	753	2.9	air, water	yes	388,230	1,284	145,516	1,688	393
Lake Harbour	301	3.0	air, water	yes	102,090	67,109	U	701	185
Nanisivik	273	0.9	air, water	yes		168,313			
					494,940				
Pangnirtung	878	2.8	air, water	yes	347,741	136,817	154,037	1,861	330
Pond Inlet	649	3.0	air, water	yes	354,369	32,848	156,570	1,718	480
Sanikiluag	326	2.9	air, water	yes	108,481	7,822	87,600[b]	1,071	U
KEEWATIN REGION									
Baker Lake	1007	2.8	air, water	yes	396,680	10,913	250,772	3,318	725
Chesterfield In.	291	3.4	air, water	yes	166,114	22,414	65,091	660	130
Coral Harbour	414	2.8	air, water	yes	133,691	30,578	161,341	2,213	473
Eskimo Point	960	2.7	air, water	yes	400,980	17,625	170,008	2,164	640
Rankin Inlet	978	5.2	air, water	yes	614,839	22,008	400,402	5,214	1,130
Repulse Bay	295	2.5	air, water	yes	143,482	26,374	86,918	781	160
Whale Cove	201	3.1	air, water	yes	106,023	18,623	53,656	518	165
INUVIK REGION									
								1,981	463
Aklavik	763	2.3	air, water, winter road	yes	355,436	11,504	174,914	982	290
Fort Franklin	512	1.6		yes	140,532	1,188	84,535	1,030	270
Ft. Good Hope	446	1.5	air, water, winter road	yes	117,481	144	84,100		
Ft. McPherson	813	1.4	air, water, winter road	yes	349,466	14,816	162,331	1,936	490
Ft. Norman	329	1.2	air, water, winter road	yes	124,374	2,099	80,684	742	220
Inuvik	2938	1.3	air, water, road	yes	1,217,196	299,672	1,937,364[c]	23,236	6,400
Norman Wells	352	0.7	air, water, winter road	yes	3,461,666	1,109,137	283,787	4,301	800
Tuktoyaktuk	760	2.8	air, water, winter road	yes	348,032	81,737		3,425	950
CAMBRIDGE BAY REGION									
Cambridge Bay	853	2.7	air, water	yes	646,593	6,155	297,381	3,919	910
Coppermine	803	3.1	air, water	yes	304,383	7,319	157,646	1,999	663
Gjoa Haven	464	2.7	air, water	yes	204,140	24,220	82,906	1,174	283
Holman Island	328	3.0	air, water	yes	90,718	17,835	61,607	617	170
Paulatuk								396	160
Pelly Bay	287	2.4	air, water	yes	101,551	40,063	57,991	1,303	370
Spence Bay	454	2.8	air, water	yes	266,965	34,273	115,418		

TABLE 4 - TERRITORIAL COMMUNITIES AND THEIR ENERGY SITUATION

Community	1978 Population	1978-1978[a] Annual Population Growth Rate %/Yr.	Current Transportation Links	Off-Grid	Energy Consumption: Heating Fuel gal.	Energy Consumption: Non-Electric Diesel Fuel gal.	Energy Consumption: Diesel Electric Fuel gal.	Total Energy Consumption kWh (ooo)	1979 Peak Load kW
FORT SMITH REGION									
Fort Liard	327	1.6	air, road	yes	40,835	15,697	43,435	394	125
Fort Providence	556	1.5	air, water, winter road	yes	446,634	2,300	150,000	1,436	427
Fort Resolution	521	0.9	air, water, road	no	215,018	23	165,000	1,613	450
Fort Simpson	1,050	1.1	air, water, road	yes	838,829	280,082	411,586	5,867	1,210
Fort Smith	2,347	0.8	air, road	no	1,094,079	228,328	94,583	14,397	3,690
Hay River	3,398	2.4	air, water, road	no	1,959,467	11,400,759	1,841,000	22,948	5,370
Lac la Martie	225	1.5	air	yes	19,698	759	22,891	183	70
Pine Point	1,763	2.2	air, road	no	125,000	1,811,692	316,492	12,614	2,832
Rae Edzo	1,269	1.4	air, water, road	no	118,899	1,586	U	3,496	1,450
Snowdrift	262	1.3	air, water	yes	54,574	1,678	47,476	421	117
Tungsten	423	0.7	air, road	yes	249,516	124,188[d]	U	U	U
Yllowknife	9,981	4.0	air, water, road	no	6,063,942	1,139,621	1,437,516	107,405	24,800
YUKON REGION									
Beaver Creek	120	2.9	air, road	yes	24,207	U	130,000	1,283	230
Burwash Landing	67	2.9	air, road	yes	13,449	U	e		
Carcross	206	2.9	air, road	no	41,244	U			
Carmacks	381	2.9	air, road	no	76,210	U	180,000	1,770	346
Clinton Creek	500	2.9	air, road	yes	99,523	U			
Dawson	1,118	2.9	air, road	yes	222,352	U			
Destruction Bay	82	2.9	air, road	yes	16,136	U	125,600	1,228	285
Elsa	574	2.9	air, road	no	113,869	U			
Faro	1,633	2.9	air, road	yes	325,460	U			
Haines Junction	426	2.9	air, road	no	85,176	U	367,900	3,598	605
Johnsons Crossing	20	2.9	air, road	yes	17,932	U	3,170	31	U
Keno City	U	2.9	air, road	yes	U	U	34,100	335	69
Mayo	479	2.9	air, road	no	95,040	U			
Old Crow	206	2.9	air	yes	41,244	U	58,000	582	135
Pelly Crossing	141	2.9	air, road	yes	27,795	U	62,000	606	160
Quill Creek	35	2.9	air, road	yes	7,170	U			
Ross River	338	2.9	air, road	no	67,244	U	U	1,700	324
Stewart Crossing	43	2.9	air, road	yes	8,068	U	36,000	349	96
Swift River	U	2.9	air road,	yes	U	U	2,800	279	65
Togish	U	2.9	air, road	no	U	U			
Teslin	372	2.9	air, road	yes	74,415	U	160,000	1,567	400
Upper Liard	219	2.9	air, road	yes	43,932	U			
Watson Lake	1,360	2.9	air, road	yes	270,773	U	990,000	9,830	2,150
Whitehorse	16,191	2.9	air, road	no	3,225,932	U	U	177,753	38,000

LEGEND: U - unavailable

SOURCES:
1. N.W.T. Energy demand data were gleaned from: N.W.T. Science Advisory Board, Energy in the Northwest Territories, Preliminary Report, 1980.
2. N.W.T. population data were gleaned from: N.W.T. Government Statistical Section, Population Projections 1978 to 1988 Methodological Report, 1980.
3. Yukon energy and population data were gleaned from TRU-Techno-economic Research Unit with Victor & Burrell, Role of Renewable Sources of Energy in Remote Locations. A study prepared for the Conservation and Renewable Energy Branch, E.M.R., 1980, Foster Research. Forecast Electric Energy Requirements in the Yukon Territory. A study prepared for the Northern Canada Power Commission, 1980, and D.I.A.N.D., Facts and Figures Yukon Territory.

NOTES:
a. N.W.T. population growth rates are taken from the N.W.T. Government Statistics Section, Population Projections Northwest Territories 1978 to 1988. See the N.W.T. Report for a discussion of two population growth rate scenarios, p. 127. The Yukon population growth rate of 2.9% was based on the Foster Research report "Base Case" projection, p. 111-14.
b. Where diesel-electric consumption had to be derived from annual electricity consumption, a conversion efficiency of 20% was assumed.
c. Inuvik supplies electricity to Tuktoyaktuk.
d. Includes mine diesel demand.
e. Where no figures are listed, data were unavailable.

of wind regimes that may be the major limitations to development. In this context, Table 6 suggests that wind/diesel hybrid systems may be the more realistic conversion system to utilize.

Since most appropriate wind turbines, i.e., at 200 to 1000 KW capacity, are at the research or demonstration stage, it is difficult to note specific costs. Nevertheless, based on preliminary cost estimates, capital cost is listed as a development limitation. It should be noted that where cost is not listed as a specific development limitation, a lack of appropriate economic data often precluded making specific conclusions.

ii) For some of the northwestern Arctic communities, such as Arctic Bay, coal is another energy option. However, development and transportation costs in bringing coal on-stream to meet small heating and electricity loads appear to represent major limitations.

iii) For communities in the western Arctic, i.e.,the N.W.T.'s Keewatin region, micro-hydro development is an option. Tables 5 and 6 indicate, however, that physical barriers such as icing conditions and storage needs, and development costs are major limitations. It should be noted that micro-hydro options were assessed in keeping with the focus on community-scale energy development. However, as noted in Section 7, cost factors may dictate large scale developments either in an export oriented scheme or in a Territorial grid-extension phase (unlikely for the Keewatin region).

iv) Communities in the N.W.T.'s Inuvik region, i.e., lower Mackenzie Valley, have access to a much more varied energy supply. Forest biomass is identified as an option but a major limitation is the uncertainty of a sustained feedstock at those northern latitudes. Although forest biomass is recommended as only a space heat option, as opposed to both a space heat and electricity input, the region's ecological fragility suggests problems in maintaining a sustained supply. Small-scale applications could entail forest biomass combustion in commercially available stoves or furnaces.

Coal is identified as an option for such lower Mackenzie communities as Aklavik, Fort Norman, and Fort Good Hope. In excluding coal stoker furnaces from the discussion, due to potential emission impacts, Section 5 focused on fluidized-bed combustion (F.B.C.) and coal gasification as two potentially appropriate conversion technologies. One of the major problems identified for coal development was applying these technologies to small heating and electricity loads. It appears that this is more of a problem for F.B.C. units than for coal gasifiers; in fact, small-scale wood gasifiers can be easily modified to produce low Btu coal gas. Another uncertainty associated with coal development is the lack of more complete reserve data, information that can suggest whether or not investing in a coal delivery infrastructure is feasible for the long-term (greater than ten years).

The lower Mackenzie communities also have access to significant N.G. reserves. Athough supply appears to be adequate for the long-term, the major problem once again is scaling down production and delivery to Territorial communities in a cost-competitive manner. The development of N.G. could entail the investment in more elaborate infrastructure, not only for pipelines but for possible district heating schemes. Combined cycle gas turbine systems and total energy systems have been identified as efficient conversion technologies.

v) The upper Mackenzie communities also have access to a varied energy supply resource base. Forest biomass is a more likely option for both space heat and electricity supply. It should be noted, however, that this is a region where grid-extension is highly possible. Therefore, forest biomass may be more applicable as a space heat fuel input. In this context, forest biomass is identified as a supply option with no significant development limitations.

Micro-hydro development is also identified as a potential upper Mackenzie supply option. However, icing and storage problems also pertain to this area. In fact, icing may be more of a limitation for the larger rivers.

Transportation may prove to be an important factor in assessing Territorial energy supply options. In the N.W.T., road access is limited. However, in the Mackenzie region, it is possible that forest biomass could be transported by road to a central processing facility and then transported for delivery by either road or barge down the Mackenzie River. Coal, on the other hand, could conceivably be shipped up the Mackenzie for community-site conversion.

vi) In the Yukon, most of the communities, off or on-grid, are located on year-round roads. Therefore, the possibility for inter-community transportation of identified supply resources is heightened. The four major energy options in the Yukon are hydro, forest biomass, coal and N.G.

As noted in Section 7, hydro-electric grid extension is a strong possibility for the southern Yukon. This option may preclude the feasibility for other indigenous resources to be cost competitive electricity-generation feedstocks.

Forest biomass potential appears to be substantial, especially in the southeastern Yukon. As detailed in Section 8, the Watson Lake cogeneration scheme represents a model that, depending on the scale of Yukon forest development, may be readily applicable to other communities.

As Table 6 indicates, it is likely that each energy system will need diesel back-up to provide either peak or low load electricity supply. For hydro developments this may be a necessity due to reservoir shortages. For other energy systems, diesel may be needed due to technical and/or economic limits to load following fluctuations.

Table 6 also lists a number of institutional factors that have been identified as likely to be necessary in aiding indigenous Territorial

TABLE 5 - COMMUNITY ENERGY MATCHES

Community	Potential Energy Sources	Proximity To Community (km)	Best End-Use Match	Development Limitations
Arctic Bay	wind coal	immediate 160-241	electricity space heat	wind potential is variable[a] development and transportation costs, reserve uncertainties
Broughton Island	wind	immediate	electricity	wind potential is variable
Cape Dorset	wind	immediate	electricity	
Clyde River	wind	immediate	electricity	wind potential is variable
Frobisher Bay	wind	immediate	electricity	wind potential is marginal[b]
Hall Beach	wind	immediate	electricity	c
Igloolik	wind	immediate	electricity	
Lake Harbour	wind	immediate	electricity	
Nanisivik	wind coal	immediate 100-160	electricity space heat, electricity	wind potential is variable development and transportation costs, reserve uncertainties
Pangnirtung	wind	immediate	electricity	wind potential is marginal
Pond Inlet	wind coal	immediate 43-55	electricity space heat	wind potential is variable development and transportation costs, reserve uncertainties
Sanikiluaq	wind	immediate	electricity	

TABLE 5 - COMMUNITY ENERGY MATCHES

Community	Potential Energy Sources	Proximity To Community (km)	Best End-Use Match	Development Limitations
Baker Lake	wind	immediate	electricity	
	hydro	< 80 km	electricity	general limitations that pertain to micro-hydro such[d] as icing conditions and storage requirements
Chesterfield Inlet	wind	immediate	electricity	
Coral Harbour	wind	immediate	electricity	
Eskimo Point	wind	immediate	electricity	
	hydro	<80 km	electricity	
Rankin Inlet	wind	immediate	electricity	
	hydro	< 80 km	electricity	
Repulse Bay	wind	immediate	electricity	
Whale Cove	wind	immediate	electricity	
	hydro	< 80 km	electricity	
Aklavik	hydro	< 80 km	electricity	
	biomass	immediate	space heat	sustained supply is questionable (S.S.Q.)
	coal	10-76	space heat, electricity	reserve uncertainties
Fort Franklin	biomass	immediate	space heat	S.S.Q.
Fort Good Hope	biomass	immediate	space heat	S.S.Q.
	N.G.	274	space heat, electricity	development and transportation costs
Fort McPherson	biomass	immediate	space heat	S.S.Q.
	hydro	< 80 km	electricity	

TABLE 5 - COMMUNITY ENERGY MATCHES

Community	Potential Energy Sources	Proximity To Community (km)	Best End-Use Match	Development Limitations
Fort Norman	biomass	immediate	space heat	
	hydro	immediate	electricity	
	coal	8-56	space heat, electricity	reserve uncertainty
Inuvik	biomass	immediate	space heat	S.S.Q.
	coal	15	space heat, electricity	reserve uncertainty, development and transportation costs
	N.G.	56-113	space heat, electricity	development costs
Norman Wells	biomass	immediate	space heat	
	hydro	80 km	electricity	
	N.G.	immediate	space heat, electricity	
Tuktoyaktuk	coal	80	space heat, electricity	development and transportation costs
	N.G.	48-64	space heat, electricity	development costs
Cambridge Bay	wind	immediate	electricity	
Coppermine	wind	immediate	electricity	wind potential is marginal
	hydro	80	electricity	
Gjoa Haven	wind	immediate	electricity	wind potential is marginal
Holman Island	wind	immediate	electricity	wind potential is marginal
Paulatuk	wind	immediate	electricity	
	coal	10-171	space heat	reserve uncertainty
Pelly Bay	wind	immediate	electricity	wind potential is marginal

TABLE 5 - COMMUNITY ENERGY MATCHES

Community	Potential Energy Sources	Proximity To Community (km)	Best End-Use Match	Development Limitations
Spence Bay	wind	immediate	electricity	wind potential is marginal
Fort Liard	hydro	80	electricity	
	biomass	immediate	space heat, electricity	unproven technology for electricity generation
	N.G.	48	space heat, electricity	
Fort Providence	biomass	immediate	space heat, electricity	S.S.Q.
	N.G.	85	space heat, electricity	development costs
Fort Simpson	biomass	immediate	space heat, electricity	S.S.Q.
	N.G.	88	space heat, electricity	development costs
Fort Smith	hydro	80	electricity	
	biomass	immediate	space heat, electricity	e
Hay River	biomass	immediate	space heat	
	N.G.	76-161	space heat	development costs
Lac La Martre	biomass	immediate	space heat	S.S.Q.
Pine Point	biomass	immediate	space heat	S.S.Q.
Rae Edzo	biomass	immediate	space heat	S.S.Q.
Snowdrift	hydro	80	electricity	
Tungsten				
Yellowknife	biomass	immediate	space heat	S.S.Q.[f]

TABLE 5 - COMMUNITY ENERGY MATCHES

Community	Potential Energy Sources	Proximity To Community (km)	Best End-Use Match	Development Limitations
Beaver Creek	hydro	< 80	electricity	S.S.Q.
	biomass	immediate	space heat	
Carcross	biomass	immediate	space heat	S.S.Q.
	coal	32	space heat	
Carmacks	biomass	immediate	space heat	S.S.Q.
	coal	3	space heat	
Clinton Creek	biomass	immediate	space heat	S.S.Q.
Dawson	biomass	immediate	space heat	S.S.Q.
	grid extension			
	hydro	< 80	electricity	
	coal	5-257	space heat, electricity	transportation and developments costs
Destruction Bay (Quill Creek)	biomass	immediate	space heat	S.S.Q.
Elsa	biomass	immediate	space heat	S.S.Q.
Faro	biomass	immediate	space heat	S.S.Q.
	grid extension			
	hydro	< 80	electricity	
	coal	10	space heat	
Haines Junction	biomass	immediate	space heat	S.S.Q.
	coal	24-80	space heat	transportation and development costs
Johnsons Crossing	biomass	immediate	space heat, electricity	
	coal	70	space heat, electricity	transportation and development costs

TABLE 5 - COMMUNITY ENERGY MATCHES

Community	Potential Energy Sources	Proximity To Community (km)	Best End-Use Match	Development Limitations
Keno City	biomass	immediate	space heat	S.S.Q.
Old Crow	hydro	80	electricity	
	biomass	immediate	space heat	
	coal	121-161	space heat, electricity	transportation and development costs
Pelly Crossing	hydro	80	electricity	
	grid extension			
	biomass	immediate	space heat, electricity	
Ross River	biomass	immediate	space heat	S.S.Q.
	coal	4		
Stewart Crossing	hydro	80	electricity	
	grid extension			
	biomass	immediate	space heat	S.S.Q.
Swift River and Tagish, data unavailable				
Teslin	biomass	immediate	space heat, electricity	S.S.Q.
Upper Liard	biomass	immediate	space heat, electricity	
Watson Lake	hydro	80	electricity	
	biomass	immediate	space heat, electricity	
Whitehorse	biomass	immediate	space heat	S.S.Q.
	coal	32	space heat	development costs

TABLE NOTES

a. Where wind potential is noted as variable, the actual power potential depends on the specific site location. See Section 9.

b. Where wind potential is noted as marginal, seasonal and year-to-year variations will affect reliable energy supplies.

c. Absence of notation means that no obvious limitations can be noted until site specific studies estimate technical and economic constraints.

d. As Section 7 explains, wherever micro-hydro potential is evident this note is applicable.

e. Absence of notation means that no inventory limitations are evident and a final assessment depends on more detailed technical and economic estimates.

f. There is likely a considerable municipal waste supply.

TABLE 6 A SUMMARY OF ENERGY CONVERSION TECHNOLOGIES

ENERGY SOURCE	APPROPRIATE CONVERSION TECHNOLOGY	DEVELOPMENT[a] STAGE	INFRASTRUCTURE NEEDS	INSTITUTIONAL NEEDS	DEVELOPMENT LIMITATIONS
Natural Gas	Gas turbines, combined cycle	A	Diesel unit conversion or replacement. District heating system. Diesel back-up.	Development cost sharing agreements. Clarification of utility control.	Development (extraction, delivery, processing) costs.
	Total Energy Module	D	District heating system. Diesel back-up.	As above.[b]	Development cost. Technical reliability. Load following abilities.
Coal	Fluidized-bed Combustion Unit, atmospheric	A & D	Diesel back-up Transmission lines. District heating system. Ash disposal.	As above.	Community-scale application Energy inputs.
	Fluidized-bed Combustion Unit, pressurized	D	As above.	As above.	As above.
	Coal Gasifiers	A	Diesel back-up. Water input. Ash disposal. Effluent disposal. Transmission lines. Wood gasifier conversion.	As above. Environmental controls.	Coal mining and transportation costs.
Uranium	S.L.O.W.P.O.K.E. III	R	District heating system. Waste storage.	Safeguard controls.	Nuclear issues need to be to be resolved.
Hydro	Micro-Hydro Systems	D	Transmission lines. Storage reservoirs Diesel back-up.	Cost sharing agreements. Pricing. Development tax depreciation. Environmental controls.	Development cost. Icing. Reservoir damages.
Forest Biomass	Wood Stoves	A	Harvesting, processing. Diesel back-up.	Forest management. Environmental controls.	Supply uncertainty. Environmental emissions.
	Wood Furnaces	A	As above.	As above.	As above.
	Package Boilers	A	As above. District heating system.	As above. Utility energy sharing and price agreements.	As above. Community-scale application. Development cost.
	Wood Gasifiers	D	As above. Effluent disposal.	As above. Development tax depreciation.	Supply uncertain. Environmental emissions. Development cost.
	Fluidized-bed Combustion Units, atmospheric	D	As above.	As above.	As above.
Wind	H.A.W.T.[c] $\leq$ 12kW	A	Transmission lines. Diesel back-up.	Cost sharing agreements. Development tax depreciation. Clarification of utility control.	Variable wind regimes. Development cost.
	V.A.W.T. $\leq$ 12kW	D	As above.	As above.	As above.
	V.A.W.T. $\leq$ 200kW	R	As above.	As above.	As above.
	V.A.W.T. $\geq$ 200kW	R	As above. Grid linkage.	As above.	As above.

NOTES:
a) It is assumed that there are three development stages to the achievement of commercial availability: Research (R); Demonstration (D); and Commercial Availability (A)
b) "As above" means that the statements in the row directly above hold true.
c) H.A.W.T. means horizontal axis wind turbine.
d) V.A.W.T. means vertical axis wind turbine.

energy development. For example, in Section 4, it was noted that community scale N.G. development might not be possible without cost-sharing agreements that entail the community or Territory covering a considerable portion of development costs.

Given N.C.P.C.'s role in providing electricity, both on- and off-grid, it seems likely that district heating and cogeneration schemes, whether using N.G., coal or forest biomass, will have to be based on a pricing agreement developed with utility input. In this context, it is likely that the utility would be responsible for micro-hydro electricity pricing. For each energy option, the possibilities for community or communities ownership and control of energy systems must be assessed. Finally, a major institutional factor must be the designation of appropriate environmental management and controls.

2.2 General Recommendations

The following list represents a compilation of the major recommendations discussed in Section 4 to 10.

1. N.G. deliverability studies should be undertaken for selected communities focusing on:

   i) site - specific delivery infrastructure, including the feasibility of total energy system application;

   ii) export pipeline delivery feasibility, i.e., the costs of laterals etc; and

   iii) delivered N.G. costs in comparison with projected petroleum fuel costs.

2. Further analyses should be undertaken with respect to both coal inventory compilation and conversion technology assessment. This work should include:

   i) comprehensive geological, geophysical, and geochemical surveys of coal deposits identified to be in proximity to communities with demonstration project potential. Such an inventory compilation could be complimented by in-depth coal characteristic analyses from C.A.N.M.E.T.;

ii) further technical and economic assessment of FBC and coal gasification technology based on existing work; and

iii) a pre-feasibility study on the application of either FBC or coal gasification technologies for selected communities. Such a study should include FBC or gas turbine total energy systems.

3. No consideration should be given to the S.L.O.W.P.O.K.E. III nuclear reactor until related safety, health and socio-economic issues have been addressed in an appropriate medium.

4. From the communities identified as having hydro potential, select a number that will not likely be grid connected in the long-term (more than 10 years). Pre-feasibility studies should be undertaken to determine firm flow data; available power; plant requirements to meet 10 KW to 2000 KW peak demand; storage requirements; transmission requirements; and power back-up arrangements.

5. Consideration should be given to local community/entrepreneurial development and ownership of micro-hydro units, with possible N.C.P.C. regulation.

6. Community specific forest biomass supply data should be developed through more comprehensive surveys. The data should include: available standing biomass; productivity; forest species; and accessibility. It is recommended that Territorial liaison be developed with the E.N.F.O.R. program.

7. The development of chunk log supply infrastructure (harvesting, processing, and marketing) should be supported.

8. Further efforts should be made to examine options to overcome current barriers to wood generated electricity. These barriers include:

i) a reliable source of cheap feedstock; and

ii) technical development of reliable systems.

9. Wind/Diesel hybrid systems deserve further investigation culminating in demonstration projects for the western Arctic communities.

10. Drying, mining, and small-scale conversion limitations suggest that peat fuel, likely to be in competition with other Mackenzie Valley energy resources, should not be considered as a Territorial fuel supply.

11. For each energy supply option, the Territorial governments and D.I.A.N.D. should make an effort to liaise with existing government departments or programs involved in the development of those resources. Possible sources for liaison include the:

Canada Centre for Mineral and Energy Technology
Conservation and Renewable Energy Branch, Energy, Mines and Resources Canada
National Research Council
Environment Canada
Institute of Petroleum and Sedimentary Geology

12. Strategies and processes should be conceptualized and developed that would provide an appropriate medium for community input into the selection and development of identified energy supply resources.

3. TECHNOLOGY CONSIDERATIONS

As noted in Section 1, the approach in assessing potential conversion technologies is based, in part, on technology assessments employed by R. Overend at N.R.C. and by the Alaska Council on Science and Technology. Although specific technology considerations are identified for each supply option, there are also general considerations that often pertain to most energy technology assessments. These general considerations are identified and commented upon in the following discussion.

(a) Technical Reliability: This category should discuss such characteristics as the technology's ability to operate with a minimum of maintenance, length of lifetime, and operating efficiency.

(b) Commercial Availability: This category should discuss what stage the technology is at in achieving market penetration. As noted in Section 2, Table 6, the two common stages prior to commercial availability are research and demonstration. Where possible, these characteristics might also indicate the time period when the technology is expected to reach commercial availability.

(c) Load Following Abilities: Both electrical and space heating loads are subject to variability on an annual basis. This category should discuss the ability for the technology to follow fluctuating loads and identify limitations to load following abilities. Therefore, this category should assess whether or not the technology is suited to meet base or peak loads.

(d) Infrastructure: This category should discuss infrastructure needs associated with both supply and distribution. For example, coal supply depends on appropriate mining and transportation infrastructure. Coal derived heat distribution may depend on appropriate district heating infrastructure.

(e) Economic Feasibility: This category should discuss the capital and operation/maintenance cost inputs to an estimated delivered cost of energy. As Sections 4 to 10 indicate, a paucity of data precludes any reliable conclusions of delivered costs for the identified energy supply options.

Where possible, it is useful to compare the delivered cost of the potential energy source with current and forecasted costs (prices) of existing sources. For example, a perusal of N.C.P.C. Cost of Service Rate Adjustments indicates government commercial electricity rates of 29.6¢/kWh to 41.6¢/kWh in the Baffin region of the N.W.T. or $82/gigajoule to $115/gigajoule. In Inuvik, however, the electricity rate is about 12¢/kWh or $33/gigajoule. In the Yukon costs range from Whitehorse at $9.41/gigajoule to Johnson's Crossing at $53.18/gigajoule. Depending on the location, these energy costs can be projected at estimated indigenous or imported oil prices or at hydro rate projections. One of the major questions in comparing the delivered cost of new energy resources is what criteria should be employed.

Recently, the Economic and Policy Analysis Sector of E.M.R. released a paper describing a methodology which could assist analysts in determing the social cost-effectiveness of solar projects and energy-related investments in general.[2] Using a <u>life-style</u> costing methodology, the paper develops a set of energy cost premiums that reflect the current divergence between market prices and the social costs of conventional fuels. For example, N.G. under the National Energy Program is priced at $2.98/Mcf at the Toronto city-gate in 1981. The energy reference cost is calculated as $6.15/Mcf (1980) at the Toronto city-gate. This difference indicates that delivered cost estimates for identified Territorial energy resources should be carefully evaluated in comparison to the "real" costs of current supply.

(f) <u>Operating Personnel</u>: This category should discuss personnel requirements necessary to operate the technology. For example, a large number of highly skilled technicians could escalate operating costs to the level where they become prohibitive for the project as a whole. In addition, this discussion could also illuminate on the possibilities for the community to supply operating personnel, e.g., as part of a funded training program.

3.1 References

1. N.C.P.C. Proposed Rate Adjustments, N.W.T. Rate Zone, April 1980.

   ________. Proposed Rate Adjustments, Yukon Rate Zone, April 1980.

2. Economic and Policy Analysis Sector, E.M.R. Energy Reference Cost Premiums. June, 1980.

4. NATURAL GAS

4.1 Supply Inventory

As indicated in the N.W.T. Report (pages 68-73), there are considerable natural gas reserves in the N.W.T. that could serve both Territorial and export needs. Utilizing more recent data, Table 7 and Map 1 present the mainland gas discoveries in terms of their proximity to Territorial communities. Using an arbitrary radius of 100 miles as a guideline, Table 7 indicates potential community scale natural gas (N.G.) discoveries for a number of Lower and Upper MacKenzie Valley communities.

4.1.1 Supply Data Limitations

There are no significant supply data limitations. Coordination of N.G. data among the Calgary based Institute of Sedimentary and Petroleum Geology (I.S.P.G.), Energy, Mines and Resources, and D.I.A.N.D.'s Oil and Gas Division provides up-to-date descriptions (less than one year old) of N.G. discoveries and marketable reserves (albeit, some of this data is understandably confidential). As well, ownership and lease data are available for most N.G. locations.

4.2 Technology Review

4.2.1 Specific Considerations

While the general considerations outlined in Section 3 pertain to the development of N.G., one major consideration that applies to a number of conventional energy resources must be identified. That is, can what is conceived as large scale energy infrastructure be scaled down to the size of Territorial community needs? N.G. development is commonly developed at a scale that demands considerable revenue to offset exploration and development costs. In pursuing this question, two stages of technology are explored, extraction/processing and conversion.

TABLE 7

COMMUNITY SPECIFIC TERRITORIAL NATURAL GAS DISCOVERIES

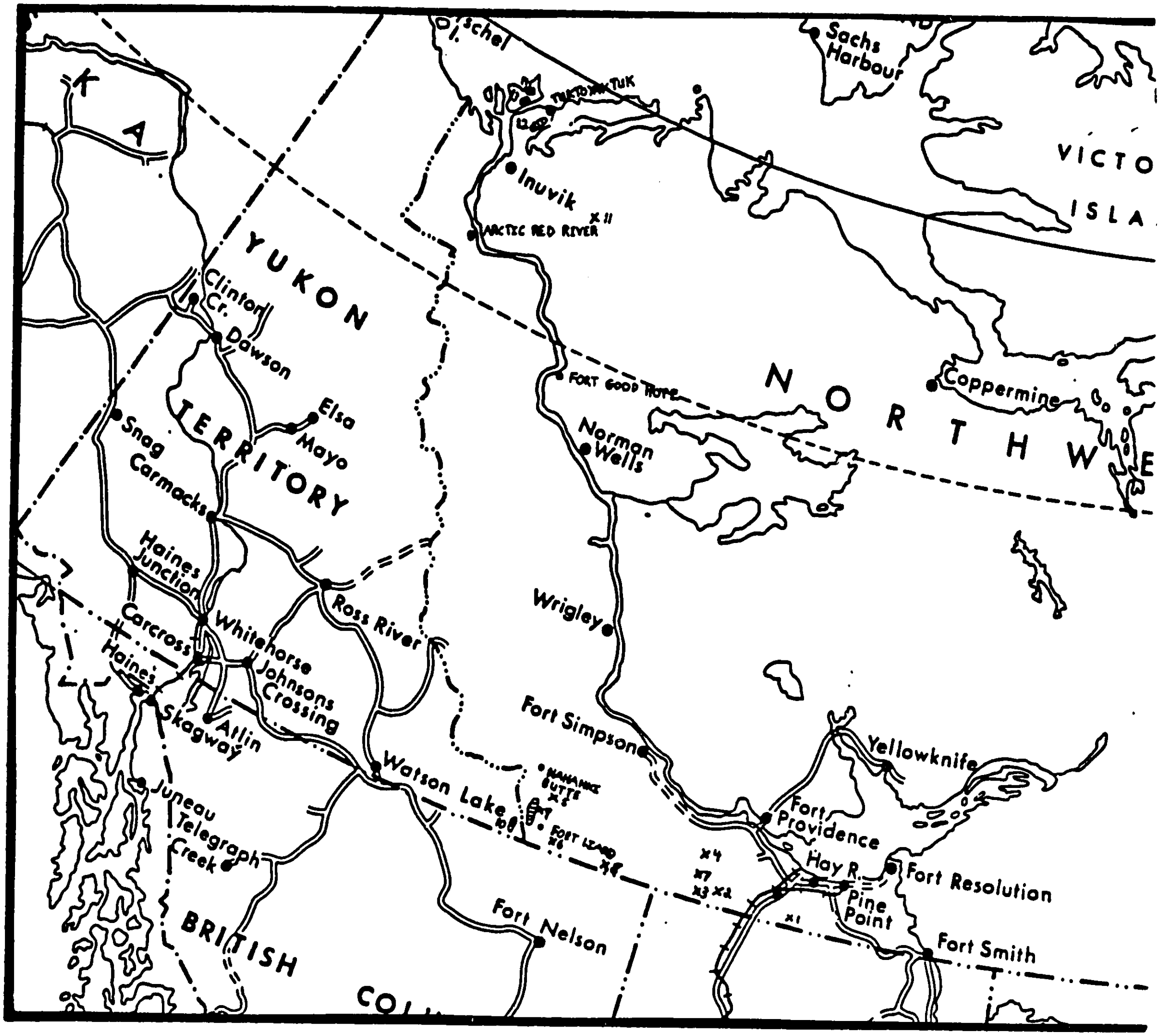
Community	Gas Well/Field[a] Number/Name	Map Reference Number	Gas Source Proximity[b] To Community (km)	Reserve Status	Marketable Reserve	Ownership	Lease Expiry Date
Enterprise	G-63	1	50	gas discovery	CONFIDENTIAL INFORMATION	vacant	surrendered 9/3/72
Hay River	G-63	1	76				
Enterprise	J-62	2	100	gas discovery		U	U
Enterprise	A-05	3	110	gas discovery		Hudson's Bay Oil and Gas Limited	7/4/92
Hay River	A-05	3	135	gas discovery			
Hay River	B-07	4	161	gas discovery		G.A.O. Canada Ltd.	27/09/84
Fort Providence	B-07	4	85				
Fort Simpson	B-07	4	88				
Fort Liard	C-07	5	68	gas discovery		Suncor Inc.	6/12/86
Nahanni Butte	C-07	5	54	gas discovery			
Fort Liard	J-72	6	27	gas discovery		Texaco Canada Resources Ltd. Mobil Oil Canada Ltd. Gulf Canada Resources Inc.	7/8/2001
Hay River	N-18	7	152	gas discovery		U	U
Fort Liard	M-41	8	135	gas discovery		U	U
Fort Liard	Pointed Mountain Field	9	34	in production		U	U
Nahanni Butte	Pointed Mountain Field	9	80				
Fort Liard	Kotaneelee Field	10	48	available for production		U	U
Fort Good Hope	F-24	11	274	gas discovery		U	U
Inuvik	Parsons Field	12	56-105	gas discovery		U	U
Tuktoyaktuk	Parsons Field	12	48	gas discovery			
Inuvik	Ya Ya Field	13	113	gas discovery			
Tuktoyaktuk	Ya Ya Field	13	64				
Tuktoyaktuk	Taglu Field	14	64	U		U	U

LEGEND: U represents unavailable; this does not mean that the necessary data are non-existent, rather, some of it is confidential while other categories of data were not asked for by the author.

SOURCES:
1) D.I.A.N.D. - Oil and Gas Activities 1979 (Ottawa: DIAND, 1980)
2) D.I.A.N.D., Oil and Gas Division
3) D.I.A.N.D. Oil and Gas Well Location Maps

NOTES:
a) Gas wells may represent individual gas pools
b) An arbitrary radius of 100 miles or 161 km was established to indicate community proximity. This limit is not based on any feasibility studies and serves merely to illustrate community specific resources. One exception, well F-24 is listed because of its significant potential.

MAP 1 - TERRITORIAL NATURAL GAS DISCOVERIES



SCALE: 38mm = approximately 322km

LEGEND: x = natural gas location
1-14 are reference numbers to correspond to Table 7.

4.2.2 Technology Description (Extraction/Processing)

Raw gas extracted from underground resevoirs frequently contains significant amounts of heavier hydrocarbons and organic contaminants[2] (pages 28,29 Executive Summary). Field processing at the well may be necessary to separate liquids from gaseous components which are then reinjected to improve recovery. Small diameter pipelines commonly carry the raw gas to processing plants where marketable gas, hydrocarbon liquids, and sulphur are separated.

A recent report completed by Canuck Engineering Limited of Calgary provides a useful example of the extraction/processing infrastructure required to supply a Territorial community. More specifically, the report examines the feasibility of a N.G. supply to Inuvik from gas wells at either the Parsons Lake or Ya Ya fields.[3]

The Canuck design approach includes using the simplest gas processing facilities consistent with a satisfactory gas product by eliminating carbon dioxide removal or extensive liquid hydrocarbon processing. The well design was based on a "cluster" arrangement:

- 2 gas production/injection wells
- 1 water disposal well
- 1 liquid hydrocarbon well at formation depth

Each well in the cluster would be connected to a central processing plant by above-ground connecting facilities. Similar cluster arrangements have been proposed as part of the expanded Norman Wells development, primarily to power oil pumping stations.

4.2.3 Technology Assessment (Extraction/Processing)

(a) Economic Feasibility: N.G. extraction and processing technology is commercially proven and reliable. The Canuck Engineering report shows, however, that the estimated cost of delivered gas from the more favourable well location at the Parsons Field is \$6.71/Mcf (1980 \$), a cost considerably higher than current Inuvik energy costs.

The cost includes $4 million per well, $8 million for a processing plant, and $5 million for pipeline facilities (including a medium pressure N.C.P.C. distribution line). However, as noted in Section 3, the social cost method employed by E.M.R. in assessing N.G. prices indicates a Toronto city-gate price of $6.15/mcf (1980 $). This approach to costing delivered N.G. may indicate, with further analysis, a feasible community supply for not only Inuvik but other identified communities.

Consultations with both government and industry officials (see Section 4.3) indicate that, depending on resevoir and N.G. characteristics, the same extraction and processing approach is necessary for all scales of N.G. development. For example, the Union Gas Co. of Chatham, Ontario has developed small gas pools but a company spokesperson notes that N.G. from these pools has to undergo common extraction and processing approaches and, in fact, the localized gas is fed into the main cleansing operations. Therefore, it seems likely that the scope and cost of N.G. will not be decreased in scale much further than the scheme suggested by Canuck.

(b) Institutional Considerations: Part of the Canuck Engineering study discusses the need for affected parties to agree to a cost sharing agreement. For example, in the study they suggest that the town bear a portion of the capital costs and all of the operating and maintenance costs while the developing company retains all of the tax benefits. This example raises a question that pertains to all energy development options; how will the costs of development be shared?

4.2.4 Technology Description (Conversion)

In excluding mining needs from the discussion, it can be assumed that delivered N.G. can be used to meet residential and commercial space heating and/or electricity needs. The following discussion describes some of the likely conversion technologies that may be employed, with an emphasis on total energy systems, i.e., systems that utilize as much potential energy as possible to supply both heat and electricity.

By August 1981, the N.C.P.C. will have on-line about 5 to 6 MW installed capacity of gas turbines. Although these turbines are currently operating on diesel fuel, there are no major obstacles to converting them back to N.G. usage.

Gas turbines are a proven technology and have been in operation since the 1930's. In a total energy system, gas turbines are employed along with heat recovery equipment, e.g., heat exchangers, heat recovery boilers, and heat pumps. Using gas turbines, heat and electricity recovery can be achieved in simple cycle or combined cycle systems. In the simple cycle, a gas turbine can be connected to either a non-fired or supplementary fired heat recovery boiler.[4] Depending on the boiler used, heat can be recovered either as hot water or steam in ratios of 1.4:1 to 3.0:1 heat to electricity.

Combined cycle systems include gas turbines, heat recovery boilers, and steam turbines (see Figure 1). The use of a back pressure steam turbine results in a high overall conversion efficiency.

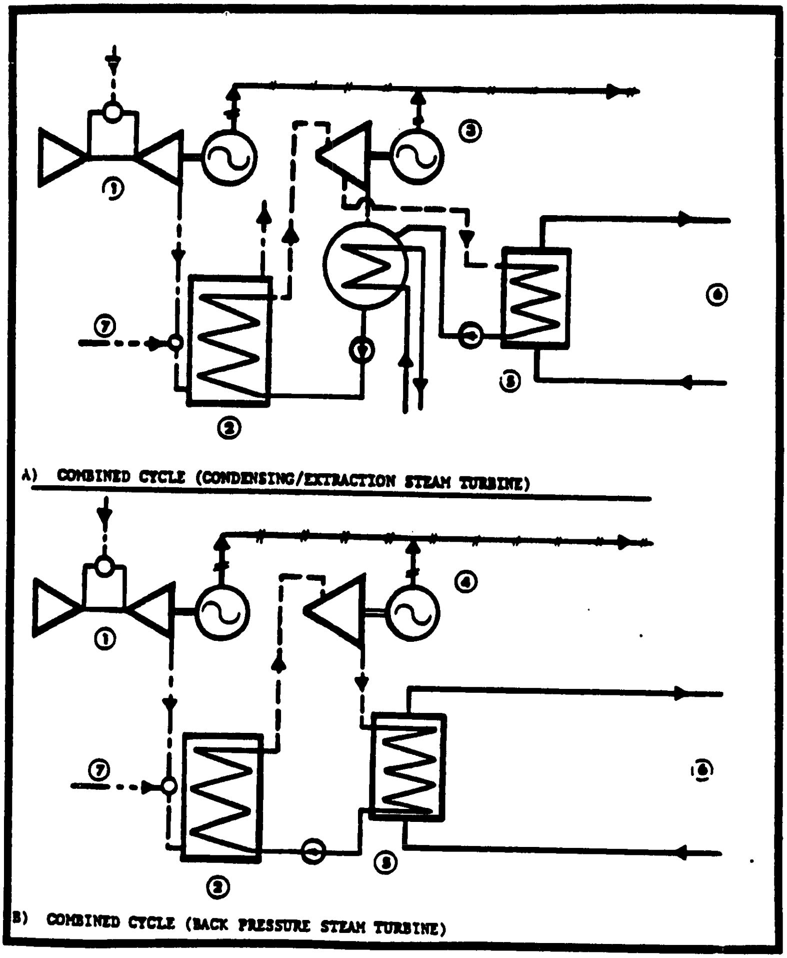
At present, a number of the major international automobile manufacturers are involved in the development of community scale total energy systems. For example, the FIAT Motor Co. has developed a total energy module (T.O.T.E.M.) that consists of a FIAT 127 car engine and an ansynchronous generator directly coupled to the engine. The T.O.T.E.M. has approximately a 70% fuel conversion efficiency with a heat to electricity ratio of 2.5 to 1.

4.2.5 Technology Assessment (Conversion)
Combined Cycle Systems

The advantages of combined cycle systems are low capital costs, low heat rates (appropriate for space heat applications), and short construction/installation times.[4] In addition, combined cycle systems offer close to 70% secondary energy conversion and can follow fluctuating heat and electricity loads.[5]

FIGURE 1

COMBINED CYCLE GAS TURBINE SYSTEMS



A) COMBINED CYCLE (CONDENSING/EXTRACTION STEAM TURBINE)

B) COMBINED CYCLE (BACK PRESSURE STEAM TURBINE)

LEGEND:
- Fuel
- Steam
- Water
- Gas Turbine Exhaust
- Elecricity

1 Gas Turbine
2 Heat Recovery Boiler
3 Condensing/Extraction Turbine
4 Back Pressure Steam Turbine
5 Heat Exchanger
6 District Heating Network
7 Auxilliary Piping

Source: Acres Shawinigan Ltd., Gas Turbines and District Heating, A study prepared for the Interdepartmental Committee on District Heating, EMR, 1977, Figure 11.

One of the major disadvantages to the system is the possibility for corrosion on the heat exchange surfaces. The Shawinigan report suggests that research and development activities will have to focus on limiting corrosion, which in turn would allow the combustion of low grade fuels such as coal derived gas (see Section 5).

(a) Infrastructure Considerations: In the Territories, gas turbine combined cycle application would have to take into account both the conversion and replacement of existing diesel units. Existing diesel units are primarily Caterpillars that are convertible. However, consultations with the N.C.P.C. suggest that conversions would be costly and that potential power is lost, i.e., the sytems would have to be derated by about 30%.

If a cost comparative N.G. supply is available for a particular community or region, then the replacement of diesel units may be feasible. It's suggested that site specific analyses would have to be pursued. Finally, the introduction of N.G. total energy systems would entail the development of distruct heating hot water and steam systems.

(b) Load Following Ability: Although combined cycle systems can follow fluctuating loads, experience in Britain indictes a need for peaking back-up supply, e.g., diesel. Total energy systems were found to be best suited for electricity load factors between 30% and 70%. As the Shawinigan report indicates, the generator capacities necessary to meet peak heating loads will increase beyond the point of cost practicality.

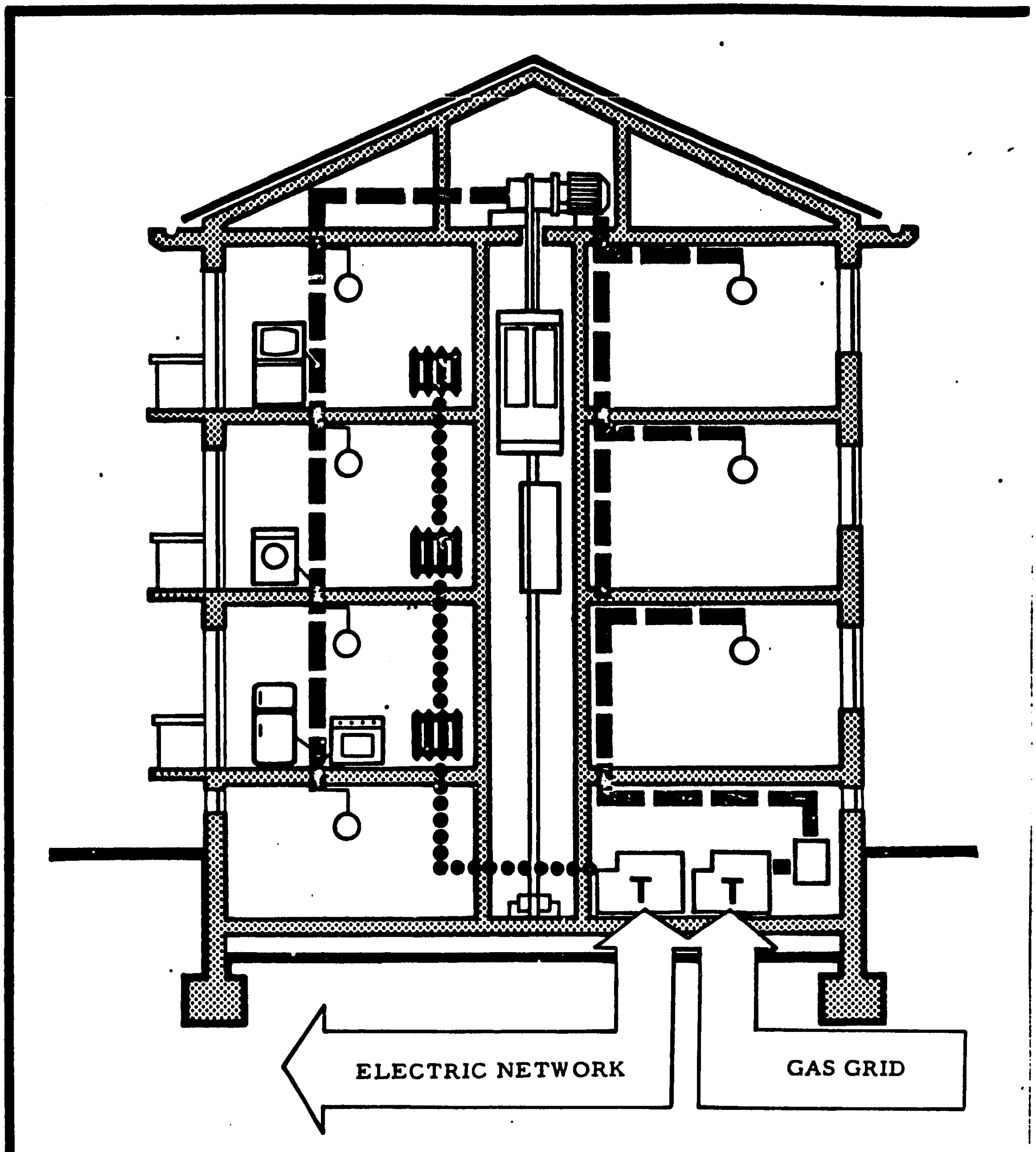
(c) Commercial Availability: Both simple and combined cycle gas system components are commercially available.

Total Energy Modules

(a) Application: With respect to Territorial needs, the T.O.T.E.M. can be used to supply a cluster of homes or small commercial buildings, e.g., multi-unit apartments, schools (see Figure 2). The FIAT company has suggested that the T.O.T.E.M. could supply base load electricity, thereby replacing considerable diesel capacity.

FIGURE 2

T.O.T.E.M. RESIDENTIAL APPLICATION



Source: FIAT Auto Group.

(b) Cost: The estimated cost is $6,500 (1979$) or $433 per installed kilowatt.

(c) Reliability: Consultations with the Consumers Gas Company and the Canadian Gas Association suggests that the T.O.T.E.M. needs considerably more development before it becomes commercially reliable. To date, the system has been beset with load balancing problems and a short engine life.

(d) Commercial Availability: It is estimated that it will take at least five more years before the T.O.T.E.M. systems are commercially proven.

4.3 Contacts and References

4.3.1 Contacts (Inventory Data)

1. Stan Kanick, Chief: D.I.A.N.D. Oil and Gas Resources Evaluation Division. (613) 997-9444

2. Jim Barrett; Land Manager, D.I.A.N.D. Oil & Gas Rights Section. (613) 997-0877

3. Dr. Jim Hea, Director General Petroleum Resources, Energy, Mines, and Resources Canada. (613) 995-9351

4. Dr. R.K. Proctor, Petroleum Resources Appraisal Secretariat, Institute of Sedimentary and Petroleum Geology, Calgary. (403) 284-0110

(Technology Data)

1.	John Overall:	Canadian Gas Association Toronto (416) 447-6465
2.	Doug Shirer:	Consumer's Gas Systems Ltd. Toronto (416) 492-5272
3.	Bob Lewis:	Union Gas Co. Chatham (519) 352-3100

4. David Black: E.M.R. advisor on petroleum technology 995-9351
5. Hector Ewing- D.I.A.N.D. Oil & Gas technology 997-9444
6. David McGinnis: Director of Engineering N.C.P.C. (403) 465-3377

4.3.2 References

1. Adelaar, Martin. Energy Demand and Supply in the Northwest Territories. A study prepared for D.I.A.N.D. and the N.W.T. Ministry of Energy, 1981.

2. Sullivan, H.F.; Fasken, L.J.; and Golem, P.J.; Thermal Engineering Group, Department of Mechanical Engineering, University of Waterloo. Study of Canadian Energy System Efficiencies by Province. Prepared for the Joint Energy Industry Conservation Committee, C.M.H.C., March 1980.

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

4. Acres Shawinigan Ltd. Gas Turbines and District Heating, A report prepared for the Interdepartmental Committee on District Heating, Office of Energy Conservation, Energy, Mines and Resources (Ottawa: E.M.R. Research Report No. 10 (1977) pp. 4-1, 4-2.

5. Brecht, Christoph Chairman. Industrial and Commercial Utilization of Gases, Committee F, 14th World Gas Conference, Toronto 1979.

6. D.I.A.N.D. Oil and Gas Activities 1979 (Ottawa: D.I.A.N.D. 1980)

7. Oil and Gas Journal (April 13, 1981).

8. Proctor, R.M.; Lee, P.J.; and Skibo, D.N. Canada's Conventional Oil and Gas Resources (Calgary: Petroleum Resources Appraisal Secretariat, Institute of Sedimentary and Petroleum Geology, 1981).

4.4 Recommendations

Territorial N.G. energy availability, in inventory terms, is proven. However, since the majority of this proven supply is off-shore, it is recommended that an inventory data bank be compiled with the specific purpose of logging community specific N.G. discoveries and energy potential.

The technical/economic limits in supplying N.G. at a community scale appear to make the N.G. option unfeasible in the very near term (5 years). However, given the likelihood that the marginal cost of petroleum supply (excluding Norman Wells) is likely to increase at a faster rate than that of N.G., it is recommended that N.G. deliverability studies be undertaken for selected communities that would examine:

i) site - specific delivery infrastructure, including the feasibility of total energy system application, and

ii) comparative delivery costs from and export pipeline lateral.

5. COAL

5.1 Coal Inventory

Both the N.W.T. and Yukon reports identify Territorial coal resources.[1] Although the N.W.T. report draws upon the results of the community specific assesment employed by Arctech Services[2], the data were still incomplete. Table 8 and Map 2 is an attempt to identify Territorial coal resources from a community perspective. Briefly, the main coal bearing regions are the: [2,3]

i) East Mackenzie Arctic Plain (nos 1-15 on the map), low, glaciated terrain, near marine transportation; near possible hydrocarbon and mine development;

ii) North Richardson Mountains and Arctic Plateau (nos 17-22), moderately rugged terrain, near Dempster highway and Beaufort Sea;

iii) Fort Norman Basin (no. 43), rugged and isolated area;

iv) Tirtina Trench (nos 34-42), moderately rugged terrain; near the Dawson highway; coals are structurally complex and are likely to be limited to small scale development;

v) Whitehorse Trough (nos 44-45), rolling to rugged terrain near Alaska highway and major load centres

Although Table 8 indicates the data are incomplete, it is clear that most Territorial coal is of low grade lignite or sub bitiminous quality. It appears that sulphur content is low while ash content may be high for certain locations.

5.1.1 Inventory Data Limitations

It is quite evident that coal inventory data, with regard to both quantity and quality is incomplete. Much of the available data is the result of preliminary field surveys, conducted for the most part by the Geological Survey of Canada.

TABLE 8

TERRITORIAL COAL OCCURENCES

Community	Individual Coal Occurences (Map Reference Number)	Proximity To Community km	Coal Type	Sulphur %	Ash %	Seam Thickness (Maximum) M
Paulatuk	1-15	10-171	lignite	U	U	3
Inuvik	16	15	lignite	U	U	U
Tuktoyaktuk	16	80	U	U	U	U
Aklavik	16-18	10-76	lignite	U	U	2.4
Old Crow	19-22	121-161	lignite	U	U	U
Sacns Harbour	23	40	lignite	U	U	U
Resolute	24	30	lignite	U	U	U
Arctic Bay	25-27	160-241	lignite	U	U	U
Pond Inlet	25-27	43-55	lignite	U	U	U
Fort Norman	28-30	8-56	lignite	U	U	3
Nahanni Butte	31	40	lignite	U	U	2
Watson Lake	32-35	4-50	lignite	.15-1.4	4.7-41.5	2
Ross River	36	4	bitiminous	.23-0.8	10.4-31.9	3
Faro	37	10	U	U	U	U
Dawson	38-42	5-50	lignite	.39-1.47	3.6-26.9	13
	43	257	lignite	U	U	11
Carmacks	44	3	lignite		Operating mine	
Whitehorse	45	32	bitimous	U	U	2
Johnsons Crossing	45	70	U	U	U	U
Carcross	45	32	U	U	U	U
Haines Junction	46-49	24-80	U	U	U	2

LEGEND: U - Unavailable

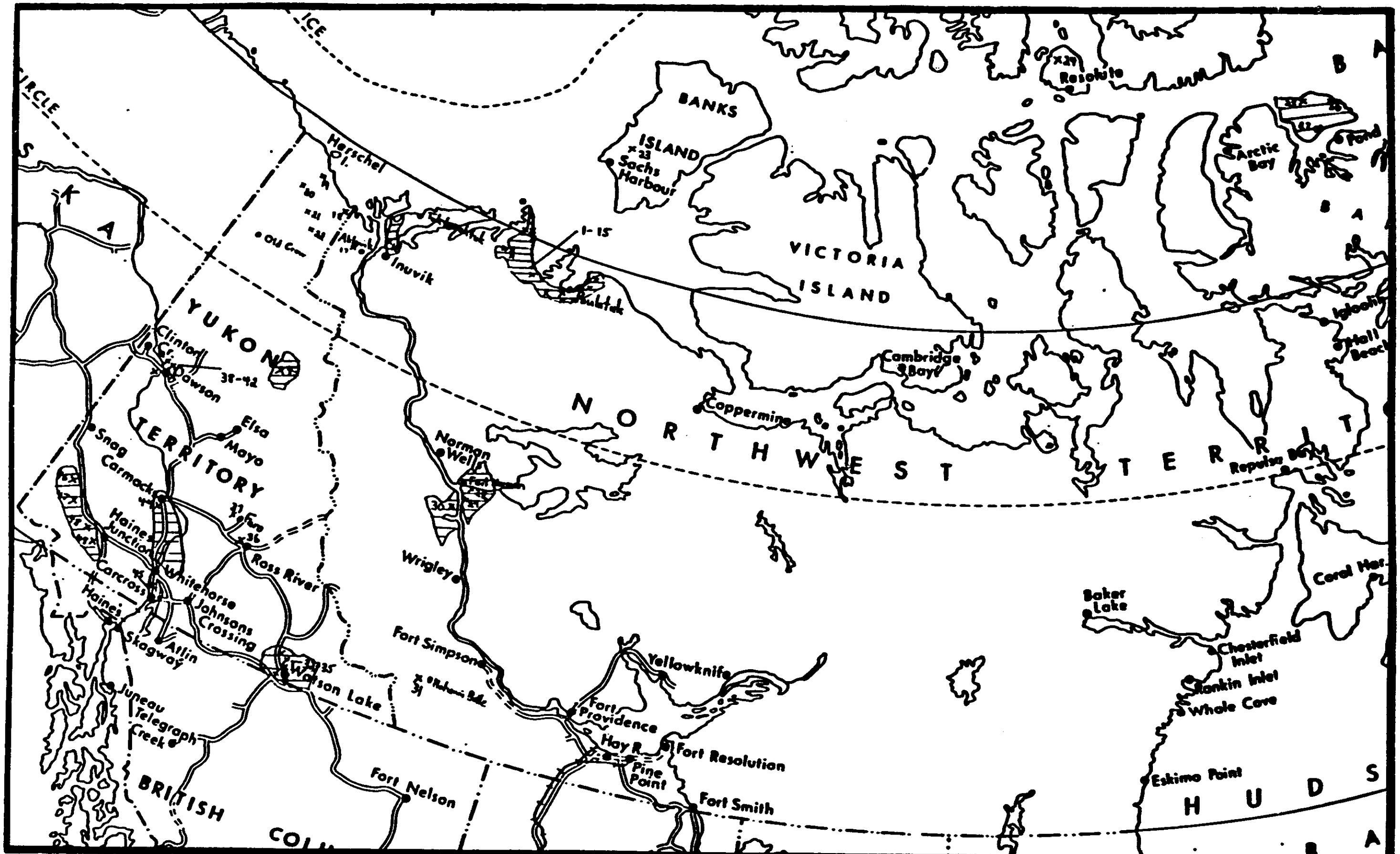
SOURCES: 1. Arctech Services, Inuvik, Community Coal Utilization in the Northwest Territories, A report prepared for the Department of Economic Development and Tourism, Government of the Northwest Territories 1978.

2. J.D. Campbell, Guide to Coal Deposits, Yukon and Mackenzie Territories: A Compilation Research Council of Alberta Report 66-6

3. J.D. Hughes, D.G.F. Long, Geology and Coal Resource Potential of Early Tertiary Strata Along Tintina Trench, Yukon Territory, Geological Survey of Canada Paper 79-32.

4. D.F.G. Long, Lignite Deposits in the Bonnet Plume Formation, Yukon Territory Geological Survey of Canada Current Research Paper 78-1A, 1978, pp 399-401.

MAP 2 - TERRITORIAL COAL DEPOSITS



SCALE: 25.4mm = 322km

LEGEND: x = coal deposits
1-49 are reference numbers for Table 6
▤ = coal bearing rock units

SOURCES: See Table 8.

5.2 Technology Review

5.2.1 Specific Considerations

While the general considerations outlined in section 3 pertain to the development of N.G., two major considerations that must be emphaiszed are approriate extraction and transporation system and community-scale energy conversion technologies

a) Mining: The Tantalus Butte mine, serving the Cyprus Anvil mining operation, is a surface strip operation. Strip mining is possible when coals seams are exposed or near the surface. Favourable conditions for strip mining also include a low dip deposit with thick seams. High subsurface deformation and variable or steep dips will restrict the volume of mineable coal. As suggested in the Arctech report, permafrost conditions in the N.W.T. are likely to prohibit strip mining. However, in the Yukon, such areas as the Whitehorse Trough and Tintina Trench could probably be strip mined.

b) Transporation: Table 4 describes the communities in "nearest" proximity to identified coal deposits. It is clear that coal transportation distances can be considerable, assuming that electricity is not generated at the mine. The type of coal transportation depends on the market, e.g., domestic or export use, physiography, e.g., a mine to load centre route over rough terrain; and climate, e.g., permafrost conditions. For example, one Arctech Services report suggests that in the Arctic Region, a barge-tug system could be used during ice free periods. During freeze-up, options include a sleigh or wheel wagon pulled by a cat or big wheel trucks on winter roads. In additions to coastal barge or winter roads, coal could be transported by highway, river barge or rail.

One recent study at the University of Alaska examines transportation options for bringing North Slope low grade coal to export shipping facilities.[4] Rail construction, while technically feasible in permafrost conditions, is considered very costly.

In examining another option, slurry pipelines, the study notes that they must be linked to large-scale development, i.e., both large reserves and long-term markets are needed. Slurry pipeline development in the Territories also seems limited by potential the impacts of permafrost construction and the need for significant volumes of water as a slurry flow medium.

The University of Alaska report also concludes that road development and truck operation costs would make that option unfeasible. The report concludes that on-site coal gasification will likely become the feasible method for bringing coal resources on-stream. Of course, gasification entails certain transportation requirements, as is discussed in Section 5.2.3.

c) End-Use Considerations: The Arctech Services study identifies an important consideration with respect to end-use. That is, it is possible that the development of coal to meet one end-use could foster development to meet others. For example, as Arctech suggests, low grade coal from the East Mackenzie Arctic Plain (Nos. 1-15 on the map) might be used to supply mine development or Beaufort Sea oil and N.G. exploration. In developing the deposits, communities such as Paulatuk and Aklavik could then tie into the supply infrastructure.

The following discussion examines the energy conversion options once the coal is supplied to the community, although it should be noted that the conversion processes are applicable at the mine site. The N.W.T. and Yukon Reports suggest that coal could be utilized for mine, residential, or commercial space heat and electricity needs. As previously noted, one of the major considerations is whether or not the conversion technologies can be scaled down to community loads, e.g., Pond Inlet with a 1979 peak electricity laod of 1.7 MW and an annual heating load of 62 terajoules.

At the community scale, the Arctech Services report suggests the use of multi-fuel forced air furnaces or fully automated stoking furnaces, the former for residential purposes and the latter to meet commercial needs. Further analyses will have to assess the economics of installing furnaces in each residence versus the use of community district heat or cogeneration systems. Nevertheless, as noted in the N.W.T. Report, conventional furnace combustion of coal can emit both particulates and chemicals that are potentially harmful to the environment. Given the uncertainty associated with such coal combustion, two other options are considered: fluidized-bed combustion and coal gasification.

5.2.2 Technology Description

Fluidized-bed Combustion

Figure 3 is a schematic that illustrates the fluidized-bed concept. Essentially, if a vertical cyclinder of any cross section is closed off at the bottom with a perforated plate and is partly filled with a granular solid material, and if sufficient air or gas is blown up through the perforated plate, then the bed of granular material is vigourously swirled by the rising bubbles; i.e., it is fluidized.

Fluidized-bed combustion consists of a granular bed material, usually silica or char and air or oxygen as the fluidizing medium. When the fluidizing medium is preheated, a temperature high enough for ignition results.[5] Under these conditions virtually any fuel will burn; in fact, numerous studies have suggested fluidized-bed combustion (F.B.C.) as an appropriate conversion process for wood, peat, and municipal refuse.[6]

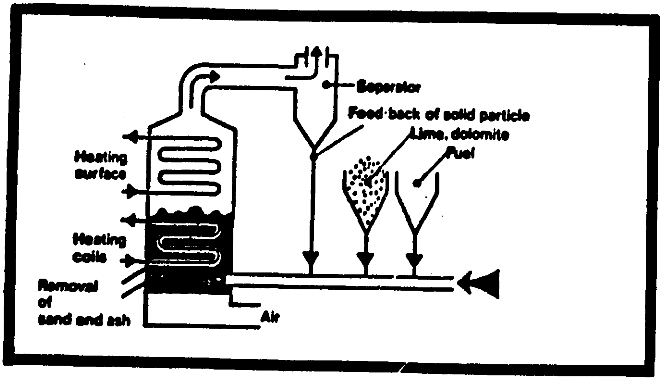
5.2.3 Technology Assessment

Fluidized-bed Combusion

a) Advantages and Disadvantages: The F.B.C. process is characterized by the excellent mixing of solids, solids and gases, and excellent

FIGURE 3

FLUIDIZED COMBUSTION



Source: F.D. Friedrich, Fluidized-Bed Combustion - An Emerging Technology, CANMET Report 79-39.

heat transfer. Moreover, the heat sink provided by the large mass of inert bed material serves to moderate the temperature at which the combustion proceeds. The advantages of low temperature F.B.C. include the capacity to:

i) minimize problems associated with slagging and sintering of ash;

ii) minimize oxide and heavy metal emissions;

iii) minimize sulphur dioxide emissions; and

iv) use fuel with minimal preparation.[5,7]

The major disadvantage of F.B.C. is the high power requirement needed in providing combustion air at pressures of 12 to 15 kPa. Consultations at C.A.N.M.E.T. indicate the possibility of using a coal char light-up, similar to lighting a barbecue or the use of process energy that would be fed back into the system.

b) <u>Commercial Availability and Range of Application:</u> There are basically two types of F.B.C. units, <u>atmospheric</u> and <u>pressurized</u>. The atmospheric F.B.C. units include adiabatic* and cooled types.

Adiabatic atmospheric F.B.C. units have been commercially available for a number of years primarily as incinerators for high-moisture waste materials including bark, sawdust, sewage sludge, and industrial wastes, e.g., Great Lakes Paper Co. in Thunder Bay uses a unit to incinerate wood waste.

The cooled atmospheric F.B.C. unit is based on the need for cooling when the heat in the fuel exceeds that which can be carried away by the combustion products. These units have been employed primarily as demonstration projects by utilities in the U.S. and Britain. For example, in the U.S., the Tennessee Valley Authority (T.V.A.), is

* Where temperature changes do not involve the exchange of heat with the surroundings.

most active in promoting atmospheric F.B.C. and has recently constructed a 20 MW(e) pilot plant. In Canada, C.A.N.M.E.T. has established a demonstration atmospheric F.B.C. boiler at C.F.B. Summerside using wood chips as a supplementary fuel (up to 30% heat input) for Cape Breton coal.

Pressurized F.B.C. units provide a high rate of combustion and heat transfer making it possible for compact, economical systems having a high energy output. They offer the potential for high efficiency combined - cycle power generation using gas/steam turbine combinations. Discussions at C.A.N.M.E.T. indicate that this design will require about ten to fifteen years of development before it can be used commercially.

Literature reviews and consultations indicate that current and projected F.B.C. development is aimed at large-scale power generation, e.g., 50 MW to 200 MW. Although demonstration projects indicate the technical feasibility of F.B.C. at 20 MW, arguments have been put forward for economies of scale. Discussions with the Saskatchewan Power Corporation (S.P.C.), which is examining various means for utilizing Saskatchewan's low grade coal, indicate their research suggests F.B.C. at a scale of less than 10 MW to be impractical. However, both C.A.N.M.E.T. and S.P.C. officials agree that the focus on large scale use has obscured the possibilities for Territorial-scale community application.

c) Heat Storage: The application of total energy systems is based on the use of as much available energy as possible. Work going on at the Department of Chemical Engineering, University of Waterloo is exploring means for storage of F.B.C. produced heat. In particular, they are examining a baffled fluidized bed heat transfer column that would transfer heat between the storage solids and a heat transfer blind burried in the fluidized mass. Potential Territorial applications include:

i) power generation storage;
ii) solar power plant storage; and
iii) commercial and domestic heating system storage.

5.2.4 Technology Description

Coal Gasifiers

Recent research and actual application indicates that coal gasifiers may be an appropriate community-scale coal conversion technology. At present, a number of utilities, including the S.P.C., Ontario Hydro, and C.A.N.M.E.T. are researching the applicability of gasifiers for a variety of Canadian coal types.

Coal can be gasified in either fixed bed atmospheric gasifiers or fluidized-bed atmospheric and pressurized gasifiers. When gasified using air as a medium, a low Btu nitrogen rich gas is produced that can be utilized as a fuel gas in a power station or industrial plant. Medium Btu gas produced in a process with pure oxygen can be used as an input to the production of synthesis oil, gasoline or N.G.

Recently, the Alberta Energy Resources Conservation Board in forecasting prices for N.G. and mineable coal concluded that synthesis N.G. will be directly competitive with N.G. prices by 1980.[8] This forecast suggests that gasified coal should be considered as a Territorial supply option.

5.2.5 Technology Assessment

Coal gasifiers

A 1979 S.P.C. report describes the technical and economic evaluation of four commercially available small coal gasifiers.[9] The focus of the evaluation was to assess the applicability of coal gas for industrial processes, e.g., for cement production. However, consideration was also placed on the possibility of power generation. All four gasifiers were found to be suitable for producing industrial fuel gas from Saskatchewan lignites.

a) Commercial Availability: All four of the gasifiers evaluated in the report have commercial provability in North Dakota and are well suited to lignite coals.

b) Infrastructure Requirements: The S.P.C. report concludes that a four unit Wellman-Galusha gasifier is probably the most appropriate plant for Saskatchewan coals. Infrastructure needs at the plant site include water and electricity inputs as well as a landfill site for ash disposal. One of the major questions to consider regarding infrastructure is transportation. The options include gasification of the mine site and delivery by pipeline or transport of the raw coal input. As mentioned in Section 5.2.1, coal gasification and pipeline distribution was concluded to be the likely option for the large-scale development of lignite coals in Alaska. The S.P.C. report notes, however, that the low heating value of low Btu gas likely precludes the feasible transportation of gas via pipeline.

c) Load Following Abilities: The S.P.C. evaluation was based on an output capacity of 5.3 terajoules/day or approximately 1.32 terajoules/day peak electricity at 25% conversion. This output indicates that the gasifier plants have more than enough capacity to meet Territorial community power loads. The gasifiers have a turndown to 20 or 25% capacity to meet fluctuating loads. However, the S.P.C. report suggests that due to higher gas costs at low throughput, gas plants should only be considered as base load plants.

d) Economic Feasibility: Process inputs were costed at values that would be much less than input costs in the Territories. For example, coal was $6.50 per standard ton, water $0.55/m^3$, and electric power was 1.4¢/kWh. The S.P.C. report examines the possibility of using hot coal gas for certain industrial processes. For power generation using a gas turbine, a clean gas is required. The cleaning process results in a cool gas with a lower energy potential. Cleaning requirements increase plant costs. For example, the S.P.C. report indicates a plant cost increase of approximately $6 million (1979 $)

to $22 million. With the Wellman-Galusha plant, the cost of producing a medium Btu cold, clean gas was estimated to be $3.41/gigajoule (1979 $).

The S.P.C. report does not examine the possibility for district heating using the components described in Section 5.2.3. The economics of a total energy system using coal gas, especially pertaining to Territorial communities, is still open to analysis.

e) Applicability of Wood Gasifiers: A recent N.R.C. report describes a variety of projects aimed at the develoment of community-scale wood gasifiers.[10] The gasifiers are described further in Section 8. Discussions with C.A.N.M.E.T. officials indicate, however, that wood gasifier technology is, without considerable technical difficulty, often applicable to the conversion of coal.

5.3 Contacts and References

5.3.1 Contacts (Inventory Data)

1. Dr. D. Gibson, Coal Resources Assessment Group, Institute of Sedimentary and Petroleum Geology, Calgary, (I.S.P.G.) (403) 284-0110

2. Dr. Davis Hughes, Coal Resources Assessment Group, I.S.P.G., Calgary. (403) 284-0110

3. Dr. John Walsh, Senior Advisor Coal Branch, Conservation and Non-Petroleum Energy, Sub-Sector, Energy, Mines and Resources Canada. 995-9351

Technical Data

1. Graham Taylor, C.A.N.M.E.T. (613)996-4570 (176)
2. Guy Sirianni, C.A.N.M.E.T. (613)996-4570 (236)
3. David Fung, C.A.N.M.E.T. (613)996-4570 (234)
4. Luigi Mysack, C.A.N.M.E.T. (613)996-4570 (132)

a) Commercial Availability: All four of the gasifiers evaluated in the report have commercial provability in North Dakota and are well suited to lignite coals.

b) Infrastructure Requirements: The S.P.C. report concludes that a four unit Wellman-Galusha gasifier is probably the most appropriate plant for Saskatchewan coals. Infrastructure needs at the plant site include water and electricity inputs as well as a landfill site for ash disposal. One of the major questions to consider regarding infrastructure is transportation. The options include gasification of the mine site and delivery by pipeline or transport of the raw coal input. As mentioned in Section 5.2.1, coal gasification and pipeline distribution was concluded to be the likely option for the large-scale development of lignite coals in Alaska. The S.P.C. report notes, however, that the low heating value of low Btu gas likely precludes the feasible transportation of gas via pipeline.

c) Load Following Abilities: The S.P.C. evaluation was based on an output capacity of 5.3 terajoules/day or approximately 1.32 terajoules/day peak electricity at 25% conversion. This output indicates that the gasifier plants have more than enough capacity to meet Territorial community power loads. The gasifiers have a turndown to 20 or 25% capacity to meet fluctuating loads. However, the S.P.C. report suggests that due to higher gas costs at low throughput, gas plants should only be considered as base load plants.

d) Economic Feasibility: Process inputs were costed at values that would be much less than input costs in the Territories. For example, coal was \$6.50 per standard ton, water \$0.55/m^3, and electric power was 1.4¢/kWh. The S.P.C. report examines the possibility of using hot coal gas for certain industrial processes. For power generation using a gas turbine, a clean gas is required. The cleaning process results in a cool gas with a lower energy potential. Cleaning requirements increase plant costs. For example, the S.P.C. report indicates a plant cost increase of approximately \$6 million (1979 \$)

5. Frank Friedrich, C.A.N.M.E.T. (613)996-4570
6. David Brown, C.A.N.M.E.T. (613)996-4570 (191)
7. Mick Barrabas, S.P.C. Regina (306)359-1216
8. Donald S. Scott, University of Waterloo (519)885-1211 (3376 or 2703)
9. Maurice Bergeron, University of Western Ontario (519)679-3326

5.3.2 References

1. N.W.T. Report, pp 76-83
   Yukon Report, pp 65-67
2. Arctech Services. Community Coal Utilization in the Northwest Territories. A report prepared for the N.W.T. Department of Economic Development and Tourism, 1978.
3. Campbell, J.D. Guide to Coal Deposits, Yukon and MacKenzie Territories: A Compilation Research Council of Alberta Report 66-6.

   Hughes, J.D. and Long D.G.F. Geology and Coal Resource Potential of Early Tertiary Strata Along Tintina Trench, Yukon Territory. Geological Survey of Canada Paper 79-32.

   Long, D.G.F. Lignite Deposits in the Bonnet Plume Formation, Yukon Territory. Geological Survey of Canada Current Research Paper 78-1A, 1978.
4. Clark, Paul R. Mineral Industry Research Laboratory, University of Alaska. Report No. 30. Fairbanks Alaska, 1973.
5. Friedrich, F.D., Canada Centre for Mineral and Energy Technologies (C.A.N.M.E.T.). Fluidized-Bed Combustion - An Emerging Technology. C.A.N.M.E.T. Report 79-39.
6. See Section 8.
   B.H. Levelton and Associates Ltd. An Evaluation of Wood

Waste Energy Conversion Systems Western Forest Products Lab, Vancouver, 1978.

7. C.H.2M Hill Canada Ltd. Pollution Control Implications of Fluidized-Bed Technology For Coal-Fired Steam Electric Power Generations. Environment Canada March 1981.

8. Northern Miner. Canadian Coal Industry Report. Northern Miner Press Ltd., 1980, p. 101.

9. Saskatchewan Power Corporation. Small Gasifiers Applications. S.P.C., 1979.

10. B.A. Summers ed. Bioenergy Research and Development. A Summary of the Programs to March 1980 (Ottawa N.R.C. 1980).

5.4 Recommendations

It is suggesed that further analyses be carried out with respect to both coal inventory compilation and conversion technology assessment. This work should include:

i) comprehensive geological, geophysical, and geochemical surveys of coal deposits identified to be in proximity to communities with demonstration project potential. Such an inventory compilation could be complimented by in-depth coal characteristic analyses from C.A.N.M.E.T.;

ii) further technical and economic assessment of F.B.C. and coal gasification technology based on existing work;

iii) pre-feasibility studies on the application of either F.B.C. or coal gasification technologies for selected communities.

iv) exploring F.B.C. or gas turbine total energy systems.

6. NUCLEAR POWER

A recent submission by R.W. Spence (Giant Yellowknife Mines) to a House of Commons sub-committee recommends that the N.C.P.C. invest in the deployment of Safe Low Power Critical Experiment (S.L.O.W.P.O.K.E.) 2 MW (thermal) reactors to provide space heating in selected N.W.T. remote communities.[1] The submission represents major implications for the development of indigenous energy resources in the Territories.

First, the Spence submission suggests that there may be a certain level of Territorial interest and support for small-scale nuclear development, especially among the mining community. Second, it suggests that the developers of nuclear technology perceive remote community heating as a potential future market. Third and most importantly, the submission suggests that all of the issues and debates associated with nuclear technology development must now enter the realm of northern energy strategy planning.

Given the importance of the third implication, it seems evident that an approach somewhat different from that taken for the previous sections in this report be applied to nuclear technology. More specifically, a thorough review would have to evaluate not only technical factors but: health and safety impacts from the entire nuclear fuel "cycle"; the costs of development intangibles, e.g., health costs, decommisioning; the contribution of civil nuclear technologies to weapons proliferation; and the potential diversion of research and development monies that could promote the development of renewable community-scale energy options.[2] Since addressing the foregoing factors is not within the mandate of this report, the following discussions review the S.L.O.W.P.O.K.E. technology and identifies apparent limitations to some technical and economic arguments.

6.1 Technology Description

The research and development of the S.L.O.W.P.O.K.E. is one of the latest stages in the evolution of Canadian nuclear technology. Since the wartime collaboration on the atomic bomb development, Canada's peacetime nuclear industry has grown to a level where it supplies approximately 8% of installed electrical generating capacity in Canada, approximately 22% in Ontario.[3] The technology behind this power is the C.A.N.D.U. reactor.

The C.A.N.D.U. (Canadian Deuterium Uranium) reactor has been designed to produce power at the 1000 MW plus scale. The reactor uses natural uranium in fuel bundle arrangements with deuterium (heavy water) acting as both moderator and coolant. In producing electricity at such a high scale of output, the C.A.N.D.U. must operate at extremely high temperatures and pressure, thereby necessitating the availability of stringent safety systems.

Conversely, the small-scale S.L.O.W.P.O.K.E. reactor is currently used in a number of Canadian Universities as a research and teaching tool. The fuel consists of enriched uranium and light water acts as both coolant and moderator (see Figure 4).[4] The advantages of S.L.O.W.P.O.K.E. II as a reserach tool are that:

(i) it avoids complexities and high costs normally associated with existing nuclear reactors;

(ii) it can be easily turned on or off;

(iii) it can operate continuously for ten years on a single fuel charge;

(iv) its safety of operation is "assured" by limiting the maximum excess reactivity, i.e., if the water overheats, it becomes less dense and at a certain minimum density the reaction stops along with the overheating; and

(v) no full-time operators are needed.

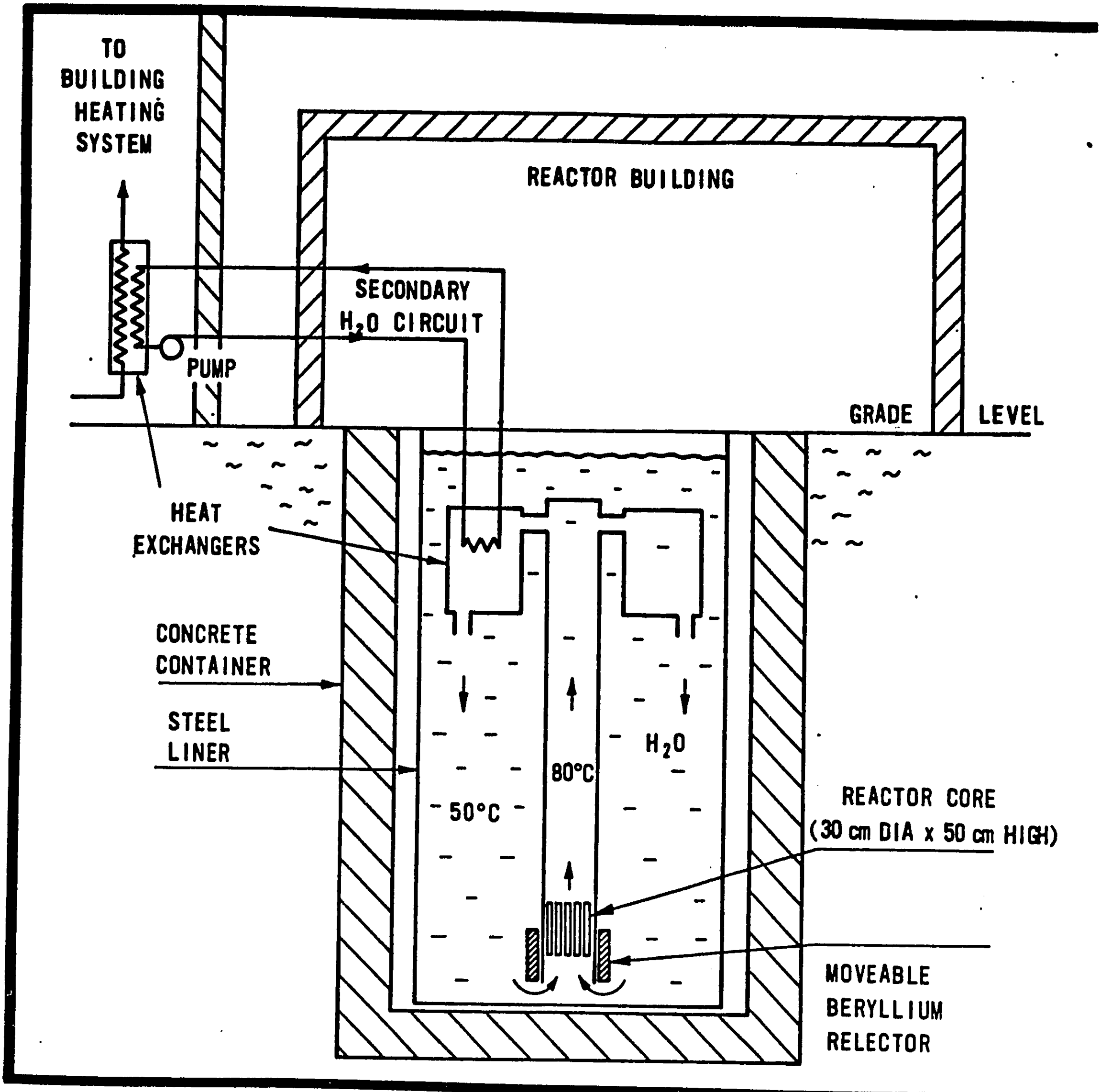
These attributes are the goal of S.L.O.W.P.O.K.E. III.

S.L.O.W.P.O.K.E. III is essentially a scaled-up version of the university model. In the application that R.W. Spence envisages, the scaling-up involves a transition from 20 KW to 2000 KW thermal. At present, a number of European countries have installed or are in the process of installing small scale, i.e., 60 to 200 MW reactors for district heating systems.[5] With a similar focus, A.E.C.L.'s research at Chalk River, Ontario is aimed at developing a commercially feasible reactor "... for the 1990's which A.E.C.L. can manufacture in quantity and sell in world markets."[5] (page 2)

According to Hilborn and Spence, the economic analaysis for the S.L.O.W.P.O.K.E. III is based on the following variables: a capital cost of $1

FIGURE 4

2 MW SLOWPOKE HEATING REACTOR



Source: J.W. Hiborn and J.S. Glen; Small Reactors For Low Temperature Heating, Summary of a paper presented to the Canadian Nuclear Association, 1981.

million (1981$), a 20-year reactor life, two years per fuelling at a 50% annual capacity factor; a discount rate of 4% real; and Territorial fuel oil at $3.75 /gigajoule (domestic) and $6.19/gigajoule (imported). Spence concludes that the deployment of 50 S.L.O.W.P.O.K.E.S. at $1 million each would result in a profit of $25 million per year for N.C.P.C. Hilborn concludes that S.L.O.W.P.O.K.E. thermal power at $29 thousand/kWh is comparable in 1981 with delivered oil costs.

6.2 Technical and Economic Questions

1. One of the major attractions of the S.L.O.W.P.O.K.E. II used in universities is that it does not produce enough energy for a major catastrophe, e.g., a meltdown, to occur. However, a scaling-up by a factor of 100 also means a signficant increase in heat production, an increase that may be high enough for meltdown temperatures to occur and for gaseous or volatile fission products to be emitted. Furthermore, if the S.L.O.W.P.O.K.E. design is modified to meet both heating and electricity loads, as appears to be necessary for both northern communities and mining companies, the energy output of the reactors would have to be higher, i.e., electrical installed kW capacity = 3 X thermal installed.

2. Although the aim of the S.L.O.W.P.O.K.E. III, as shown by S.L.O.W.P.O.K.E. II, is to limit or avoid the need for supervisory personnel, the design modifications may result in a model that necessitates refuelling and maintenance personnel. Past experience with small-scale U.S. army reactors indicates that the infrastructure needs made nuclear heating costs prohibitive.[6]

3. The simplied economic analyses presented by Spence and Hilborn do not take into account the costs of district heating systems. In addition, operation and maintenance costs are not made explicit.

4. The economic analyses presented by Spence and Hilborn are based on a 4% real rate of return. The real rate of return to capital in the private sector is about 7.5% before taxes.[7] It appears that the reasoning behind a 4% rate is similar to that of Ontario Hydro:

(i) low rate bonds are guaranteed by the province;
(ii) the utility is not subject to provincial income tax; and
(iii) the utility does not have to pay dividends to its owners.

If a higher discount rate was used, i.e., one that more clearly reflects investment risks, the cost of S.L.O.W.P.O.K.E. nuclear power would be higher.

5. According to the A.E.C.L., S.L.O.W.P.O.K.E. III is not likely to be commercially available until the late 1980's at the earliest. Given the district heating, transportation and storage infrastructures associated with reactor deployment in each community, it is important to consider the costs of investing in one energy option to 1990 and then converting at escalated costs to nuclear power.

6.3 Contacts and References

6.3.1 Contacts

1. Colin G. Lennox, A.E.C.L. Ottawa (613) 236-6444
2. John Hilborn, A.E.C.L. Chalk River (613) 584-3311
3. Norm Rubin, Energy Probe Toronto (416) 978-7014

6.3.2 References

1. Spence, R.W. A Brief Respecting the N.C.P.C. Presented to the Sub-Committee on the N.C.P.C., a sub-committee to the standing committee of the House of Commons on Indian Affairs and Northern Development. Yellowknife, April 27, 1981.

2. There is a considerable volume of books and reports devoted to the debate of nuclear power technologies. Some of the more relevant are:

   (a) Lovins, Amory B. and Price, John H. Non-Nuclear Futures, San Francisco: Friends of the Earth International and Ballinger Publishing Co., 1975.

   (b) Lovins, Amory. Soft Energy Paths: Toward A Durable Peace, San Francisco: Friends of the Earth International and Ballinger, 1977.

(c) Nash, Hugh, ed. The Energy Controversy, Soft Path Questions and Answers, San Francisco: Friends of the Earth, 1979.

(d) Regehr, Ernie. The Utilization of Resources for Military Purposes in Canada and the Impact on Canadian Industrialization and Defense Procurement. A report prepared for the U.N. Group of Governmental Experts on the Relationship Between Disarmament and Development, May 1980.

(e) Stobaugh, R. and Yergin D. Energy Future: Report of the Energy Project at the Harvard Business School. Random House, 1979.

(f) Harding, Bill. Uranium: Correspondence with the Premier, Regina Group for a Non-Nuclear Society, 1979.

(g) Porter, Arthur B. Report of the Royal Commission on Electric Power Planning in Ontario (seven volumes) 1979.

3. Energy, Mines and Resources Canada. Electric Power in Canada, 1979.

4. Atomic Energy of Canada Ltd. S.L.O.W.P.O.K.E. A descriptive brochure.

5. Hilborn, J.W. & Glen J.S. Small Reactors for Low Temperature Heating. Summary of a paper presented to the Canadian Nuclear Association, Ottawa, May 1981.

6. Rosen, M.A., Roll, T.B., and McFarren, R.D. United States Atomic Energy Commission Portable Reactor Power Plants (undated).

7. Gibbons, Jack O. Electric Heating: Does it Make Sense for Ontario. Toronto: Energy Probe 1981.

6.4 Recommendations

The complex issues associated with nuclear power development have prompted numerous suggestions for a moratorium on further nuclear development until all of the issues have been reviewed with full public input. It seems necessary, therefore, for at least the same level of concern to be focussed on the northern environment. It is recommended that no consideration be given to S.L.O.W.P.O.K.E. applications in the Territories until all issues are addressed in an appropriate medium.

7 HYDRO POWER

7.1 Hydro Inventory

This section considers community hydro-electric supply from two source options: grid-extension and micro-hydro units. Given that the current peak electrically demand in Territorial communities is small, generally less than 1 MW, it should be kept in mind that the impetus for grid extension may come from major demand sources such as mines, smelters, or pipelines. On the other hand, micro-hydro application, which can supply up to 2 MW power, can be considered for community residential/commercial demand.

1. Grid Extension

At present, the N.C.P.C. is considering the grid extension option primarily for the Yukon River system. However, such grid extension options are based on uncertain mine development in the 1980's. The development uncertainty is exemplified by the shelving of at least three proposed mining developments in the 1970's. As a result, only tentative grid extension forecasts are available from N.C.P.C.

Since 1962, a variety of reports have been compiled on the potential of the Yukon River Basin to produce power[1,3,11] and as many as seventeen potential sites identified. Recently, N.C.P.C. commissioned a series of preliminary feasibility/engineering studies on five selected sites in the Yukon River Basin. Three available reports identify power potential, and develop preliminary plans for hydro site development and connection with a grid. Table 9 is a summary of the major findings of these reports [12,13,14] and Map 3 shows their location. Should any of these projects proceed, it is not yet clear what grid extensions will be implemented.

To a large extent, the possible grid extensions will depend on mine developments. As Map 3 shows however, it is likely that a new line will eventually be completed to Dawson, connecting the now isolated Mayo-Elsa transmission grid and serving the remote communities of Dawson, Stewart

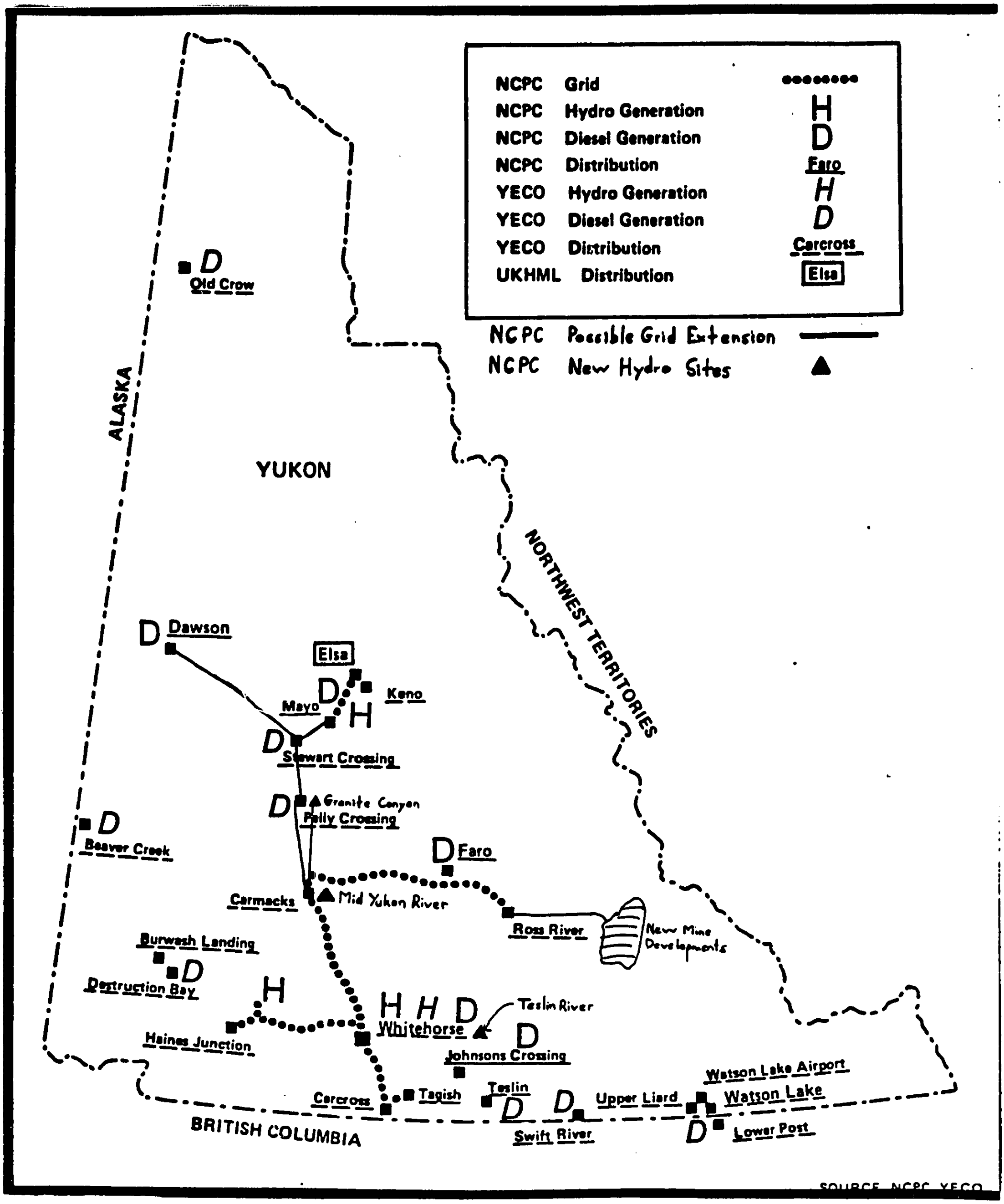
TABLE 9 - A SUMMARY OF FEASIBILITY STUDIES IN THE YUKON RIVER BASIN

River	Consultant and Date of Study	Site and Location	Scheme	Head m	Total Installed Capacity MW	Average Generation Cost ¢/kWh 1980$	Storage Requirements km^2	Transmission Requirements
Mid-Yukon	Monenco, 1980	15 km west of Carmacks	A	40[a] 86	320	3.1	152	on existing grid
			B	86	240	2.9	152	on existing grid
Teslin	Shawinigan, 1980	60 km ENE of Whitehorse		27	55	6.2	380	60 km of 138 kW to Whitehorse
Pelly River	Acres, 1980	15 km east of Pelly Crossing		40	120	3.9	264	125 km of 138 kW to Carmacks

SOURCES: 12, 13, 14

NOTES: a) Scheme A involves 2 dams

MAP 3 - POSSIBLE GRID EXTENSION IN THE YUKON



Crossing and Pelly Crossing.

In the Northwest Territories, no immediate plans for major hydro development or grid extensions are evident. The location, timing, and extent of these will depend on major industrial growth. Developments such as the Norman Wells pipeline may spur hydro power supply. In this regard, the N.C.P.C. is reexamining the considerable potential of the Great Bear River system.

2. Micro-Hydro

To date, studies have never been initiated to explore micro-hydro potential in the Territories. Therefore, essential community-specific inventory data such as river flow, storage requirements, and community proximity are not available. A range of reports do exist, however, (see Section 7.3.2) that estimate the potential of Territorial Rivers for large-scale hydro develpoment. In the absence of more complete data, Table 10 and Map 4 were compiled by identifying Territorial communities and noting potential hydro sites within an 80km radius.

7.1.1 Inventory Data Limitations

The following list is a compilation of both grid extension and micro-hydro inventory data limitations.

Grid Extension

(a) Although it may be relatively easy to identify communities that could be linked to the grid, the actuality of grid extension depends on factors such as major development prospects. Therefore, the grid projections illustrated on Map 3 are incomplete and tentative.

Micro-Hydro

(a) River flow data are outdated.
(b) Identified costs do not include transmission and maintenance.
(c) The 80km radius chosen for the hydro inventory determination does not

TABLE 10

COMMUNITY SPECIFIC TERRITORIAL HYDRO RESOURCES

Community	On-Grid	Rivers	Assessed Firm Power Sites at 80km. Proximity	Estimated Capital Cost		Storage Factors	Map Reference
			MW	$/KW	(Year)		
Whitehorse	yes	Yukon	34	264	1961	No storage	1
		Teslin	83	650	1961	storage required	
Carmacks	yes	Yukon	215	368	1961	storage required	2
		Yukon	336	272	1961	storage required	
Mayo	yes	Stewart	174	333	1961	storage required	3
		Stewart	139	699	1961	storage required	
Minto Bridge	yes	N. McQuestern	3	3740	1967	diversion to McQuestern	3
Elsa	yes	Ethel Lake	5	903	1967	diversion to Stewart	3
Keno Hill	yes	Lake Creek	8	1475	1967	Diversion to Stewart	3
Calumet	yes	Mayo	5	860	1967	downstream to existing plant	3
Pelly Crossing	no	Pelly	333	602	1961		4
		Pelly	112	843	1961		4
		Mica Creek	10	1,600	1967		4
		Pelly	181	380	1967	storage required	4
			124	350	1967	storage required	4
		Yukon	360	335	1961	storage required	4
Stewart Crossing	no	Stewart	250	493	1961	storage required	5
McQuestern	no	Stewart	101	396	1961	storage required	5
Dawson	no	Yukon	500	286	1961	storage required	6
		Sixty Mile	12	1,830	1967	U	6
		Indian	4	2,610	1967	U	6
		Forty Mile	9	1,170	1967	U	6
		Fifteen Mile	4	2,360	1967	U	

Community	On-Grid	Rivers	Assessed Firm Power Sites at 80 Km. Proximity	Estimated Capital Cost		Storage Factors	Map Reference
			MW	$/KW	(Year)		
Old Crow	no	Porcupine	105	923	1964	storage required	7
Aklavik	no	Porcupine	67	870	1964	storage required	8
		Arctic Red	24-36	U	1970	on site	8
Fort McPherson	no	Peel	319	U	1964	storage required	8
		Arctic Red	24-45	U	1970	on site	8
		Arctic Red	51	U	1972		8
		Arctic Red	41	U	1972		8
Arctic Red River	no	Arctic Red	30-51	U	1970	on site	8
		Peel	68	U	1972		8
Beaver Creek	no	White	10	1,560	1967	storage available with a	9
		White	10	2,640	1967	diversion to the White River	9
Snag	no	Donjek	26	3,660	1967		9
Burwash Landing		Kluane	7	880	1967		10
Haines Junction	yes	Aishihik	4	643	1967		11
Carcross	yes	Primrose	19	1,100	1967		12
		Watson	2	4,450	1967		12
Ross River	yes	Pelly	8	1,260	1967		13
		Ross	20	1,500	1967		13
Faro (Cyprus Anvil)	yes	Dreery Lake	3	1,210	1967	two schemes have been suggested	14
		Pelly	50	965	1967	that would entail river diversions	14
		Anvil Creek	6	1,310	1967	to the Pelly river	14
		Tay	19	1,400	1967		14
		Earn	4	2,130	1967		14

Community	On-Grid	Rivers	Assessed Firm Power Sites at 80Km. Proximity MW	Estimated Capital Cost $/KW	(Year)	Storage Factors	Map Reference
Thompson Landing	no	Lockhart	6	490	1968		15
Fort Reliance	no		38	272	1968		15
			30	276	1968		15
			38	349	1968		15
			20	383	1968		15
			31	416	1968		15
			12	449	1968		15
			15	452	1968		15
			19	444	1968		15
Snowdrift	no	Snowdrift	6	2,500	1968	storage required	16
Fort Smith	yes	Tazin	5	1,243	1968	storage required	17
		Tazin	8	816	1968	storage required	17
		Tazin	3	810	1968	storage required	17
Fort Liard	no	Beaver	5	2,967	1969		18
Watson Lake	no	Francis	8	1,157	1969		19
		Liard	12	1,301	1969	no storage required	19
Baker Lake	no	Kazan	8	710	1969	storage provided	20
			41	782	1969		20
Norman Wells	no	Mountain	6-36		1970	on-site resevoir	21
(Fort Norman)			6-21		1970	on-site resevoir	21
			6-42		1970	on-site resevoir	21
			6-15		1970	on-site resevoir	21
			6-12		1970	on-site resevoir	21

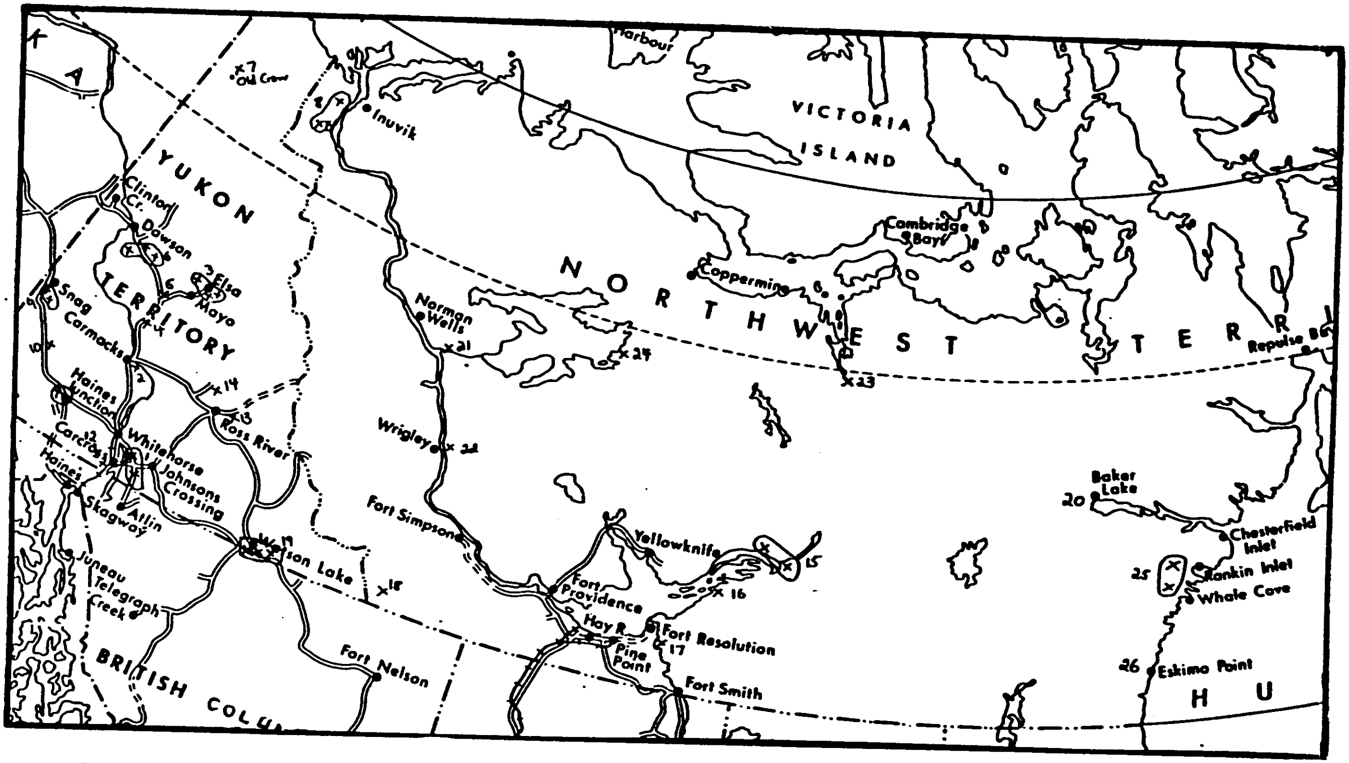
Community	On-Grid	Rivers	Assessed Firm Power Sites at 80Km. Proximity	Estimated Capital Cost		Storage Factors	Map Reference
			MW	$/KW	(Year)		
Norman Wells	no	Great Bear	162-210		1970	storage at outlet of	21
(Fort Norman)			126-162		1970	Great Bear Lake	21
			114-144		1970		21
Wrigley	no	Redstone	51-81		1970	upstream storage required	22
			30-51		1970	on-site resevoir	22
		Dahadinni	15-96		1970	upstream + on-site resevoir	22
		Root	21-33		1970	on site resevoir	22
			18-33		1970	on site resevoir	22
Bathurst Inlet	no	Burnside	57	6,700	1978	on site storage required	23
			189	7,400	1978	on site storage required	23
Port Radium	no	Camsell	20	6,058	1978		24
Whale Cove (Rankin Inlet)	no	Ferguson	3	11,700	1979	dams recommended to divert flow	25
Eskimo Point	no	Magise	7	11,900	1979	dams recommended to divert flow	26
			5		1979		26

LEGEND: U represents unavailable data

SOURCES: 1. See Section 7.3.2.

NOTES:
a) Firm power is an estimate of maximum energy output during minimum flow conditions
b) On-site storage represents storage behind a dam structure at the generating site. Upstream storage generally indicates storage behind a dam structure upstream from the generating site.

MAP 4 - HYDRO-ELECTRIC RESOURCES IN THE YUKON AND NORTHWEST TERRITORIES



SCALE: 25.4mm = 322km

LEGEND: x indicates potential power site
1 to 26 are reference numbers to correspond to Table 4

SOURCES: See Section 7.3.2.

represent a distance at which power delivery has been assessed to be economically feasible.* Rather, the radius represents the maximum distance at which potential was noted.

(d) In general, data were accumulated from studies that surveyed the potential for large scale (greater than 100 MW) hydro-electric development. Therefore, it should be noted that identified rivers may supply small and micro-scale hydro at considerably different costs.

(e) Data do not indicate whether or not up-stream or on-site storage will be necessary for small and micro-hydro sites.

(f) Table 10 does not establish firm power potential.

---

* Recent studies in Northern Ontario and British Columbia have used 20 km. and 24 km. as the maximum distance at which power delivery would be profitable.

See Ontario Hydro Report No. 307-1, Inventory of Potential Hydro-Electric Power Sites for the Supply of Power to Isolated Northern Railway Communities, 1979.

Ontario Hydro Report No. 303-2, Inventory of Potential Hydro-Electric Power Sites for the Supply of Power to Remote Native Communities in Northern Ontario, 1979.

and

Crippen Consultants, A Survey of Potential Micro-Hydro Developments for Use by Remote Communities in British Columbia. A study prepared for the Conservaion and Renewable Energy Branch, E.M.R. Ottawa, 1980.

7.2 Technology Review

This section consideres the current state of development of micro-hydro technology (up to 2 MW) and the considerations to be taken in applying the technology.

7.2.1 Specific Considerations

While the generation considerations outlined in section 3 pertain to the development of micro-hydro sites, the following list describes both specific technical and economic considerations that are likely to affect micro-hydro feasibility.

(a) Technical Considerations:

- The amount of head provided at the site. Power produced is in direct proportion to the available head (fall of water).
- The firm flow of available from the river. Power produced is in direct proportion to the available flow. Minimum flows are important to establish for estimates for available firm power.
- The efficiency of the powerplant to use the available head and flow. Power produced is in direct proportion to the efficiency. Matching the optimum turbine to the available head and flow is important.
- The appropriate design for expected ice conditions.
- The design to augment diesel - back-up

(b) Economic Considerations:

The cost factors of a micro-hydro installation essential to an economic analysis are listed in Appendix B.

In addition to site costs, it is necessary to consider the following:

- The transmission distance to the load centre.
- The preassembly and standardized engineering at the factory that can reduce costly on-site technical work.

- The complexity of civil works, e.g., site clearance, road development, line right-of-way clearance.

7.2.2 Technology Description

A micro-hydro installation may be described as having three key features (see Figure 5 as an example): Civil; Mechanical; and Electrical.

These features will be briefly reviewed here but the reader is referred to Microhydro Volume II by Crippen Consultants[3] for an in-depth report on micro-hydro systems.

(a) Civil works include:

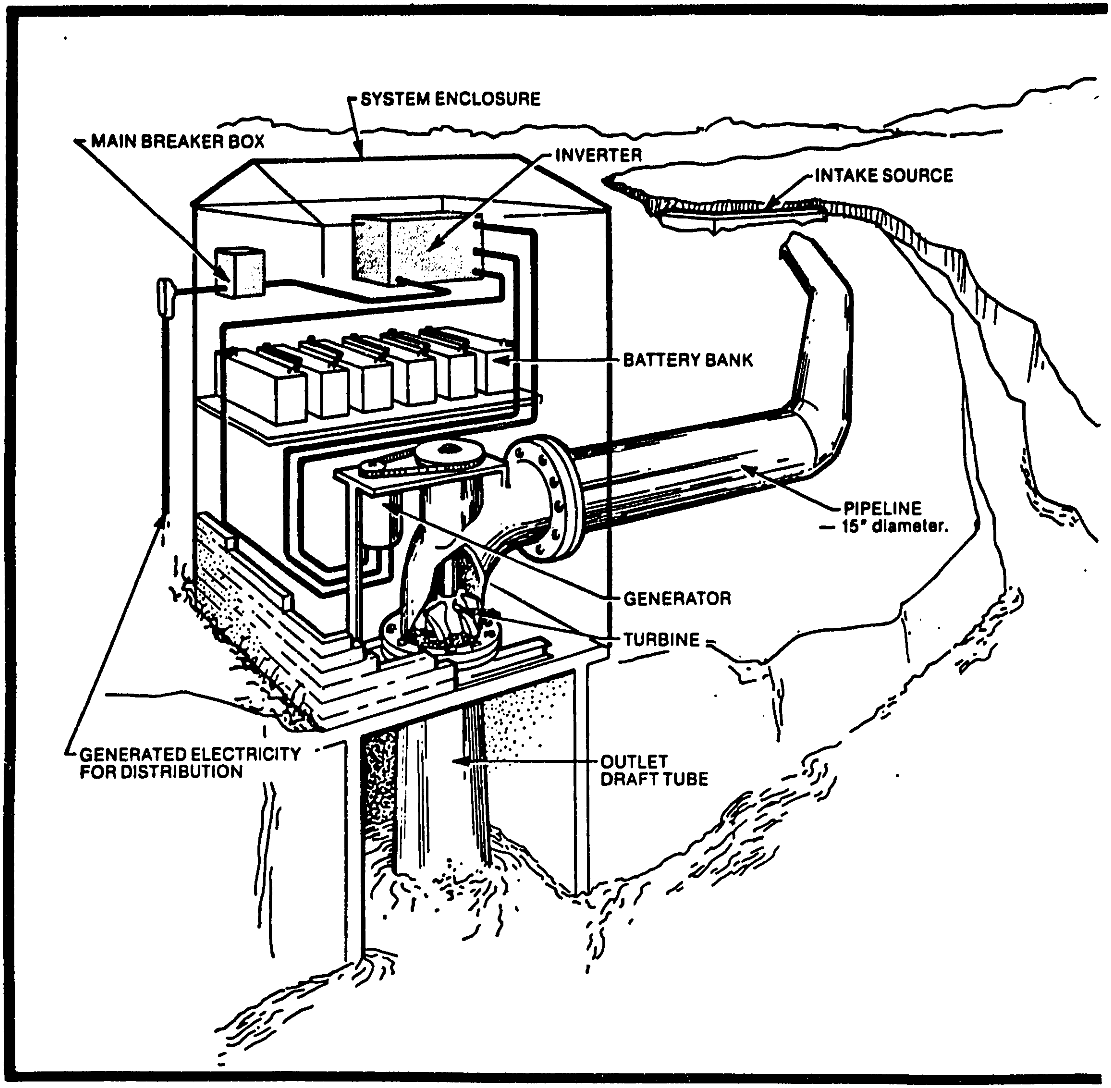
- Dams on diversion structures
- Intake; the entrance through which water is diverted to the turbine. The intake is often supplied with a gate to control flow and a track rack to collect debris.
- Canal or penstock (pipe), the channel by which water is carried to the turbine.
- Powerhouse.
- Tailbrace, the canal emptying water into the river.

(b) Mechanical Equipment:

- Micro-hydro turbines vary according to type and size and exhibit different efficiencies depending on head and flow conditions. The following table illustrates the expected output when specific turbine types are applied to varying heads.

FIGURE 5

A DIVIDED FALL MICRO-HYDRO DEVELOPMENT



Source: Ontario Ministry of Energy, Micro-Hydro Power.

Turbine Type	Head (m)	Output (kW)
Pelton	over 100	50 - 2000
Turgo	15 - 200	50 - 2000
Francis	15 - 200	500 - 2000
Banki (crossflow)	2 - 170	50 - 1000
Propellor (Kaplan)	2 - 15	500 - 2000
pumps (run backwards as turbines)		up to 150

(c) Electrical Facilities:

- Generators.
- Governors which maintain generator speeds within suitable limits by either regulating water flow at the inlet or outlet or by diverting excess electrical capacity to an "energy sink".
- Protection devices include failure and overload devices, relays and shutdown facilities.
- Transmission line and transformers.
- Diesel Back-up is necessary to provide assured power during conditions of low flow or mechanical failure. It is possible to drive the same generator with either a diesel engine or water turbine under proper design considerations. In fact, with clutch linkage between the diesel engine and the generator and with governor settings for the turbine and diesel engine, it is possible to have both governed inputs driving the generator simultaneously.[5] (Vol. II p.7-4)

7.2.3 Technology Assessment

(a) Commercial Availability:

Hydro electricity technology is commercially proven and has changed little over the past fifty years. However, it is only recently that a renewed interest in micro-hydro, primarily for remote applications, has prompted commercialization of these small-scale technologies. As a result, the micro-hydro technology is proven for southern conditions; i.e. south of the Territories, but is yet to be tested in the north.[3]

(b) <u>Major Northern Limitations:</u>

The major problem likely to be encountered is ice. More specifically, it is possible for:

i) river sources to freeze leading to zero flow conditions in the winter when power is most needed. Even in the largest rivers, winter flow can often be reduced to 5% of summer flow;[17]

ii) large storage reservoirs to be required as an assurance of water supply during winter conditions. This could lead to extensive flooding and high civil works costs;

iii) frazil ice* conditions to occur in fast flowing northern rivers. This ice will quickly block intakes and damage mechanical equipment. To avoid frazil ice, intakes should be placed deep within large reservoirs dammed behind the intake where a solid protecting ice sheet can form in the still waters. Others measures to avoid damage to civil and mechanical sturctures include: air bubbling; heated "trash" racks; and mechanical scraping or removal of the trash racks.

(c) <u>Economic Feasibility:</u>

Economic comparisons between micro hydro and large hydro installations or between micro-hydro and diesel installations are difficult to make without specific assessment. Experience in southerly areas suggests that site proponents should attempt to reduce costs by pre-packaging and minimizing civil works.

---

* Frazil ice is a small crystal of ice formed in fast flowing turbulent rivers at freezing temperatures. The crystals readily collect, forming massive ice conglomerates.

Micro-hydro, because of its small size, lends itself to pre-packaged generation units. Pre-assembly eliminates much of the need for costly on-site assembly and engineering staff. As well, it also reduces installation time, a benefit in the short northern construction season*. Sites that can be developed without a dam for run-of-the-river installations are less costly and take less time to install.[6] Run-of-the-river installations, however, are likely to experience the icing problems discussed above.

Micro-hydro costs can be delineated as follows: pre-feasibility and pre-engineering studies; mechanical equipment; and civil works. Pre-feasibility and pre-engineering costs tend to be disproportionately high for micro-hydro because the scope of such pre-construction studies is often comparable to that of large installations. For example, costs for a 2000 MW plant have been cited as \$ 10 million or \$ 5 thousand/MW.[4] The scope of a micro-hydro study would result in a cost considerably higher than \$ 5 thousand/MW.

The total electrical and mechanical equipment costs of a micro-hydro unit have been quoted in the \$350 - \$600 kW range (1979\$).[9] Barber Hydraulics quotes a 1981 installed price of \$722/kW for a pre-assembled micro-hydro unit. This quote, however, does not include site analysis, civil works, transmission costs, and assumes maximum efficiency at a 25 ft. head and 300 ft^3/sec. flow. Costs of civil works, depending on the site, are typically four times \$722/kW.

While overall cost figures for remote location micro-hydro stations are not available, the component costs suggest a figure of \$4 thousand/kW. Other sources have cited a cost of \$10 thousand/kW.[4] In comparison, typical costs for large grid-connected installations are in the range of \$ 1000 to \$ 3000/kW.[4] A 1973 study of the Yukon Basin by Sigma Resource Consultants indicated that the unit costs of thirteen large-scale hydro sites decline with increasing size.[15]

* Two Canadian manufacturers, Barber Hydraulics and Galt Energy Systems, now offer pre-packaged micro-hydro units and prefeasibility services as part of one package.

Typical costs excluding transmission costs and interest payments during construction were:

- $ 1200 - $ 1300/kW for 30-50 MW
- $ 900 - $ 1200/kW for 75-150 MW
- $ 750 - $ 900/kW for 300-350 MW

It is suggested that life cycle cost accounting be used as a method to derive the actual feasibility of a project option over its lifetime, for example, the methodology employed by Underwood McLelland Ltd in a study of eastern N.W.T. rivers.[15]

(d) Institutional Factors:

- To build and operate small plants efficiently requires a flexible and informal style of management. Large organizatoins often have difficulty doing this. One alternative is to allow local mini-utilities or private entrepreneurs to own, build, and operate the facilities. This would require a controlling body (like N.C.P.C.) to set standards for reliability, accountability and profit-making.

- Encouragement can be given to small private owners through tax incentives. The federal incentive allowing owners of micro hydro plants to depreciate investments at a rapid rate is one example.

- Environmental approval is required in most locations before proceeding with a project. Procedures are complex, time-consuming and geared to large projects.

Micro-hydro will have a sometimes small but inevitable impact on the local environment. Community members are often sensitive to these changes and it is prudent to involve them in the development schemes from the beginning to avoid potential conflict.

(e) Current Canadian Applications:

At present, B.C., Ontario and Newfoundland have demonstration projects underway. Table 11 is a compilation of available data on the installations in Ontario, Newfoundland and a proposed development that was scrapped in Saskatchewan.

7.3 Contacts and References

7.3.1 Contacts

a) Supply Inventory

1. J. Long, General Manager, N.C.P.C. Edmonton.
2. D. McGinnis, Head of Engineering, N.C.P.C.
3. Allan Jones, Chief Water Resources Division, D.I.A.N.D. (819) 997-0339
4. Allan Waroway, Water Resources Division, D.I.A.N.D. (819) 997-0339
5. Jack Beale, N.C.P.C. Edmonton

b) Technology Review

1. Bruce Pratte, Hydraulics, Research and Engineering, National Research Council, Ottawa, (613) 993-9381
2. M.R. Wilson, President, Barber Hydraulic Turbine Ltd. Port Colbourne, Ont. (416) 834-9303
3. Fred Schwarz, Remote Community Programs, Ontario Ministry of Energy, Toronto (416) 965-6542
4. Phil Graham, Renewable Energy Demonstratoin Programs, Mines and Energy, St. John's, Newfoundland, (709) 737-2411

TABLE 11 - MICRO-HYDRO DEVELOPMENTS IN CANADA

Name	Wasdell Falls	Sultan	Roddikton	Rapid River
Place	Washago, in mid-Ontario	Ontario (near Sault Ste. Marie)	Newfoundland	Stanley Mission N. Saskatchewan
HEAD (m)	3.1	7.7	47	4
PEAK FLOW (m^3/s)	5.7	2.8		
STORAGE	Behind existing dam	Headpond of 40ha and large lake		Lac La Ronge 38,850 ha
PEAK OUTPUT (kW)	135	150	440	(2 x 500) 1000
TURBINE	Francis Barber Hydraulic Mini Hydel	Francis Barber Hydraulic Mini Hydel	Crossflow	2 turbines Crossflow
COMPLETION DATE	October 1980	April 1980	1981	Scheduled 1980
COMMENTS	Connected to grid Used existing dam	Remote community of 350 Used existing dam	Interconnected with remote diesel back-up	Due to local public resistance the installation was never constructed

SOURCES: 6,2,1

NOTES: See attached page

NOTES

Two Canadian manufacturers of micro-hydro systems are building systems based on principles of pre-assembly, pre-wiring, plumbing and engineering. Prefabrication also minimizes on-site requirements for highly skilled personnel. Pre-assembly of plumbing and wiring permits verification of control systems operation at the shop, thereby reducing commissioning requirements. All these measures help to reduce costs and permit rapid and easy assembly.

(a) Barber Hydraulic Turbine Ltd.
P.O. Box 340
Por Colbourne, Ontario L3K 5W1

(b) Micro Hydel: Head 3-15 m
Power 10-115 kW

Mini Hydel: Head 3-8 m
Power 100-400 kW

(c) Galt Energy Systems Ltd.
Box 1354
Cambridge, Ontario

Head 1-6 m
Power 7.5 kW and up

7.3.2 References

Inventory Data

All of the following studies are available from the Northern Renewable Resources Branch, D.I.A.N.D. Ottawa.

1. Canada, Department of Northern Affairs and National Resources, Yukon River Basin Report, Dec. 1962.

2. Canada, Department of Northern Affairs and National Resources, Hydroelectric Power Resources of the Porcupine, Peel and Rat River Region, Yukon and NWT, April 1965.

3. T. Ingledow and Associates Ltd., Hydroelectric Resources Survey of the Central Yukon Territory, January 1968.

4. T. Ingledow and Associates Ltd., Power Survey of the Central Mackenzie District, NWT, Jan. 1969.

5. T. Ingledow and Associates Ltd., Power Survey of the Liard River Basin, Yukon and NWT, Feb. 1970.

6. T. Ingledow and Associates Ltd., Power Survey of the Kazan, Dubawnt, Thelon and Hanbury River Basins, NWT, March 1970.

7. Gepac Consultants Ltd., Yukon and Northwest Territories Power Survey, Pre-Reconnaissance Study, Sept. 1971.

8. Underwood, McLellan (1977) Ltd., Power Site Survey Northwest Territories for the Burnside, Hood, Camsell, Back and Hayes Rivers, March 1979.

9. Underwood, McLellan (1977) Ltd., Power Site Survey Northwest Territories for the Tha Anne, Thlewiaza, Ferguson and Maguse Rivers, March 1980.

10. Canada, Department of Indian Affairs and Northern Development, Preliminary Field Investigations of Hydro Potential Dam Sites on the Willowlake Root, Redstone, Kule, Mountain, Carcajou, Arctic Red and Peel Rivers, June 1973.

11. Sigma Resource Consultants. The Development of Power in the Yukon. 1974.

12. Monenco Consultants Pacific Ltd. Mid-Yukon Power Development Feasibility Study - Year 1, Volume 1, Summary Report, A Report Completed for N.C.P.C., 1980.

13. Acres Consulting Services Ltd. Granite Canyon Development, Preliminary Engineering Study. A report completed for N.C.P.C. 1980.

14. Shawinigan Consultants Ltd, Teslin River Hydro Power Study. A report completed for N.C.P.C., 1980.

15. Foster, Mel. Northern Resource Development and Availability of Hydro Power. A report completed for N.C.P.C., 1981.

Technology Review

1. Anderson, D.J. and Conner, D.M. Rapid River: Case Study of a Small Hydro Project in Northern Saskatchewan undated.

   A paper prepared for the Conference on Environmentally Compatible Hydro, Ottawa, May 1981.

2. Conservation and Non Petroleum Department of Energy Mines and Resources. Hydro-Electric Power Development: Mini-Hydro Demonstration Roddikton, Newfoundland.

   A paper prepared for the Conference on Environmentally Compatible Hydro, Ottawa, May 1981.

3. Crippen Consultants, Micro-Hydro: A Survey of Potential Micro Hydro Developments for Use by Remote Communities in British Columbia. Volume I and Volume II.

   A study completed for C.R.E.B., Energy Mines and Resources, Ottawa, October 1980.

4. Diddens, J.H. Current Assessment of Prospects for Further Hydro Development in Canada.

   A paper prepared for the Conference on Environmentally Compatible Hydro, Ottawa, May 1981.

5. Everdell, R.A., Mohino, A. "Mini-Hydro Installations in the Province of Ontario." in Small Hydro-Power Fluid Machinery. Edited by D.R. Webb and D.N. Dapadakis. The American Society of Mechanical Engineers, N.Y., N.Y.

6. Everdell, R.A., Near F.M., Provision of Energy Requirements for Remote Communities by Small-Scale Hydro Development. A paper prepared for the Conference on Environmentally Compatible Hydro, Ottawa, May 1981.

7. Gigiger, P.E. "Safeguarding Hydro Plants Against the Ice Menace. "Civil Engineering" (No. 1, 1947).

8. Gordon, L.T. and Penman, A.C. "Quick Estimating Techniques for Small Hydro Potential". Water Power and Dam Construction. (Sept. 1979).

9. King, R.M. "Mini-Hydro Developments for Small Areas." Water Power and Dam Construction (January, 1979).

10. McGuigan, D. Small-Scale Water Power. Dorset, G.B.: Prism Press, 1978.

11. Ontario Hydro, An Inventory of Potential Hydroelectric Powersites for the Supply of Power to Remote Native Communities in Northern Ontario. Hydraulic Studies and Development Department. Ontario Hydro, March 1979.

12. Ontario Ministry of Energy, Micro-Hydro Power: Energy from Ontario Streams. May 1981.

13. Seltz-Petrash, A. "The New Energy Boom: Small-Scale Hydropower." Civil Engineering-ASAE (April 1980).

14. TRU. Techo-Economic Research Unit with Victor and Burrell. Renewable Energy in Remote Locations: Energy Demand and Resource Base EMR Report ER80-10E, Oct. 1980

15. Underwood McLelland Ltd. Power Site Survey, Northwest Territories for the Tha Anne, Thlewiaza, Ferguson and Maguse Rivers

A study completed for D.I.A.N.D., 1980.

16. Ziemke, P. "Bubbles Protect Refurbished Dam". Compressed Air Magazine (_____, 1960).

17. Clark, Paul R. Mineral Industry Research Laboratory, University of Alaska, Fairbanks, 1973. MIRL Report No. 30.

18. Stephens and Strong. "Hydro Power Resources in the Yukon. "Fifth Northern Resources Conference Proceedings, 1975.

7.4 Recommendations

1. From the communities identified as having water power potential, Table 5, select those that will not likely be grid connected in the forseable future. Undertake pre-feasibility analyses to determine:

   - firm flow data
   - power available
   - plant requirements for power from 10 kw to 2000 kw
   - storage requirements
   - transmission requirements
   - back-up arrangements

   Identify any related costs, benefits or technological considerations such as ice conditions which may have an impact on the installation and community.

2. Construct micro hydro units only after careful engineering analyses. The first unit(s) should be installed on a pilot basis.

3. Community residents should be involved in decision-making about the use of local hydro resources.

4. Consideration should be given to local community or entrepreneurial, construction, operation and ownership with regulations under N.C.P.C.

8. FOREST BIOMASS

8.1 Forest Biomass Inventory

In reviewing forest biomass potential, the N.W.T. and Yukon reports indicate that Territorial forest biomass energy potential could meet a significant portion of space heating demand. This section is an attempt to identify Territorial biomass potential from a community-specific perspective.

Little of the Territorial forest biomass described in Map 5 is utilized as an energy source by the forest industry. In the Territories, the forest industry is small and scattered. Therefore, while wood waste generated by mills is often used as fuel in other parts of Canada, Territorial operations which are often portable, leave waste in scattered forest locations with poor access. All of these mills except for one in Watson Lake serve a local market. As noted later in this section, the Watson Lake operation is already supplying energy for itself and the town. For the most part, white spruce, common to river valleys and floodplains about one mile back from the river, is the primary sawlog species used by the forest industry. While certain volumes of the non-saw timber could be harvested as pulpwood, there is no pulp industry in the Territories and transporation and infrastructure requirements appear to limit further development.

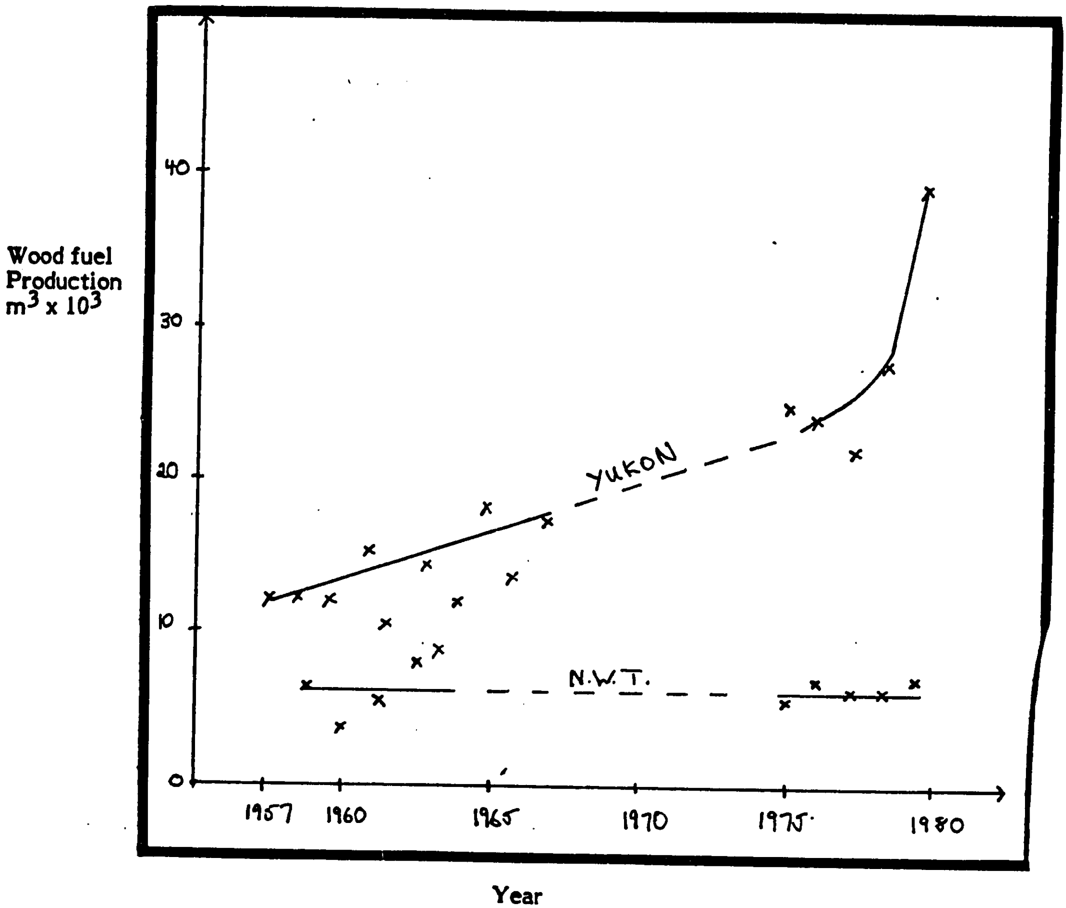
Wood burning in Canada's rural areas has always been common but today, as conventional home heating costs increase, it is becoming popular in urban areas. The use of wood is on the increase in the Teritories as shown by Figure 6 which describes the number of wood permits during the 1957-1979 period. The Yukon government is undertaking a firewood study to develop access plans for each community. These plans may set the basis for community management of wood fuel resources.

Biomass inventory researcch and practice indicates that biomass supply estimates ideally require on-site evaluation fo the forest resources for:

i) biological productivity of natural tree stands;

FIGURE 6

ESTIMATES OF WOODFUEL USE
IN THE TERRITORIES 1957-1979



Sources: 7,8

Notes: Correspondence with district forresters indicates that data are not accurate and should be used mainly to suggest trends. The data are based on permits issued for 25 cord Allotment cuts but what portion of these allotments is not taken is unknown. Also, permits in northern communities are often not required or enforced.

ii) standing biomass per unit of land areas;

iii) species distribution;

iv) accessibility of the resource; and

v) specification of a "forest biomass collection zone" around communities large enough to allow for long term forest utilization.

Given that the foregoing data is clearly unavailable for the Territories, it is only possible to identify an approximate biomass stand.

Maps 5 and 6 respectively illustrate the location and productivity of Territorial biomass. The somewhat theoretical zones of productivity can be applied to forest biomass to esimate the quantity of new growth or annual productivity. The area of land around a community within which it is considered economic to harvest and transport biomass is a biomass "collection zone". The size of this zone will depend on various economic criteria like the cost of transportation and accessability. Researchers for northern communities, report an area of 1158 km^2, (i.e., a radius of 19.2km) as being adequate for profittable biomass supply.[6]

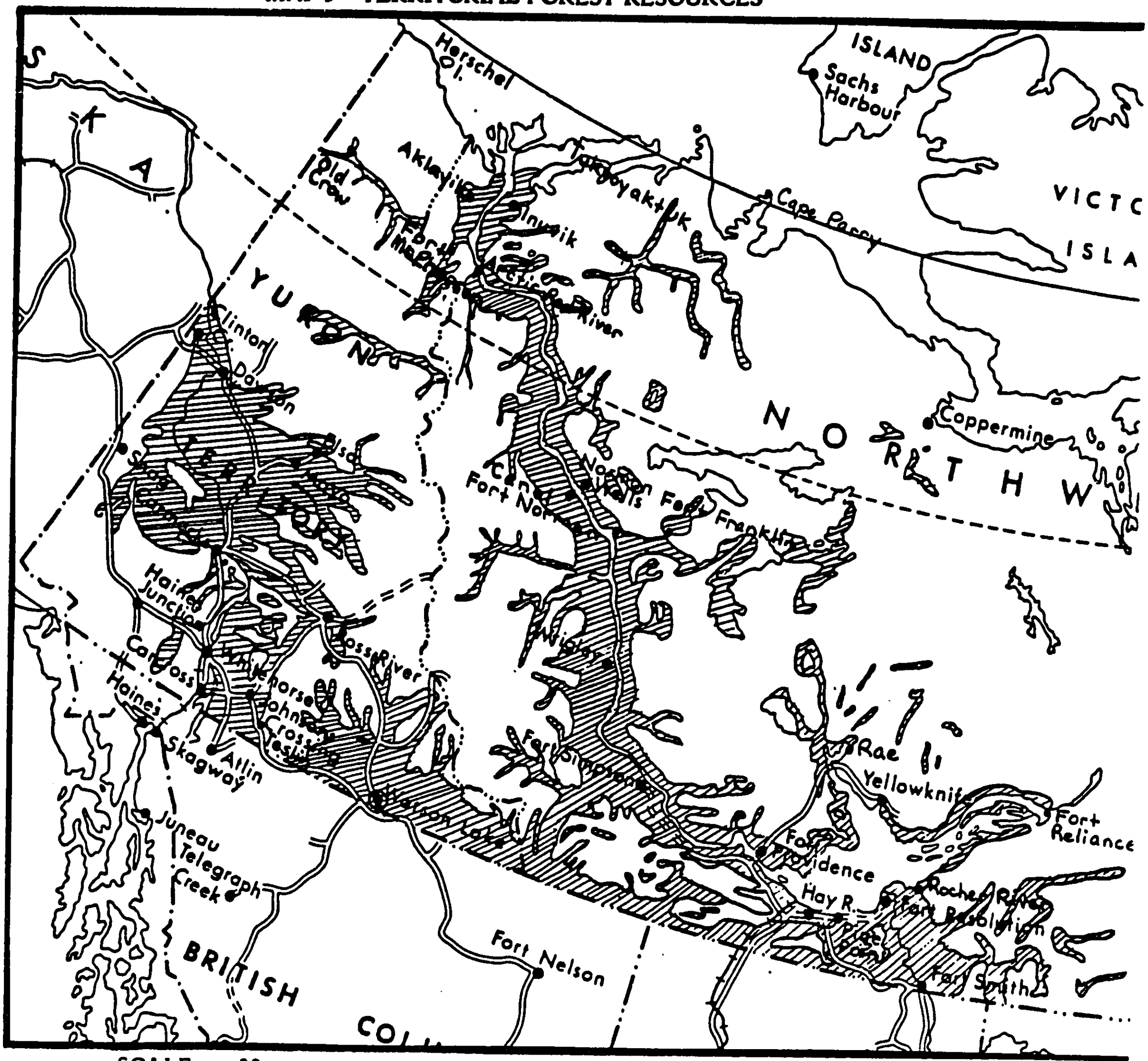
8.1.1 Inventory Data Limitations

1. Explicit data on available standing biomass and biomass productivity of northern species is unavailable.

2. Map 6 is limited in its application to small forest units around communities. More specifically, it assumes a uniform distribution of forest resources and discounts historial over or under-utilization and natural disasters such as spruce budworm infestation or fire.

   In addition, it assumes uniform biological productivity rates within production zones and discounts microclimatic effects. For example productivity is higher in protected river valleys.

MAP 5 - TERRITORIAL FOREST RESOURCES

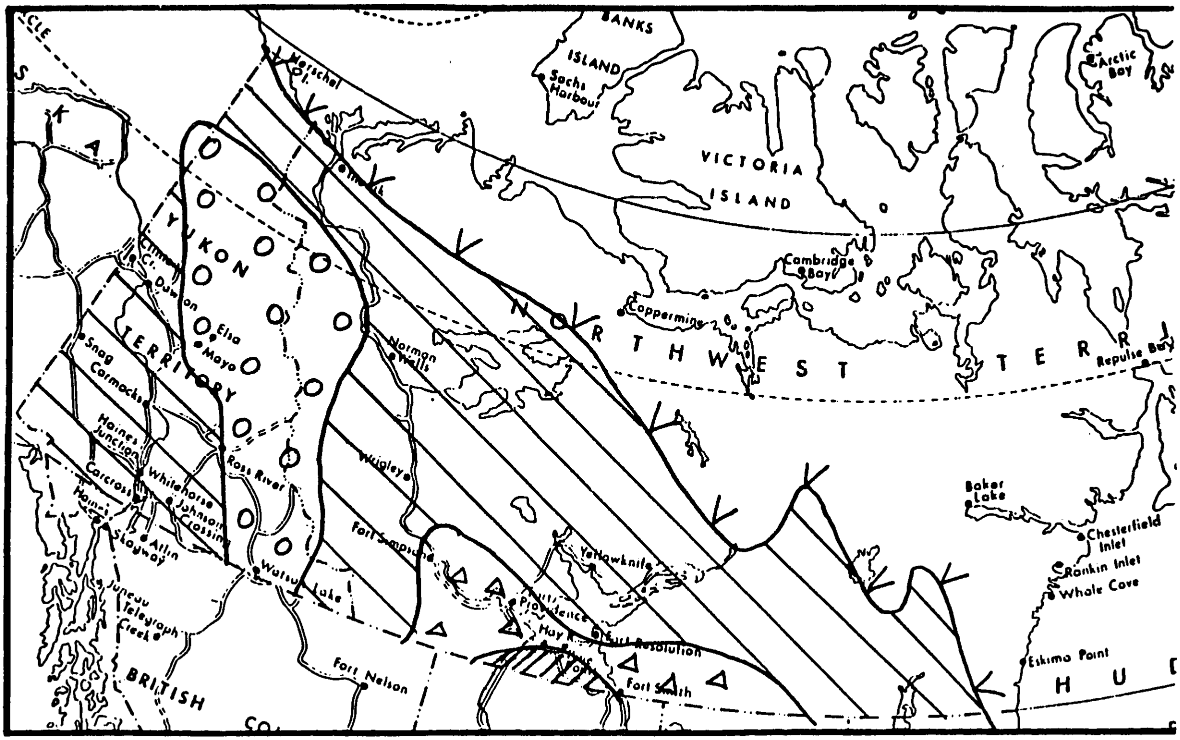


SCALE: 38mm = approximately 322km

LEGEND: ▨ timber lands includes both saw timber and non-merchantable wood
⊙ major sawmill operation

SOURCE: Adapted from the Energy, Mines and Resources map, Transportation Facilities - 1972 Northwestern Canada

MAP 6 - BIOLOGICAL PRODUCTIVITY ZONES IN THE TERRITORIES



LEGEND:

up to 250 oven dried tonnes (OD+)/km^2/PA

260 - 400

410 - 600

610 - 800

810 - 1000

SOURCE: TRU Report, p. 101

8.2 Technology Review

8.2.1 Specific Considerations

Beyond the broad considerations described in Section 1, a number of specific considerations apply to the generation of direct heat or electricity from wood.

(a) An adequate resource base is necesary. Feedstock requirements will have to be satisfied in the short and long term without competing directly with other wood-fibre industries or depleting the forests.

(b) A conversion technology must be chosen that is reliable and one that will be commercially available in the near future.

8.2.2 Technology Description

This section discusses the following technologies:

i) furnace/stove for domestic space and water heating;

ii) fluidized bed units, package boilers, and water heating suspension burners for centralized district heat and cogenerated steam electricity; and

iii) wood gasification/diesel units for electricity production and cogenerated space heat

(a) <u>Stoves and Furnaces:</u>

A variety of wood burning stoves and furnaces are available today. Stoves, more suited to residential units, provide heat through radiation and convection. Furnaces, applicable to both commercial and residential units, are designed to heat air or water which is then conducted through pipes or ducts to the rest of the building.

(b) Package Boiler:

Package boilers have been used primarily in the forest industry for process and space heat and in cogeneration systems. Package units, much smaller in scale that large field-erected units, generally have a capacity of about 60,000 lbs of steam per hour, about 2000 kW. They are also available in a range of sizes as small as 500 kW.[8]

(c) Fluidized-Bed Combusters:

As noted in section 5, fluidized-bed combustion (F.B.C.) units have the advantage of being able to accept wet and non-homogenous residues as fuel. As wood combusters, the F.B.C. technology has been successfully demonstrated but is not yet fully commercial. So far, mainly units up to 2.7 MW have been demonstrated; technical limitations dictate that the minimum size of F.B.C. unit produce at least 1 MW electricity.[6]

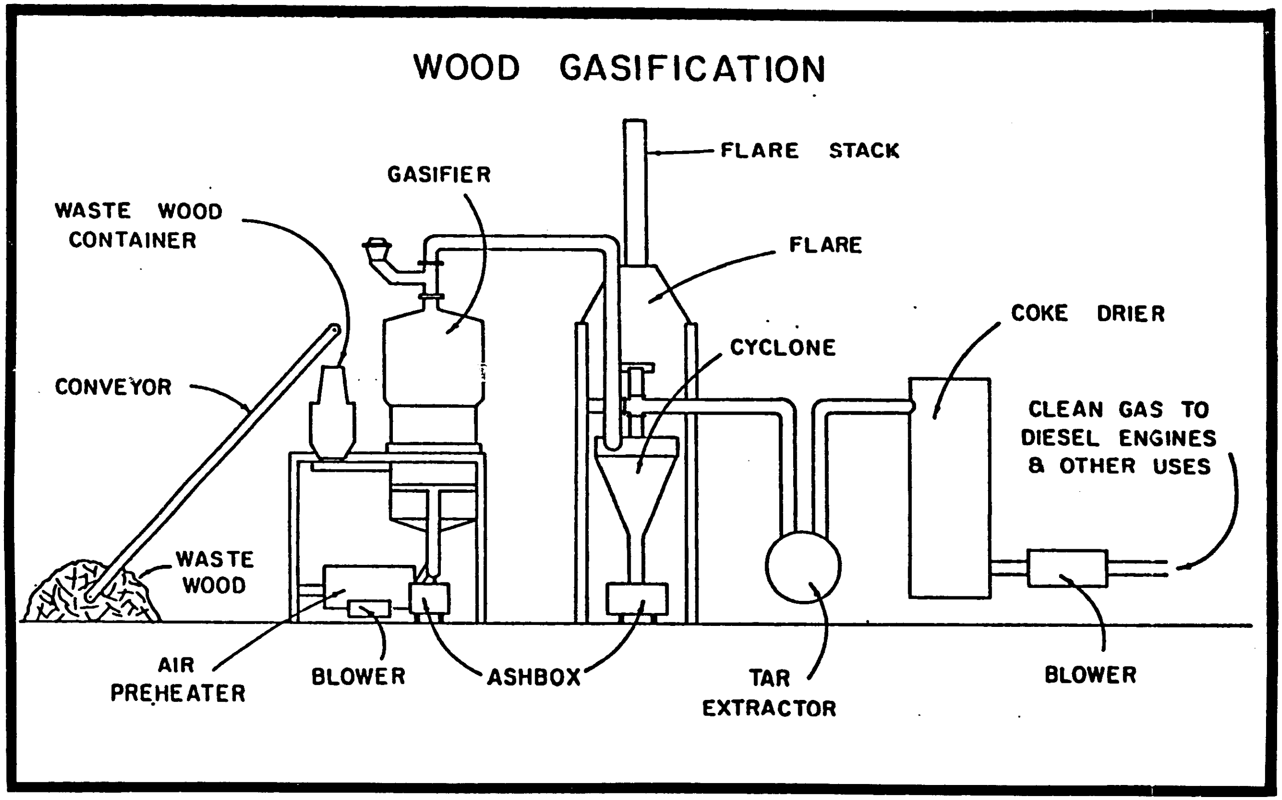
(d) Wood Gasifiers:

When heat is applied to organic material in the absence of sufficient oxygen for fuel combustion a variety of chars, liquids, and gases are produced. Gasification takes place in a reactor vessel currently in three different producer modes:

- wood is fed from the top into a fixed-bed updraft air unit.
- wood is fed from the top into a fixed-bed downdraft air unit.
- air is driven from the bottom into a F.B.C. unit (see Figure 7).

The "producer" gases typically produced have a heating value of 4-6 megajoules (1×10^6J)/m^3 when cleaned. The raw gas has to be cleaned and cooled before it can be injected into a modified diesel engine to drive the electrical generator. After cleaning, low Btu gas, produced from combustion in air, can be used directly in a variety of internal combustion engines.

FIGURE 7 - WOOD GASIFICATION



Source: Saskatchewan Power Corporation, <u>Evaluation of a Wood Gasifier at Hudson Bay, Saskatchewan,</u> ENFOR Project C-8(1)

8.2.3 Technology Assessment

Package Boilers

(a) Commercial Availability:

At present, at least forty-two pulp and paper mills in Canada are using steam boilers. Wood-fired steam boilers can be coupled to either reciprocating steam engines or turbines. Steam engines are available, from 5 to 3000 kW and it appears that their simplicity makes them more suitable for remote locations.

(b) Personnel Needs:

Steam cycle systems need to be tended by highly qualified engineering personnel.

(c) Range of application:

Steam generated electricity is common to the forest industries but because of the need for cheap feedstock, high technical requirements, and large scale (not less than 500 KW), these units have not been installed in remote communities. It appears that unless waste heat is utilized in residential/commercial district heating systems, steam cycle systems will be impractical.

(d) Load Following Abilities:

It appears that load following problems can be overcome through proper boiler design.[8]

(e) Economic Feasibility:

A recent study estimates that a 1 MW boiler unit with feedstocks at $45 /tonne could produce electricity at a cost of $.54/kWh, an extremely high cost.

(f) Territorial Experience:

In the Territories the wood products mill at Watson Lake has installed two 25,000 lb/hr field-erected waste burners. Steam is produced in a water tube boiler which drives two 15000 kW steam turbines units. Waste heat from one unit is used for process heat in the drying kiln, the other unit is cooled in a water pond used year-round as a fire security reservoir.

During off-hours and in the winter when the mill is closed, the plant provides electricity to the diesel system in Watson Lake. The community's peak demand is 2200 kW but the mill generates enough waste to provide 10,000 kW. The feedstock is virtually free and power costs are estimated at about 3-4¢/kWh.

Wood Gasifiers

(a) Commercial Availability:

Wood gasification systems are under intensive development and will be commercially available in the near future (less than 5 years).

(b) Major Limitations:

Cleaning the low Btu gas is a major problem.[5,8] Tests on a 1.2 MW pilot gasifier at Hudson Bay, Saskatchewan, indicate that large quantities of fresh water are required to be injected into a gas washer and tar extractor. The resulting effluent is highly acidic and toxic. Researchers have recommended that:

i) feedstock be dried and stored to remove as much moisture as possible; and

ii) liquid cleaning methods be formulated and tested.

(c) Personnel Needs:

With appropriate automation modifications; plants do not have to be continuously supervised and operator skills can be learned through practical experience.[8]

(d) Load Following Abilities:

Dual fuel engines, operating on a fixed charge of diesel fuel (about 10% of the full load requirements) appear to be the most appropriate for Territorial use. During low load periods, gas flaring can aid in achieving the proper load following. However, it appears that back-up generation will be necessary to ensure both low and peak load needs.

(e) Economic Feasibility:

With feedstock costs of $ 45/tonne (1978 $) produced electricity has been priced at $.40/kWh (1978 $).[8] Other estimates using $45/tonne feedstock for a 1.2 MW plant indicate a cost of $.33/kWh.[5] These cost estimates suggest that wood gasification may not be economically feasible in the near term.

8.3 Contacts and References

8.3.1 Contacts

Inventory Data

1. Dr. R.C. Dobbs, Head of the "Energy from Forests" (E.N.F.O.R.) subcommittee on Biomass Production. Ottawa, 997-1878

2. Ralph Overend, National Research Council (N.R.C.) Energy Project. Ottawa, 993-3405

3. Walter Moore, Mike Fajrajsi, Forestry Resources Division, D.I.A.N.D. Ottawa, 997-0048

4. David Morgan, Regional Forester D.I.A.N.D. Whitehorse Y.T. (403) 668-5151

5. Chris Carlisle, Jack Gilmour, Regional Forester D.I.A.N.D. Fort Smith N.W.T. (403) 872-2139

Technology Data

1. R.J. Neale, ENFOR Program Coordinator Canadian Forestry Service Hull (819) 997-1682

2. Robin Guard, V.P. and General Manager Omnifuel Gasification Systems Limited Toronto (416) 485-0701

3. Jim Carrier Cattermole Timber Chilliwack, B.C. (403) 536-7427

8.3.2 References

Supply Inventory

1. Adelaar, M. N.W.T. Report.

2. Brooks, D.B. Yukon Report.

3. D.I.A.N.D. Territorial Wood Production Summary Sheets

4. Reid Collins and Associates Ltd. Forest Inventory Lower Liard River. A study prepared for D.I.A.N.D., 1970.

5. TRU Techno-Economic Research Unit with Victor and Burrell. Renewable Energy in Remote Locations: Energy Demand and Resource Base. Oct, 1980.

6. Saskatchewan Power Corporation. The Social, Environmental and Resource Impact of Wood Gasification on Isolated Communities, Part I and Part 2. ENFOR Project C-8(2), 1979, Environment Canada.

7. Sandwell and Co., A Review of the Forest Resources and the Pulp and Paper Potential of the Northwest Territories and the Yukon Territory. A study prepared for D.I.A.N.D. (undated)

8. D.I.A.N.D. Forest Resource Branch. Forest Production Summary Sheets.

Technology Data

1. Overend, R. Gasification, an Overview. A report prepared for the Conservation and Renewable Energy Branch, EMR (undated)

2. 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.

3. Mitre Corporation. Status Review of Wood Biomass Gasification, Pyrolysis and Densification Technologies, 1979

4. Saskatchewan Power Corporation. Pilot Plant Investigation of a Wood Gasifier for Generation of Electricity. ENFOR Project C-29, June 1980.

5. ________________. Evaluation of a Wood Gasifier at Hudson Bay, Saskatchewan. ENFOR Project C-8(1)

6. Love, Peter. Biomass Energy in Canada: Its Potential Contribution to Future Energy Supply. A study prepared for the Conservation and Renewable Energy Branch, EMR, March 1980.

7. Graham, S. Woodfuel Supply Business in Canada: An Overview. A manual prepared for the Conservation and Renewable Energy Branch, EMR, 1980.

8. Biomass Energy Institute Inc. Utilization of Wood and Other Biomass for Small Scale Electric Power Generation. A study prepared for Canadian Electrical Association, Montreal (undated)

9. Overend, Ralph, Bioenergy Research and Development: A summary of the Program to March 1980. Energy Project, N.R.C., Ottawa, 1980.

8.4 Recommendations

1. Community specific supply data should be developed through more comprehensive surveys. The data should include: available standing biomass; productivity; forest species; and accessibility. Given that the federal Energy from Forests (E.N.F.O.R.) program is currently evaluating Territorial forests for standing biomass per unit area, it is suggested that the Territorial governments develop an appropriate liaison with E.N.F.O.R.

2. The development of chunk log supply infrastructure (harvesting,

processing, and marketing) should be supported. This development should be coordinated with environmental impact monitoring; development of fuel supply standards to ensure equitable quantity, quality, and price; and the "education" of wood burners.

3. Table 12, a summary of forest biomass conversion technologies, indicates that furnaces, stoves, package boilers, and steam generators have the potential for near-term Territorial applications. It is recommended that further efforts be made to overcome identified barriers to utilization including the unreliability of a cheap feedstock source.

TABLE 12 - SUMMARY OF WOOD BIOMASS CONVERSION TECHNOLOGIES SUITABLE FOR REMOTE APPLICATIONS

End Product	Conversion Technology	Remote Community Applications	Commercial Readiness	Comments
Combustion	Furnace/Stove	Space Heat	Commercial	Widely Used
	Package Boiler	District Heat or Cogeneration	Commercial	< 2000 kW currently used in the forest industry
	Fluidized-Bed		Demonstration	>1000 kW
Electricity	Boiler Steam/generator	Electricity and Space Heat	Commercial	used by 42 Canadian pulp and paper mills
	Gasifier Steam/generator		Demonstration	
Liquid Fuels	Methanol Synthesis	Heat or Motive Fuel	Research	The scale of plant, the amount of feedstock, and the required personnel do no warrant consideration of methanol production at remote sites.

SOURCES: 6, 7, 8, 9

9. WIND

9.1 Wind Inventory

Until recently, charting wind energy potential in the Territories has been difficult due to a shortage of compiled and analyzed data. This situation has been improved upon by a recent NWT Science Advisory Board report* which has analyzed wind data for over 50 sites.

Based on the Science Advisory Board report, Map 7 illustrates mean annual wind energy potential for the NWT. The isopleth (equal wind energy potential) lines are expressed in kWh/m^2, the energy potential per unit of swept blade area of a wind-electric machine. The map indicates that the western and northwestern Arctic is characterized by the highest wind regimes.

Map 8 illustrates wind energy-potential zones in the NWT compiled from monthly average test site windspeed data and from subjective corrections made for specific conditions that might alter data, e.g., such as a sheltered test site. The map illustrates more clearly where wind energy might be utilized. Based on Map 8, Table 13 shows the average annual potential wind energy available for communities within the promising zones.

9.1.1 Inventory Data Limitations

1. The data are insufficient to map potential for the Yukon. Site conditions for wind installations will be influenced by the mountainous terrain.

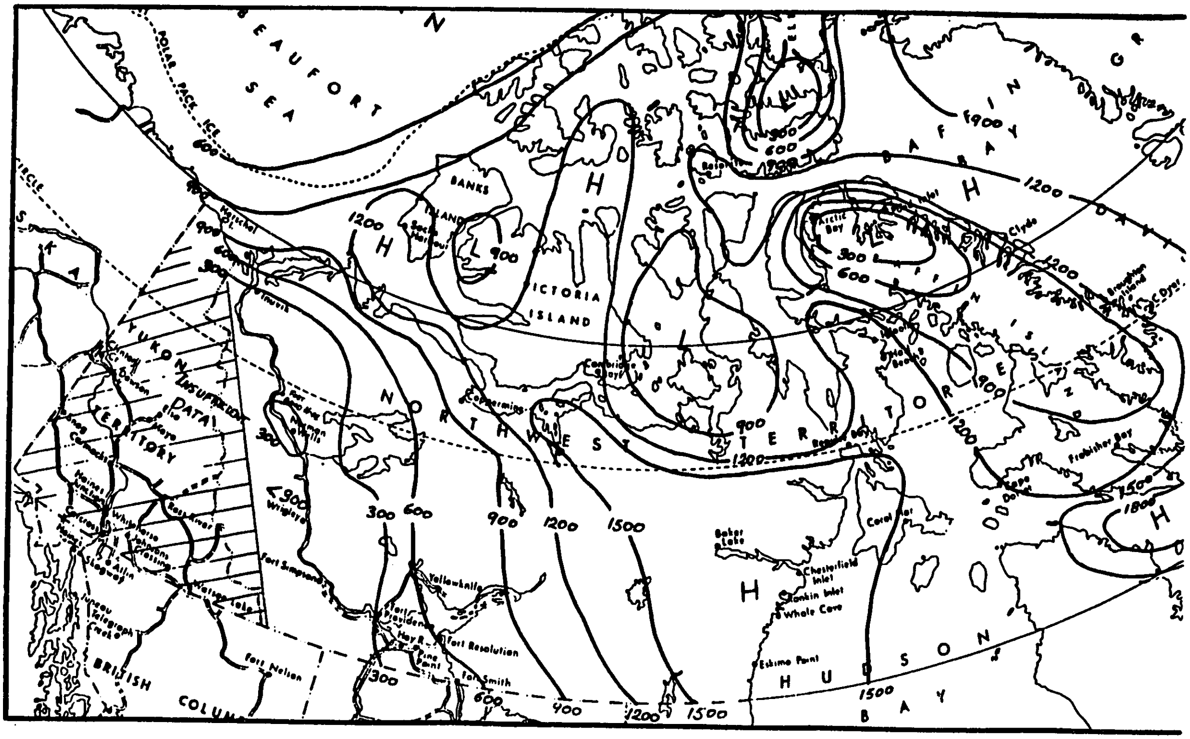
2. Map 7 has the following limitations:

   i) the data are not based on similar time intervals, for example, some stations have data in excess of thirty years while others have only two years of information. Potential energy for any one year can vary from the long-term average by a factor of 1.5 to 2.2.

---

* The report is in draft form only and, therefore, data are subject to change.

MAP 7 - MEAN ANNUAL WIND POTENTIAL MAP OF THE NORTHWEST TERRITORIES

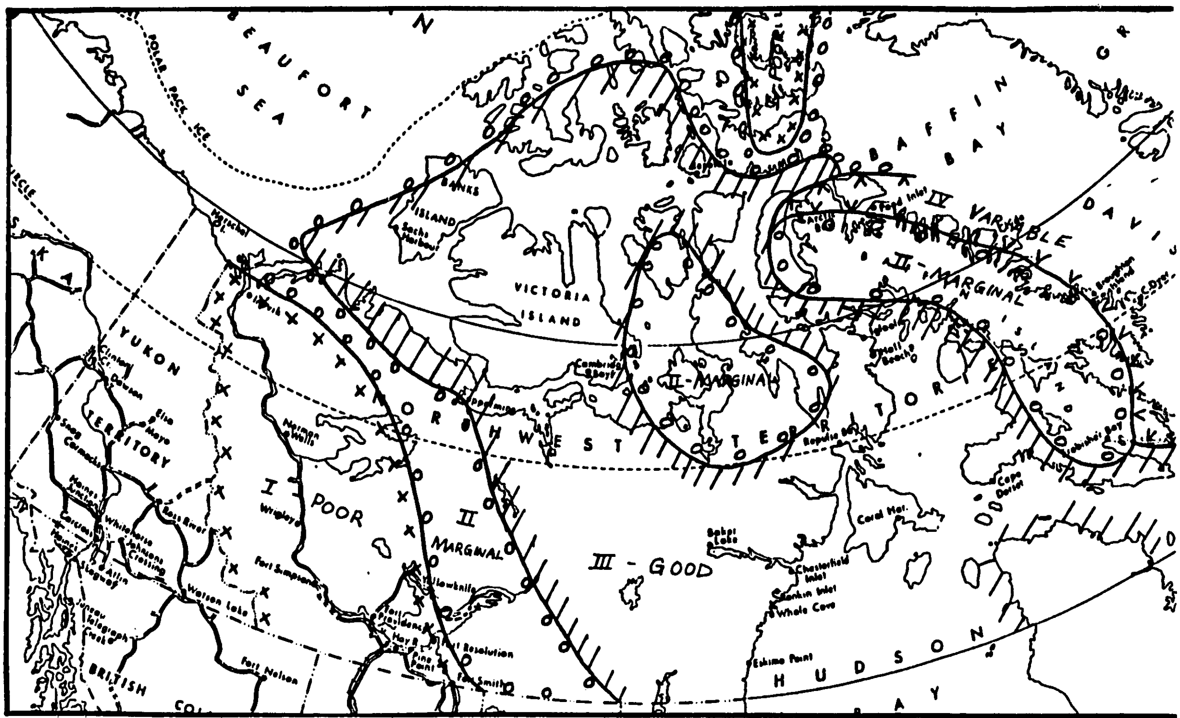


LEGEND: Wind isopleth lines are expressed in kWh/m^2 at 10 m elevations

H = high wind energy regime
L = low wind energy regime

SOURCE: Janz, B, Howell, D.G., and Serna, A. Wind Energy in the Northwest Territories. A report for the N.W.T. Science Advisory Board, April 1981.

MAP 8 - WIND ENERGY POTENTIAL IN THE NORTHWEST TERRITORIES



LEGEND:	I	××	Zone of poor potential
	II	oo	Zone of marginal potential
	III	///	Zone of good to excellent potential
	IV	^^ vv	Zone of variable potential

SOURCE: Janz et. al. Wind Energy in the Northwest Territories.

NOTES:

(a) In zones of poor potential, wind speeds are too low to produce significant amounts of energy.

(b) In zones of marginal potential, careful siting is necessary to account for seasonal and year-to-year fluctuations.

(c) In zones of good to excellent potential, there should be little difficulty in selecting a suitable site.

(d) In variable zones, low or high potential zones can be characterized by sites of excellent or poor potential.

TABLE 13

AVERAGE ANNUAL WIND ENERGY POTENTIAL FOR SELECTED NWT COMMUNITIES

COMMUNITY	MEAN ANNUAL WIND ENERGY POTENTIAL kWh / M^2	QUALITATIVE POTENTIAL
Pangnirtung	700	Marginal
Reliance	900	Marginal
Coppermine	900	Marginal
Paulatuk	1,100	Good
Bathurst Inlet	1,500	Good
Sach's Harbour	1,200+	Good
Cambridge Bay	1,200	Good
Holman	900	Marginal
Resolute	1,200	Good
Gjoa Haven	900	Marginal
Spence Bay	900	Marginal
Pelly Bay	900	Marginal
Repulse Bay	1,300	Good
Igoolik	1,200	Good
Hall Beach	1,200	Good
Arctic Bay	300 - 900	Variable
Pond Inlet	300 - 900	Variable
Clyde	600 - 1200	Variable
Broughton Island	600 - 1200	Variable
Copper Dyer	600 - 1200	Variable
Frobisher Bay	900	Marginal
Cape Dorset	1,200	Good
Coral Harbour	1,500	Good
Baker Lake	1,500+	Good
Chesterfield Inlet	1,500+	Good
Rankin Inlet	1,500+	Good
Whale Cove	1,500+	Good
Eskimo Point	1,500+	Good
Lake Harbour	1,500	Good

ii) the plotted values illustrate the theoretical maximum value that can be produced from a wind rotor and do not take into account system inefficiencies. Such system losses can account for 30 to 40% reductions from the maximum theoretical potential.

3. Map 8 does not take into account community specific variables such as:

i) the extended periods of low wind velocity and frequency;

ii) the helpful or hindering terrain features; and

iii) the distance from a community to a suitable site.

9.2 Technology Review

9.2.1 Specific Considerations

In reviewing wind potential, the N.W.T. report indicates that wind energy could:

i) power navigation aids;

ii) power telecommunication and geophysical apparati;

iii) provide supplement power to diesel-electric generating units in remote communities;

iv) provide electricity supply to isolated dwellings;

v) power pumped water storage for micro-hydro units; and

vi) provide space heating to prevent sewage and water pipes from freezing.

This report intends to focus primarily on wind as a supplement to diesel electricity in remote communities.

(a) Energy Supply Factors:

- Wind energy potential depends on the cube of the wind velocity. The amount of power generated over time is dependent on the wind frequencies.
- Wind speed varies with height. Depending on the type of terrain, windspeed is known to increase with height to about 1500 m. For example, with rolling terrain common to parts of the NWT, an increase in height from 10 m to 20 m increases windspeed by 9%.

(b) Hardware Considerations:

- Erection of heavy wind generators in remote locations may pose problems and extra expense. Parts may also be difficult to obtain in these locations.

- Problems of cold weather lubrication have not been adequately addressed in research and development.

One reference cites a hypothetical problem of a turbine sitting idle for several days at 40°C.[4] Under these conditions it is not known how its start-up speed would be affected.

- The extensive use of plastics for equipment used primarily in southern climates has not been considered in the north. The durability and failure patterns under stress at frigid temperatures must be determined.

9.2.2 Technology Description

There are three stages to harnessing wind energy for remote community application: energy conversion, energy storage, and energy use.

(a) Energy Conversion:

It appears that the two conversion systems deserving the most attention for Territorial use are the electric generator and the diesel/wind hybrid. The electric generator involves the direct conversion of the wind's full capacity to electric power.[3,4,6] Excess energy above the current load is "dumped" into battery storage or through resistance heaters into hot water storage. Diesel back-up is generally required.

The diesel/wind hybrid involves applying the wind shaft power to operate the diesel engine. This sytem is currently under research by

D.A.F. Indal in Toronto.[6] The system is based on mechanically linking the diesel engine shaft to the wind turbine thereby reducing fuel consumption. When there is sufficient wind, induction motors start up the turbine. At a sufficient rotor speed a camclutch is engaged and power is transferred from the wind turbine to the diesel engine.

A hybrid conversion system using photo-votaic cells has been suggested for potential northern application. At present, no demonstration units have been built.[2]

(b) Energy Storage:

Battery storage appears, at present, to be the most efficient method for retaining excess power.[1,2,7] Direct current power stored in batteries can be converted to alternating current for use by motors.

Heated water also presents a possible storage medium. Energy from a wind turbine can be stored as sensible heat via immersion heaters in water storage tank. Space heat can then be extracted from the storage medium.

9.2.3 Technology Assessment

(a) Technical Reliability:

Energy Conversion

Small domestic horizontal axis wind turbines (H.A.W.T.) have been available and in use for decades. Within the limited applications of their size, their technical reliability is proven.

Canada has become a world leader in the development of vertical axis wind turbines (V.A.W.T.). A recent study comparing the HAWT with the V.A.W.T. has come up with the following observations.[5]

	H.A.W.T. Benefits	V.A.W.T. Benefits
Rotor Design	Structural design criteria developed Self starting at lower wind speeds	No yaw mechanims is required, i.e., the rotor is omnidirectional. No blade angle modulation is required. Overall maintenance is easier.
Power Train		Is at ground level for ease of success.
Support Structure	Supports are more advanced.	

These observations seem to apply for all scale H.A.W.T. and V.A.W.T. units.

Based on tests comparing fuel savings at variable load conditions on Toronto Island, researchers have identified the following advantages of the diesel hybrid system versus the electrically coupled system: [6]

i) the system saves more fuel

ii) the system has less complicated mechanical coupling, electrical connections, and electrical controls;

iii) the system can be used at lower wind speeds; and

iv) the system does not require auxiliary loading such as a hot water system to absorb surplus power, although storage systems can be added if required.

Energy Storage

Batteries designed for wind ene~gy conversion systems usually have a long life if well cared for. Particularly harmful are repeated chargedischarge cycles and deep-discharge loading (as happens in extended periods of calm). Such periods are important to note in determining the wind region potential for a community.

A pilot project at Council, Alaska illustrates the application of battery storage.[5] A H.A.W.T. rated at 300 watts output for a 19.3 km/hr average wind speed was installed. Batteries with a total capacity of 6.9 kWh/day were added. To date, the system has experienced no major problems and has withstood severe winter conditions over two seasons.

A "wind furnace" demonstration unit at the University of Massachusetts has supplied residential space heat continuously since November of 1977.[9] The electricity from a 25 kW wind turbine is converted to heat along baseboard heaters. Excess energy is distributed by immersion heaters to a basement water storage tank. Supplementary heat from the tank is provided by water pipes. To date, the system has functioned without major problems and without continous supervision.

(b) Economic Feasibility:

Wind power technology has not been developed and demonstrated at the volume necessary to ensure reliable economic data. One estimate suggests that with concerted market penetration, units less than 200 kW, at 12.9 km/sec. windspeed, are expected to reach capital costs of $600/kW (1978 $) installed by the mid to late 1980's. Operating costs are generally reported in the range of 2 to 4% of capital costs.[4]

(c) Range of Application:

Table 14 is a summary of available wind energy systems. It appears that small domestic units (up to 12kw) and intermediate units (up to 200kw) are appropriate for community applications in the Territories.

TABLE 14
A SUMMARY OF WIND ELECTRIC SYSTEMS

CLASSIFICATION	OUTPUT RATINGS	APPLICATION	COMMERCIAL AVAILABILITY	INSTITUTIONAL REQUIREMENTS
Small Domestic Units	up to 12 KW	Residential or small commercial units	Horizontal axis designs currently available Vertical axis in demonstration.	Can be owned and operated privately.
Intermediate Units	up to and including 200 KW	A number of dwellings or small community	Prototype testing is underway. Off the shelf availability is estimated to be 3-5 years away.	Installation and operation would require a measure of government, cooperative or utility support
Large Units	greater than 1000 KW	Link into regional grid systems	Research and development underway through NRC (Can.) and NASA (U.S.A.) Large aerospace corporations seeking to enter market. Demonstration in Quebec and Magdelan islands.	Initial government support required.

9.3 Contacts and Resources

9.3.1 Contacts

Supply Inventory

1. Rick Berry, Atmospheric Environment Service, Toronto (416) 667-4626.
2. Ben Janz, Wind Power Potential Analysis Committee for N.W.T., Edmonton, (403) 427-6810.
3. R.J. Templin, National Research Council, Ottawa 993-2423.

Technology Review

1. R.J. Templin, National Research Council, Wind Energy Program, Ottawa 993-2423.
2. Fred Schwarz, Ontario Ministry of Energy, Remote Community Program, Toronto 965-0542.
3. H. Carl Johnson, Bristol Aerospace Ltd. Winnipeg

9.3.2 References

Supply Inventory

1. Atmospheric Environment Service, Canadian Normals (Vol. 3) U.D.C: 551.582.2(71) Toronto, 1975.
2. Janz, B. Howell, D.G. and Serna, A. Wind Energy in the Northwest Territories Report No. 6 (Draft) for the Science Advisory Board of the N.W.T. April 1981.
3. Templin R.J. Availability of Wind Energy in Canada, NRC undated.
4. Chappell M.S. Supplementary Report on Wind Energy R & D Program Prepared for Parliamentary Special Committee on Alternative Energy and Oil Substitution, NRC, July 1980.
5. T.R.U. Renewable Energy in Remote Locations: Energy Demand and Resource Base Report ER 80-10E, EMR October 1980.

6. Brown, K. What about Wind Power? Memorandum to soft energy path researchers, Institute of Man and Resources, May 1981.

Technology Review

1. Adams, G. and Casey, S. "Electrochemical Energy Storage Systems: A Small-Scale Application to Isolated Communities in the Canadian Arctic." Canadian Electrical Engineering Journal 4 (No. 3, 1979).

2. Bettignies, C. The Utilization of Wind Power in the Arctic. Department of Engineering, University of Moncton (undated).

3. Brown, C.K. and Warne, D.F. An Analysis of the Potential for Wind Energy Production in Northwestern Ontario. A report prepared by the Ontario Research Foundation land the Electrical Research Association (UK) for the Ontario Ministry of Energy, 1975.

4. Brown, K. What about Wind Power? Memorandum to Soft Energy Path Researchers, Charlottetown, Institute of Man and Resources, May 1981.

5. Cranford, M.A. and Bergen, T.J. "Wind Generated Electric Power for Sanitation Service: A Case Study" Proceedings of Utilities Delivery in Northern Regions, pp 59-105 Environment Canada Report EP53-WP-80-5, March 1979.

6. Development, Installation, and Testing of a Wind Turbine Diesel Hybrid A report prepared by D.A.F. Indal Ltd. for the Ontario Ministry of Energy and the National Research Council.

7. Janz, B. Howell, D.G. and Serna, A. Wind Energy in the Northwest Territories A report prepared for the Science Advisory Board of the N.W.T. April 1981. (Draft)

8. Shawinigan Engineering Co. Ltd. A Study of Large Wind Turbine Generators for Electrical Power Generation. A study prepared for Hydro Quebec, NRC and EMR, 1980.

9. Cromack, McGowan and Heroneums. "The Status of Windpower Research and Development for Space and Water Heating in the United States".

and

Menzies, R.W. and Mathur R.M. "Alternator Designs for Direct Coupling to Remote Wind Energy Systems" in The Third International Symposium on Wind Energy Systems, Copenhagen, Denmark, 1980.

9. T.R.U. Technical - Economic Research Unit with Victor and Burrell. Renewable Energy in Remote Locations: Energy Demand and Resource Base A study prepared for C.R.E.B., 1980.

9.4 Recommendations

1. In order to select communities for potential demonstration projects, wind inventory data for the N.W.T. will have to be developed to be applicable on a community or region specific basis.

2. Wind/Diesel hybrid systems deserve further investigation culminating in demonstration projects for the western Arctic communities.

10. PEAT BIOMASS

10.1 Peat Biomass Inventory

A Montreal Engineering Co. study in 1977 assesses peat and energy potential for all of Canada. The report identifies over one hundred sites in the Territories. Based on this data, Map 9 shows the location of Territorial peat bog sites.

10.1.1 Inventory Data Limitations

Community or even site specific peat bog volume data are unavailable.

10.2 Technology Review

10.2.1 Specific Considerations

(a) Moisture content: Fuel peat* deposits can contain as much as 98% moisture by weight. To make peat acceptable for fuel, moisture contents should be reduced to about 55%. Moisture removal has historically been carried out by the sun and wind. However, solar drying is dependent on the effective number of frost-free sunny days.

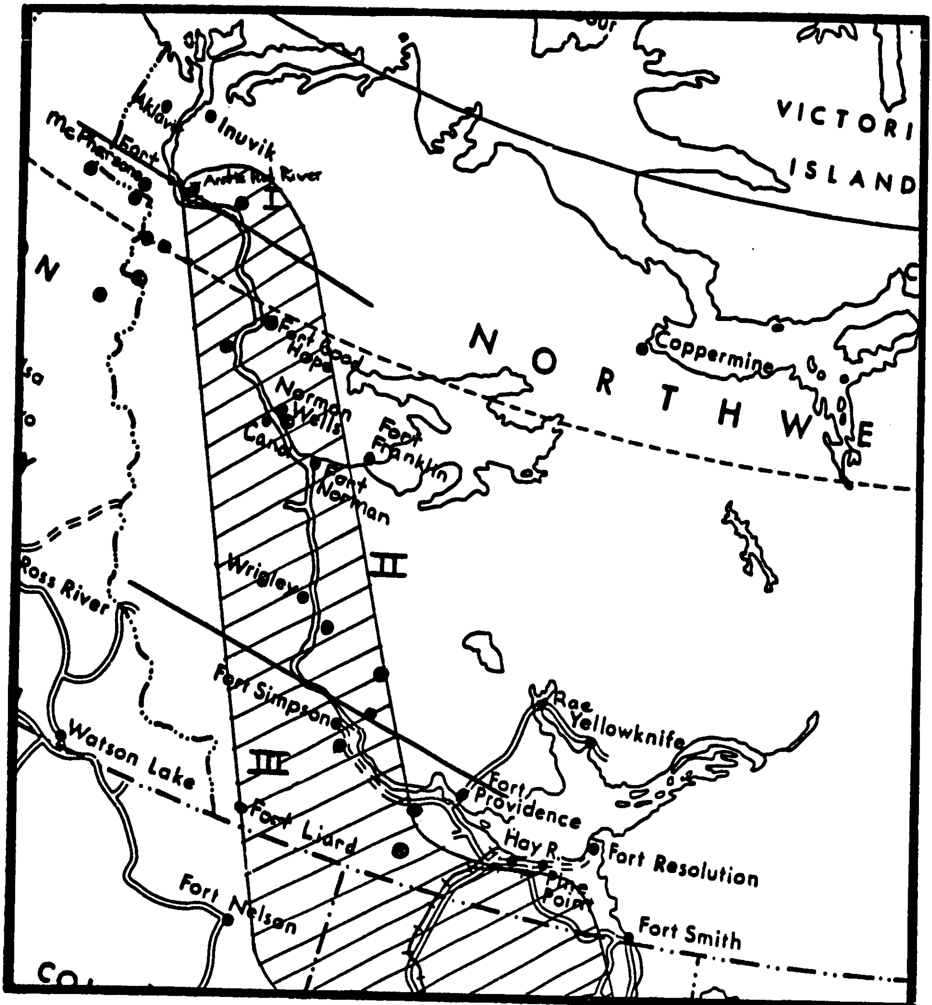
10.2.2 Technology Description

Experience in utilizing peat in northern communities appears to be wanting. There is some postulation, however, that peat pellets or charcoal from peat could be used as feedstock for a gasification plant.[2] A recent publication from the American Chemical Society indicates that research is intensifying in the area of peat conversion to liquid hydrocarbons or synthesis gas.[3] There are basically three conversion processes being examined, **hydropyrolysis**, **hydrogasification**, and **biogasification**.

---

* Peat is classified according to the degree of humification or decomposition. Peat with a higher level of humification is generally considered suitable as fuel.

MAP 9 - TERRITORIAL PEAT DEPOSITS



SCALE: 38mm = approximately 322km

LEGEND:
- ⊕ Surveyed Peat Region
- /// Regions where peat deposits and peat lands are common
- I continuous permafrost
- II widespread permafrost
- III discontinuous permafrost

MAP 9 - SOURCES AND NOTES

SOURCES: 1. Montreal Engineering Co. Ltd., Assessment of Canadian Peat as an Alternative Fuel for Power Generation, A study prepared for the Department of Energy, Mines and Resources, Canada, 1977.

2. ....., The Mining of Peat - A Canadian Energy Resource, A report prepared for E.M.R., Canada, 1978.

NOTES: 1. Permafrost is earth where the temperature is below 0°C for more than a year. The zone of continuous permafrost constitutes ground that is perennially frozen, except for the thawed "active" surface layer. The zone of discontinuous permafrost constitutes ground where the underlying soil is not perennially frozen. Permafrost in this case consists of bodies or lenses of ice.

In the widespread permafrost region the zone of continuous permafrost is occasionally interrupted by "openings" of discontinuous permafrost.

Fuel peat is currently used in Ireland, Finland and the Soviet Union. In Finland, peat provides about 2% of the country's total energy, mainly in the large-scale on-site electricity and district heating schemes. Recent Finnish reports indicate that commercially available peat conversion technologies include suspension, grate, cyclone or fluidized-bed boilers. In the Soviet Union, peat use consists of over 100 million tons annually, primarily for electricity generation.

10.2.3 Technology Assessment

(a) Feedstock Limitations: Territorial climatic zones are not a suitable environment for solar drying of peat, e.g., ≤ 25 production days are available in some peat areas.

(b) Economic Feasibility: Peat mining costs depend, in part, on the applicability of large-scale vacuum harvesters. Experience suggests that vacuum harvesting is feasible only for the large-scale developments in Europe. As a result, it has been suggested that peat fuel utilization be oriented towards plants of 25 MW or more placed at bogside.

10.3 Contacts and References

10.3.1 Contacts

1. Cam McNeil, Director: Energy, Mines and Resources Canada Federal-Provincial Demonstration Agreements Program (613) 995-9447

2. Ralph Overend, National Research Council Energy Project (613) 993-3405

3. T.E. Tibbets, Director: Coal and Peat Resources Evaluation, Canada Centre for Minerals and Energy Technology (C.A.N.M.E.T.), Energy, Mines and Resources Canada (613) 996-4570

10.3.2 References

Supply Inventory

1. Montreal Engineering Company Ltd., Assessment of Canadian Peat as an Alternative Fuel for Power Generation. A study prepared for Energy, Mines, and Resources Canada, 1977.

2. Montreal Engineering Company Limited. The Mining of Peat - A Canadian Energy Resource. A report prepared for Energy, Mines and Resources Canada, 1978.

3. Tibbets, T.E. & Fraser, J.A. "The Utilization of Canadian Peat as an Alternative Energy Source" CIM Bulletin (September, 1978): 107-110.

4. Williams, P.J. Pipelines and Permafrost: Physical Geography and Development in the Circumpolar North (London: Longman Group Ltd., 1979).

Technology Review

1. Montreal Engineering Company Ltd. The Mining of Peat - A Canadian Energy Resource. EMR, 1978.

2. Biomass Institute of Canada. Utilization of Wood and Other Biomass for Small Scale Electric Power Generation, Canadian Electrical Association 1977.

3. American Chemical Society. Liquid Fuels From Coal, Coal Liquids Upgrading, Utilization of Peat and Lignite. Volume 25, No. 1 Preprints of Papers presented at Houston, Texas, 1980.

4. Asplund, D. Peat as a Source of Energy in Finland. Proceedings of a Finnish Energy Conference, 1979. Available from the Finnish Embassy, Ottawa.

10.4 Recommendations

Drying, mining and small-scale conversion limitations suggest that peat fuel, likely to be in competition with other MacKenzie Valley energy resources, should not be considered as a Territorial fuel supply. This conclusion seems to be enforced by the environmental problems of harvesting under permafrost or semi-permafrost conditions.

APPENDIX A

Types of Technology and Products	Domaines of Application	Present Stage of Technical Maturity: Basic Research	R and D	Pilot Installation	Demonstration	Estimated Time Of: Wide Commercial Availability	Economic Competitiveness in ECE	Major Constraints and Remarks	Potential (theoretical)
1. SOLAR ENERGY								General constraint: capital investments costs	
Flat plate	(water heating								
collectors	(water space heating					now	now	-	
(warm air	(air space heating			+	+	+now	1980s	)	+
or water)	(air conditioning		+	+		1985	1980s	) seasonal storage	++
			+	+	+	1985	1990s	local applicability	+
Tracking and	(industrial steam								-
focusing collectors	(electricity generation	+	+	+		1985	1990s		
(steam)	(cooling and refrig.	+	+	+		1990s	1990s	) local applicability	+
		+	+			1985	1990s	) aesthetic problems	+
Photovoltaic	(low-power uses					now	now	) land use	-
cells	((telecommunications)			+	+	now	now	land use and aesthetics	++
(electricity)	(medium power uses								
	((water pumping)			+	+	now	now	) competitive only	-
	(large power uses	+	+				1990s	) locally	-
	((power plants)								
Greenhouses						now	now	resistance of materials	+
	(agriculture					1980s	1980s	local applications,	●
	(desalination							safety	
				+	+	1985	1985-90		++
Biomass	heating, cooking					now	now	) locally competitive only,	
- synthetic gas	(heating	+	+	+		now	now	) air pollution	
- heat	(electricity production			+	+	1980s	1980s		+
- alcohol	transportation	+	+	+	+	2000	2000	safety	+
- hydrogen	transportation	+	+	+		2000	2000		+
- photobiological	to be explored	+							
processes									
		+							

APPENDIX A

Types of Technology and Products	Domaines of Application	Present Stage of Technical Maturity: Basic Research	R and D	Pilot Installation	Demonstration	Estimated Time Of: Wide Commercial Availability	Economic Competitiveness in ECE	Major Constraints and Remarks	Potential (theorectical)
II. WIND ENERGY								General constraints capital investmens costs	
Small machines (electicity, mechanical power	(all uses of electicity		•	•	•	1985	1985-90	local importance	•
	(water pumping					now	now	local importance	•
Large machines (electricity)	all uses of electricity	•	•	•		1990s	1990s	aesthetics, integration safety	•
III. GEOTHERMAL ENERGY									
Low and medium temperature water (warm water)	(space heating					1980s	now	) local avelability	••
	(agriculture					1980s	now	)	•
High temperature water and steam	(electricity					1980s	now	) corrosion, mineralization,) reinjection of water) used	-
Hot dry rocks systems (steam)	electricity	•	•			2000	2000	)	••

SOURCE:

1. Alaska Council on Science and Technology. Alaskan Energy, Research Priorities and Recommendations. A special report based upon the results of the A.C.S.T. Energy Committee Workshop held in February 1980, Anchorage Alaska, March 1980.

Appendix B

Micro-Hydro Installations:

Cost Elements

Civil Work Costs

a) Water storage and control (i.e. dams or retaining dyke)
b) Access roads
c) Canals
d) Intake structure
e) Penstock
f) Power house construction

Mechanical Works Costs

a) Values
b) Turbine
c) Control of flow

Electrical Works Costs

a) Generator
b) Voltage regulator
c) Generator protection and control
d) Transformers
e) Transmission line

Back-up Costs

a) Diesel plant
b) Electrical or Mechanical linkages

Indirect Costs

a) Construction camp and subsistence
b) Administration
c) Insurance
d) Engineering
e) Interest during construction
f) Inflationary price escalation
g) Contingency