PROCEEDINGS —

Twenty-second Annual Meeting

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TRANSPORTATION RESEARCH FORUM

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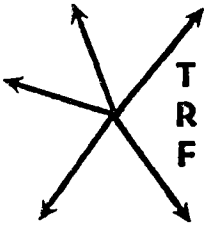

TRANSPORTATION RESEARCH FORUM

Transportation of LNG from the Arctic to Eastern Canada

by Lee S. Sims and Neal A. Irwin**

ABSTRACT

THE Arctic Pilot Project represents a new approach at exploiting the natural resources of the Canadian Arctic. Using existing technology combined in a new way it offers the promise of significant economic stimulus to the Canadian economy. It also presents some interesting problems in the selection of a terminal in Southern Canada. Two main alternatives have been proposed: Gros Cacouna in the Province of Quebec and Melford Point in Nova Scotia. The selection of the best terminal depends upon assumptions about the future delivery and use of natural gas in Canada and therefore is dependent upon national strategies and plans. The availability of large supplies of liquified natural gas in Eastern Canada opens up the possibility for various new uses of this substance, as a transportation fuel and for other purposes.

1 THE PROBLEM

Large volumes of natural gas have been discovered in the Canadian Arctic. These have included discoveries on Melville Island, Ellef Ringnes Island and in the Mackenzie Delta Estimates of the total amount of commercial gas vary but the consensus is that there may be over 3,000 billion cubic metres of commercial gas in this area To put this into perspective the total domestic consumption of natural gas in Canada was about 46 billion cubic metres in 1980 Thus the Arctic fields offer the potential of many years of gas supply. The problem, of course, is how to move this gas from the wells in the Arctic to the potential markets in Southern Canada and elsewhere.

The most obvious solution is to build a pipeline. This is being explored by the Polar Gas Project developed by a consortium of public and private sector agencies. The current proposal is the so-called "Y" line which would connect both the Arctic Islands and the Mackenzie Delta to the south. This system is planned to carry some 22 billion cubic metres of natural gas a year with possible expansions beyond that capacity. The current estimate for the cost of this project is over $7 billion in 1978 dollars which would bring it to almost $9 billion in 1980 dollars. The great size of the capital requirements and the magnitude of the volume of gas carried compared to current Canadian production and consumption show the scale of the project. The very large commitment of resources needed make the decision to go ahead with this project very difficult, particularly in light of new discoveries of gas being made in Western Canada and offshore on the East Coast of Canada on the Scotian Shelf and Hibernia fields. The construction of the Polar Gas pipeline would also require considerable research and development, especially with respect to the two marine pipelines required across straits in the Arctic Ocean.

A second proposal which represents the first stage of a more incremental approach is the Arctic Pilot Project (APP). This, again, is a proposal put forward by a consortium of companies. It proposes to construct the pipeline from gas fields on the Sabine Peninsula of Melville Island to a port on the southern coast of that island, to liquify the natural gas at a liquefaction plant to be located there, to move the liquified natural gas (LNG) by special tankers to a port in Eastern Canada and to regasify the LNG at this point and feed it into the pipeline network. The total capital costs of the APP are estimated at $1.4 billion in 1980 dollars and the system would carry approximately 2.6 billion cubic metres of gas to market each year. Thus, the capital costs are somewhat higher in proportion to the volume of gas to be moved However, the total commitment of capital required is much less than the Polar Gas Project and, as will be shown later in this paper, the project is much more flexible and can be expanded at incremental costs which decrease with throughput.

The Government of Quebec was very interested in the project from the beginning and commissioned various studies including an analysis of alternative sites for the southern terminal within the Province, and analyses of the safety implications and other aspects of the development. We were retained to make comparisons of terminals in Que-

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bec and in other Provinces and to help them prepare for hearings on the project before the National Energy Board where Quebec may appear as an intervenor.

2. THE ARCTIC PILOT PROJECT

Exhibit 1 shows the main components of the Arctic Pilot Project. These are:

—the pipeline on Melville Island;
—the liquefaction plant and port facilities at Bridport Inlet;
—the marine transportation system;
—the receiving terminals in Eastern Canada.

The first section is a conventional 100-mile pipeline from the Borden Point gas fields on the Sabine Peninsula to the south coast of Melville Island. The best port location was found to be at Bridport Inlet. A map of the pipeline route is shown on Exhibit 2. This pipeline is expected to cost $131 million in 1980 dollars.

The port and facilities in the port are interesting because of the construction methods to be used. The liquefaction plant will be built on a barge and moved to the site as a completed whole. In addition there will be storage tanks to take the products of the liquefaction plant and from which the vessel will be loaded. Like the liquefaction plant, the storage tanks will be mounted on barges and moved to the site as a whole. Unlike the liquefaction plant, however, the barges will not be left floating but will sit on a prepared gravel bed. The total cost for these port facilities is expected to be some $608 million (1980 dollars).

The liquefaction plant will cool and compress the natural gas to make it convenient to transport by ship. Liquified natural gas (LNG) is some 625 times as dense as the substance in its gaseous state at standard temperature. The temperature of the LNG is approximately —160°C.

The movement of LNG by tanker is not new. Exhibit 3, taken from the APP application to the National Energy Board, shows nine LNG transportation projects currently in operation. In addition there are several other projects now under design or construction. What makes this project unique is the combination of LNG carriers and icebreaking technology required. The voyages of the Manhattan and the motor vessel Arctic have indicated that the icebreaking technology has been developed sufficiently although this is still a "pilot project."

Each of the two LNG carriers proposed for the Arctic Pilot Project has the following characteristics:

—cargo capacity	140,000 cubic metres
—length	374 metres
—beam	43 metres
—draft	
—icebreaking	13 metres
—open water, laden	11 metres
—horsepower	180,000

One of the most interesting features of the design of the ships is that they will be fuelled by natural gas. In other words they will use part of their own cargo for the main propulsion energy. This natural gas used is part of the normal "boil-off" which will occur in any case during the voyage. The natural gas fuel will be supplemented by fuel oil. The vessels will be built to Arctic Class 7 standards which would allow them to operate between Melville Island and the East Coast on a year-round basis.

Our colleagues on this project, Albery, Pullerits and Dickson Associates, have estimated that round trip voyage times would vary between 17 days in the best month (September) to 23⅓ days in the worst month (April) for the voyage between Melville Island and Gros Cacouna, the terminal site proposed by the project sponsors. The routing of the vessels has been shown in Exhibit 1.

The vessels will use the Northwest Passage and, as planned by the APP, the Strait of Belle Isle to the northwest of the Island of Newfoundland. Taking account of changes in navigation conditions over the year and annual periods of refit, the operation of two vessels results in an arrival at the eastern terminal approximately once every 12 days. The total volume of gas that would be carried would be approximately 2.6 million cubic metres (measured when regasified) per year. The vessels are expected to have a total capital cost of some $530 million.

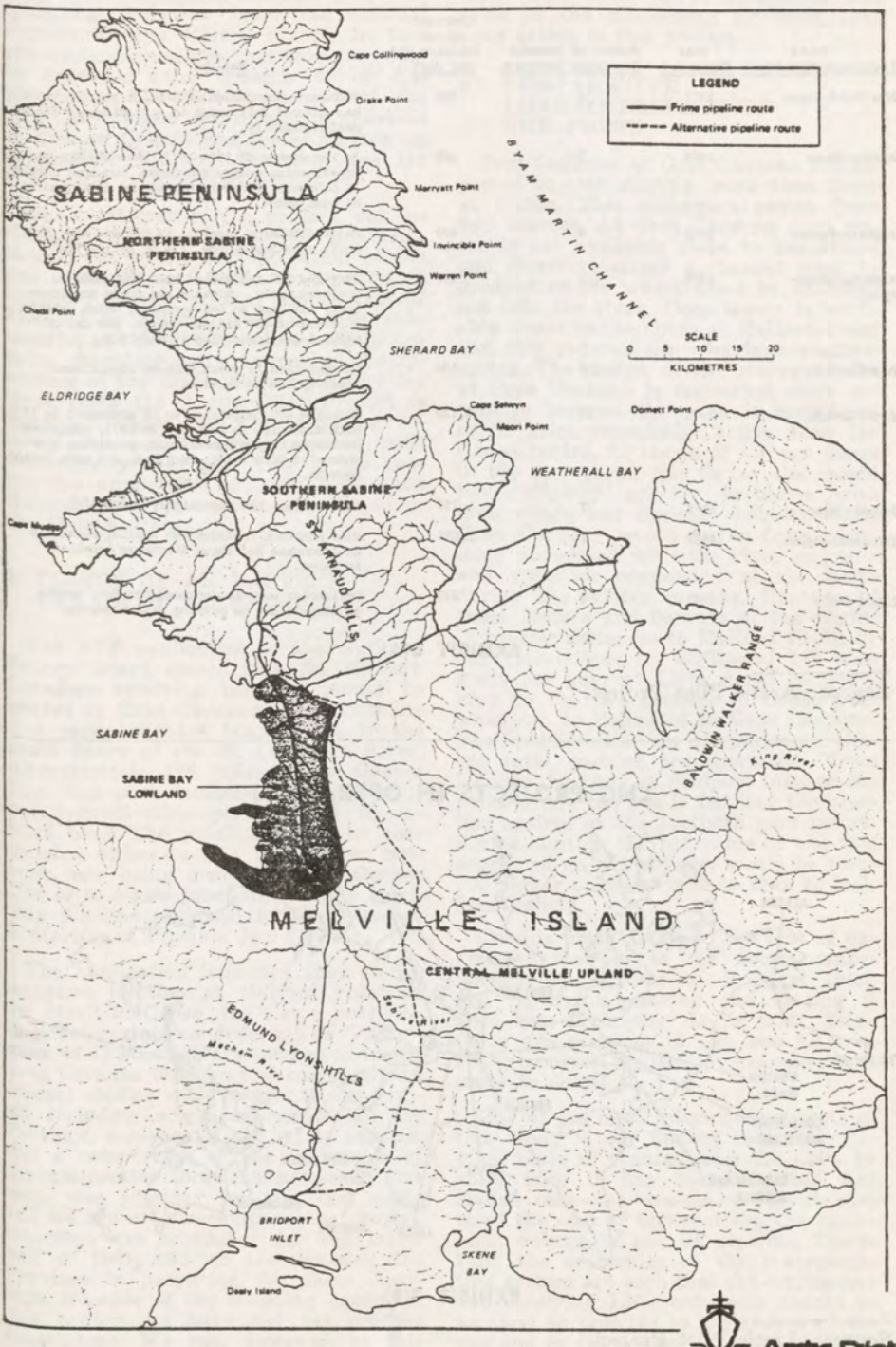
At the Eastern Canadian terminal there would be storage tanks for the ships to unload into. The unloading time is expected to be 12 hours. The APP has proposed a total storage of some 200,000 cubic metres of LNG (that is, gas in the liquid state) although our engineers indicate that this may be somewhat low. The port facilities, regasification plant and storage tanks have been estimated by the Arctic Pilot Project to cost $160 million.

After leaving the storage tanks, the LNG would be regasified and fed into a pipeline network for movement to the centres of consumption. It should be noted that the application of the APP


GREENLAND
BAFFIN BAY
DAVIS STRAIT
LABRADOR SEA
HUDSON BAY
GULF OF ST. LAWRENCE
GROS CACOUNA TERMINAL
MELFORD POINT TERMINAL
LEGEND
PIPELINE CORRIDOR
Arctic Pilot Project
PRINCIPAL COMPONENTS

EXHIBIT 1

UNITS ALONG PROPOSED PIPELINE ROUTES



Arctic Pilot Project

EXHIBIT 2

EXISTING LIQUID NATURAL GAS PROJECTS

Route (origin-destination)	Year Commenced	Number of Vessels Servicing Contract	Contract Volume (million ft³ per day)	Remarks
Abu Dhabi-Japan	1977	4	355	Problems encountered with plant storage tanks has reduced deliveries to approximately 85% of design capacity.
Alaska-Japan	1969	2	160	In the winter of 1976-1977, when the USA was experiencing energy shortages, two spot cargos of LNG were loaded in Alaska and delivered to US east coast.
Algeria-France	1965	4	400	Major discharge terminal is Fox-Sur-Her. Le Havre receives approx. 12% of deliveries.
Algeria/Libya-Spain	1974	1	110	Very few LNG deliveries have been made to Spain recently. Algeria and Spain have recently ratified an LNG agreement which entails delivery of 450 million cu. ft. per day of natural gas commencing in mid-1980.
Algeria-U.K.	1964	2	100	In operation 15 years with no significant interruption in service.
Algeria-U.K.	1971	15	1,120	Algerian LNG deliveries to US commenced in 1971 with discharge in Boston. In 1977, additional contracts became operational, providing discharge at Cove Point, Maryland, and Elba Island, Georgia.
Brunei-Japan	1972	7	750	This project has been highly successful.
Indonesia-Japan	1977	7	1,085	This contract includes two loading terminals in Indonesia and three discharge terminals in Japan.
Libya-Italy	1971	4	235	Deliveries were interrupted for four months in 1975-76 due to pricing disagreements.

EXHIBIT 3(A)

Source: Arctic Pilot Project.

LNG PROJECTS IN OPERATION

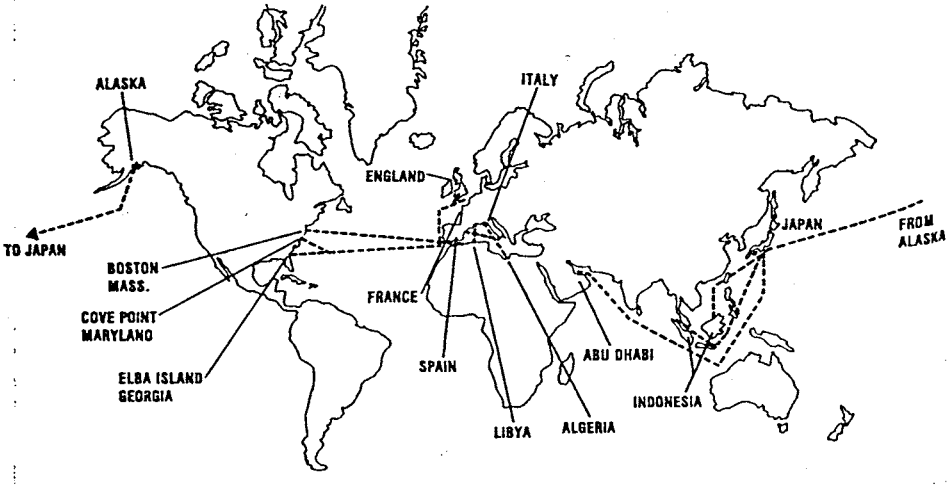


EXHIBIT 3(B)

Source: Arctic Pilot Project.

for this project is contingent upon getting export approval for this gas, plus additional volumes from conventional sources, to the United States. In fact the application states that this gas could be delivered either directly or by displacement. This latter means that the APP gas might serve certain markets in Eastern Canada and therefore free up or displace Western Canadian gas for delivery to the United States.

The total cost of the project, not including the development of the gas fields themselves or the transportation of the gas in Southern Canada by pipeline, is expected to have a total capital cost of $1.4 billion dollars. This is very substantial and in addition there will be ongoing operating costs incurred in the operating of the LNG tankers. To pay for these costs the Arctic Pilot Project is dependent upon the higher prices received for export gas compared with domestically used gas. This is the reason the application is contingent upon obtaining the approval to export gas to the United States.

3. CHOICE OF AN EASTERN CANADIAN TERMINAL

The APP application to the National Energy Board states that the Eastern Canadian receiving terminal would be located in Gros Cacouna. Gros Cacouna is a rocky, wooded island close to the South Shore of the St. Lawrence River, approximately 125 miles below Quebec City. The port facilities, storage tanks and regasification plant would be located here. The pipeline would be constructed either to join the Quebec network now being constructed to Quebec City or to a new junction with the Maritime pipeline proposed by TransQuebec & Maritimes Pipeline Inc. (TQM).

The application indicated that an alternative location at Melford Point on the Strait of Canso was also a possibility under certain conditions. The Government of Quebec is very interested in the Gros Cacouna location and commissioned several studies with respect to the project including site selection within the Province, analyses of the safety aspects, and a comparison of the economics of the alternative locations proposed. Our team was retained for this last study and we are still working on the project. Hearings are scheduled for the latter half of 1981, and we are assisting the Province in preparing for these hearings. Because of the on-going nature of this project we have not yet reached conclusions. We can, however, at this time indicate to you some of the questions that have to be addressed and some of the interesting problems that have arisen in this project.

3.1 COMPARATIVE CHARACTERISTICS OF THE PORTS

Port facilities at Gros Cacouna are expected to cost slightly more than those at Canso. This difference comes from two sources. At Gros Cacouna deep water is not available close to the Island and therefore either a channel must be dredged or the wharf must be extended out into the river. Deep water is available closer to the shore at Melford Point and this reduces the wharfage requirements. The design of the storage tanks at Gros Cacouna is somewhat more expensive because the area is considered to be more seismically active than the Canso region. In terms of voyage times to the two ports, the Canso site would have slightly greater problems with high winds and limited visibility while Gros Cacouna would suffer from problems associated with the river currents and with ice congestion at the berth during the winter months. Because of these factors and because of the slightly shorter distances to Melford Point, by our calculations an additional 1½ ship loads per year of LNG would be delivered by the two tankers to Canso over what can be delivered to Gros Cacouna. The final result of our comparison is that the total cost of transportation, from loading the LNG at Bridport Inlet to the point where the gas is fed into the pipeline system at the southern port including accounting for the value of the fuel consumed on the voyage, would be some 7% higher to Gros Cacouna than to Melford Point.

To this must be added the cost of extracting the gas in the Arctic, transporting by pipeline to Bridport Inlet, and liquifying, storing and loading it onto vessels in the Arctic port. Since these are common to the two alternatives, however, we did not examine these costs in detail.

One of the most interesting aspects of this study is our finding that the marginal costs of transporting the LNG by ship, once it has been liquified and loaded onto the vessels, is about one-third the cost of transporting the equivalent volume of gas by pipeline. Therefore, the economics of the transportation system are such that the originating and receiving LNG terminals should be as close as possible to the source of the gas and to the consumer, respectively.

3.2 PIPELINE TRANSPORTATION COSTS

The cost of transporting the gas to market obviously depends upon the location of markets that can absorb this gas, the existing pipeline infrastructure and the origins and therefore flows of gas from other sources. In the analysis of the best location of a southern terminal for the Arctic Pilot Project there is uncertainty in all three of these elements because of the following factors:

1. The size of the Maritimes market is not yet known. The estimates of the NEB in their decision in the previous applications for a Maritime pipeline issued in April, 1980, indicated that the Maritimes market might take approximately half of the volume of the gas to be delivered by the Arctic Pilot Project. The current application of TQM has higher estimates of the market, indicating that the Maritime Provinces could absorb essentially all of the Arctic Pilot Project gas by 1993. These projections have just recently been issued and have not yet been examined by others in detail.
2. The future of the TQM pipeline is yet to be decided. Although the government has declared that it is part of the National Energy Policy, the relative timing is still uncertain and, in fact, there is some resistance on the part of the Alberta gas producers to the Maritime pipeline extension.
3. Significant finds of natural gas have occurred offshore on the East Coast, on the Scotian Shelf and in the Hibernia field off Newfoundland. The introduction of these volumes of gas would significantly alter the patterns of flow.

Exhibit 4 shows the possible permutations of these factors and indicates which port is more economic under each of these combinations. Of the eight possible cases, Gros Cacouna is indicated to be preferrable in five, it is a "toss-up" in two, and Melford Point is the more cost-effective site in one case. The case in which Melford Point is the preferrable port assumes that the Maritimes market is large enough to absorb all of the APP gas, that the TQM pipeline has been built as proposed and its costs are assumed to be "sunk," and that there is no major development of the gas fields on the East Coast; otherwise, Gros Cacouna appears to be preferrable.

In one way these comparisons are ar-

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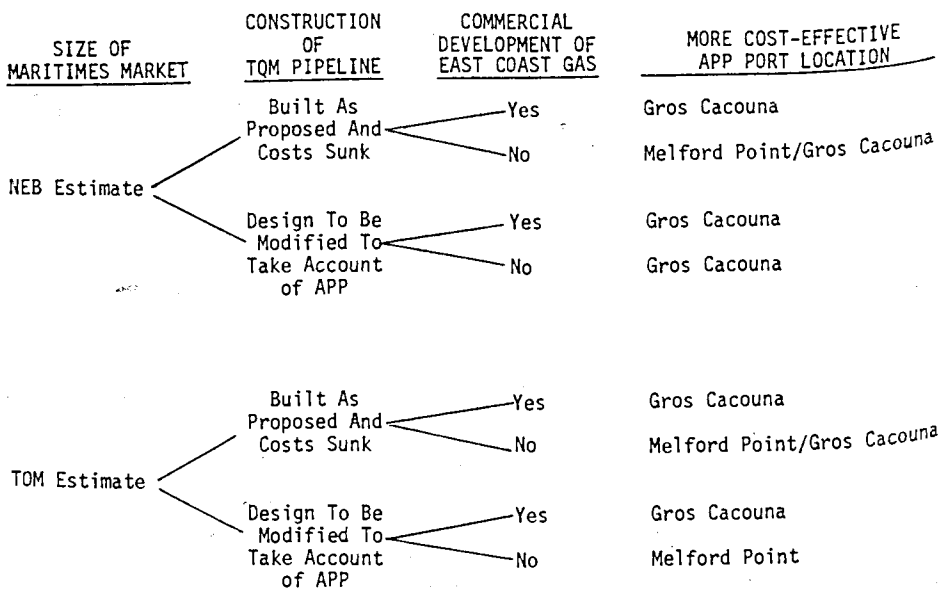

EXHIBIT 4

tificial; it is not likely that the TQM pipeline would be built entirely as originally planned if, after the commencement of construction, the Arctic Pilot Project were to start. In another way, though, this comparison reflects the current decision-making environment in Canada. The NEB will probably rule upon the TQM pipeline application before considering the Arctic Pilot Project. By the time the Arctic Pilot Project is committed, the commercial possibilities of the East Coast fields will probably be better known.

There is a further consideration. The APP is a "pilot project" and, if successful, will probably be expanded. We have examined the costs of such an expansion. Marine transportation costs per unit of gas carried remain relatively constant. However, per unit port costs go down rather steeply with larger throughputs. In fact, we have estimated up to eight or ten LNG carriers could use either port without experiencing any significant congestion or necessitating any additional wharfage. Some additional storage would have to be proposed but this does not vary linearly with throughput; there are economies of scale. The cost of the regasification plant also does not increase directly with the throughput. Any additional volumes of gas would obviously be beyond the capacity of the Maritimes market to absorb and, from this point of view, Gros Cacouna would be a more logical terminal site, being closer to other major Canadian and U.S. markets.

As well as there being a potential for additional volumes of gas moving from the Arctic, it is quite possible that it will be decided that gas cannot be landed economically by pipeline from the Hibernia fields because of problems with icebergs, etc. In such a case it is quite possible that the gas will be liquified in the field and will be landed by ship. Again, if these volumes are significant, Gros Cacouna would be the preferrable site since it is closer to major markets.

4. THE POTENTIAL IMPACTS OF THE ARCTIC PILOT PROJECT

The Arctic Pilot Project is a very major project for Canada. It will have significant impacts on the Canadian economy both during the construction phase and later. Although some of the capital costs will be spent abroad, a very high proportion will be spent in Canada. Ongoing operations will be less significant in terms of expenditures and labour employment but will still be quite large.

The development of the Arctic Pilot Project will also lead to the development of regular cargo service to the Arctic to supply the installations on Melville Island. In addition the passage of the LNG carriers throughout the entire year will maintain an open channel through the Northwest Passage. This has great implications for other users of this waterway. This would probably include oil tankers at the same time or shortly afterwards.

The Arctic Pilot Project, if successful, will undoubtedly lead to further development of the gas fields and other resources of the Canadian Arctic. Estimates of the number of LNG carriers that might be built range up to 30. At a cost of well almost $300 million each, this would have a very considerable impact on the Canadian economy, on the Canadian shipbuilding industry, and on the development of a Canadian Merchant Marine.

4.1 OTHER USES OF LNG

To this point we have been speaking of the LNG carrier as part of the supply route to a conventional pipeline system, but, once the gas is liquified, it can be used directly for a number of purposes.

Present designs call for the burning of fuel to provide the heat of vapourization needed in the regasification plant; these "cold" BTU's could be used for other purposes. A combination of an LNG terminal and a thermal generating plant would result in increased efficiency. The very cold LNG can be used as a coolant in an air separation plant to produce oxygen and nitrogen. The Japanese are investigating the use of cold produced by the regasification of LNG for a desalinization plant. Food freezing and cold warehousing is also another obvious potential use of LNG.

Our investigations have also indicated that, once the gas is liquified, it can be handled by surface modes of transport, rail and truck, at costs which are very comparable with pipeline transportation. Thus, with a large source of LNG at a site such as Gros Cacouna, LNG could be carried to peak-shaving gas storage facilities in some of the larger metropolitan areas which already create their own LNG to handle peak demand periods. LNG could also be carried to areas not presently served by the pipeline network and thus could be an instrument for introducing the use of natural gas to many smaller communities in Eastern Canada.

LNG also has great promise as a transportation fuel, for railways, for automobiles and for aircraft. The siting of an LNG terminal in one of the more

populated regions of our country improves its attractiveness as such a fuel because the cost of liquification, a major consideration, would no longer be required.

For all of these reasons the Arctic Pilot Project would have a very significant impact on Canada and would impact it in ways which might not be expected at first examination. It is to be hoped that these impacts will be given due weight as decisions are made regarding whether and how to proceed in this important development.