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The International Dimensions
of the Canadian Nuclear Industry

by

James A. Casterton, B.A.

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A thesis submitted to the Faculty of
Graduate Studies and Research in partial
fulfilment of the requirements for the degree of
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Carleton University
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ABSTRACT

Due to the decreased domestic demand for nuclear power, Canada's nuclear industry is suffering from overcapacity. The industry is relying heavily on the export market to provide a sufficient volume of new orders.

This paper focuses on the export component of Canada's nuclear power program and its implications for the nuclear industry. It argues that, although export orders will be difficult to obtain, action can be taken which could make the task easier. Specifically, there should be a fundamental revision of CANDU export marketing methods designed to improve the way that the CANDU system is packaged for export and the export marketing organizational structure. This argument is supported by analyses of a) Canada's previous attempts to market the CANDU internationally, b) the size and nature of the international nuclear market and c) the factors which influence the sale of CANDU technology to foreign countries.

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INTRODUCTION

The Canadian nuclear power program represents Canada's largest and most successful venture in research and development. In economic terms, this thirty year investment has already paid handsome dividends. Nevertheless, the program has had its problems, some of which have created several difficulties for the nuclear reactor manufacturing industry. This paper deals with the major problem currently plaguing the Canadian nuclear industry, that is, an insufficient volume of new orders. In doing so, it focuses almost exclusively on the export component of the nuclear power program. It argues that with a major effort at coordination and with a vigorous and aggressive marketing campaign, the export market could help the industry cope with the effects of the temporary lull in domestic demand for nuclear power.

The problem that is addressed in this paper should be of great concern to Canada since it poses a very serious threat to Canadian nuclear technology and manufacturing capability. There are indications that several firms within the nuclear component manufacturing industry may be forced to withdraw from the nuclear program because of an unprofitable volume of business. If Canada's nuclear manufacturing base is diminished, there could be a number of negative repercussions. First, there may not be sufficient capacity to meet the

VIII

increased demand for nuclear power that is expected before the turn of the century. This could adversely affect Canada's efforts to establish secure energy supplies. Secondly, it would augment the already sharp decline of Canada's employment-intensive secondary manufacturing sector. Third, the nuclear industry is valued as a symbolic lead sector in high technology industry. Failure to ensure its viability could undermine Canada's future attempts to establish additional high technology manufacturing operations.

With the decreased domestic demand for nuclear power, the nuclear industry is relying on the export market to provide an adequate base load of work. In analysing this situation, the paper focuses on the following five critical questions. How much success has Canada had in marketing the CANDU system internationally? To what extent will previous experiences affect future marketing endeavours? What is the size and nature of the international nuclear market? What factors, both positive and negative, influence the sale of CANDU technology to foreign countries? Lastly, can practicable measures be taken to facilitate the acquisition of the export orders that the nuclear industry so desperately requires?

The answers to these questions and, hence, the recommendations that are proposed, are based, for the most part, on research that was undertaken up to the beginning of 1979. Where possible, the paper incorporates more recent

material. This is particularly evident in Chapter V and the Postscript. Most of the material used in this paper is available to the public. However, the study also includes information obtained during interviews with personnel from Atomic Energy of Canada Limited, Ontario Hydro, various firms within the nuclear manufacturing industry and the Department of Industry, Trade and Commerce.

Finally, although this paper stresses the economic incentives for nuclear exports, it is not suggesting that Canada should adopt a nuclear export policy that is based solely on economic self-interest. The international impact of Canada's nuclear exports must also be considered. In essence, this means that policy-makers must be concerned with issues such as the relationship between the export of nuclear technology, equipment and materials and the proliferation of nuclear weapons capability as well as the appropriateness of nuclear technology as an economic development tool for the developing countries. These issues are extremely complex and a detailed discussion of them is beyond the scope of this study. They are referred to only as factors which tend to impose restraints on nuclear exports.

The paper is divided into five chapters. The first chapter provides a brief description of the evolution of Canada's domestic nuclear power program and a detailed discussion of the overcapacity problem that is jeopardizing the viability of the nuclear industry. Chapter II outlines

how and why nuclear exports began and discusses the previous sales of CANDU reactor technology. Chapter III attempts to establish the size and characteristics of the international market for nuclear power reactors in the short-term future; i.e., to the turn of the century. Chapter IV outlines some of the technical merits of the CANDU system which may make it more attractive to the developing countries than the light water reactor system. Some of the restraints on CANDU exports are also discussed. It then presents an analysis of the prospects for CANDU export sales in the short-term future. The final chapter briefly reviews the main points outlined in the previous chapters and then advances some specific recommendations with respect to the acquisition of CANDU export orders.

CHAPTER I
NUCLEAR ENERGY IN CANADA

A. INTRODUCTION

The purpose of this chapter is twofold: 1) to outline the development of Canada's domestic nuclear power program with particular emphasis placed on the role played by Canadian industry, and; 2) to establish the importance of the acquisition of export orders for the Canadian nuclear industry and the nuclear program as a whole.

Accordingly, the chapter is divided into two main sections. The first section provides a thumbnail sketch of the program from its inception after World War II to the present. It explores the rationale behind the development of nuclear power as a source of electricity, the objectives of the program and the relationships between Atomic Energy of Canada Limited and Ontario Hydro.

Section two focuses on the Canadian nuclear industry and is divided into three parts. Part one relates the history of industrial participation in the program. The second part outlines the present structure of the industry. Finally, there is a lengthy examination of what is labelled the "industry's predicament"; i.e., the slowdown in the domestic program resulting in the very serious problem of substantial overcapacity throughout the industry.

B. THE CANADIAN NUCLEAR POWER PROGRAM: A BRIEF HISTORY

The seeds of Canada's present nuclear power program were sown during World War II when Canada participated with the United States and Great Britain in the Manhattan project.¹ Canada was chosen as the site for the construction of major experimental facilities and this resulted in the development of two heavy water moderated, natural uranium reactors: ZEEP (Zero Energy Experimental Pile) which went critical on September 5, 1945; and the larger NRX (National Research Experimental) reactor which achieved criticality on July 22, 1947. The latter reactor was the precursor of the CANDU family of reactors.

When the war ended, Canada had to decide what to do with the nuclear facilities at Chalk River. One alternative was to let the project die a natural death with the rest of the war machine. A second alternative was to continue research but, since Canada felt no need for an atomic bomb, to direct it toward the development of atomic energy for peaceful purposes. The government of the day chose the second alternative and, with the passing of the Atomic Energy Control Act in 1946, provided for the control and supervision of the project.

The legislation introduced a new body, the Atomic Energy Control Board, which was authorized "to regulate and control atomic energy materials and equipment in the interests of safety and physical welfare, to control atomic energy materials, equipment and information in the interests of national and international security and to promote atomic energy research".² In order to carry out its mandate, the

Board was granted a great array of powers including the powers to regulate and to license. However, the application and enforcement of the Board's regulations have been carried out with assistance from several government departments such as the Departments of National Health and Welfare, Environment, External Affairs, Industry, Trade and Commerce and National Revenue. The AECB also encourages the cooperation of provincial government departments, primarily through the appointment of technical experts and representatives to safety advisory committees and to other advisory groups, as well as through the appointment of "medical advisors" and "inspectors".³

The National Research Council first directed the atomic energy program in Canada under the supervision of the AECB. During the late 1940's the NRC was interested mainly in fundamental research. By 1950, however, there was considerable interest in the possible commercial aspects of the program, particularly the generation of electricity using atomic energy. In early 1951 discussions took place between the NRC and the Hydro-Electric Power Commission of Ontario (now Ontario Hydro) related to this possibility. The Commission felt that a source of power, other than hydro-electric, would be necessary in order to satisfy Ontario's future energy needs. Thus a strong interest was shown in the development of nuclear power.⁴ One year later Atomic Energy of Canada Limited was created. This new crown corporation took over the research and development work on atomic energy from the NRC and accordingly, the Chalk River laboratories were transferred to AECL.

In June 1953, AECL and Ontario Hydro decided to proceed with a nuclear power project. The next step was to choose a method of producing electricity using atomic energy that would be efficient and competitive with alternative energy sources. Consideration was given to both the British graphite moderated gas-cooled reactor and the American light-water enriched uranium reactors, but ultimately, neither of these options were pursued. Instead, AECL decided to develop a natural uranium heavy-water moderated reactor. Two major factors influenced this choice:⁵

- 1) this type of reactor was consistent with the previous work done at Chalk River; and
- 2) Canada's large supply of uranium would ensure self-sufficiency with respect to fuel supply.

Early in 1954 a study team was organized to undertake the preliminary design of a nuclear power demonstration plant. The team consisted of personnel from Ontario Hydro, several manufacturing and consulting firms and the Chalk River laboratories. It recommended the construction of a 22 MWe demonstration reactor (NPD). In keeping with the earlier decision, the reactor would be cooled and moderated with heavy water (deuterium oxide) and fuelled with natural uranium. Hence the acronym CANDU (Canada-Deuterium-Uranium).

The design and development of the plant was undertaken jointly by AECL, the Canadian General Electric Company and Ontario's hydro-electric utility.⁶ CGE, with assistance from AECL, was responsible for the detailed design of the nuclear systems while Ontario Hydro undertook the same responsibility

for the conventional portion of the plant. In addition, several Canadian firms participated in the project through the acquisition of sub-contracts for the design and supply of specific components. These firms also worked closely with AECL. Operational responsibility was assigned to Ontario Hydro and the power that was to be generated would enter its grid system.⁷

NPD's main objective was to establish the feasibility of the Canadian design and to provide verification of the basic principles of the heavy water, natural uranium system. However, prior to the completion of NPD, work began on the second stage of the nuclear power program - a study to produce a conceptual design of a larger commercial nuclear power plant. This study recommended a significant change in the proposed CANDU configuration. The original NPD design was based on the use of a large pressure vessel which would contain both the fuel and the moderator. According to the new design, however, the heart of the reactor would consist of a horizontally-oriented cylindrical tank (calandria) which contains the heavy water moderator. This tank is penetrated by a number of horizontal tubes containing the natural uranium fuel and pressurized high temperature heavy water coolant. The coolant is pumped through the tubes, removing the heat produced by the fissioning of the uranium fuel, and then through the boilers where the heat is given up to produce steam which, in turn, is fed to the turbine. The pressure tube concept was adopted and is now one of the major distinguishing characteristics of the

CANDU family of reactors (see TABLE 1-A). As we shall see in chapter IV, the use of pressure tubes rather than a pressure vessel gives the CANDU system a number of important advantages over its competitors.

TABLE 1-A

CANDU - A FAMILY OF REACTOR CONCEPTS

Distinguishing Characteristics:

1) Heavy-Water Moderation

fuel economy - freedom to use natural uranium
spreads out fuel - allows pressure tubes

2) Pressure Tubes of Neutron Economic Material

ease of proof testing
ease of scale-up
allows evolutionary improvements

3) On-Power Fuelling

Members of Family Characterized by Coolant:

PHW - Pressurized Heavy-Water Coolant

BLW - Boiling Light Water Coolant

OCR - Organic-Cooled Reactor

Source: E.C.W. Perryman "Canadian Power Reactor Program - Present and Future", (Paper presented at the 27th Annual Congress of the Canadian Association of Physicists, Edmonton, Alberta, on 27 June, 1972), AECL Report - 4265, p. 2.

In February, 1958, AECL issued a statement outlining the corporation's objectives in developing a nuclear power program and expounding the future role of AECL in the development process.

The objectives of the program were fivefold:⁸

- 1) to reduce the future dependence on a foreign source of energy;
- 2) to reduce the adverse effect of such imports on the balance of trade;
- 3) to minimize the increased load on Canada's transportation systems;
- 4) to reduce Canada's energy costs through the utilization of Canadian uranium; and
- 5) to stimulate the Canadian manufacturing sector by creating domestic and possibly foreign markets for plant components and fabricated fuels.

More importantly, however, the statement announced the creation of a new division within AECL - the Nuclear Power Plant Division - to direct the future development of nuclear power on a commercial basis. Henceforth, this unit would be responsible for designing the nuclear steam supply systems of nuclear stations and for providing project management services as required by the customer.⁹

The first project under this new arrangement was the development of the 220 MWe Douglas Point Nuclear Generating Station. Douglas Point was committed on June 18, 1959, while NPD was still under construction. The detailed design and construction of the station was the joint responsibility of AECL and Ontario Hydro: the Nuclear Power Plant Division provided the full scope of its services and Ontario Hydro was assigned the tasks of designing the conventional systems (the balance of plant) and of operating the station upon completion. Arrangements were made for the utility to purchase the station from AECL once the plant had demonstrated that it could be

successfully operated within the utility's grid system. However, several problems arose which adversely affected the performance of the reactor and, for this reason, these arrangements were never completed.

The rapid development of the CANDU system continued into the next decade. On April 11, 1962, NPD achieved criticality and two months later it began generating electricity for Ontario Hydro's grid system. In 1964, with only two years operating experience on NPD and with Douglas Point still under construction, AECL and Ontario Hydro decided to proceed with the construction of the first full-scale commercial nuclear power station. This station, located at Pickering, Ontario, consists of four 514 MWe units. The four unit station concept, destined to become characteristic of the nuclear power program in Ontario, was chosen because it offered several advantages over the single unit station. According to J.S. Foster, past-president of AECL:

*Multiplicity of units made it possible to borrow components destined for later units to replace faulty components in the first unit; to eliminate faults in later units in advance of the commissioning of these units; and to apply proven procedures and trained staff to the construction and commissioning of later units.*¹⁰

The Pickering Generating Station is also noteworthy for another reason: it established the relationships between AECL, Ontario Hydro and Canadian industry with respect to the construction of subsequent nuclear power stations in Ontario. The reactors at Pickering are owned and operated by Ontario Hydro. Ontario Hydro hired AECL as nuclear consultants and to provide engineering services for the nuclear steam supply system but the utility designed and engineered the balance of

plant, purchased the necessary hardware on the open market and built the station themselves. Since the construction of Pickering, there has been only one major change in these arrangements. Ontario Hydro gradually developed its own capability in the field of nuclear engineering and as a result, AECL's input diminished accordingly. Now AECL is employed principally as a nuclear consultant.

Meanwhile, on November 15, 1966, Douglas Point achieved criticality. The station generated electricity for the first time on January 7, 1967.

A further demonstration of Ontario Hydro's faith in the CANDU system occurred in 1969. Although the system had not yet been proven on a commercial basis, the utility decided to build another four unit station adjacent to the Douglas Point reactor. This station, known as Bruce A, was designed to have an output of 3000 MWe net (750 MWe per unit).

All four of the Pickering units came into service between 1971 and 1973. With the exception of problems with some of the pressure tubes in units three and four, the performance of these reactors has been remarkable. In 1977, the capacity factors (i.e. the amount of electricity produced as a percentage of the theoretical maximum) were 86.5%, 88.4%, 96.1% and 92.4% respectively, yielding an average of 90.9% for the four units.¹¹ This constitutes a world performance record for multi-unit nuclear stations of over 1000 MWe gross. In addition, three of the four Bruce A units are now in service with the fourth unit expected to be in operation sometime this year (1979).

Ontario, with nine power reactors currently in operation, possesses over 90% of Canada's nuclear capacity. The only other completed nuclear power installation is the 250 MWe Gentilly -1 reactor near Trois-Rivieres, Quebec, which first achieved criticality in 1970. Gentilly -1 was originally intended to be the prototype for a second and potentially more efficient generation of reactors in the CANDU family: i.e., reactors cooled by boiling light water instead of pressurized heavy water. However, the reactor has been plagued with several teething problems which have resulted in numerous shutdowns and AECL has decided to delay efforts to perfect the boiling water variant until some later date. Thus the future role of Gentilly -1 in the Canadian nuclear program is currently being re-evaluated.

As the following data for 1977 illustrate, nuclear power is making a significant contribution to Canada's, and particularly Ontario's energy requirements. During that year, nuclear power accounted for almost 8% of Canada's total electrical energy supplies.¹² Cumulatively, the nine power reactors operating in Ontario supplied approximately 28% of that province's electrical energy needs.¹³ Furthermore, given the current replacement costs of imported coal, it was estimated that the Pickering Generating Station improved Canada's balance of payments position by about \$350 million in 1977 alone.¹⁴

Currently, Canada has 4786 MW of installed nuclear capacity. As Table I-B indicates, additional nuclear power stations now under construction or committed for construction in the domestic market include: Gentilly -2 (600 MWe) and

Gentilly -3 (size undetermined) in the province of Quebec; Point Lepreau (600 MWe) in New Brunswick; the duplication of both the Pickering and the Bruce generating stations; and a 3400 MWe station at Darlington, Ontario. On the basis of this program Canada is expected to have at least 15,192 MW of installed nuclear capacity by 1988. While there are plans for further installation of CANDU reactors after 1988, they are only tentative. Nevertheless, a recent study suggested that, if these provisionally-planned stations are constructed, by the year 2000, Canada's installed nuclear capacity would be 33,040 MW.¹⁵

Table I-B also indicates that Canadian-designed nuclear reactors are operating or under construction in several foreign countries. The role of CANDU technology abroad is the major concern of this paper and therefore will be examined in detail in the following chapters. However, in order to present a complete picture of Canada's nuclear power program, it is necessary and appropriate at this time to comment briefly on the extent of the Canadian involvement in the international marketplace.

In 1956, under the Colombo Plan, Canada agreed to supply India with a research reactor based on the NRX design. This reactor, known as CIRUS, began operation in July, 1960. Later agreements between Canada and India made provision for the building of two 203 MWe units - RAPP-1 and RAPP-2. The first unit was completed and achieved criticality on August 11, 1972. RAPP-2, originally scheduled for operation in 1976, is not

TABLE I-B

CANDU REACTORS IN OPERATION, UNDER CONSTRUCTION, COMMITTED,
AND PLANNED

<u>NAME^a</u>	<u>LOCATION</u>	<u>POWER MWe</u> <u>NET</u>	<u>NUCLEAR</u> <u>DESIGNER^b</u>	<u>DATE OF FIRST</u> <u>POWER</u>
NPD	Ont.	22	AECL & CGE	1962
Douglas Point	Ont.	208	AECL	1967
Pickering A	Ont.	514x4	"	1971-73
Gentilly 1	Que.	250	"	1971
KANUPP	Pakistan	125	CGE	1971
RAPP 1	India	203	AECL	1972
RAPP 2	India	203	"	-
Bruce A	Ont.	745x4	"	1976-79
Gentilly 2	Que.	600	"	1981
Point Lepreau	N.B.	600	"	1980
Cordoba	Argentina	600	"	1980
Pickering B	Ont.	514x4	"	1981-83
Wolsung 1	Korea	600	"	1981
Bruce B	Ont.	750x4	"	1983-86*
Darlington	Ont.	850x4	"	1986-88*
	<u>TOTAL</u>	16,903		
Gentilly -3	Que.	at least 600		- construction to begin before end of 1980

^a NPD Nuclear Power Demonstration
KANUPP Karachi Nuclear Power Project
RAPP Rajasthan Atomic Power Project

^b AECL Atomic Energy of Canada Ltd.
CGE Canadian General Electric

* Tentative dates

Sources: J. S. Foster and J. H. Russell, AECL Report - 5707
(Ottawa: May 1977) and AECL Annual Report 1977-1978

yet completed. The main reason for this delay was Canada's termination of nuclear co-operation with India following the detonation of a nuclear device by that country in 1974.

In 1965, the Canadian General Electric Company agreed to supply and build a 125 MWe CANDU unit at Karachi, Pakistan. This reactor went critical on August 1, 1971 and began commercial operation on December 7, 1972.

In 1968, CGE decided not to continue as an international supplier of nuclear technology and AECL assumed the responsibility for marketing the CANDU abroad. Since that time the crown corporation has sold a 600 MWe unit to Argentina (in partnership with an Italian firm) and a 600 MWe unit to South Korea. In addition, AECL has signed licensing agreements with Italy and with Romania.

Finally, there is another aspect of the Canadian nuclear power program that should be noted. To a large extent, the success of the program depended upon the acquisition of an abundant and reliable supply of heavy water. Thus, in addition to the resources devoted to the development of the reactor technology, Ontario Hydro and AECL made substantial investments in the development of heavy water production facilities. Ontario Hydro's supply program includes two active plants, Bruce 'A' and Bruce 'B', and a third plant, Bruce 'D', which is currently under construction. AECL has a plant at Glace Bay and another one at Port Hawkesbury, both in Nova Scotia, to supply heavy water to the other provincial utilities and for export.

As a result of these investments, there is sufficient heavy water production capacity to supply all the present and planned reactors. In fact, Canada is now facing the possibility of having a serious oversupply of heavy water. However, this problem and its resolution is beyond the scope of this study. Suffice it to say that since May, 1978, Ontario Hydro, AECL and the energy departments of the provincial and federal governments have been discussing the Canadian heavy water supply and demand situation in an effort to rationalize the production and the marketing of heavy water.¹⁶ These discussions undoubtedly influenced AECL's decision to 'mothball' its La Prade heavy water production facility and they may also determine the future of Ontario Hydro's Bruce 'D' plant.

This section has presented a brief history of the development of the Canadian nuclear power program. Two of the major participants in the program have been identified - AECL and Ontario Hydro. The close cooperation between the nuclear designer/developer and the major utility/owner has contributed greatly to the success of the CANDU program to date. However, the private sector has also played a significant role in the development of the CANDU technology. The next section examines the role played by industry with special emphasis on the industry's development, structure, size and problems.

C. THE CANADIAN NUCLEAR INDUSTRY

In the broadest terms, the Canadian nuclear industry is defined as the aggregation of all the firms, both public and private, involved in nuclear-related activities in support of the nuclear power program. This includes: public utilities (Ontario Hydro, Hydro-Quebec and the New Brunswick Electric Power Commission); federal agencies (AECL, AECB and Eldorado Nuclear Limited); and approximately 365 privately-owned firms which supply services and materials ranging from uranium exploration to the manufacture of components and equipment for nuclear power stations and heavy water plants. Collectively, these firms provided direct employment for approximately 31,400 persons in 1977 (see Table I-C). An additional 53,600 persons were also employed indirectly.¹⁷ The Canadian Nuclear Association has suggested that by the year 2000, direct employment in the industry could reach 122,000 Canadians.¹⁸ This estimate, however, does not include those employed in uranium mining, uranium refining and the construction of electric transmission facilities. Finally, the annual dollar value of the industry is approximately \$1.2 million.¹⁹

This paper, however, is primarily concerned with only one sector of the industry - the manufacturing sector. Therefore, whenever the term "nuclear industry" is used, it is in reference to the 100 or so private firms which manufacture a wide range of components and equipment for the CANDU reactor system. This system can be broken down into two main subsystems: the nuclear steam supply system (NSSS) and the power generation system (PGS). The latter is often referred to as the balance

TABLE I-C

ESTIMATED DIRECT EMPLOYMENT IN
THE CANADIAN NUCLEAR INDUSTRY, 1977

<u>SECTOR</u>	<u>DIRECT EMPLOYMENT</u> <u>(Persons)</u>	<u>PERCENT</u>
Uranium Mining	500 (a)	1.6
Uranium Refining	235 (c)	0.8
Research & Development	3,280 (d)	10.5
Engineering & Design	4,110 (d)	13.0
Manufacturing	6,000 (d)	19.1
Construction	11,450 (d)	36.4
Utilities (b) (operations, maintenance)	5,600 (d)	17.8
Public Administration	250 (d)	0.8
TOTAL	31,425	100.0

NOTES: (a) Total employment in the uranium mining sector in 1977 is estimated at 5,000 persons. Ten percent of employment has been attributed to CANDU reactor fuel requirements.

(b) Total utility employment - Ontario Hydro, Hydro-Quebec, New Brunswick Power Corporation - exceeded 9,000 in 1977. 5,000 is the estimate of employment in operations and maintenance, training, etc.

(c) 50 percent of Eldorado Nuclear's reported Port Hope refinery employment.

(d) Leonard & Partners Limited estimates.

SOURCE: Leonard & Partners Limited, The Economic Impact of Nuclear Energy Industry in Canada (Executive Summary), (Ottawa: August 1978), p. 14.

of plant (BOP). The main components of the NSSS are the reactor, the primary heat transport system, the fuel handling system, the moderator circulation system and auxiliary systems. All of this equipment is contained within the reactor building at the nuclear generating station site. The PGS is the conventional section of the nuclear power plant and its components are housed in the turbine-generator building. The major components of the PGS are the turbine-generator, condensers, pumps, valves and various electrical apparatus such as transformers, switchgear, small motors and process control equipment.²⁰ In 1977, there were approximately 6000 persons engaged in the manufacture of all of these components.*

(i) Industrial Participation

Canadian private industry has made and continues to make a significant contribution to the development of atomic energy in Canada. Throughout the years, however, the extent of industrial input has been modified by the policies of AECL and Ontario Hydro.

The private sector initially became involved in the nuclear program by participating in both the design and the manufacture of nuclear components for the research reactors at Chalk River. When the decision was made to develop nuclear energy as a power source, the continued contribution of private industry, in these same capacities, was deemed essential for the success of the program. In 1956, Dr. J.L. Gray of Atomic Energy of Canada Limited stated:

* Strictly speaking, nuclear manufacturers are those who manufacture components for the NSSS. These firms are the main concern of this paper. However, PGS component manufacturers may also benefit from export sales of complete CANDU stations and, thus, are included in the "industry".

... The only logical approach to the combined problem of putting Canada in its proper position in the new field of nuclear engineering and of getting reactors and their equipment designed and manufactured is to encourage industrial participation, and this the Company is doing, but with considerable difficulty.²¹

The "considerable difficulty" mentioned by Dr. Gray was in reference to the problems that many companies were encountering, especially in the design and manufacture of nuclear grade components. The nature of this new technology demanded a level of expertise which heretofore had not been required in the individual pursuits of these firms and thus, was not forthcoming. However, rather than attributing this shortcoming to an inherent weakness in the Canadian industrial sector, AECL believed that, in time, it could be overcome. All that the industry needed to rectify the problems was experience. AECL's strategy relating to industrial participation in the nuclear program was in accordance with this belief: through a substantial involvement in the design, development and fabrication of a demonstration reactor, Canadian industry would obtain the necessary experience to enable it to make similar contributions on commercial stations.

When work commenced on the preliminary design of the NPD, engineers were seconded from Canadian companies interested in the project. Moreover, as the previous section indicated, the Canadian General Electric Company was awarded the contract for the detailed design and development of the reactor's nuclear systems. Several other firms designed and supplied a broad range of components for the reactor.

Consequently, under the guidance of AECL, Canadian industry seemed destined to play a multi-faceted role in the nuclear power program. However, the strategy was short-lived. In 1958, the newly-formed Nuclear Power Plant Division of AECL assumed responsibility for the design and development of commercial power reactors, thereby limiting the extent of industrial participation to the manufacture of AECL-designed components.

Why did AECL feel that a redistribution of responsibility was necessary? Dr. Gray later explained:

This procedure [allowing private industry to design and develop a power reactor] was in fact tried in the first nuclear power station [NPD] but, for a number of reasons, the procedure was changed. The monopoly position of a designer-supplier of large power stations was not acceptable to the customer [Ontario Hydro] from a competitive price point of view; other Canadian suppliers were inhibited from getting into a competitive position for equipment supplies for prospective Canadian and foreign nuclear power stations; and normal industrial competition, to ensure maximum ingenuity in equipment supply and performance, was to be inhibited.²²

Thus AECL was concerned about the long-range consequences of the original arrangement. The company obviously felt that one of its objectives, i.e., the promotion of participation of Canadian industry in the nuclear power program, would not be realized if the design of prospective nuclear power stations was left in the hands of one firm - CGE. Other firms would be reluctant to undertake the necessary risks and expense to establish themselves as competitors with CGE for the supply of equipment, thereby giving the latter a monopoly. This possibility was totally unsatisfactory since Ontario Hydro steadfastly refused to tie itself to one commercial supplier.

Therefore, in order to prevent this situation from developing, AECL assumed the design responsibility and, at the same time, made a commitment "to permit voluntary participation by Canadian companies in the electric utility, manufacturing and consulting engineering fields, and thereby provide for maximum dissemination of experience in this new field throughout Canadian industry".²³

By way of a final comment in the rationale underlying this important change in procedure, the author suggests that a third consideration may have influenced the decision-makers. The development of the CANDU system was intended to be a Canadian project - a testimony to the ingenuity and the capability of Canadians in a field of high technology. However, CGE is an American subsidiary whose parent, General Electric, is involved in the nuclear program of the United States as a champion of a competing reactor system. This corporate relationship posed two potential problems: a) CGE, in fulfilling its responsibility, might make use of the research and development facilities and the nuclear expertise of its parent company thereby undermining the "Canadianness" of the CANDU concept; and b) the parent/ subsidiary relationship provided a channel through which proprietary knowledge and/or technology may be transferred, directly or indirectly, from CGE to its parent. This is not to say that either of these scenarios would have materialized if CGE had continued as the designer of the CANDU system but the possibility of their occurrence was probably a cause for concern on the part of the program planners. By assuming the design responsibility, AECL effectively eliminated these

potential problems and, at the same time, removed any suspicion that may have arisen concerning CGE's corporate relationship with its parent.

For Canadian General Electric, the change in procedure marked the beginning of the end of its role as a nuclear power station supplier. The company had invested more than \$2 million to establish this capability in anticipation of serving the domestic and possibly the foreign market.²⁴ At their own expense, CGE developed the Civilian Atomic Power Department (CAPD) at Peterborough, Ontario and staffed it with several hundred very competent scientists and engineers. However, apart from the work on NPD, the only domestic assignment that this group obtained was for the design and development of the WR-1 test reactor at AECL's Whiteshell Nuclear Research Establishment in Manitoba. Without access to the domestic market, CGE attempted to market its reactor abroad but, as the next chapter illustrates, they had little success. Finally, after many frustrating years, CGE decided to pull out of the reactor designing business and, in 1968, several of the CAPD design personnel joined AECL.

Even with AECL's commitment to voluntary participation and Ontario Hydro's policy of purchasing the necessary hardware on the open market, most firms were still reluctant to invest in the nuclear program and, as a result, the industry grew very slowly. In many cases, the reluctance stemmed from an awareness of the fact that the production of equipment for nuclear stations is a very risky business. Prospective suppliers would have to incur large expenses, especially in the area of quality control,

because the equipment, both nuclear and conventional, had to be manufactured to a higher standard of workmanship and material integrity than was previously available in Canada. Most of the firms would not commit themselves to this level of investment until a) the CANDU concept had been proven to be a viable and commercially exploitable system, and/or b) there was a reliable indication of the market potential of the CANDU reactor.

During the early 1970's, both of these conditions were met and, accordingly, the initial unwillingness of several firms began to wane. Forecasts of installed nuclear capacity in Canada suggested that the domestic market alone would provide a worthwhile return on investment for the suppliers. As an example, one forecast suggested that the installed nuclear capacity in Canada would increase from 480 MWe in 1970 to 35,000 MWe by 1990.²⁵ Moreover, "in terms of 1971 dollars, Canadian utilities will spend about \$3.5 billion(10^9) for equipment, \$1.5 billion to install and house the equipment and \$1.9 billion for heavy water".²⁶ Table I-D presents a breakdown of these estimated expenditures. Forecasts of dramatic growth in both the domestic and the export market became even more optimistic after the success of the Pickering reactors in 1972.²⁷ As a result, several firms sought and acquired the nuclear label for their products thus establishing themselves as qualified suppliers.

When India exploded a nuclear device in 1974 using plutonium gathered from the CIRUS research reactor, there was a general concern among the participating firms that future export opportunities might be threatened and that the domestic

TABLE I-D

MARKET POTENTIAL FOR CANADIAN INDUSTRY
WITH CANDU-PHW'S MEETING NUCLEAR DEMAND

PLANT COMMISSIONED BETWEEN	Millions of 1971 Dollars		
	1971-75	1976-80	1981-85
Nuclear equipment ^a	45	85	165
Pumps	20	35	75
Heat exchangers	40	80	170
Pipes, valves & fittings	30	60	115
Turbine generators	55	125	265
Electric systems	20	40	80
Instrumentation	15	25	45
Civil works material	25	50	95
Miscellaneous	10	15	30
Total Equipment	260	515	1040
Installation Labour	80	150	285
Heavy Water	340	665	1325
	110	230	490
	450	895	1815
			3710

^a Nuclear equipment includes fuel channel assemblies, calandries, reactivity mechanisms and fuel handling equipment.

SOURCE: H.B. Merlin, "Nuclear Energy its Growth and Impact", (a paper prepared by the Economic Development Committee of the CNA and presented at the 11th Annual International Conference of the CNA, Montreal: June 1971) p. 12.

program might be restrained. But, in 1975, a new forecast appeared in a report issued by the Department of Industry, Trade and Commerce which calmed the industry's anxiety.²⁸ The report projected that during the years 1973 to 1983 inclusive, there would be 43 CANDU reactors under construction in Canada with 12 more under construction in foreign countries (see Table I-E). As a result of this anticipated construction program the total potential business accruing to Canadian industry, over the projected period, was to be in the order of \$6 to \$7 billion, which would be seven to ten times the value of the nuclear business Canadian industry had obtained in the previous ten-year period.²⁹ These figures were broken down into the following categories: \$2 billion for nuclear equipment, \$2 billion for related conventional power equipment, \$1 billion for engineering services and an additional \$1 billion for Canadian equipment and services on export sales.³⁰ Canadian industry was said to have the overall capacity to supply NSSS components for 2 or 3 reactors per year and this would have to be expanded to 6 reactors per year in order to meet the requirements of the projected program.³¹

The information contained in this study served as the basis for a paper presented at the CNA conference in June of the same year. In the paper the author stated:

*... If I were to characterize the nuclear business in a few words, I would say that it is big, it is demanding, it is concentrated, it is important and, even though it has an element of risk, it should be very rewarding and profitable.*³²

TABLE I-E

PROJECTED CONSTRUCTION STARTS - NO. OF CANDU REACTORS

	<u>500 MW</u>	<u>Domestic 600 MW^a</u>	<u>750 MW^b</u>	<u>Total</u>	<u>Export 600 MW</u>
----			3	3 ^c	-
1974	1	1	1	3	-
1975	1	1	1	3	1
1976	1	2	2	5	2
1977	1		2	3	2
1978			4	4	2
1979			3	3	1
1980			4	4	1
1981			4	4	1
1982			5	5	1
1983			6	<u>6</u>	<u>1</u>
				43	12

NOTES: a) Where reference is made to 600 MW reactors in this study, the comments are generally applicable to 500 MW reactors as well.

b) In those instances where definite sizes have not been indicated in the planning forecasts of utilities, 750 MW units have been assumed.

c) Three units on which construction started before 1974.

SOURCE: Canada, Department of Industry, Trade and Commerce, Canadian Nuclear Industry Study (Ottawa: March 1975), p. 6.

This remark and the study upon which it was based, were obviously intended to encourage Canadian industry to make a greater commitment to the nuclear power program. The strategy worked. Several firms, already involved in the program, undertook additional investment to expand their facilities in anticipation of increased volume.³³ Others decided that the time was right to commit at least some of their resources to the program. The result was an increase in the overall capacity of Canadian industry to supply components and equipment for the CANDU reactor system. Currently, Canadian industry can supply 75% of the nuclear steam supply system and 69% of the balance of plant (including turbine generators).³⁴

(ii) The Structure of the Industry

As an introduction to this section, two general comments are appropriate. First, the present structure of Canada's nuclear industry is a direct result of AECL's and Ontario Hydro's early commitment to the concept of competitive contracting and to keeping the research and development of the reactor system in-house. In most cases, there are at least two qualified suppliers of particular items for the CANDU reactor system. Secondly, as noted in the previous section, the size of the industry can be attributed to what now must be considered the overly optimistic demand projections made during the 1970-1975 period.

The manufacture of nuclear components and equipment has made, and continues to make, a substantial contribution to both the nuclear program and the Canadian economy in general.

For the nuclear program the role of the private sector is essential since AECL does not manufacture any of the components that it designs. For the Canadian economy, nuclear component manufacturing is a valuable asset. It represents the type of industry that Canada has sought to develop for a number of years: i.e., a high technology, high value-added industry. According to a recent study of the industry, the average value-added in nuclear manufacturing is approximately 65% which is 22% higher than that of Canadian manufacturing in general.³⁵

Currently, there are about 100 firms, located in Canada, that supply components, equipment and services for the program.³⁶ Of these 100, 30 can be considered as having a major commitment to the nuclear program.³⁷ The remainder rely on the acquisition of sub-contracts for work in the nuclear field. In keeping with the general trend in Canada's manufacturing sector, most of the firms, especially the larger ones, are subsidiaries of foreign companies, but they have developed their CANDU-manufacturing capability in the Canadian subsidiary independently of the parent.

A survey of the industry reveals that it consists of a broad and diversified group of companies "ranging from large heavy engineering equipment manufacturers to small highly skilled machine shops and precision machining firms".³⁸ However, the majority of the companies, in terms of size, are located at the midpoint of the spectrum. The largest firms are those that manufacture the highly specialized equipment for the four basic areas of the nuclear steam supply system. These include: Canadian Vickers Limited and Dominion Bridge Company Limited

(calandria structures); Babcock & Wilcox Canada Limited and Foster Wheeler Limited (steam generating system components); Canadian General Electric Company Limited and Standard-Modern Tool Company Limited (fuel channel components); and Bingham-Willamette Limited and Byron Jackson Division, Borg Warner (Canada) Limited (heat transport system components).

In terms of geographical distribution, most of the firms are located in Ontario (67%) and Quebec (30%).³⁹ A few suppliers are also situated in the western provinces.

Generally, companies do not produce nuclear products exclusively. The manufacture of nuclear components and equipment must compete with the production of more conventional products. One estimate suggests that approximately 15% of the overall production by these firms is for the nuclear program.⁴⁰ However, this should not be interpreted as a lack of commitment on the part of the industry. On the contrary, approximately \$214 million (current dollars) has been invested in buildings and equipment for supplying the nuclear equipment market.⁴¹

Finally, it should be noted that the production of nuclear components necessitates the installation of special facilities in order to satisfy the rigid quality control requirements. On the average, the amount that a firm spends on quality control represents approximately 20% of the total manufacturing cost of its nuclear products.⁴² For Canadian manufacturing in general, quality control expenditures are about 5% of the total manufacturing cost of a product.

(iii) The Industry's Predicament

To date the Canadian nuclear program has been very successful. As a result of the collaboration among AECL, the utilities (principally Ontario Hydro) and Canadian industry, the program has developed a reactor system that is efficient, reliable and, most importantly, commercially viable. Furthermore, the CANDU has an enviable safety record and, in terms of performance, it rivals reactor systems developed in other countries. Notwithstanding all of this, however, the program has had and continues to have its problems.

From the industry's perspective there are several problem areas.⁴³ These include: a) the separation of the design responsibility from the manufacturing responsibility; b) the virtual monopsonistic position of Ontario Hydro in the domestic market; and, c) the concept of competitive contracting.

Most of the components of the CANDU reactor system are manufactured by the private sector to AECL designs. This has been the source of several difficulties for the manufacturers, particularly because AECL and Ontario Hydro have not been sufficiently sensitive to the need for standardization. Most of the present or planned nuclear generating stations in the Ontario Hydro program are a different unit size and this has necessitated numerous design changes.

Presently, Ontario Hydro is the only Canadian utility with a substantial commitment to nuclear power. Some firms have expressed a concern about the potential dangers inherent in this situation. If, for example, a supplier falls into

disfavour with the purchaser, it could conceivably result in that firm's withdrawal from the industry. Also, the purchaser may use its leverage to dictate proposals and decisions to the suppliers which may not be in the interest of the industry as a whole.⁴⁴ So far, neither of these scenarios have occurred but the possibility remains.

The concept of competitive contracting presents a very real problem for the experienced supplier. As previously mentioned, in order to become a qualified supplier a firm must undertake considerable expenditure for highly advanced and sophisticated facilities. To amortize these expenses, the firm relies on the acquisition of repeat orders. As a general rule, competitive contracting often results in the awarding of the contract to the supplier who submits the lowest bid. However, a low bid from an inexperienced supplier oftentimes does not reflect the complexities and the hidden costs associated with the manufacture of nuclear components. The experienced supplier that submits a higher, but likely more realistic, bid is therefore at a disadvantage.

This short list of the problem areas perceived by the nuclear industry is by no means complete. There are several other contentious issues which the industry would like to see resolved. However, each issue, although serious in itself, is secondary to, and to some extent exacerbated by, what is considered to be the critical issue for the manufacturing sector - the lack of volume with respect to new orders. Recent developments in Canada have led to a slowdown in the domestic nuclear energy program and, for the manufacturers, this is a particularly

dangerous situation. The remainder of the chapter examines some of the factors responsible for the slowdown, the present state of the domestic program and the implications of the situation for the industry.

The fears of impending oil shortages instilled by the Yom Kippur War of 1973, coupled with the rising demand within Canada for energy and the realization that any future reserves of Canadian fossil fuels would be expensive to develop, gave a major boost to the prospects for alternative sources of electrical energy during the first half of the 1970's.⁴⁵

One alternative, nuclear energy, was particularly attractive. As previously indicated, a 1975 study of the nuclear industry suggested that installed nuclear generating capacity in Canada would increase dramatically by the turn of the century: from approximately 2500 MW in 1974 to 120,000 MWe by the year 2000.⁴⁶ Based on these estimates, the study concluded that "the projected CANDU construction program in Canada is, by itself, large enough to provide the basis for a large and strong manufacturing industry".⁴⁷

However, as Canada began the second half of the 1970's there were several indications that the domestic nuclear program would not grow as rapidly as anticipated. The first major setback for the industry occurred early in 1976 when, in response to the provincial government's restraints on borrowing, Ontario Hydro deferred the construction of a number of facilities including three nuclear complexes. This illustrates that the rate of growth of the Canadian nuclear program may be quite

independent of the demand for electricity. Since nuclear plants have high capital costs, the availability of capital may become a major constraining factor in determining their rate of construction (see Graph I-A).⁴⁸ As long as Canada's inflation rate hovers around the double-digit level, this should be a real concern of the nuclear industry.⁴⁹

Later in the same year, the industry received another blow - the election of the Parti Quebecois in the province of Quebec. Since coming to power, the Quebec government has imposed a three-year moratorium on further nuclear power development, effective until 1980.⁵⁰ Previous to this announcement, Hydro Quebec had recommended to the government the construction of 30 nuclear generating stations by the year 2000.⁵¹ The significance of the developments in Quebec and Ontario becomes apparent when one realizes that, according to the projections, these two provinces had been expected to constitute 75% of the installed nuclear capacity in Canada by the turn of the century.⁵²

A third major reason for the slowdown of the domestic program is that the growth in demand for electricity has not been consistent with the rates previously projected by the various provincial utilities. Undoubtedly, this is the result of several interrelated factors including increasing prices, the poor performance of the Canadian economy in recent years and the energy conservation programs instituted by the federal government in concert with the utilities. For illustrative purposes, let us look at the electrical energy situation in Ontario since this province is, by far, the largest market for nuclear reactors.

GRAPH I-A

CAPITAL COSTS OF ONTARIO HYDRO'S GENERATING PLANTS: PRESENT AND PLANNED

SOURCE: D. E. Anderson, "Comparative Electrical Generation Costs", CNA 16th Annual International Conference, vol. 5, (Toronto, 1976), p. 28

Traditionally, Ontario Hydro's long range forecasts for electrical energy demand have been based on an annual growth rate of 7%. With this rate of growth, the utility anticipated that its installed generating capacity would be 33,108 MW by 1985.⁵³ Thirty-five percent, or approximately 11,590 MW, of this capacity, was to be supplied by nuclear units.⁵⁴ Looking further into the future, it projected that by 1995 nuclear power would supply 63% of the province's total installed generating capacity.⁵⁵ However, in 1976 the growth in demand for electricity was only 5% and in 1977 it was only 2.3%.⁵⁶ These fluctuations have seriously undermined the traditional basis for system growth projections and planning. The utility now projects that rather than growing steadily at a rate of 7% per annum, the average rate of growth in demand for electricity will be 4.7% annually to 1990, and 4.2% in the last decade of this century.⁵⁷ Consequently, Ontario Hydro has already decided to mothball an oil-fired generating station at Wesleyville and is contemplating delaying the completion of the Bruce B and the Darlington nuclear power stations by as much as four years.⁵⁸

A fourth contributing factor is the growing public anxiety with respect to questions of safety and the potential environmental effects of nuclear reactors per se as well as with the question of the management and safe disposal of radioactive wastes. This anxiety has been augmented by the increasing amount of publicity given to the anti-nuclear lobby in Canada and the absence of an effective nuclear information program.

Data released at the 1978 annual conference of the Canadian Nuclear Association illustrate the effect that these developments have had on the domestic nuclear program. Throughout the period 1970-1975, fourteen units were ordered for the domestic market, an average of 2.3 units per year (see Table I-F). Most of these units (9) were ordered in the last two years of the period. The burst of activity, however, was short-lived. There were no domestic units ordered during 1976 and 1977. Ontario Hydro has recently begun placing orders for its Darlington Generating Station which accounts for the 4 units in 1978. Thus, the average number of units per year during the 1976-1978 period was 1.4.

Table I-G compares a 1975 forecast for the 1976-1980 period with what actually occurred and with what is likely to happen during the next two years. According to the 1975 forecast, 25 reactors were to be ordered for domestic use within this five-year span. However, it appears now that only 5 orders will be placed - the four units for Darlington and a third unit for Hydro Quebec. This means that only 1/5 of the orders anticipated in the 1975 forecast will materialize.

Table I-H gives the most recent data on reactor orders placed and possible in the five-year periods 1976-1980 and 1981-1985. Reference has already been made to the 5 units expected during the present period. The annual average, therefore, is 1.0 units. This is a decrease of 1.3 units compared with the previous five-year span. However, increased activity is expected during the 1981-1985 period. In this span, there

TABLE I-F
CANDU REACTOR ORDERS PLACED

YEAR	1970-1978		
	DOMESTIC	EXPORT	TOTAL
1970	4		4
1971	0		0
1972	0		0
1973	1		1
1974	5	1	6
1975	4		4
1976	0	1	1
1977	0		0
1978	4		4
TOTALS	18	2	20
AVERAGE PER YEAR			
1970-1975	2.3	0.2	2.5
1976-1978	1.4	0.3	1.7

SOURCE: J.M. Douglas, "Nuclear Manufacturing - A Year For Decisions, (a paper presented to the Annual International Conference of the CNA, Ottawa, June 1978), p. 96.

TABLE I-G

CANDU NUCLEAR PLANTS: FORECASTED SALES

YEAR OF COMMITMENT	1975 FORECAST		ACTUAL AND 1978 FORECAST	
	DOMESTIC	EXPORT	DOMESTIC	EXPORT
1976	5	1	0 ^a	1
1977	5	1	0	0
1978	9	1	4	0
1979	1	1	0	3
1980	5	0	1	2
SUB-TOTALS	25	4	5	6
TOTAL (DOMESTIC & EXPORT)	29		11	

SOURCE: J.M. Douglas, "Nuclear Manufacturing - A Year for Decisions", pp. 97-98.

^a In Mr. Douglas' forecast he included 1 reactor sale domestically in 1976. This apparently was an error since in the text Mr. Douglas states that there were no domestic sales in 1976. The only sale during that year was to South Korea.

TABLE I-H

APPARENT TOTAL REACTOR ORDERS PLACED AND POSSIBLE

YEAR OF COMMITMENT	DOMESTIC	EXPORT	TOTAL
1976	0	1	1
1977	0	0	0
1978	4	0	4
1979	0	3	3
1980	1	2	3
SUB-TOTAL	5	6	11
AVERAGE PER YEAR	1.0	1.2	2.2
1981	5	0	5
1982	8	1	9
1983	0	1	1
1984	5	1	6
1985	0	1	1
SUB-TOTAL	18	4	22
AVERAGE PER YEAR	3.6	0.8	4.4

SOURCE: J.M. Douglas, "Nuclear Manufacturing - A Year for Decisions", pp. 102 & 103.

is a possibility of 18 orders being placed - an average of 3.6 units annually.⁵⁹

The sporadic order placement in the domestic market is obviously a cause for concern on the part of the manufacturers. While the relative boom that is expected in the first half of the next decade will eventually provide a more acceptable loading in many firms, it does not relieve the severe over-capacity problem currently plaguing the industry. One recent assessment indicates that manufacturing capacity is about 3,000 MW a year.⁶⁰ Another survey suggests that the industry can provide, on the average, approximately six 600 MW reactors or four 850 MW units per annum.⁶¹ Currently, however, most of the firms in the industry are operating at about 60% capacity.⁶²

For some companies, especially those which do not receive orders for the Darlington station, significant layoffs may be necessary in 1979. Due to the nature of the nuclear manufacturing industry, if such a situation arises, the viability of the industry as a whole may be seriously weakened. As one industry official noted:

*Personnel require special training for nuclear work because of the special standards and codes involved, and particularly because of the extremely demanding quality assurance levels required. When work is not available, the staff is often dispersed and it is not always possible to reassemble the teams when later nuclear orders are received. Retraining and requalification of staff in such cases is time consuming and expensive.*⁶³

Thus temporary layoffs may conceivably result in a firm's permanent withdrawal from the nuclear industry.

With the current uncertain demand for nuclear reactors in Canada, the export market assumes a new importance for the

industry and for the domestic nuclear program - at least temporarily. For the industry, the acquisition of export orders is vital in order to maintain an adequate base load of work. This, in turn, will ensure that the industry will have sufficient capacity to accommodate the anticipated expansion of the domestic program in the future.

Table I-H shows the actual and the potential export orders in the five-year periods 1976-1980 and 1981-1985. The forecast suggests that by the end of 1980 five export orders, in addition to the order which was received from South Korea in 1976, are possible. These include two units for Romania, an additional unit for Argentina in 1979 and two units for Italy in 1980. If these possibilities actually occur, then export sales could outnumber domestic sales for the current five-year period. During the next five-year span, when the domestic program is expected to pick up, the forecast suggests that there could be, on the average, one export order per year.⁶⁴ Again, if these sales materialize, the average number of orders received per year (including domestic orders) would increase to a respectable 4.4 units. But, as chapter 4 will illustrate, these future export orders should not be taken for granted.

Graph I-B provides a well-delineated illustration of the importance of the export market for the Canadian nuclear industry. Industrial capacity is shown as averaging five reactors per year until 1983. Thereafter, as the average reactor size increases, capacity decreases. During 1976 and 1977, firm loading in the industry was equivalent to the production of only three reactors

GRAPH I-B

ACTUAL AND PROJECTED MANUFACTURING LOAD

(REACTORS PER YEAR)

SOURCE: J. M. Douglas, op. cit., p. 105

per year. More importantly, since 1978, the average firm loading has begun to decrease. If no orders are forthcoming, the backlog of orders will provide work only until the end of 1983. However, as previously indicated, additional sales in the domestic market are expected during the first half of the next decade. Nevertheless, average firm loading will not even return to its 1977 level - 3 reactors per year or 60% to 70% capacity - until 1983. Furthermore, the industry will not be working at full capacity, or close to it, until 1986.

It is the dip in production between 1978 and 1983 that is the greatest concern for the industry. As previously noted, several firms may be forced to withdraw from the industry during these lean years, thereby posing a serious threat to Canadian capability to supply equipment and services for future nuclear power generating stations in Canada and/or abroad.

In addition to ensuring the short term well-being of the Canadian nuclear industry, the immediate acquisition of export orders will provide several additional benefits for the Canadian economy. Perhaps the greatest benefit will be in the areas of job creation and balance of payments. A recent estimate suggested that each direct sale of a CANDU reactor abroad could provide approximately 1.5 million manhours of employment.⁶⁵ This is particularly significant because of the high unemployment that Canada is currently experiencing. It has also been estimated that each export sale has the potential of improving Canada's balance of payments position by about \$300 million.⁶⁶ Other benefits which could accrue to Canada

include:

- a) reduction of domestic power costs emanating from economies of scale in reactor production and increased efficiencies as operating experience is gained;
- b) reduction of costs for the further development of the CANDU system as revenue received by AECL could be used for this purpose;
- c) enhancement of Canadian prestige in the international marketplace; and
- d) relief for Canada's potentially serious over-supply of heavy water.

Thus, the immediate acquisition of export orders should have a beneficial impact on Canada's nuclear industry, nuclear program and economy.

D. SUMMARY

The CANDU reactor system ranks as one of Canada's major technological achievements. Its successful development and commercial deployment were accomplished through the diligent, cooperative efforts of AECL, Ontario Hydro and private industry. As a result of this undertaking, Canada possesses an efficient and reliable method of generating electricity which is extremely valuable in terms of its current and potential contribution to the country's electrical energy supply.

However, while the CANDU system is sound, the industry which supports it is not. For a number of reasons, the early estimates of demand, both domestic and foreign, have been sadly off the mark and the viability of Canada's substantial nuclear industry is now in jeopardy. The situation is particularly critical for the manufacturing sector of the industry. The

current level of manufacturing capacity, which has taken more than twenty years to establish, is only about half utilized. Unless their volume of work is increased, several firms may be forced to withdraw from the nuclear program. If this occurs, Canada's nuclear manufacturing capability will be considerably diminished.

Since the depletion of Canada's nuclear manufacturing base could have several very serious repercussions, decisive action must be taken to prevent this occurrence. Specifically, new orders, over and above those that have already been confirmed, are required. With the present lack of commitment and continuity in the domestic nuclear power program, Canada must rely heavily on the acquisition of export orders to sustain the nuclear industry. Before discussing the global prospects for the CANDU system, let us examine Canada's previous experience in the international nuclear marketplace.

FOOTNOTES

CHAPTER I

1. For a detailed account see Wilfred Eggleston, Canada's Nuclear Story (Toronto: Clarke, Irwin and Co., 1965) and Margaret Gowing, Britain and Atomic Energy, 1939-1945 (London: Macmillan and Company, 1964).
2. G. Bruce Doern, The Atomic Energy Control Board, (a study prepared for the Law Reform Commission of Canada, October 1976), p. 5.
3. R. W. Blackburn, "Licensing and regulations of the Canadian nuclear program", Nuclear Engineering International (June 1974), p. 512.
4. See Canadian Nuclear Association, The Role of Nuclear Power in Ontario, a Report submitted to the Royal Commission on Electric Power Planning, (August 1976).
5. Report of the Senate Special Committee on Science Policy (The Lamontagne Committee), A Science Policy for Canada, Vol. 1, (Ottawa: 1970), pp. 73-74.
6. Canadian General Electric was chosen after competitive bids had been called for. Seven manufacturing firms bid on the project.
7. L. R. Haywood, The CANDU Power Plant, AECL - 5321 (Ottawa: January 1976), p. 4.
8. J. L. Gray, A Statement of the Nuclear Power Development Program, AECL - 561 (Ottawa: February 1958), pp. 1-2.
9. AECL's involvement with project management is now limited to overseas projects. Since Pickering, Ontario Hydro has provided this service themselves. The other two provincial utilities that have ordered CANDUs - Hydro Quebec and the New Brunswick Electric Power Commission - also manage the entire project themselves although they do hire nuclear consultants to assist them.
10. J. S. Foster, The Canadian Nuclear Power Program, AECL - 5534 (Ottawa: May 1976), p. 4.
11. Atomic Energy of Canada Limited, Annual Report 1977-78, p. 10.
12. Interview with an Ontario Hydro official.
13. Ibid.
14. AECL, Annual Report, p. 9.

15. Leonard and Partners Ltd., The Economic Impact of Nuclear Energy Industry in Canada (Executive Summary), (Ottawa: August 1978), p. 20. This study was commissioned by the Canadian Nuclear Association.
16. Malcolm Rowan [Deputy Minister of Energy for Ontario], "Canadian Nuclear Policy and Federal-Provincial Relations", (paper presented to the Conference on Canadian Nuclear Policy, Mont Ste. Marie, Quebec, 9 November 1978), p. 10.
17. Leonard & Partners Ltd., p. 15.
18. Canadian Nuclear Association, Nuclear Canada Yearbook 1977 (Toronto: CNA, 1977), p. 33. This projection is based on an estimated 75,000-95,000 MW of nuclear generating capacity in Canada by 2000.
19. Ibid.
20. For a complete description of the CANDU system see Atomic Energy of Canada Limited, CANDU 600 Station Design, AECL - PP - 28, (Ottawa: May 1976).
21. J. L. Gray, "Canadian Industry and Atomic Energy", House of Commons Committee on Research, Minutes of Proceedings and Evidence, No. 9, June 1956, Appendix II, pp. 257-258.
22. The Senate of Canada, Proceedings of the Standing Committee on Science Policy, 1968, p. 651.
23. J. L. Gray, "A Statement", p. 5.
24. Interview with Canadian nuclear industry official.
25. H. B. Merlin, "Nuclear Energy: Its Growth and Impact", (a paper prepared by the Economic Development Committee of the CNA and presented to the Annual International Conference of the Canadian Nuclear Association, Montreal, June 1971), p. 12.
26. Ibid.
27. A. W. Parfitt and J. Robinson, "A Review of Problems in Nuclear Industrial Expansion", (a paper presented to the Annual International Conference of the CNA, Toronto, June 1976), p. 2.
28. Canada, Department of Industry, Trade and Commerce, Canadian Nuclear Industry Study (Ottawa: March 1975).
29. Ibid., p. 7.
30. Ibid., p. 1.

31. Ibid. With respect to the P.G.S., capacity from both domestic sources and imports was considered adequate.
32. J. P. Reny, "Manufacturing Opportunities in the Canadian 'CANDU' and Heavy Water Programs", (a paper presented to the Annual International Conference of the CNA, Ottawa, June 1975), p. 16.
33. In an interview with an industry official the following examples were given of the industrial expansion that occurred shortly after 1974: Canadian Vickers Limited doubled its shop space; Dominion Bridge Company Limited built a new loading bay in Montreal; and Bingham-Willamette Limited constructed a new test facility for its pumps.
34. Leonard and Partners Ltd., p. 15.
35. Ibid., p. 10.
36. For a list of the major companies with details of their products and services see The Canadian Nuclear Association, Nuclear Energy: Canada's Resources and Industry (Toronto: CNA, 1975). A more complete listing can be found in The Canadian Nuclear Association, Nuclear Canada Yearbook, 1977 (Toronto: CNA, 1977).
37. Leonard and Partners Ltd., p. 9.
38. Canadian Nuclear Industry Study, p. 9.
39. Ibid., p. 10.
40. Personal communication from an ~~industry~~ official.
41. Leonard and Partners Ltd., p. 10.
42. Canadian Nuclear Industry Study, p. 12.
43. See A. W. Parfitt and J. Robinson, "A Review of Problems in Nuclear Industrial Expansion", (a paper presented to the Annual International Conference of the Canadian Nuclear Association, Toronto, June 1976); J. J. Shepherd, "The Structure of the Canadian Nuclear Industry", (a paper presented to the Annual International Conference of the CNA, Montreal, June 1977); and J. M. Douglas, "Nuclear Manufacturing - A Year for Decisions", (a paper presented to the Annual International Conference of the CNA, Ottawa, June 1978).
44. Parfitt and Robinson, "A Review of Problems", p. 6.
45. Canada, Department of Energy, Mines and Resources, An Energy Strategy For Canada: Policies For Self-Reliance (Ottawa: Supply and Services Canada, 1976).

46. Canadian Nuclear Industry Study, p. 7.
47. Ibid., p. 35.
48. Also see Allan Blair, "The case for nuclear", Financial Post Special Report on Nuclear Power, 28 January 1978. Dr. Blair estimated that the capital cost of CANDU nuclear plants is \$1,500 per installed MW vs \$1,000 per installed MW for equivalent thermal plants. However, because of smaller operating and fuel costs, nuclear power is cheaper over the long run (15 mill/kwh for nuclear vs 35 mill/kwh for thermal).
49. The effects of inflation on nuclear plants is briefly outlined in D. E. Anderson, "Comparative Electrical Generation Costs", (a paper presented to the Annual International Conference of the CNA, Toronto, June 1976). See also L. J. Schofield, "The Effect of Inflation on Nuclear Energy", (a paper presented to the Annual International Conference of the CNA, Ottawa, June 1975).
50. "Quebec applies brakes to nuclear energy development", The Citizen (Ottawa), 17 November 1977.
51. Ian Anderson, "Boyd: Nuclear Energy is Quebec's Only Option", The Gazette (Montreal), 10 November 1977.
52. The actual breakdown is as follows: Ontario 50%; Quebec 25%; Western Canada 15%; and the Maritime Provinces 10%. See Robert Steklasa, "Scarce sales worry industry", The Financial Post Special Report on Nuclear Energy, 28 January 1978.
53. Blair, "The case for nuclear", p. 28.
54. Ibid.
55. Ibid.
56. Personal communication with an Ontario Hydro official.
57. Thomas Cláridge, "Hydro to mothball one plant, study a slowdown for 3 others", Globe and Mail, 14 February 1979.
58. Ibid.
59. The statistics cited above relate to the year that an order is placed for a unit. Given that the minimum time frame for bringing into service a single unit or the first unit of a multiple unit station is approximately 11 to 12 years, these statistics are based on forecasts of installed nuclear capacity to the turn of the century.

60. Leonard and Partners Ltd., p. 10.
61. J. M. Douglas, "Nuclear Manufacturing - Year For Decisions", (a paper presented to the Annual International Conference of the CNA, Ottawa, June 1978), p. 90. This survey noted that the capacity varies according to the type of component being manufactured. Mr. Douglas stated:

"A very few plants have a capacity for one type of component of only about three 600 MW reactors per year whereas there is capacity for some components of as many as eight reactors per year. The mean is six. Lower capacity are [sic] appropriate for the 850 MW size reactors ..."
62. This figure was arrived at after consulting several sources. An official at the Department of Industry, Trade and Commerce estimated that firms manufacturing components for two of the major areas of the NSSS (the calandria and the heat transport system) are operating at 50% capacity. All other firms were said to be operating at 75% capacity. Leonard and Partners Ltd. estimated that manufacturing capacity is a little over 50% utilized. Finally, Mr. Douglas conducted a mini-survey of 17 companies and found that those firms were operating at 70% capacity which was somewhat higher than the average for the industry.
63. J. M. Douglas, "Nuclear Manufacturing", p. 91.
64. Mr. Douglas assumes a fairly low level of export sales during this period.
65. R. Steklasa, "Scarce sales worry industry", p. 27. It is assumed that this and the other statistics refer to the export of a 600 MW reactor since this is the only reactor that Canada is currently offering in the export market.
66. J. M. Douglas, "The Economic Viability of Nuclear Exports", (a paper presented to the IX Conference on International Relations, Quebec City, October 1977), p. 3.

CHAPTER II

THE CANADIAN NUCLEAR EXPORT PROGRAM

A. INTRODUCTION

This chapter traces the development of the export component of the Canadian nuclear program from Canada's involvement with India to AECL's licensing agreement with Romania. An undertaking of this nature provides some insight into the problems which have hindered the spread of CANDU technology in the international market. These problems and their implications for the acquisition of additional export orders will be discussed in greater depth in Chapter IV.

The chapter is divided into two main sections: pre 1968 and post 1968. The year 1968 is significant because it was then that AECL inherited the responsibility for international marketing.

B. REACTOR SALES - PRE 1968

(i) India

Canada became involved in the export of nuclear technology in 1956 when, under the Columbo Plan, India was provided with a research reactor. This endeavour formed the basis for a cooperative program between the two countries designed to exploit the peaceful uses of nuclear energy. The program was in existence until May 1974, at which time, as a result of India's detonation of a nuclear device, it was abruptly terminated.

The Indian reactor, originally known as the Canada-India Reactor (CIR) but subsequently labelled CIRUS*, was similar to the NRX reactor at Chalk River which had been designed for the efficient production of plutonium. Accordingly, CIRUS used natural uranium for fuel and heavy water as a moderator. The total estimated cost was \$14 million with Canada financing the equipment purchased in Canada and India paying for items that were supplied locally. CIRUS began operation in July, 1960.

Following the collaboration on CIRUS, agreements were signed in December, 1963 between the Government of Canada and the Government of India for the supply of a nuclear power reactor. Atomic Energy of Canada Limited and Montreal Engineering Company Limited also signed agreements with the Indian government.

This reactor is a 200 MWe CANDU reactor similar to the one that was being constructed at Douglas Point. It is known as RAPP-1, signifying the first reactor for the Rajasthan Atomic Power Project, and is owned by the Department of Atomic Energy in India. Construction work on RAPP-1 commenced at the end of 1964 and criticality was achieved on August 11, 1972.

Under the terms of the agreement with the Indian government, AECL provided the design and engineering for the nuclear portion of the reactor. Also, in conjunction with the Hydro Electric Power Commission of Ontario, AECL supplied commissioning services for the station up to and including the steam raising equipment.¹ Montreal Engineering rendered similar services for the conventional portion of RAPP-1 "along with

* The "US" was added to the original name because the United States supplied the heavy water for the reactor.

providing procurement and expediting functions for equipment supply and resident engineering staff at the site of the plant".² For its part, the Department of Atomic Energy was responsible for construction, project management (including the purchase of nuclear steam supply system components) and operation and maintenance of the station.

The total cost of the goods and services for the reactor was approximately \$80 million. A little more than half of this amount was spent in India for the purchase of conventional components. The government of Canada provided credit facilities, through the Export Credit Insurance Corporation (now the Export Development Corporation), for the purchase of material, equipment and services supplied from Canada. The loan was for \$38.5 million to be repaid by 29 semi-annual payment commencing on February 1, 1973.³

In January, 1967, after the decision was made to construct a second 200 MWe unit (RAPP-2), the consultancy agreements with AECL and Montreal Engineering were revised. In addition, a new agreement was negotiated with the ECIC to cover additional financing. The Department of Atomic Energy projected that RAPP-2 would achieve criticality in April, 1974.⁴ However, the termination of nuclear assistance from Canada has delayed this occurrence.

Canada's nuclear assistance program with India was undertaken principally to facilitate the attainment of some of that country's development goals. Consequently, the reactor exports become symbols of Canada's willingness to share her

technology with developing countries. Nevertheless, the Indian agreement had several obvious and natural benefits for Canada: it enhanced Canadian prestige by providing an opportunity to display her technical expertise; it enabled Canada to share some of the developmental costs of the CANDU technology with India; and finally, the contracts obtained from the Indian reactors provided Canada's budding nuclear industry with the opportunity to gain experience in the fabrication of nuclear components.⁵

(ii) Pakistan

During this period India was not the only country receiving nuclear technology from Canada. In 1962, the Pakistan Atomic Energy Commission (PAEC) began discussions with Canada regarding the possibility of acquiring a nuclear power plant. These discussions ultimately led to a contract between the Canadian General Electric Company Limited and the PAEC, which was signed in May, 1965. Prior to the signing of this contract Pakistan and Canada entered into an agreement for an exchange of technical information and assistance which was to be implemented at the time the plant was completed.⁶

The nuclear power station, a 125 MWe CANDU unit known as KANUPP (Karachi Nuclear Power Plant) was supplied on a turnkey basis.⁷ CGE acted as prime contractor for the design, supply, construction and commissioning of the station. The design and procurement services for the conventional portion of the plant were subcontracted to the Montreal Engineering Company. The Government of Canada, through the ECIC, provided financial support. In December, 1965, a loan was made by the

ECIC for a little more than \$24.5 million to be repaid in 31 semi-annual installments commencing December 15, 1970.⁸ Work on the project began early in 1966 and criticality was achieved on August 1, 1971.

CGE was also active in several other markets. In 1967, the company submitted a bid in Argentina. The Comision Nacional de Energetica Atomica (CNEA) of Argentina was interested in a Canadian reactor because it used natural uranium for fuel and the design and engineering made it particularly suitable for high local industry participation.⁹ Despite these preferences, the contract was awarded to Siemens, a German firm, which also offered a natural uranium reactor.

It is worthwhile noting the main reasons for accepting the German bid since on many items there was little difference between the Siemens offer and the CGE offer. In addition, this experience in Argentina would greatly influence AECL's approach to international marketing when it acquired the responsibility in 1968.

There were three major factors that led to the rejection of the CGE bid.¹⁰ First of all, Germany was a traditional buyer of Argentine goods whereas Canada and Argentina were competitors in the world market. Thus, balance of trade considerations were important. Secondly, Siemens was judged to be the "stronger" of the two companies. The German firm also had a subsidiary in Argentina which was very active in several kinds of public works. Therefore, Siemens was very familiar with local conditions. Finally, the German government supported

Siemens with all of its technical and economic might. This gave the CNEA a sense of security in case any problems were encountered during the construction of the reactor.

The importance of these types of considerations to the CNEA makes it easier to understand why AECL agreed to the use of agents the next time a bid was submitted in Argentina and later, in South Korea. They also partially account for the greater participation of the Canadian government in international marketing after 1968.

Besides Pakistan and Argentina, Canadian General Electric attempted to sell a reactor to Finland. This attempt also failed but it was for different reasons; the Finns decided not to build the reactor after it was arranged that they would obtain their reactor from Russia.¹¹

As indicated in Chapter I, CGE's involvement in the exportation of nuclear technology was necessitated by the fact that they did not have access to the domestic market. Ontario Hydro had refused to deal with private monopolies. Thus, with the domestic market closed and with little success in the international marketplace, CGE decided to withdraw from its role as a supplier of nuclear power stations. In 1968, AECL took over the total marketing responsibility for the CANDU reactor.

C. REACTOR SALES - POST 1968

Upon assuming the role of international marketer for CANDU reactors, Atomic Energy of Canada Limited made several

attempts at selling a nuclear power plant on commercial terms. Marketing ventures were conducted in countries such as Romania*, Australia, Mexico and Iran. In Romania, the negotiations broke down. In Australia and Mexico, AECL submitted tenders but no contracts were obtained.¹²

Although AECL was unsuccessful in these efforts to sell a power reactor, a firm-price contract was signed with Taiwan in September, 1969, for the supply of a research reactor. The deal proved to be economically beneficial to all parties. The total cost of the project was approximately \$35 million of which \$28 million was for goods and services purchased from Canada.¹³ AECL was the prime contractor and several Canadian firms were awarded contracts for the supply of components, engineering services, fuel and project management. Since the project was a cash transaction, no lending arrangements or other financial considerations were necessary. The reactor itself was similar to the CIRUS reactor and was to be used for the production of cobalt-60.

A little more than a year later, Taiwan made an overture to AECL for two 600 MWe power reactors. This situation seemed ideal for a company that was experiencing considerable difficulty in trying to sell its product. Unfortunately, for AECL, the prospective customer was the wrong country at that particular time. A decision was made not to pursue the sale.

* AECL continued negotiations that were initiated by Canadian General Electric. These negotiations have proceeded on an irregular basis since 1968, and, as of this writing, are still in progress.

The decision was clearly political since Canada was about to terminate diplomatic relations with Taiwan and it illustrated one of the several non-commercial considerations which inhibit AECL's efforts to penetrate world markets. These considerations will be examined in Chapter IV.

There were several factors which accounted for AECL's inability to sell nuclear power reactors during this period. Two of the most important factors were: a) the CANDU technology had not yet been proven as a viable energy source; and b) the marketing operations conducted by AECL could not compare with those of the major international suppliers such as General Electric and Westinghouse.

An examination of the geneology of CANDU reactors reveals that during the period in question (1968-1972) the Ontario Hydro nuclear power program was just getting underway with the completion of the first 500 MWe unit at the Pickering Generation Station. The Douglas Point prototype was in operation but it was experiencing several difficulties. Thus, in effect, AECL was attempting to sell a reactor system which the company believed would work but which had not yet been successfully demonstrated.

The type of marketing operation that was devised by AECL seemed to indicate that, although attempts were being made, the penetration of export markets was not a high priority within the company. Dr. A. M. Aikin, a former vice-president of AECL, stated:

... basically our marketing has been a response type marketing, that is to say we do not send people out trying to sell the CANDU reactor; we have only responded to expressions of interest on the part of other countries who would like us to talk to them about the possibilities of providing CANDU reactors.¹⁴

This policy was later changed. Nevertheless, during the 1968-1972 period, the corporation only had two men actively involved in international marketing. This contrasted sharply with the strong and aggressive marketing group that CGE had assembled to perform the same function.¹⁵ Accordingly, AECL could not compete with the large and powerful American firms that were vigorously selling light water reactors around the world. With tremendous marketing resources and a proven technology at their command, these firms enabled the United States to capture approximately a 90% share of the world reactor market by 1972.

A lack of experienced marketing personnel undoubtedly influenced AECL's decision to adopt a passive marketing approach, but it certainly was not the only factor which was taken into consideration. AECL always believed that the domestic market was sufficient to support the Canadian nuclear program. Moreover, the company felt that the CANDU system was the best system available and thus other countries would come to AECL for CANDU reactors.

The early 1970's marked a change in this strategy. The Canadian nuclear program was struggling for survival; domestic orders were not being received at the anticipated rate and attempts at exporting a reactor on commercial terms were not bearing fruit. Mr. Gray succinctly described the predicament

facing AECL in this way:

Once we had the CANDU system going and had Douglas Point built and running, and Pickering committed, we started to think about the future. Some of us, I do not say all of us, but some of us ... came to the conclusion that if we did not sell a CANDU system to a recognized country in direct competition with somebody other than the deal in India and the deal in Pakistan, the last one was mainly a CIDA deal which the world did not really recognize as being a competitive program, that the system we had developed, the CANDU system, would finally fall by the wayside. It could not be supported on a Canadian program alone. We in the staff were absolutely sure of this. We might have six plants running in Canada and there would be 600 light water reactors running around in the world and when you get out to the Western utilities they were more likely to go American than they were to stay Canadian ...

Thus, AECL implemented a new strategy based upon the aggressive pursuit of export contracts. This did not mean that the domestic market was to become secondary to the export market. On the contrary, the ability to bring safe and economic power to Canadian utilities continued to be the main objective of AECL and the Canadian nuclear program. However, in order to achieve this goal, a healthy nuclear industry was deemed vital. The added sale abroad would supplement domestic sales and thereby provide continuity of orders during lulls in the domestic market.

A similar rationale motivated the federal government to support AECL's efforts to develop an export market. According to Donald MacDonald, Minister of Energy, Mines and Resources during the early 1970's, the main reasons for Canadian involvement in the international nuclear marketplace were to "support the engineering and manufacturing capacity which had been developed in Canada for servicing our own market and,

.... perhaps most obviously, for the purpose of the foreign exchange which was to be gained from this particular system".¹⁷

There was also a third reason, equally as important as the first two, for adopting this new export strategy. By successfully selling a CANDU reactor in direct competition with the other international suppliers, AECL and the Canadian government could perhaps silence the critics who were attacking the system and the scientific and technological decisions which had led to its development.

Throughout the 1968-1972 period the technical merits of the CANDU system were being increasingly questioned. The criticisms took many forms and came from several sections of the Canadian populace. In 1970, the Senate Committee on Science and Technology (The Lamontagne Committee) issued the first volume of its report. The report seriously questioned both the decision that was made in the 1950's to proceed with the development of a heavy water reactor and the way in which that development was undertaken.¹⁸ In addition, several articles appeared in the press expressing doubts about Canada's reactor technology. This prompted Mr. Gray to suggest that the press was anti-CANDU, pouncing on every failure of Canada's nuclear program but ignoring its successes.¹⁹

In the House of Commons, the opposition parties frequently alluded to Canada's futile attempts at selling a reactor to a foreign country. The following excerpts illustrate the type of criticism that the Liberal government encountered:

MR. JOHN GILBERT (NDP - BROADVIEW): Mr. Speaker, on November 4, 1970 I asked that the contract between Atomic Energy of Canada Limited and the Atomic Energy Council of Taiwan regarding the sale of a nuclear research reactor be tabled in this House. The reason I asked that the terms of the contract be tabled is that there is a growing suspicion among many Canadians that we are having difficulty in selling reactors in the export market. This growing suspicion was confirmed in the month of March, 1970 by the Minister of Energy, Mines and Resources [Mr. Greené], who admitted that Canada's attempt to sell nuclear reactors in the export market had been a dismal failure. The minister went on in no uncertain terms to cite the poor record Canada has in this regard and indicated that efforts to sell nuclear reactors in Finland, Argentina, Yugoslavia, Roumania [sic] and now Australia had failed.

... In other words, we have been up to bat five times and have struck out five times. The question therefore arises whether we are in the right league in this expensive and important field. Perhaps it is a field that is too expensive, one from which Canada should withdraw.²⁰

Furthermore:

MR. DONALD MACINNIS (CONSERVATIVE - CAPE BRETON - EAST RICHMOND): The hon. member for Thunder Bay [Mr. B. Keith Penner] talked of the tremendous potential of the plant [CANDU] and referred to the competition Canada is facing in the field of nuclear reactors. I say this is absolute nonsense. The fact is that we cannot sell them; we have to give them away. Only two countries have looked at these reactors, Pakistan and India. And what did they pay for them? I should like to see a financial statement proving that they paid one penny.²¹ Probably they became part of the foreign aid scheme.

These attacks on the CANDU system within the House of Commons coupled with the growing anti-CANDU sentiments in the press were, to say the least, a source of embarrassment for the government. Ultimately, this situation increased the pressure on AECL to sell a reactor in the export market. It was in these circumstances that the reactor sales were made to Argentina and South Korea.

Direct Sales

(i) Argentina

In the fall of 1971, AECL, along with other international suppliers such as General Electric and Westinghouse, received an inquiry from the Comision Nacional de Energia Atomica (CNEA) of Argentina concerning the possible purchase of a nuclear power reactor. Originally, AECL did not particularly want to sell to Argentina (a sale to the United States, Britain, France or Italy would do more to promote the international acceptability of the CANDU system) but, according to Mr. Gray, "it happened to be the only game in town".²² Thus, AECL decided to make a serious effort to obtain the contract.

As previously mentioned, AECL's marketing approach was probably conditioned by CGE's experience in Argentina. The CGE experience had demonstrated that, in a situation where the bids of two suppliers were very similar, the CNEA was inclined to award the contract to the firm which a) was more willing to accept local participation, b) had strong government backing and, c) was more knowledgeable about local conditions and customs because of previous activity in Argentina. If this situation arose, AECL's bid would not be seriously threatened by the first two considerations - the amount of local participation was negotiable and AECL did have the support of the Canadian government - but it would be jeopardized by the third consideration. One way to alleviate this potential problem area would be to establish a partnership with a firm that was familiar with the South

American market, particularly Argentina, and then jointly submit a bid to the CNEA.

For this reason a joint venture was established with an Italian engineering firm, Italimpianti. Why Italimpianti? A few years earlier, in preparation for a prospective bid in Italy, AECL had made a similar arrangement with this firm.²³ In addition, Italimpianti was well acquainted with the Argentine market.

The Italians viewed AECL as "babes in the woods" when it came to international marketing and suggested that they take the commercial lead in Argentina.²⁴ AECL would be responsible for promoting the technical side of the sale. Furthermore, Italimpianti suggested that the services of a commercial agent would be required if the bid was to succeed. They would select and interact with the agent and the fee would be shared 50-50. AECL accepted.²⁵

AECL and Italimpianti jointly submitted a bid for a 600 MWe station in June, 1972. Nine months later, in March, 1973, the bid was selected by the CNEA and contractual negotiations began. On December 20, 1973, a master contract was signed -- a tripartite agreement between AECL, Italimpianti, and the CNEA. Two other contracts were also signed; a supply contract between AECL and the CNEA as well as a joint venture contract between AECL and Italimpianti. Contained in AECL's supply contract with the CNEA was a provision stipulating that a safeguards agreement between Argentina and the International Atomic Energy Agency must be concluded within a year. This

agreement was successfully completed on time and the commercial contract came into effect on April 11, 1974. In this manner, AECL obtained what has frequently been referred to as its first commercial order in the international market.

According to the joint venture agreement, AECL would provide the nuclear steam supply system while the conventional portion of the plant would be the responsibility of Italimpianti. The total value of the project was approximately \$420 million.

AECL's supply contract with the CNEA was a firm-price contract, with a ceiling on the allowable escalation, for approximately \$150 million. This was broken down into four major components: \$61 million for the supply of goods and services from Canada; \$56 million for the supply of goods and services in Argentina; \$30 million for heavy water; and finally, \$3 million for the supply of uranium if Argentina was unable to live up to its intentions of supplying uranium itself.²⁶ Part of the financing for the project was arranged through the Export Development Corporation in the form of a \$129 million loan at subsidized interest rates.

By 1975, AECL's inexperience in negotiating supply contracts became apparent. If the original contract remained unaltered, AECL would lose in excess of \$200 million by the completion of the project.²⁷ Part of the reason for this projected loss was AECL's failure to estimate accurately the heavy water costs and to secure an adequate allowance for escalation on Canadian goods and services. However, part of the loss was also due to circumstances external to the contract

which significantly altered the cost estimates contained therein; i.e., the oil crisis of 1974 which contributed to the rising uranium prices and the unexpected high rate of inflation throughout the world from 1973 to 1975. The detrimental effects of these external influences enabled AECL to obtain permission from Argentina to renegotiate the contract.²⁸

The renegotiation process began in January, 1976 and was completed by June of the same year. By altering the ceilings on escalation and by amending the price of heavy water, AECL was able to reduce the projected loss to somewhere between \$23 and \$38 million. This new contract was signed by AECL, Italimpianti and the CNEA in February, 1977. Besides the decreased losses, the contract provided for the extension of the project schedule by eight months and an alteration in the financial arrangements. An additional \$25 million loan was made to Argentina, again at subsidized interest rates.

By May, 1977, the projected loss had increased to approximately \$131 million.²⁹ Table II-A provides a breakdown of the projected losses and outlines the reasons for the substantial increase between June, 1976 and May, 1977. Although inflationary pressures continued to haunt the cost estimates contained in the contract, several other areas where AECL had made substantial underestimations became apparent after the renegotiation process. These include such vital areas as: 1) the amount of heavy equipment needed to complete the project; 2) the cost of producing heavy water; and, 3) the number of engineering man-hours.³⁰

TABLE II-A

BREAKDOWN OF PROJECTED LOSSES ON ARGENTINE CONTRACT

January 1976 June 1976 May 1977
 (Before Renegotiation) (After Renegotiation)

PRINCIPAL ELEMENTS:

REASONS FOR INCREASE

LOSSES

PRINCIPAL ELEMENTS:	January 1976 (Before Renegotiation)	June 1976 (After Renegotiation)	May 1977 (After Renegotiation)	REASONS FOR INCREASE
Canadian Goods & Services	\$33M	\$19M	\$45M	-unrecoverable costs for additional equipment not provided for in original contract -unrecoverable escalation (above 33%). Between 33% and 90% inflation, AECL and Argentina split 50-50 -Canadian inflation rose -Additional engineering costs -locked into contract and couldn't be changed -cost of production increased from \$180-\$200 a kilogram to \$235 a kilogram
Argentine Goods & Services	\$10M	\$2-8M	\$8M	
Heavy Water	\$55-64M	\$2-11M	\$22M	
Uranium	\$5-10M	—	—	
Contingency amt. against the possibility of delay in delivery (added after renegotiation)	—	—	\$56M	-safety measure
TOTAL	\$103-117M	\$23-38M	\$131M	

SOURCE: Testimony of Mr. Ross Campbell before the Standing Committee on Public Accounts, House of Commons, Nov. 17, 1977. Issue No. 4, pp. 70-73.

To say the least then, AECL's debut as an international supplier of commercial power reactors was very inauspicious.

(ii) South Korea

The next CANDU sale was to South Korea. This marketing venture was undertaken concurrently with the negotiations for the Argentine project. As in Argentina, AECL relied on someone else to take the commercial lead while it supplied technical information.

The initiative for the Korean sale was provided by Mr. Shaul N. Eisenberg, President of United Development Incorporated, who approached Mr. Gray in 1968. According to Mr. Gray, Mr. Eisenberg intimated that "we [AECL] had a Sleeping Beauty in this reactor system but we did not know what to do with it, we did not know how to market it".³¹ Furthermore, he indicated that, with the help of his organization, AECL could sell a nuclear power station to Korea. This obviously intrigued Mr. Gray and he agreed to the proposition. For the purposes of the Korean contract alone, Mr. Eisenberg was appointed exclusive agent for AECL. The fee was dependent upon the sale of a reactor, or reactors, to Korea and the amount would be negotiated prior to an agreement being entered into between AECL and the South Koreans.

The main competition in Korea came from Westinghouse which had previously supplied two reactors to the Korean Electric Company (KECO); KORI-1 and KORI-2. Apparently the presence and influence of Westinghouse caused several problems for Mr.

Eisenberg.³² These difficulties, however, were not insurmountable and contract negotiations between AECL and KECO began in 1973.

On December 30, 1974, AECL signed a letter of intent with the Korean Electric Company for the supply of a 600 MWe power reactor. Mr. Gray also committed AECL to pay Mr. Eisenberg \$20 million (approximately 5% of the sales price) when the final contract was signed. In 1976, the fee was reduced to \$18.5 million.

The supply contract was signed on January 25, 1975 and became effective a year and a day later. The total value of the contract, which included the supply of both the nuclear and conventional systems for the station, was approximately \$514 million. Canadian goods and services were negotiated on a firm-price basis subject to escalation but, unlike the Argentine project, there was no ceiling applied.

While the Canadian nuclear industry was generally satisfied with the Canadian content on both the Argentine and the Korean deals, the latter contract was the closest to what the industry perceives as an ideal export order.³³ This was because the Korean sale was for a complete nuclear power station and it was also a solely Canadian project. In the case of Argentina, AECL contracted for the supply of the nuclear steam supply system and Italimpianti supplied the balance of plant. The only foreign content in the Korean contract came from a British firm, Howard Parsons Limited, which supplied the turbine-generators. Even so, according to one official,

the Canadian subsidiary of the firm probably received some work because of the order.³⁴

Most of the financing for the project was arranged through the Export Development Corporation. The EDC negotiated a \$330 million loan with Korea at subsidized interest rates.³⁵ The loan is repayable in 30 semi-annual installments commencing no later than six months after commissioning or on October 15, 1982, whichever comes first.³⁶

Licensing Agreements

The CANDU sales to Argentina and South Korea are classified as direct sales; i.e., transactions involving the transfer of a complete station to recipient countries. This method of technology transfer is most appropriate for developing countries which generally have limited capital resources and technological capacity. However, Third World countries do not represent the entire market for nuclear power reactors. Several industrialized countries, seeking to reduce their dependence on imported oil, are expected to introduce nuclear power into their domestic energy programs. Others, who have already done so, may increase the extent of their commitment to nuclear power. Since many of these countries either already possess nuclear industries or have the capability to do so, they are mainly interested in obtaining "the most rapid transfer possible of the most technology possible at the least possible cost, in order to provide for the building of the nation-buyer's own industrial base".³⁷ This can best be

achieved by negotiating a licensing agreement with the supplier. Accordingly, to facilitate the spread of CANDU reactors globally, AECL is also currently pursuing this method of technology transfer.

Obviously, from the point of view of the supplier, licensing agreements are not likely to be as lucrative as direct sales to developing countries because the purchaser will be pressing for a significant amount of locally supplied equipment and services. Generally, for such sales, the first reactor will represent the largest percentage of imported equipment and services. With subsequent reactors this percentage will decrease. Furthermore, selling the design and manufacturing technologies to other firms may result in a loss of potential markets as the licensees would be able to re-export the technologies themselves.

Despite these disadvantages of licensing agreements, it is the contention of AECL that "if the full marketing potential of the CANDU system is to be realized, the licensing of suppliers would seem to be a logical and necessary expansionary route".³⁸ AECL believes that a CANDU offered for sale by a company in another industrialized country will ultimately enhance, rather than hinder, the Canadian nuclear program.³⁹

The rationale for this belief was explained by Dr. J.S. Foster, past-president of AECL. According to Dr. Foster, Canada was at a serious disadvantage, vis-a-vis the other international suppliers, as the only supplier of a natural uranium, heavy water moderated reactor system. He stated that:

... In adopting a program based on natural uranium heavy water reactors a country [a prospective buyer] is initially dependent on a single foreign country for most of the technology and much of the equipment.⁴⁰

This situation was perceived as a factor inhibiting the spread of CANDU reactors to developing countries. To overcome the problem, AECL decided to transfer the proprietary technology to developed countries thereby enhancing the international reputation of CANDU and stimulating sales opportunities in the Third World. As Dr. Foster pointed out:

... The licensing of others to supply these plants in the Third World will provide buying countries with a diversity of supply necessary to convince certain of them to adopt the system and a total supply that can maintain CANDU market penetration at a viable level.⁴¹

In addition to the advantages cited above, licensing agreements can be beneficial for the Canadian nuclear program in a number of other ways. Future competitors may have greater access to some countries than AECL. The spread of the CANDU system in world markets, regardless of the seller, will likely provide greater opportunities for Canadian industry; i.e., tendering for specific components, consulting services, etc. Additionally, there could also be benefits in sharing research and development costs, in orienting safety and regulatory procedures, and in relieving Canada's capital burden in heavy water.

Having stated the rationale for the pursuit of licensing agreements, we will now examine the one agreement that has been signed and the one that is pending.

(iii) Italy⁴²

During the early part of the 1970's, AECL attempted to sell a CANDU reactor in Italy, but the company did not succeed. The main reason for the failure was that the Italian utilities preferred to deal with Italian firms. This being the case, a local firm later approached AECL and suggested that a licensing agreement be arranged. AECL agreed and the terms were subsequently worked out.

In the latter months of 1977, the Canadian Cabinet approved the licensing agreement between AECL and Progettazione Meccaniche Nucleari (PMN) which will become effective when the firm succeeds in obtaining an order from an Italian utility. The terms of the agreement are quite complex. However, enough information is available to discern its general nature.

The licensing agreement is to be in effect for 15 years and all costs are subject to escalation. According to the terms, PMN is to be the nominal builder of the first two reactors.⁴³ AECL would be hired as nuclear consulting engineers, and PMN would act as the prime contractor. Canada would supply the design of the nuclear steam supply system, while PMN would be responsible for the balance of plant and the balance of the nuclear island.

During the negotiation process the Department of Industry, Trade and Commerce, as well as representatives of the nuclear industry expressed concern about the total lack of Canadian technology and engineering in the impending contract. To rectify this situation and to pacify the critics, AECL

introduced a provision for Canadian content into the negotiations. Ultimately, PMN acquired the licenses for a fee (which AECL has kept secret for competitive reasons) plus an agreement to purchase \$60 million worth of goods and services from private Canadian firms. This \$60 million does not include the purchase of heavy water and AECL's engineering services which are estimated to be worth another \$120 million.

The conciliatory nature of the Canadian content provision is evidenced by the fact that, for the nuclear steam supply system alone, the nuclear industry can supply over \$100 million worth of components. However, AECL suggested that the actual purchases involving Canadian goods and services could actually be \$120 million instead of \$60 million. This estimate is based on two assumptions:

- 1) that the Italian firms have overestimated their initial capabilities with respect to manufacturing components for the CANDU system; and
- 2) that the Italian utility will prefer as much Canadian content as possible in the first reactor so as to guarantee its success.

In addition to acquiring the right to manufacture and sell the CANDU system within Italy, PMN is also permitted to export the technology "five years after they have built their first reactor, or two years after they have built their second".⁴⁴ However, there are at least three stipulations which accompany the right to export. First, PMN will not be allowed to export CANDU reactors or reactor components into Canada or any other nations having an exclusive license from AECL.⁴⁵

The second condition is with respect to the required safeguards on any export sale. According to the agreement:

... before any right is given to the licensee to export, there would have to be an agreement between Canada and Italy or Canada and Euratom, in which Italy was a party to an EEC agreement with Canada, which would ensure the Canadian safeguards position.⁴⁶

Presumably this means that PMN will have to secure from the prospective buyer exactly the same safeguard regulations as Canada secures from its customers.

The third condition for export is tied in with equipment purchases from Canadian companies. Before PMN can acquire an export order it must have purchased a minimum of \$35 million of the \$60 million worth of goods and services it is obligated to buy from Canadian companies. Again, this does not include the heavy water and the engineering services supplied by AECL. Thus, this \$35 million is a "trigger figure" as far as PMN is concerned. It was designed to protect the interests of Canadian industry, but it also allows for the possibility whereby the Italians can export a CANDU reactor before they have purchased the total amount of Canadian goods and services as stipulated in the contract. However, if, as AECL assumes, PMN purchases the total \$60 million for the first reactor, then this export condition will be satisfied as will the terms of the contract.

There is one other condition relating to re-export. A provision has been included in the licensing agreement that PMN must allow a certain percentage (15%-20%) of Canadian tenders with respect to the supply of nuclear steam supply components on Italy's export contracts. If the Canadian bids

are competitive (within approximately 10% of the other bids) and if they are accompanied by similar arrangements for financing, delivery times, etc., as the other tenders, then the Canadian bids will be accepted. Reciprocally, AECL will allow the Italians to tender for the future export orders acquired by Canada (up to four orders).

A final condition, unrelated to the question of re-export, was included in the licensing agreement. If PMN has not received an order for a CANDU reactor by December, 1979, AECL has the option of cancelling the agreement. However, PMN has received a bid invitation from an Italian utility and is presently preparing to tender.

(iv) Romania*

A second licensing agreement is currently being negotiated with Romania and, should the deal be completed, it would represent the first major commitment to CANDU technology by a foreign country. The current negotiations involve the construction of four 600 MW CANDU reactors. This agreement is considered to be a forerunner of a larger and longer-term licensing agreement between the two countries since Romania, seeking to become self-sufficient in nuclear electric power production as soon as possible, is reportedly planning a program which would incorporate as many as 16-20 CANDU reactors, the majority of which would be manufactured by Romanian industry.⁴⁷ Since the negotiations are still in progress, the exact details of the complete agreement are unknown. The

* see postscript

following information is based on numerous press releases and some personal interviews.

The complete package involves three separate stages: a safeguards agreement; a commercial agreement; and an engineering services agreement. The safeguards agreement is an inter-governmental agreement between Romania and Canada. It was signed in October, 1977 and took the form of a nuclear co-operation agreement. According to External Affairs Minister, Don Jamieson, it "contains binding assurances that any nuclear material, equipment and technology transferred subject to the agreement may only be used for peaceful, non-explosive purposes".⁴⁸ To ensure that these assurances are maintained, Romania has accepted the use of IAEA inspection services and all that that implies. The agreement also states that the retransfer of items could only occur with the consent of both countries but, to date, there is no provision for re-export.⁴⁹

The commercial agreement has two separate components. The first part concerns licensing arrangements while the second part outlines the procurement arrangements. Due to the nature of the transfer, i.e., from a Western country to an Eastern-bloc country, consultations were held between Canada and its NATO allies and between Canada and COCOM, thereby clearing the way for the negotiation of the supply contracts.⁵⁰ In mid-November, 1977, the licensing arrangements were initialled. Under the terms of the agreement, AECL will provide Romanergo, a Romanian state trading company, with an "off-the-shelf" design for a 600 MW CANDU reactor.⁵¹ Romania will be

responsible for compensating AECL for any additional costs incurred by adapting this standard design to specific siting and regulatory requirements in that country.⁵² AECL will also provide the necessary information to connect the nuclear portion of the station or stations to the conventional portion. As in the Italian deal, the licensing fee has not been and probably will not be disclosed.

The second part of the commercial agreement - the procurement arrangements - is still being negotiated. This section of the contract concerns the amount of Canadian content to be incorporated in the first four units. The contribution of private Canadian firms will be limited to the supply of components and equipment for the nuclear steam supply systems of the reactors. Romania is reportedly negotiating with Alsthom of France and GEC Turbine Generators of Britain for licenses to build the 600 MW turbine-generators.⁵³

The actual value of the procurement agreement to Canadian firms is not yet known, but some estimates are available. According to the general format of the agreement, Canadian content will be substantial in the initial units but by the fourth unit it will have declined appreciably. A prominent industry official stated that Canadian firms are anticipating the supply of \$120 million worth of components and equipment for the first two units and \$60 million worth for units three and four.⁵⁴ Thus, according to these figures, the total value of the contract to Canadian firms could be about \$180 million.* However, another estimate indicated that

* Excluding AECL's contribution

this total may be too low. It suggested that the supply of components and equipment would probably amount to \$100 million on the first reactor, \$50 million on the second and \$33 million on the third and fourth units respectively.⁵⁵ Canadian content for the complete package (excluding AECL's participation) would then be approximately \$216 million. Of course, both of these estimates are unofficial but they do indicate that, as far as Canadian industrial participation is concerned, the Romanian licensing agreement will likely be more attractive than the Italian agreement.

The third section of the package is an agreement between AECL and Romania covering engineering services. The two parties reached an agreement in principle on this contract in January 1978, but the agreement was not finalized until July.⁵⁶

A final note with respect to the scope of Canadian-supplied items is necessary. It was reported that the agreements already signed or under negotiation do not include provisions for the initial supplies of heavy water and uranium fuel.⁵⁷ This situation, if in fact it does exist, seems incomprehensible. Not only would the inclusion of these items result in additional revenues for Canada but more importantly, in the case of heavy water, it would help relieve this country's over-supply problem. Therefore, AECL should take appropriate action to ensure that provisions pertaining at least to the supply of heavy water are included in the overall agreement.

Finally, because of the controversy which surrounded the Argentine sales, AECL adopted a very cautious approach in the present negotiations. This has undoubtedly contributed

to their exceedingly long duration. At the outset Romania insisted on a fixed-price contract (similar to the type acquired by Argentina) while AECL was opting for a cost-plus contract to protect against unexpected cost escalations. The two parties ultimately agreed to the former type of contract but with escalation clauses. AECL's critics may question the acceptance of another fixed-price contract, however, Romania's economy is considerably more stable than that of Argentina and is unlikely to encounter the rampant inflation which plagued the latter. Furthermore, if AECL learned anything from the Argentine experience, the escalation clauses should be sufficient to cover all costs and still leave a profit. Only time will tell.

D. SUMMARY

Almost from the beginning, exports of nuclear technology have been an important part of the Canadian nuclear program. In 1956, under the Colombo Plan, Canada provided India with a research reactor. Subsequently, Canada sold two 200 MWe CANDU units to India; one in 1963 and the other in 1966. In addition, the Canadian General Electric Company sold a 125 MWe CANDU unit to Pakistan in 1965. These early exports provided Canada's budding nuclear industry with the opportunity to gain additional experience in the design and fabrication of nuclear equipment. They also became symbols of Canada's willingness to share its advanced technology with developing countries.

AECL assumed total responsibility for international marketing in 1968. The corporation had little success in the export market and by the early 1970's it was under considerable pressure to obtain a foreign sales. Export sales were valued because of

the economic and political benefits that they would provide to Canada. But, more importantly, by selling a CANDU reactor in direct competition with the light water reactor system AECL and the Canadian government could perhaps silence the critics who were attacking the CANDU system as well as the scientific and technological decisions which had led to its development.

Finally, in 1973, AECL sold a 600 MWe CANDU unit to Argentina. Two years later, another order was received from South Korea. However, in both instances the sale probably would not have been obtained if AECL had relied solely on its own marketing abilities. Furthermore, it quickly became evident that the Argentine deal would be a financial fiasco. Clearly, on these two sales, AECL did not demonstrate international marketing and contracting competence.

AECL has also signed a licensing agreement with an Italian firm and is negotiating a potentially more lucrative agreement with Romania.

FOOTNOTES

CHAPTER II

1. R.J. Graham and J.E.S. Stevens, "Experience with CANDU Reactors Outside of Canada", (Paper presented at the Annual International Conference of the Canadian Nuclear Association, Montreal, June 1974), p.23.
2. Ibid.
3. Export Development Corporation, Annual Report 1969, P.18. The interest rate for the loan was 6%. See Ciro E. Zippo, "Toward A U.S. Policy on Nuclear Technology Transfer To Developing Countries," (Paper presented at the California Arms Control and Foreign Policy Seminar, July 1973).
4. Graham and Stevens, "Experience with CANDU Reactors", p. 39.
5. See G. Bindon and S. Mukerji, "How Canada's and India's nuclear roles have been sadly misrepresented," Science Forum 55, (February 1977), pp. 3-7.
6. Ibid., p.3.
7. With a turnkey project the seller typically contracts to design and build the physical facilities and to train local personnel to operate them. There is no transfer of technology.
8. EDC, Annual Report, p.19.
9. Jorge A. Sabato, "Atomic energy in Argentina: a case history," World Development, 1, (August 1973), p.33.
10. Ibid., p.35.
11. J. Lorne Gray, testimony before the Senate Special Committee on Science Policy, (Lamontagne Committee), Proceedings, 30 October 1968, No. 5, p.654.
12. The attempts in Australia and Mexico were expensive. According to J.S. Foster, it costs approximately \$500,000 to \$1 million to put a bid together. See House of Commons Standing Committee on Public Accounts (hereafter referred to as PA Committee), Proceedings, 21 December 1976, No.8, p.19.
13. Canada, Parliament, House of Commons Debates, (hereafter referred to as Debates), 11 March 1971, p.4184.
14. Canada, Senate, Special Committee of the Senate on Science Policy, Proceedings, 11 August 1976, No. 17, p.14.

15. The marketing team of Canadian General Electric consisted of 25 people.
16. J. Lorne Gray, PA Committee, Proceedings, 25 January 1977, No. 9, p.49.
17. D. MacDonald, PA Committee, Proceedings, 3 February 1977, No. 12, p.8.
18. Lamontague Committee, A Science Policy for Canada, 1970, pp. 72-78.
19. Walter Stewart, "Lorne Gray's Gamble to Make Canada a Nuclear Great Power," MacLean's, (September 1970), p.54.
20. Debates, 11 March 1971, p.4179. The Hon. member proceeded to compare Canada's nuclear power program with the ill-fated Avro Arrow project.
21. Debates, 25 May 1972, p.2567.
22. J. Lorne Gray, PA Committee, Proceedings, 25 January 1977, No. 9, p.49.
23. Ibid., p.14.
24. J. Lorne Gray, PA Committee, Proceedings, 15 November 1977, No. 3, p.21.
25. AECL accepted the terms of the joint venture relationship for several reasons. One major factor which influenced the officials of the corporation was that if AECL was successful in Argentina with an Italian partner, the chances of later success in Italy would probably improve greatly. See J. Lorne Gray, PA Committee, Proceedings, 25 January 1977, No. 9, p.15.
26. PA Committee, Proceedings, 27 January 1977, No. 10, p.49. Estimates obtained from interviews with officials at AECL and the Department of Industry, Trade and Commerce place the value of Canadian goods and services at approximately \$75-80 million.
27. As of January 1976, the projected loss was between \$103 and \$117 million.
28. The original contract was written in accordance with Argentine law which is based on Roman law. This meant that there was a provision for adjustment if circumstances outside a contract change significantly so that the contract became too onerous for one party or the other.

29. This total includes a provision for \$56 million for contingencies on warranties as well as on a delay in the delivery of the station (50 week delay). However, until the contract expires, it is difficult to estimate how much of the \$56 million will be used.
30. In discussing the reasons for the underestimation of engineering man-hours, Mr. Foster noted:

"We used the number of man-hours in that estimate, as I recall, that was about the same as the number of man-hours in the Gentilly - 1 project. But experience since has been that the amount of effort in all of these jobs... has taken more. The Gentilly - 2 project, the 600 megawatt unit, in effect the prototype for this Argentine job, and the New Brunswick job, have all taken about twice the amount of engineering that the earlier Gentilly - 1 job did."

PA Committee, Proceedings, 22 November 1977, No. 5, pp.19-20.
31. J. Lorne Gray, PA Committee, Proceedings, 25 January 1977, No. 9, pp. 22-23. Mr. Eisenberg, according to Mr. Gray, had been a representative of Canadian General Electric at the time when that company was supplying a plant to Pakistan.
32. Ibid., p. 16 and 23. According to Mr. Gray, Westinghouse continually fed misinformation about the CANDU system to KECO. In 1969, Westinghouse officials also succeeded in pressuring the Koreans to cancel a meeting between the officials of AECL and KECO which had been arranged by Mr. Eisenberg.
33. Interview with an industry official.
34. Interview with an official with the Department of Industry, Trade and Commerce.
35. "The total Canadian export loan was comprised of \$50 million under the authority of the EDC Board of Directors, \$250 million under authority of the Government of Canada, and \$30 million from the Royal Bank of Canada acting on behalf of a consortium of Canadian chartered banks. On January 16, 1976, the agreement was amended, changing the borrower to the Government of Korea [instead of KECO]". Export Development Corporation, Annual Report, 1975, p. 10.
36. Ibid.
37. J.J. Shepherd, "The Structure of the Canadian Nuclear Industry", (Paper presented to the Annual International Conference of the Canadian Nuclear Association, Montreal, June 1977), p. 9.

38. G.T. Leaist, "AECL Nuclear Power Marketing", (Paper presented to the Annual International Conference of the CNA, Toronto, June 1974), p. 6.
39. As noted in Chapter V, the Canadian manufacturers of CANDU components generally concur with this sentiment but not without reservations.
40. J.S. Foster, "Marketing the CANDU - An Overview", (Paper presented to the Canadian Nuclear Association International Marketing Seminar, Ottawa, 29 March 1977), p. 3.
41. Ibid., p. 6.
42. Most of the information contained in this section (except where otherwise stated) was obtained from interviews with officials at AECL.
43. A. Gillespie to House of Commons Standing Committee on National Resources and Public works (hereinafter referred to as NRPW Committee), Proceedings, 29 November 1977, No. 1, p. 23.
44. Ross Campbell [Chairman of the Board of AECL], NRPW Committee, Proceedings, 29 November 1977, No. 1, p. 24.
45. Robert Steklasa, "Scarce sales worry industry", The Financial Post Special Report on Nuclear Energy, 28 January 1978.
46. A. Gillespie, NRPW Committee, Proceedings, 29 November 1977, No. 1, p. 24.
47. See Jeff Carruthers, "Romania likely to buy CANDU reactors", Winnipeg Free Press, 3 November 1977 and John Best, "Romania - Canada nuclear deal nearing completion", Ottawa Journal, 9 November 1977.
48. The Gazette (Montreal), 25 October 1977.
49. A. Gillespie, NRPW Committee, Proceedings, 29 November 1977, No. 1, p. 24.
50. Interview with an official at AECL.
51. Jeff Carruthers, "Romanian CANDU deal clears second stage", Globe and Mail, 29 July 1978.
52. Ibid.

53. Pearl Marshall, "Romania plans to start building CANDUs next year", Nuclear Engineering International, (June 1977), p. 29.
54. Interview with a nuclear industry official.
55. Jeff Carruthers, Globe and Mail, 29 July 1978.
56. Ibid. Also see Ottawa Journal, 4 January 1978.
57. Ibid.

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CHAPTER III
THE INTERNATIONAL NUCLEAR MARKET

A. INTRODUCTION

The purpose of this chapter is to try to establish the size and the characteristics of the international market for nuclear power reactors in the short-term future, i.e., to the turn of the century. It must be stated at the outset, however, that this task is extremely difficult because the growth of nuclear power is conditioned by several factors.

The first part of the chapter examines the current status of nuclear power globally. The second part presents various estimates of the projected growth of nuclear power. This section is divided into two subsections: industrialized and developing countries. In each case an attempt is made to outline the size and the nature of the market in these countries.

B. CURRENT STATUS OF NUCLEAR POWER

In 1977 there were approximately 170 nuclear power plants operating throughout the world.¹ With a total output of slightly more than 85,000 MWe, these plants provided about 5% of the world's electrical energy requirements.² However an additional 350 units, capable of supplying 330,000 MWe, are either under construction, on order or in the planning stages.³

The use of nuclear power as an alternative energy source to fossil fuels and coal has gained international acceptance. Currently thirty-five countries have nuclear power plants in operation, under construction or on order. The largest

percentage of the world's installed nuclear power capacity however, is located in the industrialized countries of Europe, Japan, the United States and Canada. In 1975 when this capacity was approximately 76 GWe, 89.4% was in the developed countries, 9.2% in countries with centrally planned economies (the USSR and Eastern Europe) and 1.4% in the developing countries.⁴

In terms of reactor types, the most widely used is the light water reactor developed by the United States. Once again, using the 1975 data, 80% of the world's installed nuclear capacity was provided by light water reactors, 12% by gas cooled, graphite-moderated reactors, 4% by heavy water reactors and the remaining 4% by prototypes of the liquid metal cooled fast breeder reactor and the high temperature gas cooled reactors.⁵

C. PROJECTED GROWTH OF NUCLEAR POWER

Although the current contribution of nuclear power to the world's electrical energy requirements is small (5%), recent surveys suggest that it will grow steadily in the future. According to the projections, by the year 2000 nuclear power could provide more than 1/3 of the world's electrical energy and, by 2025, it could supply approximately 50 percent.⁶

There are several assumptions underlying the rapid growth in installed nuclear power capacity. First, the relative contribution that oil and gas make to the world's energy supplies is expected to ebb before the turn of the century. It is therefore assumed that, due to high prices, uncertainties of

supply and important alternative uses in transportation, industry, residential heating and petrochemicals, these resources will increasingly be diverted from the production of electricity, thereby enhancing the future prospects for nuclear power.

The second assumption is that the large-scale use of alternative energy sources such as solar energy, geothermal energy and fusion will not be feasible for at least the next 25 years and thus cannot compete with nuclear, coal, or other fossil fuels as major sources of electric power until that time. This pessimistic assessment of the near-term prospects of these energy sources stems from the high capital costs and the serious scientific and/or technological problems currently associated with them.⁷

Thirdly, while coal will be the major competitor with nuclear power for the generation of electricity during the remainder of the century, it is assumed that, for most nations, nuclear energy represents the best alternative. This assumption is derived from a study of the international coal situation and the comparative economics of a nuclear power plant and a coal-fired electric power plant.

The major known deposits of coal are concentrated in three countries: the United States, the Soviet Union and the People's Republic of China "which together are estimated to have between 70 and 90 percent of the world total, depending upon which reserve estimate is used."⁸ Although several countries, including Canada, have recoverable coal reserves which are large enough to contribute to their respective domestic

energy programs in the short-term future, other countries are not so fortunate. Some, like Japan and the Western European countries, have seriously depleted reserves; others, such as several of the Third World countries, either have no known deposits to-date or do not have access to the technology and investment capital necessary to develop the resources that they may possess. For these countries, seeking to reduce their dependence on expensive imported oil, the coal option is perceived as inappropriate. As coal reserves are depleted they will be faced with increasing prices and uncertainties of supply and thus could find themselves in the same predicament as the one that they are currently experiencing with respect to oil. On the other hand, the development of new technologies such as breeder reactors, plutonium reprocessing and recycling, laser enrichment and the thorium fuel cycle is geared toward the indefinite extension of fuel supplies for nuclear reactors and, in addition, may provide greater independence from external fuel supplies for electricity.

Current estimates suggest that nuclear power, on the average, enjoys a small cost advantage over coal. However this advantage may only be temporary. The Ford/Mitre Report stated that:

*"Conclusions on the comparative economics of coal and nuclear power depend on estimates of future capital charges, which include construction costs and interest, and the cost of uranium and coal. Each of these cost factors involves special problems that contribute to the uncertainty and possibility of different interpretations."*⁹

Nevertheless, the assumption that nuclear power is the best alternative for many nations is based, in part, on this present economic advantage and the belief that nuclear power will continue to be economically competitive with coal.

No data or arguments will be presented here to either support or refute the assumptions outlined above. The intent is merely to illustrate the kind of assumptions which govern the growth projections for nuclear power vis-a-vis the alternative sources for electrical energy. Of course the growth of the world's installed nuclear capacity will be influenced by several other factors such as the growth rate of electricity per se and public opposition to nuclear power. These additional factors will be discussed later in the chapter.

Having stated at the outset of this section that nuclear power could provide a large portion of the world's future electrical energy requirements it is appropriate to indicate the expected magnitude of the contribution. Table III-A is an estimate of the projected global nuclear power capacity, broken down into 11 world regions. The growth pattern is based on the preliminary assessments of electricity demand prepared for the World Energy Conference Conservation Committee by the Energy Research Group of the Cavendish Laboratory, Cambridge. While other estimates do vary with respect to a) the general growth rate of nuclear power and b) the growth rate on a country-to-country basis, the figures contained in the table are at least representative of the general trend of anticipated nuclear power installation.¹⁰

TABLE III-A

PROJECTED GLOBAL NUCLEAR POWER CAPACITY, GWe

	<u>World Region</u>	<u>1975</u>	<u>1985</u>	<u>2000</u>	<u>2020</u>
1	North America	42	147	518	1202
2	Western Europe	21	63	263	780
3	Japan, Australia and New Zealand	5	37	174	441
4	USSR and Eastern Europe	7	33	396	1560
5	China and Communist Asia	-	-	6	50
6	OPEC	-	3	33	267
7	Latin America	0.34	10	75	333
8	Middle East and North Africa	-	1	10	52
9	Africa South of Sahara	-	3	18	79
10	East Asia	-	3	32	209
11	South Asia	0.76	3	18	60
TOTAL		76	303	1543	5033

Source: M. F. Duret, G. J. Phillips, J. I. Veeder, W. A. Wolfe (AECL), and
 R. M. Williams (EMR), "Report on Nuclear Resources to the Conservation
 Commission of the World Energy Conference," (Ottawa: July, 1977).

The table indicates that the world's installed nuclear capacity is expected to increase substantially during the next 50 years - from approximately 76 GWe in 1975 to about 5033 GWe in 2020. Currently, nuclear generating capacity is about 100 GWe. Although the industrialized countries (regions 1 - 3) will continue to have the largest share of the nuclear power capacity, the distribution is expected to change with time. In 1975, 98.4% of the world's capacity was located in the developed countries. By 2020 their share is expected to decrease to about 48.1%. Thus countries with centrally planned economies (the USSR and Eastern Europe) and the developing countries (particularly regions 7 - 11) are expected to increase their shares significantly: from 9.2% (1975) to 32.0% (2020) and from 1.4% (1975) to 14.5% (2020) respectively.

For the international suppliers of nuclear reactors in general, the best marketing opportunities, in terms of return on investment, will undoubtedly be found in the developing countries. Although there may be a few exceptions, e.g. Romania, countries with centrally planned economies probably will not provide a significant market for foreign suppliers, at least in the short-term future. Likewise, as the next section illustrates, the nature of the market in industrialized countries suggests that it will not be as lucrative a market as the one in the developing countries.

(i) Industrialized Countries

Most of the industrialized countries are committed to nuclear power but the degree of commitment obviously differs from country to country. A recent survey suggests that only 5 of the 24 members of the Organization for Economic Co-operation and Development will not have some installed nuclear power capacity by 1990. These are: Australia, Iceland, Ireland, Norway and Portugal.¹¹ However, any forecast pertaining to the growth of nuclear power in the industrialized countries is subject to considerable uncertainty because of several factors which must be taken into account. Although most of these countries intend to expand their nuclear electrical generating capacity as part of their efforts to reduce dependence on the petroleum-exporting countries, several developments during the last 3 years have adversely affected the planned rates of expansion. Two developments in particular are mainly responsible for the slowdown of the nuclear power programs in the developed countries: the serious recession which has plagued the industrialized world since 1975; and the increasing public opposition to the use of nuclear reactors.

Ironically, the dramatic increases in the price of oil from 1973 to 1975 which were expected to promote the greater use of nuclear power have instead slowed down its expansion. The oil price increases compounded the already high rates of inflation and led to a serious downturn in economic activity. The resulting recession affected the growth rate of nuclear

power in two ways. First, it reduced the demand for energy, particularly for electric power, in the industrialized countries. The magnitude of this decline is indicated by the following data:

From 1960 to 1973 the total energy requirements of the OECD countries rose an average of 5.1 percent, but annual growth rates are now estimated at no more than 3.6 percent.¹²

This decline is due partly to the depressed level of economic activity relative to the pre 1975 period and partly to the power conservation programs introduced by many of the countries after 1975. Secondly, the inflation increased the costs of financing and constructing the nuclear power plants.¹³

As a result of these economic influences several countries, including Canada, have either revised their estimates for installed nuclear power capacity downward or are having serious difficulty in attaining their original goals. For example: Japan has reduced its planned 1985 capacity by 10,000 MW (from 35,000 MW to 25,000 MW); Spain, although it plans to have 12 nuclear power plants operating by 1980, is reported not to have signed its contracts with Westinghouse; and Italy probably will not attain its goal of 20 power plants by 1985.¹⁴

The most important non-economic factor contributing to the slow growth of nuclear power in the developed countries is undoubtedly the increasing public opposition to this method of generating electricity. According to the OECD and IAEA:

... although economic factors have, in ~~some~~ measure, detracted from the anticipated growth of nuclear power under the stimulus of trends in the oil market, it was subsequent opposition from some public sectors that most significantly influenced nuclear programmes.¹⁵

The opposition to the use of nuclear power stems from the public sectors' concern about the safety and the environmental effects of nuclear reactors. In addition, since the Indian explosion in May, 1974, considerable attention has been focussed on the possibility that civilian nuclear power programs might contribute to the acquisition of nuclear weapons. These concerns are widespread and have adversely affected the nuclear power programs in several industrialized countries. In West Germany, the anti-nuclear protestors have stymied recent attempts to build new reactors.¹⁶ In the U.S., the anti-nuclear campaigners have not met with similar success although they may be partially responsible for halting the construction of a nuclear power plant in New Hampshire.¹⁷ The French government, influenced by the bombing of three nuclear stations in 1975, is reported to have reduced the number of nuclear plants it expects to order by 1980 (from 40 to 25 or 30).¹⁸ As previously mentioned, the Canadian nuclear power program must also contend with a growing and very vociferous anti-nuclear lobby.

Thus, these two factors - the recession and the public opposition to nuclear power - have contributed, to a large extent, to the present slowdown in the nuclear programs of the industrialized countries. Some countries are now showing signs of recovering from the economic malaise but others are still struggling. Furthermore, there is little evidence to

suggest that public opposition is waning. Hence, despite the fact that most of the countries are committed to nuclear power, there is considerable uncertainty as to the rate of growth of installed nuclear capacity. The uncertain nature of the market in the industrialized countries has increased the efforts of the nuclear suppliers to secure contracts elsewhere.

Another characteristic of the market in the developed countries indicates that, even if the aforementioned difficulties were not present, the profit potential for foreign suppliers is not as great as that in the developing countries. The national power markets in the developed countries are large but they are also restrictive. As a rule, because of the preferences of the private utilities and the certification procedures for foreign products, the indigenous nuclear power equipment and service industries act as the main suppliers for domestic orders. In addition, those countries which do not presently possess their own nuclear capability are generally interested in developing a local nuclear industry through the acquisition of licensing agreements. Thus, in order to obtain sales in these markets, the foreign supplier must be willing to transfer proprietary design and manufacturing technologies thereby introducing the possibility of increased international competition in the future. The main return for the supplier is derived from royalties, fees or dividends. This is in contrast to sales to developing countries which usually result in a wider scope of supply and greater returns for the supplier.

These then are some of the general characteristics of the market for nuclear power reactors in the industrialized countries. In a later chapter other characteristics will be examined, particularly in reference to the efforts of AECL to introduce CANDU technology into this market.

(ii) The Developing Countries

In 1977 nuclear power represented approximately 2% of the total installed electric capacity of the developing countries.¹⁹ Five nations - Argentina, India, Pakistan, South Korea and Taiwan - have nuclear power stations in operation with a combined output of 2200 MWe.²⁰ Furthermore, construction of new nuclear facilities is underway in the above nations as well as in Brazil, Iran, Mexico and Egypt. Barring any delays, all of these facilities are expected to come on stream early in the next decade thereby increasing the total installed nuclear capacity by 15,000 MWe.²¹

But what are the future nuclear power prospects in the developing countries? A 1975 study for the American government by Richard J. Barber Associates (hereafter referred to as the Barber Report) concluded that, at least until the year 2000, the nuclear market will encompass only about 20 of the larger developing countries.²² For the other nations, nuclear power will continue to be uncompetitive vis-a-vis the alternative energy sources. The report showed that the largely rural and agricultural societies of the smaller developing countries do not consume enough energy in all forms nor do they have adequate electrical grids to warrant the installation of even the smallest

unit size of proven nuclear power plants currently offered commercially.

The Barber Report noted that in 1971 the developing countries' share of world energy consumption was only 8.6 percent - an increase of 1.1 percent since 1961.²³ Sixteen countries accounted for 76 percent of this share.²⁴ Over the same period, the developing countries' share of global electric power consumption rose slightly from 5.8 percent to 6.9 percent.²⁵ Once again the bulk of this demand was concentrated in a small number of nations. In 1971 twelve countries accounted for two-thirds of the electric power consumption in the developing countries and furthermore, only six nations accounted for more than half.²⁶ The Report states:

These statistics help to place the energy demands of LDC's in perspective. What they indicate is that in the context of total energy use, LDC's play a minor role and, that within the LDC group, only a few nations have offered significant growth prospects.

The most recent data on world energy consumption suggest that this situation is relatively unchanged. However, from 1972 to 1976 the rate of growth of both total energy and electric power usage in the developing countries was higher than in the previous ten year period. In 1976 the developing countries share of global energy consumption was 10.2 percent - an increase of 1.6 percent.²⁸ At this growth rate their share would be approximately 20 percent by the year 2000. In the electrical sector the developing countries' share rose to 9.1 percent representing an increase of 2.2 percent from 1971.²⁹

The relative distribution of both total energy and electric power consumption within the group of developing countries is almost identical to the 1971 breakdown. By the end of 1976, the same 16 nations which accounted for 76 percent of total energy use in 1971, still consumed 72.2 percent (see table III-B). Table III-C shows that, in the electrical sector, 14 nations accounted for 68.5 percent of all the electric power consumed by the developing countries. Once again, 6 nations accounted for more than half. Finally, the top 12 countries which consumed two-thirds of the total electric power consumption in 1971 consumed 65.1 percent in 1976. Thus, while the demand for energy in all forms and electrical energy in particular is increasing, the bulk of this demand remains concentrated in a few of the countries.

Due to the relatively low levels of electricity consumption in many developing countries, their respective electrical grid sizes are not adequate to accommodate a 600 MW nuclear power plant which represents the smallest unit size currently being offered by the international suppliers. A 1974 International Atomic Energy Agency study pointed out that, for reasons of system stability in the case of failure of a generating unit, there is a definite limit on the maximum size of any single power plant which the system can accept.³⁰ The study estimated that an electrical grid should have approximately 9,200 MWe of interconnected installed capacity in order to support a single 600 MWe plant.³¹ Using this guideline and

TABLE III-B

ENERGY CONSUMPTION OF SELECTED
DEVELOPING COUNTRIES AND OF ALL DEVELOPING
COUNTRIES (1976)
(MILLIONS OF METRIC TONS OF COAL EQUIVALENT)

INDIA	132.924
BRAZIL	79.840
MEXICO	76.501
IRAN	49.768
ARGENTINA	46.404
SOUTH KOREA	36.583
VENEZUELA	35.079
INDONESIA	30.428
TAIWAN *	29.940
TURKEY	29.830
EGYPT	17.996
COLUMBIA	16.657
PHILIPPINES	14.380
THAILAND	13.217
PAKISTAN	13.112
CHILE	10.323
16 NATION TOTAL	632.982
ALL DEVELOPING COUNTRIES	876.316
16 NATION TOTAL AS A SHARE OF DEVELOPING NATIONS (PERCENT)	72.2

* CONVERTED FROM 1000 KL OIL EQUIVALENT.

SOURCE: United Nations, World Energy Supplies, 1972 - 1976,
Statistical Papers, Series J, No. 16 (New York: 1978)
Table 2 and Taiwan Statistical Data Book 1977,
Economic Planning Council, Republic of China (June, 1977)
Table 5-8.

TABLE III-C

ELECTRIC POWER CONSUMPTION OF SELECTED
DEVELOPING COUNTRIES AND OF ALL DEVELOPING COUNTRIES, 1976

(BILLIONS OF KILOWATT-HOURS)

INDIA	95.316
BRAZIL	88.424
MEXICO	46.812
ARGENTINA	30.463
TAIWAN	24.744
SOUTH KOREA	24.426
VENEZUELA	23.276
TURKEY	18.563
IRAN	17.311
COLUMBIA	15.343
PHILIPPINES	14.736
EGYPT	11.000
PAKISTAN	10.876
THAILAND	10.452
14 NATION TOTAL	431.742
ALL DEVELOPING COUNTRIES	630.241
14 NATION TOTAL AS A SHARE OF ALL DEVELOPING COUNTRIES (PERCENT)	68.5

Source: United Nations, World Energy Supplies, 1972-1976,
Statistical Papers, Series J, No. 16 (New York: 1978)
Table 21 and Taiwan Statistical Data Book, 1977,
Economic Planning Council, Republic of China (June, 1977)
Table 5-12a.

and their own figures for projected demand (considered by many, including the Barber Report, to be generous) the IAEA suggested that 5 countries would be potential candidates for at least a 600 MWe nuclear power plant by 1980, 13 by 1990 and 20 by 2000.³²

It should be noted, however, that the market may not be limited to those developing nations where nuclear power is competitive with alternative energy sources and where the electrical grids can accommodate a 600 MWe unit. There are a number of factors that influence a country's decision to install nuclear power stations:

*Some of them, such as prestige considerations or the desire to gain experience with new technologies, are rather directly associated with nuclear power investment decisions. Others - global economic conditions, national development strategies, and long-term trends in non-nuclear energy supply - often are more explicitly associated, though their impact on nuclear decisions may in fact be less decisive.*³³

Furthermore, the IAEA's 1974 Market Survey indicated that there is a large market for small (150-250 MWe) sized reactors.³⁴ If and when these units become available, the present market, in terms of the number of countries, could expand considerably. For the time being however, those countries which fulfill the aforementioned conditions will represent the largest segment of the market.

Table III-D identifies these countries and suggests the size of the market in terms of installed nuclear power capacity. As previously mentioned, in 1977 there was a total of

TABLE III-D

PROJECTED NUCLEAR POWER CAPACITY IN THIRD WORLD, GWe

	1976	Mid-80's ^a	1985 ^b	1990 ^c	1990 ^d	2000 ^c
Asia:						
India	0.6	1.7	1.7-2.3	31.4	27.2	130.0
Pakistan	0.1	0.1	0.1-0.7	4.9	4.8	15.9
Bangla Desh	-	-	-	-	4.0	7.5
Malaysia	-	-	-	-	1.7	3.2
Indonesia	-	-	-	-	1.7	4.0
Thailand	-	-	0-0.6	3.2	3.7	9.1
Singapore	-	-	-	3.0	4.3	13.6
Philippines	-	1.4	0.6-0.6	4.8	4.8	12.0
Taiwan	-	4.9	4.0-4.9	10.3	7.4	22.4
South Korea	-	1.8	1.9-2.8	9.8	8.6	18.9
Iran	-	4.2	3.3-4.2	10.0	10.0	28.0
Mid-East:						
Iran	-	-	-	5.0	5.0	12.6
Egypt	-	-	0-0.6	-	-	-
Brazil	-	3.2	1.9-3.2	11.4	10.8	46.9
Latin America:						
Argentina	0.3	0.9	0.9-1.5	8.1	6.6	18.1
Mexico	-	1.3	1.3-2.3	21.6	20.9	68.0
Chile	-	-	-	0.8	1.7	2.8
Venezuela	-	-	-	4.4	4.4	8.4
Peru	-	-	-	1.3	1.3	1.7
Columbia	-	-	-	1.7	1.7	5.3
Cuba	-	-	0-0.4	0.4	2.1	3.8
Total	1.3	19.5	15.7-24.1	132.1-(139.7)	132.5	447.5-(484.7)

Sources:

(a) Nuclear Power Issues and Choices, Ford/Mitre Study, Ballinger, 1977 (Mainly from Nuclear News, Feb., 1976).
 (b) S. Eklund (Director-General, IAEA), "Nuclear Energy Prospects for the Developing Countries in the Non-Proliferation Era", Nuclear Engineering International, April, 1977.

(c) R. J. Barber Associates, "LDC Nuclear Power Prospects, 1975-1990", Figures II-18 and II-19, ERDA-52.

This is a version of the IAEA 1974 market survey figures. The lower total is for reactors 600MW and larger. The higher total represents reactors 300MW and larger.

(d) Nuclear Engineering International, January, 1975.

This table (excluding the year 2000) can be found in R.W. Morrison and E. Wonder, "Canadian Nuclear Export Policy", (Ottawa: Norman Paterson School of International Affairs, 1978), p.35.

2.2 GWe of installed capacity in the developing countries.

By the year 2000 this could expand to 447.5 GWe of which 96.5 percent would be located in the 20 countries listed in the table. The regional distribution would be as follows:

Asian Countries (including India)	52.8%
Asian Countries (excluding India)	23.8%
Mid-East Countries	9.1%
Latin American Countries	34.6%

It should be noted, however, that this estimate appears to be very high. By way of contrast, Table III-A suggests that, by the year 2000, the installed nuclear power capacity in the equivalent world regions will be approximately 186 GWe.

Furthermore, assuming that 15 years is a reasonable lead time from the date a country decides to pursue the nuclear option to the date when the first station is commissioned, most of the capacity projected for 1990 should already be on order.³⁵

Nevertheless, if the surge of activity that is expected between 1990 and 2000 materializes, the international suppliers will encounter a sizable market.

As in the industrialized nations, forecasts of nuclear power capacity in the developing countries are subject to considerable uncertainty, because of the numerous factors which influence them. Some of these factors are the impact of the economic malaise in the developed countries, the future price of oil, the impact of increased energy prices on demand and the availability and developmental costs of local energy resources. In addition, due to the growing concern among the exporting countries that some of the developing nations may use the

imported technology and materials to establish a nuclear capability, uranium enrichment and spent fuel reprocessing are currently regarded as "sensitive technologies" and are no longer being sold abroad. This means that most of the developing countries will have to rely on a few developed nations for nuclear fuel. However, the ever changing non-proliferation policies and the increasingly stringent safeguard requirements which govern foreign sales have led several of the developing countries to seriously question the exporters' assurances of reliable supplies of fuel.³⁶ Some countries, therefore, may postpone their nuclear plans until these doubts are alleviated.

The introduction of nuclear technology in the developing countries presents considerable problems in itself.³⁷ In most cases, developing nations are not adequately equipped to receive, absorb and apply the technology that is transferred. Richard Masters writes:

A nuclear power plant cannot be installed in a developing country without some transfer of technology taking place. Even with the most comprehensive turnkey contract covering the supply of plant and equipment, its installation and commissioning, staff still have to be trained to man the licensing and regulatory agency, to accept responsibility for the plant and to operate it efficiently and safely.³⁸

This, of course, necessitates the existence of an adequate pool of local technicians who can receive the specialized training. In most of these countries this is a limited resource. Moreover, improvements must be made to the importing country's technical infrastructure such as port facilities, transportation facilities for heavy equipment and power transmission systems.

Finally, all of these problems adversely affect the nuclear power programs in many developing countries but perhaps the most serious constraint is financing. The large capital investment associated with a nuclear power project puts a heavy burden on the developing countries which are, for the most part, already encumbered by substantial international indebtedness.

D. SUMMARY

Although the contribution that nuclear power currently makes to the world's electrical energy requirements is small, it is expected to increase steadily in the future. Accurate forecasts, however, are difficult to make because the growth rate of nuclear power is influenced by several factors. Nevertheless, conservative projections suggest that the world's installed nuclear capacity could expand from the 85.5 GWe level in 1976 to over 1500 GWe by the year 2000. An even greater increase is expected over the longer terms. By the year 2020 it has been estimated that installed nuclear capacity could be over 5000 GWe.

At least for the remainder of this century, the major export market for the international suppliers of nuclear technology and related materials, in terms of size and return on investment, will be in the developing countries. There are several factors underlying this conclusion. The domestic nuclear programs in several of the industrialized nations are being hampered by slow economic growth and by increasing public

opposition to nuclear power. In addition, those countries with an established nuclear capability will likely reserve their domestic market for their own national nuclear industries. Export opportunities will exist in the industrialized countries which are committed to nuclear power but which do not possess an indigenous nuclear industry. However, these sales will most likely be acquired through licensing agreements. Generally, this method of exporting is not as beneficial to the seller's nuclear industry as direct sales.

On the other hand, several developing countries are pursuing or intend to pursue the nuclear option. Together they offer a sizable market for the international nuclear suppliers. Sales to these countries will, in most cases, involve the transfer of complete nuclear power stations and, therefore, will provide a more lucrative return on investment for the selling country's nuclear industry. Also, the developing countries offer a greater potential for repeat orders.

Competition for exports in this market is strong. Each of the nuclear suppliers has severe overcapacity in their domestic industries as a result of the slowdown in their respective nuclear programmes. In addition, there are a number of problems associated with the transfer of such a highly capital-intensive and complex technology in the developing countries. These factors suggest that the success of an individual supplier will depend, to a large extent, on the type of package that is offered to the prospective purchaser. Typically, an attractive package should include the largest scope of supply

at the least possible cost to the importer, provisions for assisting the importer in overcoming the technical problems associated with the introduction of nuclear power, provisions for the acquisition of loans with favourable terms for repayment to ease the financial burden as well as provisions allowing for local contributions in the form of construction labour, construction material and possibly locally-fabricated equipment and engineering services. In short, if a supplier wants to participate successfully in the market offered by the developing countries, he must be willing to undertake a substantial amount of risk in order to meet the customer's requirements.

FOOTNOTES

CHAPTER III

1. Heinrich Mandel, "Nuclear Energy in the next 21 years- a European utility outlook," Nuclear Engineering International (April 1977), p.27.
2. United Nations, World Energy Supplies 1972-1976, Statistical Papers, Series J No. 16, (New York: United Nations, 1978), Table 18.
3. Heinrich Mandel, "Nuclear Energy in the next 21 years", p.27.
4. M.F. Duret et.al., "Report on Nuclear Resources to the Conservation Commission of the World Energy Conference," (Ottawa: July 1977), p.II-6.
5. Ibid., p.1-3.
6. One study suggests that the fraction of electricity produced by nuclear means will be approximately .37 by the year 2000, and .50 by 2020. See M.F. Duret et.al., "Report on Nuclear Resources," p.II-5. Another study estimates that nuclear power will supply between 32% and 39% of the world's electrical energy demand by the year 2000 and between 43% and 57% by 2025. See Uranium: Resources, Production and Demand (Paris: OECD Nuclear Energy Agency/IAEA, December 1975), p.27.
7. For an analysis of the prospects for the alternative energy sources see S.M. Keeny, ed., Nuclear Power Issues and Choices, Fore/Mitre Report (Cambridge: Ballinger Company, 1975), Chapter 4.
8. Ibid. p.97 "Estimates range from six to twelve trillion tons or approximately 600 to 1,200 years of supply at the 1972 world level of total energy use and for 1,600 to 3,200 years at the world level of coal use."
9. Ibid., p.8.
10. M.F. Duret et.al., "Report on Nuclear Resources." p.1-3. "In the near term (before 2000) the estimate lies close to the lower limit of other projections but beyond the year 2000 they tend to lie midway between the recent 'high' and 'low' forecasts."
11. OECD/IAEA Report, "Uranium: Resources, Production and Demand," p.28. Nine other countries will have 3.5 GWe or less of installed nuclear power capacity by 1990. These include: Austria (2GWe), Denmark (2GWe), Finland 3.5GWe), Greece (1GWe), Spain (1.8GWe), Switzerland (3GWe) and Turkey (1GWe)..

12. Bruno Dethomas et. al., "The Nuclear Sweepstakes," Atlas World Press Review (September 1977), p.38. Originally published in Le Monde.
13. See Bruno Dethomas et. al., and Bernard Nossiter, "Strong opposition, rising costs blamed for nuclear slowdown," The Citizen (Ottawa), 7 February 1977.
14. Bruno Dethomas et. al., "The Nuclear Sweepstakes", p. 40.
15. OECD/IAEA Report, "Uranium: Resources, Production and Demand," p.27.
16. Steven Strasser and Timothy Nater, "Nukes Nein!", Newsweek (10 July 1978), p.46.
17. Newsweek (10 July 1978), p.83.
18. Bernard Nossiter, The Citizen (Ottawa), 7 February 1977.
19. Sigvard Eklund, "Nuclear energy prospects for the developing countries in the non-proliferation era," Nuclear Engineering International (April 1977), p.25.
20. Richard Masters, "Problems of exporting to the developing countries," Nuclear Engineering International (May 1978), p.13.
21. Ibid.
22. R.J. Barber Associates, "LDC Nuclear Power Prospects, 1975-1990: Commercial, Economic and Security Implications," (Report to ERDA, Washington, February 1975), p.xii. (Hereinafter referred to as the Barber Report.)
23. Ibid., p.I-I
24. Ibid.
25. Ibid.
26. Ibid.
27. Ibid.
28. United Nations, World Energy Supplies 1972-1976, Table 2.
29. Ibid., Table 21.
30. See International Atomic Energy Agency, Market Survey For Nuclear Power in Developing Countries, 1974 Edition, (Preliminary Report), IAEA-165 (Vienna: 1974).

31. Ibid., Tables 11 and 12.
32. Ibid., Tables 17 and 19. More recently an IAEA official implied that this market may be larger than expected. He stated that the electrical grid should normally have approximately 6 GWe to 7 GWe of installed capacity in or to accommodate a single 600 MWe nuclear power plant. See George Woite, "Can nuclear power be competitive in developing countries?" Nuclear Engineering International (July 1978), p.46.
33. Barber Report, p.III-1.
34. Also see E.I. Goodman, "Status of small and medium power reactors," Nuclear Engineering International (July 1978), p.49
35. Masters, "Problems of exporting," p.13.
36. See Simon Rippon, "Nuclear Exports: Nothing but problems," Nuclear News, (May 1978).
37. In addition to Rippon, see Masters, "Problems of exporting," and Woite, "Can nuclear power be competitive?"
38. Masters, "Problems of exporting," p.13.

CHAPTER IV

CANDU AND THE INTERNATIONAL NUCLEAR MARKET

A. INTRODUCTION

The previous chapter outlined the size and the nature of the international market for nuclear power reactors in general. This chapter deals specifically with the CANDU reactor system and the international market. The first section indicates some of the advantages of the CANDU system which may make it more attractive to some countries than the more widely-used light water reactor system. The second section outlines some of the disadvantages associated with the CANDU which make the marketing of the system a particularly onerous endeavour. Finally, the last section examines the possibilities that exist for export sales of the CANDU in the short-term future.

B. THE CANDU SYSTEM: SOME ADVANTAGES

As indicated in chapter III, the principal market for the suppliers of nuclear reactors and related technologies lies in the 20 or so developing countries which are planning to have at least 1 Gw of installed nuclear capacity by the year 2000. The primary task of most of these countries, therefore, is to select the reactor type on which their respective nuclear programs will be based. To a large extent this choice will be governed by factors that are extraneous to the technical merits of a given reactor type; e.g. the terms and conditions of the

contract offered to the prospective customer, the balance of trade between the two contracting countries, etc. However, this choice will also be influenced by an examination of the characteristics of the individual systems encompassing such factors as cost evaluations, operating experience, the variety of nuclear fuels which can be used, the reliability of the supply of fuel, access to the technology, the potential for further development and the opportunities for local participation. Even a cursory examination along these lines reveals that the CANDU heavy water system offers certain advantages over the light water reactor system (LWR) which are particularly attractive to developing countries.

The distinguishing characteristics of the CANDU system were outlined in chapter I. Briefly, these include heavy water moderation, natural uranium fuel, on-power fuelling and the use of pressure tubes instead of the more conventional pressure vessel. The implications of these features for the prospective customer are discussed below.

Heavy water is a highly efficient moderator. Relative to light water and graphite, the other materials currently in use as moderators, heavy water absorbs the least number of neutrons emitted during the fission process. This high moderating efficiency permits the use of natural uranium as fuel. The main competitor of the CANDU system, the American-designed light-water reactor, uses light water as the moderator and, to compensate for the loss of moderating efficiency, enriched

uranium for fuel; i.e., uranium in which the concentration of the fissile U-235 isotope has been raised from the natural 0.7 percent to about 3 percent.

When a country commits itself to the purchase of a nuclear power station, consideration must be given to the establishment of a reliable source of supply of fuel at an economical price. Herein lies one of the attractions of the CANDU system: it provides a much greater measure of independence with respect to fuel than the LWR. A country which purchases a CANDU reactor or a series of CANDU reactors has at least two options with respect to fuel supply. The first option is to obtain fuel from one of the fuel fabrication firms located in Canada. In doing so, however, the purchaser becomes dependent upon one source of fuel - a position which most countries would like to avoid since a number of factors may threaten the security of that supply during the 30 year lifetime of a reactor. The second option represents the advantage of the CANDU system. Fuel fabrication is simple; i.e., it does not involve the mastering of a complex technology and fabrication facilities are inexpensive.¹ Therefore, a country can establish its own facility and then purchase uranium on the open market.

In contrast, most of the developing countries with light water reactors will have to depend indefinitely on foreign sources of supply for enriched uranium.² There are two main factors constraining the spread of enrichment facilities to these countries. As chapter III indicated, at the present time

enrichment facilities are regarded as sensitive; i.e., they give countries direct access to weapons usable material, and so, in the interest of slowing the spread of nuclear weapons capabilities, they are no longer available on the international nuclear market. Secondly, the methods currently being used to enrich uranium, the gaseous diffusion process and the gas centrifuge process, require complex technologies, a fairly large scale of operation, and substantial capital investment. Thus, even if the constraints on the transfer of these technologies were removed, few developing countries possess the technical and financial capabilities to build and operate their own plants.

Although adoption of light water reactor technology implies acceptance of foreign supplies of fuel, this option is not as risky for developing countries as it once was. To date, the United States has possessed virtually all of the non-communist world's commercial enrichment capacity but gradually enrichment services are becoming more available. The USSR was the first country to break the American monopoly. In addition, two European consortia have entered this field: EURODIF, a consortium composed of France, Belgium, Spain, Italy and Iran; and URENCO, a British-German-Dutch consortium. These developments prompted J. S. Foster to warn that "the advantage for CANDU over LWRs with respect to independence in fuel supply has to be recognized as a transitory advantage which will be eroded with time."³

Due largely to the cost of the inventory of heavy water, the initial capital costs of a CANDU reactor are higher than a

light water reactor.⁴ However, the natural uranium fuel cycle gives the CANDU lower fuel costs which, extended over a thirty year period, enables the Canadian system to be cost-competitive with the American-designed reactor. Furthermore, this cycle is more efficient in its utilization of uranium resources. A "once-through" natural uranium cycle consumes about 160 Kilograms of uranium per megawatt-year of electricity generated compared with 220 kilograms in a "once-through" enriched uranium cycle.⁵

The flexibility of the reactor design is another advantage that the CANDU system offers prospective customers. With little modification the CANDU reactor can be adapted to advanced fuel cycles that are even more efficient in uranium utilization. Two such cycles now under study are a plutonium/uranium fuel cycle and a thorium/U-233 fuel cycle.⁶ At present uranium prices these cycles are uneconomic but, as the price of uranium rises, they become more competitive thereby offering the potential of extending the life and the viability of both the CANDU system and uranium supplies. The next phase for light water reactors also involves the use of alternative fuel cycles; i.e., uranium recycle and a plutonium/uranium cycle. However, in order to provide about the same advantage with respect to uranium consumption as the CANDU will have with a thorium fuel cycle, a new technology - the fast breeder reactor - is currently being developed.⁷ Thus, countries using the CANDU system may achieve efficient fuel utilization in the long term without converting to a new type of reactor.

The CANDU system is the only commercial nuclear power system which employs pressure tubes. This feature gives the CANDU a number of important advantages over its competitors.⁸ First, it reduces the possibility of a serious meltdown from an accidental loss of coolant. Secondly, it allows a scaling-up of power by increasing the size and number of pressure tubes. Thirdly, it permits a choice of heat-transfer fluid (coolant). But perhaps the most significant advantage, as far as prospective customers are concerned, is that the manufacture of pressure tubes is more conducive to local participation than the fabrication of a pressure vessel.

The CANDU system also enjoys an advantage over the LWR with respect to fuelling operations. The light water reactor must be shutdown approximately once a year in order to be re-fuelled. This process can take a few weeks or several months if problems are encountered. Moreover, defective fuel elements remain inaccessible unless additional shutdowns are undertaken for their removal. The CANDU system, on the other hand, features on-power fuelling. Thus, both of the aforementioned operations can occur while the reactor is operating at full power. This feature is most appropriate for developing countries where individual reactors can be a major source of power in a small grid. In addition, on-power fuelling enables the CANDU reactor to maintain a high capacity factor and maximum efficiency in the use of fuel.

This rather superficial examination has illustrated some of the distinguishing characteristics of the CANDU reactor

system which give it certain advantages over its competitors. However, as AECL's experience has shown, having a good product does not necessarily guarantee success in the international marketplace. There are several other factors which ultimately affect the international acceptability of the CANDU.

C. RESTRAINTS ON CANDU EXPORTS

To a large extent the export of Canadian nuclear technology is adversely affected by various factors which make the international marketing of a CANDU system, in comparison with its competitors, a particularly difficult task. This section outlines some of these factors.

(i) The Domestic Politicization of CANDU Exports

Domestically the Canadian nuclear export program is still feeling the effects of the lengthy political debate which began in 1974 when India detonated a nuclear device using plutonium acquired from the CIRUS research reactors. Prior to 1974 AECL and the Canadian government had been under considerable pressure from the opposition parties, some sectors of the media and various interest groups to sell a CANDU reactor to a foreign country in a recognized competition. After the Indian explosion these same groups began questioning and even opposing further Candu exports.

The debate focused mainly on the problem of nuclear proliferation and how the nuclear policy of the Liberal government was or was not contributing to it. Several questions were raised in the House of Commons by opposition members regarding the effectiveness of both the Canadian safeguards policy and the inspections by the International Atomic Energy Agency. The questions were augmented by frequent calls for a moratorium on the licensing or the export of CANDU reactors.

The Trudeau government responded in two ways. First, Canadian safeguards were strengthened in December of 1974 and again in December of 1976.⁹ In announcing the latest changes, External Affairs Minister Don Jamieson stated that the new policy "puts Canada many steps in front of every other supplier in the world in terms of the kinds of conditions it places on international sales."¹⁰ Secondly, although nuclear co-operation with India was terminated, the Liberals refused to institute a moratorium on the export of nuclear technology and material arguing that Canada has a moral obligation to share its technology with the developing countries of the world.¹¹ Moreover, the government and AECL argued that a moratorium, even if it were temporary, would severely cripple the Canadian nuclear industry and adversely affect the country's economy.

Nevertheless, by unilaterally imposing the strictest and most comprehensive safeguards of all the nuclear suppliers, Canada severely affected the international marketability of the CANDU system. Potential customers were able to purchase a nuclear reactor and related technologies from other suppliers under less stringent conditions. Furthermore, by eventually cutting off nuclear exports to some of its previous reactor and uranium customers, Canada's image as a reliable supplier was undermined.

By the end of 1976 the intensity of the political debate had subsided somewhat. The proliferation issue had been raised periodically in the House of Commons but it was no longer in the public eye. However, on November 22, 1976, another controversy developed which gave the critics of the nuclear export program new ammunition for their attack.

The controversy erupted when the Auditor - General, Mr. James J. Macdonnell, reported to parliament that AECL had been paying out millions of dollars in "agent's fees" to secure overseas contracts and, in addition, that these payments were inadequately documented. Specifically, the monies in question were a \$2.5 million payment made by AECL to a Swiss bank as part of the Argentine deal and a \$20 million agent's fee (later reduced to \$18.4 million) payable to Mr. Shaul Eisenberg for his efforts in securing the Korean contract. The report also revealed that AECL stood to lose millions of dollars on the Argentine deal.

As a result of these disclosures the international marketing practices of AECL come under close scrutiny from several quarters. Investigations focusing on the question of agents' fees were launched by the Royal Canadian Mounted Police and by the Public Accounts Committee. The story received extensive coverage by the news media and one public affairs program devoted two hours of prime-time television to their own research into the affair.¹² Ultimately, because several basic questions remained unanswered, speculation increased that the payments were used for illegal or corrupt purposes.¹³

The allegations of bribery and the blundering of the Argentine contract illustrated the marketing incompetence of AECL. The first report of the Public Accounts Committee indicted the Board of Directors and the senior management of AECL for failing to take "the necessary action to prepare the Crown corporation for its enormous commercial undertakings" and for not following "acceptable business practices."¹⁴

As expected, AECL officials were extremely annoyed. They argued that these investigations, particularly that of the Public Accounts Committee, seriously damaged the company's reputation as an international supplier of nuclear reactors. Mr. Gray, who had been president of AECL when the contracts were negotiated, intimated that "AECL is finished in the export of nuclear power."¹⁵ He later qualified his statement by suggesting that the company would henceforth have "great difficulty in exporting nuclear power plants."¹⁶ Mr. Campbell summed up the situation in this way:

I suppose ... that if a country badly enough wants the CANDU reactor they will still have it. But in highly competitive situations I think it is going to be damaging in two ways. In the first place, I do not think we are going to get agents of the kind that can help us in this sales effort if they think every document they exchange with us, every contract they have with us, is going to appear in the press. Secondly, I am just waiting for somebody to say that we had to buy our way into these countries, because of the innuendoes of bribery, and that no one will take the CANDU unless you pay them off. This is terribly damaging to what most international experts now agree is the most economical and efficient reactor in the world.¹⁷

In addition to criticizing AECL's performance in the international arena, the committee's report revealed that a more fundamental problem confronted the Canadian nuclear export program. The report noted that:

...the evolution of AECL from a research organization to a substantial commercial enterprise has not been subjected to appropriate scrutiny by the Government and Parliament.¹⁸

Therefore:

AECL was permitted to move into highly competitive and financially risky activities without the proper evaluation of its objectives, the adequacy of its financial systems and the ability of its management to cope with the new demands involved.¹⁹

It should be noted that the lack of government surveillance with respect to the international activities of AECL was mainly due to the "hands-off" approach which characterized the government's relationships with all of the Crown corporations during this period. Nevertheless, the CANDU marketing program is supposedly based upon the cooperation and the support of the Canadian Government, AECL and the industrial sector. In order to compete effectively with the other international suppliers, it is imperative that these three participants work jointly towards the same goal; i.e. to facilitate the sale of Canadian nuclear technology to foreign countries. The sales to Argentina and South Korea, however, revealed a noticeable absence of concerted action.

As a result of the disclosures of the Auditor General's report and the Public Accounts Committee, there were renewed cries for a moratorium in CANDU exports. This time the government responded by tightening its control over the activities of AECL. The authorizations needed by the corporation before it can become involved in nuclear or nuclear - related projects, either domestically or in foreign countries, have been substantially altered.²⁰ For its part, AECL has also instituted changes which will affect the nuclear export program. These will be discussed in chapter V.

However, most of the damage has already been done. AECL's reputation as a nuclear supplier has been tarnished. Furthermore, as the next section of this chapter will illustrate, there is evidence that prospective purchasers of CANDU technology are concerned that AECL might impose stringent provisions in any future contracts because of the firm's previous mistakes. This is likely since it is inevitable that future export sales will receive considerable publicity.

(ii) Closed Markets

There is another aspect of Canada's nuclear export policy, besides the safeguards stipulations, which also limits the international spread of CANDU technology. Generally, before AECL is permitted to pursue a sale with a country interested in the CANDU, the Canadian government, through the Export Development Corporation and the Department of External Affairs, undertakes an assessment of the economic and political conditions within that country. As a result of these assessments the government has devised a list of countries to which the export of Canadian nuclear technology is prohibited. These include Egypt, Greece, Indonesia,* Iraq, Kuwait, Thailand and Turkey.²¹ Three other countries are also "off-limits" to AECL officials. Canada has terminated nuclear assistance to India and Pakistan, and has severed diplomatic relations with Taiwan. Thus AECL cannot sell reactors to 35% of those countries which are planning to have at least 1 GWe of installed nuclear capacity by 1990.

* Indonesia signed the NPT in 1979 and is now off the list.

(iii) Limited Financial Resources

As previous reactor sales have demonstrated, AECL relies on the Export Development Corporation to provide the majority of the financing for CANDU exports. However, exports of Canadian nuclear goods and services must compete with other export projects for the necessary financial assistance and the EDC's resources are limited.

Direct sales of CANDU reactors to developing countries are seriously affected by the EDC's limited financial resources. These sales are preferred by the nuclear industry since they usually involve a significant level of Canadian content. Accordingly, they also place the heaviest demands on export financing, particularly if the importing country does not have financial resources of its own. It was estimated that the total cost of a 600 MW CANDU unit was approximately \$700-\$800 million in 1978.²² The cost of the nuclear steam supply system alone (including engineering services, components and heavy water) was about \$300 million.²³ The current annual budget for the EDC is approximately \$6 billion. This suggests that if CANDU export orders are obtained at the rate necessary to provide a satisfactory loading for the nuclear industry (at least one per year) they may put a serious strain on the resources of the EDC. In fact, it is doubtful that financing on such a large scale could be made available without diverting financial resources from other export needs.

(iv) The Plethora of Light Water Reactors

In the international marketplace the CANDU reactor system must be considered as "the new boy in town". As indicated in chapter III, the most widely used reactor type is the light water reactor which, in 1975, constituted 80% of the world's installed nuclear capacity. By contrast, 4% was provided by heavy water reactors. As a result, the CANDU system is less well known than the light water reactors which are marketed by all of AECL's major competitors. This obviously hinders the marketing efforts of AECL.

AECL's problems are further compounded by the fact that it is attempting to sell 600 MW CANDU units in the international market. To date there are no such units operating either in Canada or in a foreign country although four units, one each in Quebec, New Brunswick, Argentina and South Korea, are expected to come on stream in 1981. Therefore, as yet AECL is not able to offer a demonstration of this product.

Finally, the impressive performance records of the commercial power reactors in Ontario have clearly shown that the CANDU system is a reliable and an efficient technology but, until some experience is gained by the Argentine and South Korean reactors, there is no evidence to suggest that the domestic success of the CANDU can be transferred abroad.

(v) The Competitors

The size and the marketing capabilities of AECL's major international competitors undoubtedly increases the difficulty

of marketing the CANDU system abroad. All of the principal suppliers of nuclear power reactors are larger than AECL and all possess both manufacturing capability and engineering expertise. Some are also capable of arranging financing. Furthermore, with the exception of the USSR, Canada is the only competitor in which the marketing agency is completely owned by the government. As a consequence, AECL's activities in the international marketplace are subject to considerable publicity. As one Canadian nuclear industry official noted, this combination of factors enables AECL's competitors to offer more complete packages, in terms of the scope of supply, take larger risks and offer greater inducements to potential customers.²⁴

AECL must compete with six other major international suppliers. These are: General Electric, Westinghouse, Kraftwerk Union, Framatome, ASEA-Atom and the USSR.

General Electric and Westinghouse are the largest of the suppliers. Each has developed its own variant of the light water technology and each supplies the domestic market as well as the international market.²⁵ General Electric sells boiling water reactors and Westinghouse sells pressurized water reactors. In terms of the number of reactors sold, these giant corporations have enjoyed the greatest success in the nuclear export market. This can be attributed to the fact that from the mid-1950's to the early 1970's, backed by the support of the U.S. Government, they had a virtual monopoly in the export market. Most of the early reactor sales were to developed countries such as Japan, Germany, France, Italy and Sweden. Penetration of these markets

was made "either directly or through capital participation in foreign firms and/or licensing them to sell American technology in their domestic markets."²⁶ Later sales were also made to the developing countries; eg., India, Mexico, Taiwan, South Korea and Brazil. Such was the success of General Electric and Westinghouse that between 1968 and 1971 they provided over 90 percent of the world reactor export market.²⁷

In 1971, however, the tide began to turn. Since that time several developments in the United States have drastically reduced the number of orders received in the domestic market.²⁸ In the export market, some of the foreign firms which were, or still are, licensees of General Electric and Westinghouse reached a stage where they could compete with the U.S. companies in building light water reactors and providing most of the supporting services. As a result, during the 1973-1975 period the U.S. share of the world reactor export market was 48 percent.²⁹

Although AECL acquired orders from Argentina and South Korea, the major competition for the U.S.A. during this period came from the aggressive marketing practices of West Germany's Kraftwerk Union. This company was formed in 1969 as a joint venture between two of Germany's major electrical equipment manufacturers - Siemens and AEG - Telefunken.³⁰ Originally Siemens was a licensee of Westinghouse and AEG-Telefunken was a licensee of General Electric.

Kraftwerk Union is the most diversified supplier of nuclear reactors in the world offering two kinds of light water reactors, PWRs and BWRs, as well as a heavy water reactor. It

is the major supplier for the German market. In the export market KWU receives strong support from the German government. The company specializes in turnkey projects, that is, the export of complete reactor stations, and has sold reactors to the following countries: Austria, Argentina, Brazil, the Netherlands, Spain and Iran. The responsiveness of KWU to the needs of the developing countries is evidenced by the fact that the company has set up a department of specialists "to acquire not only technical know-how, but also to visit prospective importer countries to learn about the existing infrastructure, industrial capabilities, and sociological conditions."³¹ In 1975 it was estimated that KWU could deliver six or seven systems per year.³² The capacity has probably increased since then.

Framatome is a fully integrated French company which can produce all of the major components for the nuclear steam supply system of its PWR. Like Siemens, Framatome was originally a licensee of Westinghouse but the French government has bought all of the American firm's shares. Now the company is approximately two-thirds privately owned (the majority of these shares are held by a single massive industrial group called Creusot-Loire) and one third is owned by the government through the Commissariat d'Energie Atomique.³³ Domestically, Framatome enjoys a guaranteed monopoly to supply all of the nuclear steam supply systems for the French nuclear power program.³⁴ In the international marketplace, the company has undertaken an aggressive export marketing program which rivals that of the Americans and the Germans.

In 1975, Framatome had the capability to produce at least seven or eight NSSSs per year.³⁵

The two remaining major suppliers of nuclear reactors are ASEA-Atom and the USSR. ASEA-Atom is a Swedish firm which is similar in structure to Kraftwerk Union. However, whereas KWU is 100 percent privately owned ASEA-Atom is 50 percent privately owned and the other 50 percent is owned by the government. The company builds and markets boiling water reactors, based on indigenously - developed design. The Russians have also designed and developed their own reactor technology but it is of the pressurized water variety. To date, ASEA-Atom's success has been mainly in the Scandinavian market while the Russians have primarily sold their reactor to the communist countries. However, during the past few years both of these suppliers have become increasingly active in the international nuclear market.

These, then, are AECL's principal competitors in the international nuclear export market. Each is vying for as large a share of the market as possible hence the competition is extreme. But the situation is by no means static. Additional suppliers, mainly from Japan and Italy are expected to get into the market shortly. Thus the competition will become even more intense.

D. PROSPECTS FOR CANDU

Thus far this chapter has outlined some of the advantages and disadvantages associated with the international

marketing of the CANDU. In the light of what has been said, let us now examine the prospects for CANDU exports in the short-term future; i.e., to the year 1990.

There are about nine countries which are generally considered as potential purchasers of Canadian nuclear technology during this time frame. However, as the ensuing analysis illustrates, the eventual sale of a reactor or ~~reactors~~ to any of these countries is by no means a certainty.

In discussing the prospects for CANDU exports in the short-term future, one AECL official placed the nine countries into two unofficial classifications - "most likely" and "possible."³⁶ Included in the first category are Italy, Romania, Argentina, South Korea and Japan.

As chapter II noted, Italy and Romania must be considered the most immediate prospects. An Italian firm has already entered into a licensing agreement with AECL and is currently tendering for the supply of a 600 MW unit. A similar agreement is being negotiated with Romania. A new development in Italy, however, may significantly alter the future opportunities for CANDU in that country. According to a report, a document prepared by Italy's Comitato nazionale per l'energia nucleare (National Nuclear Energy Committee), relating to nuclear development for the 1979-84 period, recommended that Italy should decide upon a single type of reactor technology.³⁷ The report suggested that if this five-year plan is formally approved, Italy will henceforth rely exclusively on light water technology.³⁸ Thus, to say the least,

the immediate prospects for a CANDU sale to Italy are remote. It is unlikely that an Italian utility will choose the CANDU technology until the fate of this plan has been determined.

Unlike Italy, Argentina has embarked on a nuclear power program based on heavy water reactors. The country currently has one reactor operating and another under construction (a 600 MW CANDU). A total of 15 power reactors are planned for operation by the year 2000.³⁹ To support this program Argentina has three uranium production facilities in operation with two more under construction. Moreover, West Germany's Kraftwerk Union is expected to sell a heavy water production plant to the CNEA.⁴⁰ This kind of program appears to be ideally suited for additional exports of CANDU technology. Argentina is interested in acquiring at least another CANDU reactor and AECL would like to accommodate the Argentinians. A recent report indicated that, despite its previous experience in that country, AECL has placed a bid, with two Italian firms as partners for the supply of a second 600 MW CANDU reactor.⁴¹ However, once again, there are obstacles that must be overcome. First, Argentina is concerned that Canada might impose excessively stringent provisions in any future contracts because of AECL's previous mistakes. Secondly, the Canadian federal government will not permit additional sales until Argentina makes definite moves towards assuring that the reactors will be adequately safeguarded.⁴² Specifically this entails either the signing of the Non-Proliferation Treaty - a document Argentina considers discriminatory - or accepting fullscope safeguards.

The prospect of another sale to South Korea also appears to be in jeopardy, at least in the short-term future. In January of 1978 an AECL official indicated that AECL and the Korean Electric company were planning to begin negotiations in 1979 with respect to undertaking a study of a four unit station.⁴³ Shortly thereafter it was reported that:

South Korea has decided to rely in future on U.S. nuclear technology and has awarded an American firm (assumed to be Westinghouse) a contract worth about \$1000 million for two 1200 MW PWR reactors.⁴⁴

The final country included in the "most likely" category is Japan. Japan's nuclear power program is currently based exclusively on U.S. technology but interest has been shown in other systems including the CANDU. In fact, Japan and AECL are about to enter the third phase of a large study, undertaken in 1976, to ascertain the possibility of a licensing agreement between the two parties.⁴⁵

However, there have been several indications that AECL may experience considerable difficulty in selling a CANDU unit or units to Japan. In April 1978, it was reported that the Electric Power Development Company of Japan, a semi-government agency, wants to install two 600 MW CANDU reactors in that country but the Japanese electric utilities that would have to purchase and operate the reactors are opposed to the scheme.⁴⁶ Shortly thereafter, one of these utilities - Tokyo Electric - announced that it intends to purchase a nuclear power plant from Kraftwerk Union.⁴⁷ This announcement is significant in that this aggressive

German firm will become the first foreign supplier to penetrate the U.S. monopoly position in the Japanese market. The KWU foothold may be particularly detrimental to AECL's interests because KWU has the capability to supply both light-water and heavy-water reactor systems. Finally, the attention that the foreign suppliers like KWU and AECL are receiving from the Japanese nuclear energy establishment is a cause of concern to the U.S. suppliers. It is rumoured that the United States may be applying pressure on its military allies, especially South Korea and Japan, to purchase U.S. nuclear power reactors and uranium.⁴⁸

Thus, despite the "most likely" designation, the eventual sale of CANDU technology to these countries should not be taken for granted. In all cases competition among the international suppliers is severe and, in the case of Argentina, the resolution of a thorny political issue will be necessary.

The second category consists of those countries which have shown an interest in the CANDU system and on this basis alone they are included in AECL's list of potential customers in the short-term future. There are four countries in this category: Mexico, Venezuela, Ireland and Denmark. With the exception of Mexico, little or no information is available concerning the status of AECL's involvement, if any, with the nuclear energy planners in these countries. AECL assisted in a study undertaken by a Mexican government company, Asesoria Technica Industrial S.A., to determine the feasibility of manufacturing CANDU components

in Mexico.⁴⁹ Furthermore, although Mexico's nuclear power plans have been deferred until the early 1980's, AECL is maintaining a "close liaison."⁵⁰ Success in the two EEC countries will likely depend upon the outcome of AECL's licensing agreement with Italy. It should be noted, however, that the EEC Commission has criticized the Italian deal stating that although each member may choose the reactor type best suited to national requirements, "any choice in this matter should take account of the need to strengthen the ties of collaboration between the community industries."⁵¹

Finally there is one other foreseeable prospect that is not included in either of the aforementioned categories but which nonetheless is being considered. It has been proposed that, if a licensing agreement can be negotiated with Japan, AECL may attempt to penetrate the Southeast Asian market in partnership with the Japanese.⁵²

Thus, it appears that the opportunities for CANDU export sales in the short term future are not as good as AECL suggests. Granted, there are a number of countries interested in Canadian nuclear technology but only Romania seems to be on the verge of replacing interest with a commitment to purchase. In many of the other countries there are influences currently jeopardizing the sale of CANDU reactors.

E. SUMMARY

This chapter has outlined some of the factors which will ultimately affect Canada's efforts to market the CANDU system internationally in the short-term future. On the positive

side of the ledger, the CANDU system compares favourably with the more widely used light water reactor system. In fact, the basic design features of the Canadian product give it certain advantages over the competition which are particularly attractive to developing countries.

These technical advantages, however, are offset by several factors which act as restraining influences on the acquisition of CANDU export sales. Two of the major factors are the stringent safeguard requirements associated with foreign sales of Canadian nuclear technology and Canada's questionable ability to provide large-scale financial assistance to potential purchasers. Others include: a) the domination of the international nuclear marketplace by light water reactors; b) the inability of Canada to provide a demonstration of the 600 MWe CANDU unit that it is attempting to sell; c) a nuclear export policy which prohibits the sale of nuclear technology to certain designated countries; and d) an export marketing organization (AECL) which is inferior to its major competitors in terms of size, resources and marketing capabilities.

Finally, analysis of the prospects for CANDU export sales in the short-term future suggests that, at the very least, Canada will have to undertake a vigorous and aggressive export marketing program if it is to have a reasonable chance of acquiring the orders that the Canadian nuclear industry so desperately needs.

FOOTNOTES

CHAPTER IV

1. See Atomic Energy of Canada Limited, CANDU 600 Station Design, AECL-PP-28, (Ottawa: May 1976).
2. Brazil acquired an enrichment facility from Germany in 1975 as part of a reactor sale but no other developing country has done so.
3. J.S. Foster, "Marketing the CANDU - An Overview", (Paper presented to the Canadian Nuclear Association International Marketing Seminar, Ottawa, 29 March 1977), p. 3.
4. R.J. Barber Associates, "LDC Nuclear Power Prospects, 1975-1990: Commercial, Economic and Security Implications", (Report to ERDA, Washington, February 1975), p. IV-28. This report stated that the capital cost of a CANDU reactor is usually estimated to be between 20% and 30% higher than light water reactors. A large portion of this additional cost can be attributed to the cost of the initial supply of heavy water. For a multi-unit station such as Darlington, this initial supply represents 24% of the total cost of the station (excluding finance). See Leonard and Partners Ltd., The Economic Impact of Nuclear Energy Industry in Canada (Executive Summary), (Ottawa: August 1978), p. 12.
5. S.R. Hatcher, "Prospects for Future CANDU Fuel Cycles", in Atomic Energy of Canada Limited, Nuclear Power: The Canadian Issues, AECL-5800 (Ottawa: April 1977), p. 92.
6. Ibid. Also see J.S. Foster, "CANDU - Future Developments", (Paper presented at the Nuclear Power Seminar, Calgary Power Limited, Calgary, September 1977).
7. J.S. Foster, "Marketing the CANDU", p. 3.
8. See K.R. Weaver, "Unique Characteristics of CANDU Nuclear Reactors", in AECL, Nuclear Power: The Canadian Issues, pp. 3-9 and J. Lorne Gray, "Why CANDU? its achievements and prospects", AECL-4709, (Ottawa: January 1974).
9. Canada, Parliament, House of Commons Debates, 20 December 1974, p. 2428 and 22 December 1976, p. 2255.
10. Ibid., 22 December 1976, p. 2258.
11. This view was expounded on numerous occasions. See Debates, 13 December 1974, p. 2235 and 23 June 1976.

12. Canadian Broadcasting Corporation, The Fifth Estate, two-part program entitled "The CANDU Affair", originally broadcast on 8 November and 15 November 1977.
13. This was one of the conclusions of the First Report of the House of Commons Standing Committee on Public Accounts, 27 February 1978. The CBC program speculated that the \$2.5 million payment in the Argentine deal was used to bribe high-ranking Argentine military officials who were backing the light-water reactors.
14. House of Commons Standing Committee on Public Accounts, First Report, 27 February 1978, pp. 3 & 4.
15. J. Lorne Gray, PA Committee, Proceedings, 25 January 1977, No. 9, p. 41.
16. Ibid., p. 51.
17. Ross Campbell [Chairman of the Board of AECL], PA Committee, Proceedings, 12 December 1976, No. 5, p. 36. Mr. Campbell's fears were realized less than a year later. See Ian Urquhart, "A scandal revisited", MacLean's (28 November 1977).
18. PA Committee, First Report, p. 3.
19. Ibid., p. 4.
20. Jeff Carruthers, "AECL authorizations tightened by Ottawa", Globe and Mail, 12 October 1977.
21. Interview with an AECL official.
22. Interviews with AECL and industry officials.
23. Ibid.
24. Interview with an industry official.
25. Two other U.S. suppliers are Babcock & Wilcox Limited and Combustion Engineering Limited. Currently these firms supply only the U.S. market.
26. Barber Report, p. IV-8.
27. Paul L. Joskow, "The International Nuclear Industry Today", Foreign Affairs (Summer 1977), p. 792.
28. John Vinocur, "Outlook Held Bleak For Manufacturers of Atomic Reactors", New York Times, 21 September 1977.
29. Interview with an industry official.

30. AEG-Telefunken withdrew from KWU in 1974.
31. Simon Rippon, "Nuclear Exports: Nothing But Problems", Nuclear News (May 1978), p. 59.
32. Joskow, "The International Nuclear Industry Today", p. 793.
33. Robin F.W. Guard, "Prospects For Reorganizing the Canadian Nuclear Industry", (Paper presented at the Conference on Canada's Nuclear Export Policy, Mont Ste. Marie, 9 November 1978), p. 3.
34. Ibid.
35. Joskow, "The International Nuclear Industry Today", p. 793.
36. Interview with an AECL official.
37. Marsha Taylor, "Italian politics could put CANDU out", The Citizen (Ottawa), 6 December 1978.
38. Ibid.
39. Nuclear Engineering International (December 1977), p. 6.
40. Nuclear Engineering International (June 1978), p. 4.
41. Nuclear Engineering International (August 1978), p. 6.
The two Italian firms are reported to be AMN and NIRA.
42. Michael Fox, "Ottawa hesitant over second reactor for Argentina", The Financial Post, 21 January 1978.
43. Interview with an AECL official.
44. Nuclear Engineering International (April 1978) p. 7.
45. Ross Campbell to House of Commons Standing Committee on National Resources and Public Works, Proceedings, 29 November 1977, No. 1, p. 22. Also see Bogdan Kipling, "Made-in-Japan CANDUs hinge on license agreement", The Citizen (Ottawa), 12 October 1976.
46. Jeff Carruthers, "Japan to install CANDUs", Ottawa Journal, 27 April 1978.
47. Nuclear Engineering International (June 1978), p. 7.
48. Globe and Mail, 22 August 1978.
49. Atomic Energy of Canada Limited, Annual Report 1976-1977, p. 78.
50. Ross Campbell, NRPW Committee, Proceedings, 29 November 1977, No. 1, p. 22.

51. Nuclear Engineering International (May 1978), p. 11.
52. Interview with an AECL official.

CHAPTER V
TOWARDS A NEW APPROACH

A. INTRODUCTION

Before advancing some specific recommendations with respect to the acquisition of export orders for CANDU reactors and before commenting more generally on the future of Canada's nuclear program, we will review briefly the main points outlined in the previous chapters.

As indicated in chapter I, the Canadian nuclear power program has been remarkably successful providing Canada with an indigenously developed, commercially viable nuclear power generating system. The CANDU system is already making a significant contribution to Canada's electrical energy supply and it will probably prove to be an even more valuable asset in meeting the country's future energy needs.

The nuclear power program has also fostered the development of a substantial domestic nuclear industry which, throughout the years, has benefitted Canada in several ways. The viability of this industry, however, is being jeopardized by the present slowdown in Canada's domestic nuclear energy program. Although this situation is detrimental to the industry as a whole, it is particularly injurious to the manufacturing sector. Most of the firms engaged in the manufacture of nuclear components and related equipment are operating at about 60% capacity. Unless action is taken to increase the volume of work, several firms may be forced to close down their nuclear operations, thereby

substantially diminishing Canada's nuclear manufacturing capability.

The depletion of Canada's nuclear manufacturing base could have a number of very serious repercussions aside from the loss of the usual economic benefits. First and foremost, the remaining firms may not have sufficient capacity to handle the increased demand for nuclear power that is expected within Canada during the 1980's and the 1990's. Secondly, Canada's secondary manufacturing sector would be further weakened. Finally, failure to maintain a viable nuclear manufacturing industry may seriously undermine Canada's continual efforts to establish major high technology based industries. Given the country's poor record in this regard, private firms may become increasingly wary of making the substantial investments necessary for such endeavours.

With the current uncertain domestic demand for nuclear power reactors, Canada must rely heavily on the acquisition of export orders to help sustain the nuclear industry during the next ten years. However, as chapter II indicates, Canada's previous attempts at selling CANDU reactors in the international nuclear marketplace have met with little success. This does not instill an air of optimism to the task at hand. Furthermore, a public inquiry revealed that, in the past, AECL's international marketing and contracting practices have been suspect.

Nevertheless, the situation is not totally bleak. Chapter III has shown that there is a sizable export market for nuclear reactors, primarily in the more industrially

advanced countries of the Third World. Moreover, as noted in chapter IV, several countries have shown an interest in the CANDU system because of its excellent performance record and because technically it offers certain advantages over the light water reactor systems. But chapter IV also pointed out that there are a number of factors, independent of the CANDU technology, which will limit Canada's ability to sell reactors abroad. Thus, at the very least, a vigorous effort will be required in order to a) persuade those countries already interested in the CANDU system to purchase it and b) arouse the interest of other countries.

B. THE CANDU EXPORT EFFORT

It will be difficult for Canada to obtain the quantity of CANDU export orders that the nuclear industry so desperately needs. However, practicable measures can be taken which could make the task somewhat easier. Specifically, a fundamental revision of CANDU export marketing methods should be undertaken with the intent of putting Canada on a more equal footing vis-a-vis the other international nuclear suppliers. To this end, two courses of action are recommended. First, immediate action should be taken to improve the way that the CANDU system is packaged for export. Secondly, an organization with strong marketing and contracting capabilities should be established to deal effectively and efficiently with the complexities of selling the CANDU abroad. Both of these courses of action will demand a greater level of cooperation between Atomic Energy of Canada Limited and the Canadian nuclear industry.

(i) Packaging the CANDU

Chapter III noted that because of a) the problems associated with the introduction of nuclear power in the developing countries and b) the intense competition among the international nuclear suppliers, the success of an individual supplier will depend, to a large extent, on the type of package that is being offered to the purchaser. The problem, however, is that customer needs vary from country to country: some countries may desire the importation of a complete nuclear power station; some may want access to design technology; some may wish to acquire licences which would enable them to design and construct additional stations for domestic use and/or for export. Thus, the supplier must be able to present a nuclear technology package which is responsive to the various demands of the potential purchasers. As a general rule such a package should consist of the largest scope of supply possible at the least possible cost to the importer. Furthermore, it should not be too complicated contractually. With this kind of straightforward, comprehensive package the supplier will be able to tailor its scope of supply to suit the needs of each customer.

Canadian capability and expertise in the nuclear energy field are sufficient to permit the assembly of an internationally competitive CANDU export package. The following items should constitute the nucleus of such a package:

- 1) the supply of the complete nuclear steam supply system for the 600 MW CANDU reactor;
- 2) the supply of the balance of plant;

- 3) provisions for the transfer of the process design of the nuclear steam supply system of the CANDU reactor;
- 4) provisions for the transfer of nuclear component manufacturing knowhow and associated design technology related to the nuclear steam supply system;
- 5) the supply of engineering and consulting services for the nuclear steam supply system and/or the balance of plant;
- 6) provisions for the supply of project management services including procurement responsibility;
- 7) the supply of heavy water;
- 8) provisions for the transfer of heavy water manufacturing technology;
- 9) the supply of uranium fuel;
- 10) provisions for the transfer of fuel fabrication technology;
- 11) technical assistance to facilitate the transfer of the design and the manufacturing knowhow to the appropriate organizations in the purchasing country;
- 12) provisions for the training of local personnel in all aspects of nuclear power station operation;
- 13) provisions for financial assistance; and
- 14) provisions for local participation in such areas as construction labour, construction materials, locally-fabricated equipment and local engineering services.

It should be noted that the recommended CANDU export package includes a provision for the supply of the balance of plant. On the surface this may appear impractical since Canadian production of the largest and most important component of this portion of the nuclear station (the turbine-generator sets) has been, for the most part, dependent upon foreign

technology and imports of highly engineered parts. However, significant benefit could accrue to Canada in general and Canadian industry in particular since Canadian production of equipment for the balance of plant is valued at approximately \$50 million.¹ Additional revenues would be generated if the existing Canadian engineering and consulting expertise in this area was also utilized. Furthermore, sales of complete nuclear power stations in the export market may ultimately increase Canadian content on turbine-generator sets by inducing manufacturers to commit additional new resources to expand their current technological capability. Finally, the inclusion of the balance of plant in the scope of supply increases the flexibility of the CANDU package: CANDU reactors could be sold on a turnkey basis whereby Canada supplies the complete nuclear power station; on a partial turnkey basis whereby Canada supplies the principal part of the plant - the nuclear steam supply system - while the purchaser selects other foreign or domestic suppliers to put together the remainder of the station; under a licensing agreement; or under any combination of the above mentioned methods.

The sale of the CANDU package in its entirety offers significant rewards for both the supplier and the purchaser. Perhaps the major advantage for Canada is the high degree of Canadian content. This will provide Canada with a greater return on its multi-billion-dollar investment in the CANDU reactor system and, more importantly, it will help reduce the severity of the overcapacity problems currently plaguing

the country's nuclear component manufacturing sector. For the purchaser the package offers the opportunity to become virtually self-sufficient in the CANDU technology. To achieve this, however, the customer must have a domestic supply of natural uranium for fuel.

As previously noted, Canadian nuclear capability and expertise are sufficiently established to accommodate the proposed scope of supply. However, Canada's nuclear power program has been built upon a strategy which has emphasized the division of labour. Thus, concerted action is mandatory in order to muster the requisite skills and resources for such a comprehensive export package. Accordingly, a major aspect of the packaging of the CANDU should be the establishment and maintenance of close liaisons between government departments, agencies and crown corporations, public utilities and private industry.

The support of the private nuclear sector in Canada is particularly important because of the nature and magnitude of the goods and services that it provides. Generally the private sector has adequately supported previous export sales of the CANDU system but there are areas where broader private participation would increase the attractiveness of the CANDU package. For example, the support of the component manufacturers is absolutely essential for those provisions that deal with the transfer of technology. AECL owns the proprietary rights to almost all aspects of the CANDU design but the crown corporation does not own the rights to the manufacturing technology.

These belong to various firms within the manufacturing sector of the nuclear industry. In addition, private Canadian companies own the rights to the fuel fabrication technologies. Therefore, private industry should be actively involved in devising methods to facilitate the transfer of these technologies to the appropriate organizations in the purchasing country.

One recommendation in this regard is the establishment of a standard technical aid agreement. Such an agreement, available to any firm that needed it, would set out the conditions governing the sale of technology. Obviously the terms will vary somewhat in order to accommodate the diversity of product lines but, at the same time, they should be as uniform as possible. Both Canadian and foreign firms would benefit from this kind of approach and it would certainly shorten the amount of time necessary to negotiate a contract.

Secondly, there is a considerable body of expertise in the private sector that could be utilized to assist AECL in the transfer of heavy water production technology. Several firms have had experience in designing, constructing and manufacturing the components for heavy water plants.

Finally, the private sector could assume greater responsibility in such areas as pricing, warranties for plant performance, delivery schedules and workmanship guarantees. This proposal will be discussed in the next section of the chapter which deals, in part, with the preparation of bids and the negotiation of contracts.

The role of the federal government in the exportation of the CANDU system will also be discussed in later sections

of this chapter. Suffice it, to say, however, that government support is a fundamental ingredient of any nuclear export endeavour; the government must approve the content of the proposed package, the terms and conditions under which it is negotiated and the potential recipients. Moreover the federal government, through the Export Development Corporation, has played an important role in arranging the financing for previous CANDU export sales and it will have to continue to do so in the future.

Provincial public utilities, primarily Ontario Hydro, can also make an effective contribution to the proposed export package. Ontario Hydro, the utility with the most experience with CANDU reactors, can provide valuable technical assistance to the purchasing utility with respect to the construction of the CANDU station and the training of personnel for its operation.

Before proceeding to the next section of this chapter it must be reiterated that the recommended CANDU export package is not an all or nothing proposition for prospective customers. Rather, in most cases it should be considered as Canada's initial position in the negotiation process. If the complete package can be sold then all the better for Canada and, presumably, for the purchaser. But obviously, this type of package will not appeal to all of the countries interested in the CANDU system. The nature of any future sale as well as the terms and conditions which govern it will be determined by all of the concerned parties. However, the offer of a

comprehensive export package such as this increases the competitiveness of the CANDU system in the international nuclear marketplace and revitalizes Canada's commitment to share its nuclear technology with other countries.

(ii) Marketing the CANDU

Improving the way that the CANDU system is packaged for export is a necessary step for enhancing Canada's chances for greater success in foreign markets but, in itself, it is not sufficient. There must also be a competent organization to market the new package. This organization should possess a fully coordinated, integrated and informed marketing and contracting team in order to carry out effectively and efficiently the tasks assigned to it; i.e. spearheading the drive into foreign markets and negotiating contracts in accordance with the desires and needs of AECL, the Canadian government, private industry and the purchaser.

Experience has clearly shown that the present organizational structure of Canada's nuclear export program does not meet the above requirements and, therefore, is less than optimal for the attainment of the aforementioned objectives. Under the present system AECL is solely responsible for international marketing including the negotiation of contracts. Since receiving this mandate in 1968, AECL's performance record has not been commendable. The crown corporation has only secured two direct sales - deals which should offer the most lucrative returns to Canada. However, neither one of these sales would have been obtained if AECL had relied exclusively

on its own marketing abilities. Moreover, both have been sources of embarrassment for the corporation. The sale to Argentina has been plagued by severe cost overruns and numerous project delays. It is fair to conclude, therefore, that AECL has not established itself as an efficient management and business organization in the field of international marketing.

It should be noted that in the aftermath of the Public Accounts Committee's inquiry into the international activities of AECL, the corporation made several changes designed to remedy its in-house problems and to restore its reputation as a reliable supplier of nuclear reactors and related technologies. The first step involved the hiring of new personnel to handle the financial side of the business.² Not surprisingly, people with expertise in writing contracts were among those employed. Next AECL hired a new president who immediately set out to strengthen the corporation's top and middle management.³ Finally, in July 1978, AECL announced a major internal reorganization which divided the corporation into four semi-autonomous units.⁴ Each unit or division operates independently but is under the guidance of AECL's head office in Ottawa.

This reorganization resulted in a clearer distinction between the strategy and the tactics of international marketing.⁵ One of the new divisions, Atomic Energy of Canada Engineering Company (formerly Power Projects), is concerned with the tactics involved in specific marketing endeavours. It is responsible for engineering design as well as project management,

equipment acquisition, systems, sales and commercial activities, finance and administration. A corporate marketing team has been established in AECL's head office with responsibility for long range planning and the provision of marketing information.

There is now also a closer liaison between AECL and the private sector with respect to the marketing function. In 1978, the federal government set up a Task Force to examine AECL's marketing practices and to determine if a greater degree of private sector participation would be of benefit to Canada. One of the recommendations of the Task Force was the formation of an export marketing board within AECL.⁶ This board, comprised of officials from AECL, the private sector, public utilities and the Department of Industry, Trade and Commerce, would supplement AECL's international marketing activities.⁷ Ultimately, AECL followed the spirit rather than the letter of the recommendation. In lieu of the proposed export marketing board, an industrial advisory committee was set up for the interchange of information between AECL and the private sector on both the general and the specific aspects of export marketing. Through this mechanism the private sector will have a greater input in the early stages of any negotiations between AECL and potential purchasers of the CANDU system.

Even though these numerous changes have been undertaken in recent years to improve AECL's commercial competence, there are still serious structural weaknesses in Canada's marketing organization that have not been rectified. Thus, the aforementioned changes, although necessary, are not adequate. They

are tantamount to refitting an old, unseaworthy ship to do a job more aptly suited to a newly designed one. As a result, Canada does not possess a nuclear marketing organization that can effectively rival those from other countries. This situation can be remedied but it will require modifications of a more fundamental nature.

In order to increase Canada's competitiveness vis-a-vis the other international nuclear suppliers an extensive revision of the current export marketing structure is recommended. The new structure should reflect a more unified approach. In effect, this means that the primary responsibility for the promotion and the marketing of the CANDU system abroad should not remain solely with AECL. Rather, a new organization - comprised of representatives from AECL, the private sector and, for the time being, Ontario Hydro - should be formed and given this mandate.

The major attraction of a joint venture of this nature is that the companies which have had experience in designing, manufacturing the components for, and operating CANDU reactors are assembled into one body. Clearly, this will have a beneficial impact on the Canadian CANDU export marketing thrust. First, it will demonstrate to other countries that Canada has indeed taken dramatic action to put its nuclear house in order. Secondly, it will enable potential purchasers to deal directly with an organization which possesses a greater degree of the expertise underlying the success of Canada's domestic nuclear program. Under the current marketing arrangements, purchasers must deal almost exclusively with AECL - the designer of the nuclear steam

supply system. There is usually very little direct participation by the component manufacturers, private engineering firms and public utilities during the negotiation process. Thirdly, the negotiation process itself will be less difficult, particularly if the transfer of manufacturing technology is to be included in the sale. From the outset, purchasers will have the opportunity to deal directly with the people who own the technology that they desire. Finally, there is another important advantage the effect of which is impossible to measure. Undoubtedly, some countries are wary of purchasing the CANDU system because of AECL's poor performance on previous export sales. The new organization, however, will be starting with a clean slate.

Let us now examine the proposed export marketing structure in greater detail. As noted above, its major feature is the establishment of a new organization which would be given primary responsibility for marketing the CANDU overseas. The mandate would also include the negotiation of contracts. The type of organization envisaged is similar to the one that was recommended by the government's Task Force; i.e., an export marketing board. Members should be drawn from AECL, the private sector and Ontario Hydro.

The participation of AECL and Ontario Hydro is easily defined. AECL must contribute personnel who have had experience in promoting the CANDU system internationally, in the preparation of proposals and in the drawing up and negotiation of contracts with foreign purchasers. In addition, AECL must provide engineering expertise with respect to the nuclear steam supply system of

the CANDU reactor and the production of heavy water. For its part, Ontario Hydro must provide valuable assistance in the form of personnel familiar with the complexities of construction, management, and the operation of a CANDU nuclear power station.

The input from the private sector is more difficult to arrange, primarily because of the number of firms involved. It is obviously not feasible or desirable for every firm to be physically represented on the board. Accordingly, a method of representation must be devised which would be acceptable to the majority of those concerned. The following plan is proposed.

In November 1976, eight of the largest firms in the nuclear industry formed a consortium, Canadian Nuclear Equipment Suppliers Limited (CNES), with the intent of assisting and supporting AECL in the export marketing function.⁸ The consortium consists of the firms which manufacture the major components of the nuclear steam supply system and one firm of consultants specializing in nuclear power engineering design and services. The consortium is willing to undertake direct contractual responsibility for the equipment portion of the NSSS, including financial risks and warranty coverage.⁹

Due to the nature of their respective nuclear product lines, personnel from these firms should form the nucleus of private sector representation on the export board. However, the interests of the other private firms in the industry, be they component manufacturers or engineering organizations, must also be protected. To achieve this, the companies in question must take concerted action to appoint or elect representatives of

their own. There is a practical limit to the number of members in any group which must reach consensus and make decisions.

Hence, in order to keep the number of industry personnel on the board at a manageable level, it is recommended that the representatives of these firms do not exceed five people. This number is arbitrary and may have to be revised upward or downward depending upon what is acceptable to the firms that are involved.

Having established the membership of the new export organization, it is now appropriate to examine how the board should carry out its mandate. First, attention will be focused on the marketing function.

Table V-A illustrates the division of responsibility with respect to export marketing. Basically, there are three main actors: the export marketing board, the head office of AECL and a newly established industry association. The export board will take the lead position in promoting both the technical and the commercial aspects of any prospective sale. It will interact directly with potential customers. Accordingly, the board should take over all specific marketing endeavours currently being pursued by AECL and should also begin initiating new ones. However, AECL and the nuclear industry will have important secondary roles to play.

The corporate marketing group established in the head office of AECL should not be disbanded. Rather, it will continue to handle the research and the long range planning for export marketing. Specifically, this group will be responsible for keeping abreast of global developments with respect to nuclear

TABLE V-A

EXPORT MARKETING STRUCTURE: PROPOSED

power. It will gather market intelligence and provide analytic information which will be used for the selection of markets for the CANDU reactor system. In addition, the corporate marketing group will conduct studies of the individual markets which have been chosen. Some of the factors that must be considered include the country's method of trading, its government/utility relationship, its technological capabilities, its resources (if any) for financing nuclear projects and the manufacturing and construction methods and practices of the national industry. This information will guide the group in the development of appropriate marketing strategies which, in turn, will be forwarded to and discussed with the export marketing board.

The nuclear industry can provide valuable assistance to both the export marketing organization and the corporate marketing group. In order to do so effectively, however, it must establish an avenue for collective action. To this end, the creation of a new industrial advisory association is recommended. The association will serve as the mechanism for close cooperation and the interchange of information between the nuclear industry and the above-mentioned groups. Through this mechanism the industry will be able to express its viewpoint with respect to the long range planning for CANDU exports and it will also pass along to the corporate group any relevant information acquired through its own contacts. In return, the corporate marketing group will keep the industry informed as to the prospects for CANDU exports. The association will also interact with the marketing board, providing information such as up-to-date prices

for the goods and services that the industry supplies. For its part, the marketing board will keep the industry abreast of the developments in and the exigencies of specific marketing areas.

In essence, therefore, the proposed CANDU marketing structure will consist of one organization which does the actual selling and two support organizations which interact with each other as well as with the marketing agency.

The second major function of the new export marketing board is to prepare bid proposals and, after acceptance of the bid, to negotiate the necessary contracts. The former responsibility poses a major problem for the board. As previously noted, representatives from the eight firms which manufacture the four main components of the nuclear steam supply system form the nucleus of private sector representation in the marketing organization. There are two suppliers for each component. Therefore, these firms will be faced with the task of devising a mutually acceptable plan which would govern their participation on future export sales. Perhaps the easiest solution to this dilemma would be to alternate between the competing companies or, if possible, to share the work on each contract. A more difficult option would be to have competitive tenders with an impartial referee - perhaps AECL. Whatever option is chosen, it is imperative that the decision be made as soon as possible.

Obtaining bids covering the remainder of the goods and services for any export sale should present less serious logistical problems. The marketing board can, for the most part, follow procedures instituted by AECL on previous export endeavours. For those components that require long delivery

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schedules the supplier could be selected on the basis of competitive bidding before the board tenders for a foreign project. The firm prices quoted in the bid proposal would be tied down to the period of validity for the bid. This procedure would ensure that the major equipment is on order when the marketing board receives a contract thereby saving valuable time on the project schedule. Competitive bids for items with shorter delivery times could be called for, if necessary, after all terms and conditions of the contract have been settled but prior to the signing of the contract. Obviously, the board will have to rely extensively on the support of the private sector in order to obtain the most recent cost estimates for the items in question.

The principal objective of this approach to the preparation of bids is to establish firm prices for as much of the content of the proposed package as possible. This is particularly important if the deal is to involve a considerable amount of Canadian goods and services. However, because of the realities of international marketing, the attainment of this objective is extremely difficult. For example, on most, if not all, export sales there is a significant time interval between the submission of a bid, its acceptance and the final negotiation of the contract between the supplier and the purchaser. An even longer interval exists between the signing of a contract and the completion of the project.

Due to these time considerations, there are considerable risks involved in the establishment of firm prices. The proposed organizational structure should help to lessen some of the risks

by providing the suppliers with thorough analyses of the social, economic and political conditions of the country for which the bid proposal is intended. Nevertheless, an element of risk will always be present. The suppliers, therefore, must decide whether or not the degree of risk is acceptable for, once they bid on the project, they must be willing and able to accept responsibility for the prices that are quoted. In this way, the marketing board will be able to approach the prospective customer with a bid that will not only stand up to scrutiny but will, if accepted, result in a reasonable profit for all concerned.

Ultimately, the profitability of any export sale will not only depend on the accuracy of the bid proposal but also on the terms and conditions of the final contract. With the new arrangements governing the interchange of information between AECL and the industry and with the participation of personnel from the private sector and Ontario Hydro during the entire negotiation process, the export marketing board will be better prepared to negotiate tighter contracts. Furthermore, private sector representation on the board will ensure that the industry is acquiring a volume of business which it deems to be wholly adequate.

Finally, in addition to acting as prime contractor for all export sales, the marketing board should also be prepared to provide procurement and project management services if requested by the purchaser. Obviously, there are a number of risks associated with these three functions. The private sector, however, could help the board cope with some of the risks. Specifically, the component manufacturers could undertake direct responsibility for workmanship guarantees and delivery schedules

On previous export sales, individual firms were reluctant to issue long-term guarantees and, as a result, AECL assumed these responsibilities after the industry's guarantees expired. For its part, AECL must continue to provide the technical guarantees for the CANDU system.

As this section has shown, much of the onus for the formation of the new export marketing structure lies with the Canadian nuclear industry. The industry must a) make an effective contribution in terms of manpower and other resources to the export marketing board, b) establish a new advisory association to interact with the marketing board and AECL's corporate marketing group and c) undertake greater responsibility for export contracts, including financial risks and guarantees. However, as a result of these measures, Canada will be more competitive in the international nuclear marketplace and, consequently, it will have more of an opportunity to acquire the export orders that the industry so desperately requires. Furthermore, with a greater input into all aspects of export marketing - from research and long-range planning to the negotiation of contracts - the firms within the industry will be better equipped to defend their own interests. These benefits should adequately compensate the industry for the costs that it will incur by implementing the above-mentioned proposals.

In fulfilling its mandate, the new export marketing board will have to interact with the numerous departments and agencies of the federal government which are concerned with various aspects of the marketing function. By way of concluding this section,

let us briefly examine the nature of these relationships.

The government departments with the greatest influence on exports of nuclear goods and services are: External Affairs; Industry, Trade and Commerce; Finance; Treasury Board; and Energy, Mines and Resources. External Affairs is concerned principally with the proliferation implications of nuclear exports. Accordingly, it examines the proposed export contracts to make sure that they are consistent with Canadian safeguards requirements. In addition, the department conducts political assessments of those countries interested in purchasing the CANDU system. These assessments determine the countries in which marketing campaigns can be undertaken. Both Finance and Treasury Board must approve the financial terms of the proposed contracts before they are signed. Similarly, Industry, Trade and Commerce must approve the level of Canadian content in the contracts. Lastly, the Minister of Energy, Mines and Resources is responsible for AECL and his department is also concerned with uranium exports. Thus, the marketing organization cannot sign a nuclear export contract until it receives approval from these departments.

The Export Development Corporation and the Atomic Energy Control Board are the two government agencies (other than AECL) which are most concerned with nuclear exports. As previously noted, EDC plays a major part in arranging the financing for reactor deals. Accordingly, the corporation analyses the economic conditions of prospective purchasing countries to

ascertain the degree of risk associated with extending credit to them. These assessments, like those undertaken by the Department of External Affairs, have a significant impact on nuclear exports. Finally, the Atomic Energy Control Board is involved with nuclear exports because of its responsibility for regulation and licensing of the nuclear industry and for safeguards.

There is, therefore, a considerable bureaucratic maze through which a proposed contract must pass before it can be initialled. The amount of time required to traverse the maze is a function of how responsive the contract is to the interests of the aforementioned parties. Feedback from the various departments and agencies is vital throughout the negotiation process to ensure that the ensuing contract meets with their approval. This will necessitate reliable and effective lines of communication between the governmental actors and the marketing organization.

Governmental support of a different type is required at the time that the marketing organization is bidding on a project. In contrast to the "behind-the-scenes" support during the negotiating process, the government must indicate, perhaps through some sort of ministerial action, that Canada firmly supports the bid proposal. Active governmental support may not be the determining factor in the acceptance of the Canadian bid but, as noted in Chapter II, it is one of the factors which potential purchasers take into consideration.

C. CONCLUDING REMARKS

This paper has focused on the export components of Canada's nuclear program and its implications for the Canadian nuclear industry. Two major arguments were presented: a) foreign sales of CANDU reactors are necessary if the industry is to maintain its current level of manufacturing capability; and b) in order to facilitate the task of obtaining export orders, a fundamental revision of CANDU export marketing methods should be undertaken with the intent of placing Canada on a more equal footing vis-a-vis the other international suppliers. To achieve this end, the paper recommends that action should be taken to improve the way that the CANDU system is packaged for export and to establish a new organizational structure which would reflect a more unified approach to export marketing.

There have been several indications that a more unified approach to CANDU export marketing is currently being developed. For example, AECL has made a fundamental change in the way that it markets CANDU nuclear reactors abroad. The corporation is now attempting to sell complete "CANDU kits" for the nuclear steam supply system of the nuclear power generating station featuring design, engineering services and certain key components supplied by Canada.¹⁰ The potential purchaser, therefore, would be responsible for making arrangements for the supply of the non-nuclear portion of the station.

The bid proposal that AECL submitted to Argentina in March, 1979 provided further evidence of the change in

marketing methods. AECL offered to negotiate with Argentina a nuclear energy package valued at more than \$1.5 billion.¹¹ The package was very similar to the one recommended earlier in this chapter except that it did not include provisions for the supply of the balance of plant. AECL will provide the NSSS for the 600 MWe CANDU reactor but Argentina must purchase the goods and services for the remainder of the station by itself.

Two comments are necessary. First, AECL's initial bid proposal was for a much smaller scope of supply. It was altered only after a West German firm (Kraftwerk Union) offered Argentina a significantly more extensive package.¹² Secondly, as noted above, the bid that AECL ultimately submitted was not as comprehensive as it could have been. For reasons stated previously, AECL should have provided arrangements for the supply of balance of plant.

It also appears that there will be closer cooperation between AECL and the Canadian nuclear industry on future export endeavours. The preceding section of this chapter noted the formation of an industrial advisory committee for the interchange of information between AECL and the private sector on both the general and specific aspects of export marketing. In addition, CNES Limited has been dismantled and a new body - the Organization of CANDU Industries (OCI) - has been set up. As its name implies, this new organization includes approximately forty firms which contribute goods and/or services to the CANDU reactor system as well as representatives

from Ontario Hydro, Hydro-Quebec and the New Brunswick Electric Power Commission.¹³ The major aim of OCI is to assist AECL in promoting and marketing the CANDU system in foreign countries but its relationship with the crown corporation has not yet been defined.

These new initiatives, although not as extensive as those recommended in the previous section, give credence to the basic arguments of this paper. They indicate that both AECL and the private sector are aware of the need for a more unified approach to export marketing if Canada is to be more competitive in the international nuclear marketplace.

In closing, it should be noted that the proposed fundamental revision of CANDU export marketing methods, even if fully adopted, is not a panacea for all of the nuclear industry's problems. In terms of marketing capabilities and practices, the new export organization will be more comparable to those of other countries. Nevertheless, export orders will still be difficult to obtain because of the fierce competition among the nuclear suppliers. Moreover, the CANDU export drive will continue to be adversely affected by Canada's stringent safeguards policy until the other nuclear suppliers move toward equally demanding requirements. Finally, as noted in Chapter I, there are also a number of problem areas with respect to the domestic component of the program. These include a) the uneven placement of domestic orders, b) the practice of competitive contracting and c) the lack of design standardization. All of these issues will demand

attention if Canada is to maintain a healthy and viable nuclear industry.

FOOTNOTES

CHAPTER V

1. Interview with an industry official.
2. Philip Teasdale, "AECL's Lessons," The Financial Post, 22 January 1978.
3. Sarah Henry, "New AECL chief promises agency's overhaul," The Citizen (Ottawa), 13 January 1978.
4. Jeff Carruthers, "Major reorganization at AECL will involve setting up four quasi-autonomous subsidiaries," Globe and Mail, 29 July 1978.
5. Interview with an AECL official.
6. The Financial Post, 16 December 1978.
7. Ibid.
8. Jeff Carruthers, "Eight firms form nuclear consortium," Globe and Mail, 8 January 1977.
9. Ibid.
10. Jeff Carruthers, "AECL to try changing methods by selling complete 'CANDU kits'," Globe and Mail, 1 February 1979.
11. Jeff Carruthers, "AECL offers first total package in bid to secure Argentina sales," Globe and Mail, 4 April 1979.
12. Ibid.
13. Communication with an AECL official.

POSTSCRIPT

This addendum contains additional information on the Romanian licensing agreement and an update on AECL's recent marketing endeavour in Argentina.

As noted in Chapter II, Romania plans to build 16 CANDU units by the year 2000 and has already signed a licensing agreement with AECL covering the first four units. The licensing fee for these four reactors is \$20 million.¹ In addition, the Export Development Corporation has arranged a \$1 billion line of credit with Romania to enable that country to purchase the Canadian goods and services for the four reactors.² However, to date Romania has signed an engineering services contract and a procurement agreement covering only the first reactor.³ Similar documents relating to the second, third and fourth reactors are currently being negotiated.

Chapter V referred to the bid proposal that AECL submitted to Argentina in March, 1979. In early October the head of Argentina's nuclear energy agency announced that the contract for the country's second 600 MW heavy water reactor was awarded to Kraftwerk Union. Furthermore, a contract for a heavy water plant was awarded to a Swiss company. The circumstances surrounding this deal are worth noting.

According to Ross Campbell, Head of International Sales for AECL, the crown corporation lost the contract because both the current Conservative and the previous Liberal governments refused to adequately support AECL's effort.⁴ Specifically, neither government would assure Argentina that Canada's nuclear

safeguard requirements would not be further strengthened nor did they provide ministerial support to AECL's bid. As a result, according to Mr. Campbell, Argentina had serious reservations about relying on Canada for support for its future nuclear power program. Consequently, Argentina paid KWU \$2 million to re-assemble the team that had designed and built the 200 MWe Atucha I reactor and to have the team design a 600 MWe version to compete with the Canadian system.⁵

The official statement by Argentina's nuclear energy agency, however, gave a different set of reasons for the decision to reject AECL's bid proposal.⁶ Two considerations were prevalent: the first concerned the performance record of the competing companies on previous nuclear projects in Argentina and the second concerned the nature of the Canadian bid.

A comparison of the performance records of KWU and AECL certainly favoured the former. KWU had completed the Atucha I project on schedule and with no change in the original price. In contrast, AECL's Cordoba project will not be completed until March, 1982 and will cost about \$1 billion. The original contract, signed in 1973, had called for completion by January, 1980 at a cost of about \$320 million. For this reason, according to the official statement, the Argentinians regard KWU as a more efficient and reliable management and business organization. This appraisal helped to compensate for the fact that the German bid was \$500 million more expensive than the Canadian bid.

With respect to the second major consideration, the statement noted that Argentina is seeking to develop a nuclear

power program that is as independent as possible from external interference. AECL had offered a nuclear package which would have enabled Argentina to develop a nuclear energy program based on the CANDU heavy water reactor and domestic natural uranium for fuel. It featured a 600 MWe CANDU reactor, a licensing agreement to provide the technology on the nuclear steam supply system of the CANDU, a research reactor, a heavy water plant and uranium exploration and refining technology. The problem with the package, as far as the Argentinians were concerned, was that it was an all or nothing proposition. Although some individual items of the bid were attractive, the complete package was not since, in effect, it would give Canada too much influence over Argentina's nuclear program. In an effort to avoid dependence on one supplier, Argentina purchased the reactor from Germany and the heavy water plant from Switzerland.

The developments in Argentina are of particular importance to this paper for two reasons. First, the loss of the Argentine sale will undoubtedly increase the pressure on some firms to withdraw from Canada's nuclear energy program. Secondly, the factors which contributed to the rejection of AECL's bid - insufficient government support, AECL's reputation and the inflexibility of the CANDU export package - indicate that the recommendation put forth in chapter V concerning new export marketing arrangements should be given serious consideration.

FOOTNOTES

1. Jeff Carruthers, "Credit line is arranged for Romania," Globe and Mail, 22 November 1978.
2. Jeff Carruthers, "Four CANDU response credited to financing," Globe and Mail, 21 December 1978.
3. Ibid.
4. Jeff Carruthers, "AECL official warns CANDU hurt by Ottawa's waffling," Globe and Mail, 3 October 1979.
5. Ibid.
6. See Globe and Mail and The Citizen (Ottawa), 4 October 1979.

BIBLIOGRAPHY

BOOKS AND PAMPHLETS

Atomic Energy of Canada Limited. CANDU 600 Station Design.
Ottawa: Atomic Energy of Canada Limited, May, 1976.
(AECL-PP-28).

_____. Nuclear Power: The Canadian
Issues. Ottawa: Atomic Energy of Canada Ltd., 1977.
(AECL-5800).

Canadian Nuclear Association. Nuclear Energy: Canada's Resources
and Industry. Toronto: Canadian Nuclear Association, 1975.

_____. Nuclear Canada Yearbook, 1977.
Toronto: Canadian Nuclear Association, 1977.

Doern, G. Bruce. The Atomic Energy Control Board. Ottawa:
Law Reform Commission of Canada, 1976.

Eggleston, Wilfred. Canada's Nuclear Story. Toronto: Clarke,
Irwin and Co., 1964.

Foster, J.S. The Canadian Nuclear Power Program. Ottawa:
Atomic Energy of Canada Ltd., May, 1976. (AECL-5534).

_____. and Russell, J.H. Canada's Nuclear Power Program.
Ottawa: Atomic Energy of Canada Limited, 1977.
(AECL-5707).

Gray, J.L. A Statement of the Nuclear Power Development Program.
Ottawa: Atomic Energy of Canada Ltd., February, 1958.
(AECL-561).

Gowing, Margaret. Britain and Atomic Energy, 1939-1945.
London: Macmillan and Co., 1964.

Gray, J.L. Why CANDU? Its achievements and prospects. Ottawa:
Atomic Energy of Canada Limited, January, 1974.
(AECL-4709).

Haywood, L.R. The CANDU Power Plant. Ottawa: Atomic Energy
of Canada Ltd., January, 1976. (AECL-5321).

Keeny, S.M., cd. Nuclear Power Issues and Choices (Ford/Mitre
Report). Cambridge: Ballinger Company, 1975.

Knelman, Fred H. Nuclear Energy: The Unforgiving Technology.
Edmonton: Hurtig Publishers, 1976.

Leonard and Partners Limited. The Economic Impact of Nuclear
Energy Industry in Canada. Ottawa: Canadian Nuclear
Association, 1978.

Morrison, R.W. and Wonder, E. Canada's Nuclear Export Policy.
Ottawa: The Norman Paterson School of International
Affairs, 1978.

Mueller, Peter G. On Things Nuclear: The Canadian Debate.
Toronto: Canadian Institute of International Affairs, 1977.

ARTICLES

A) Magazines and Journals

Bindon, G. and Mukerji, S. "How Canada's and India's nuclear
roles have been sadly misrepresented." Science Forum,
55, February, 1977.

Blackburn, R.W. "Licensing and regulations of the Canadian
nuclear program." Nuclear Engineering International,
June, 1974.

Dethomas, Bruno; Ambroise-Rendu, Marc; Weeger, Xavier; and
Debove, Alain. "The Nuclear Sweepstakes." Atlas
World Press Review, September, 1977.

Eklund, Sigvard. "Nuclear energy prospects for the developing
countries in the non-proliferation era." Nuclear
Engineering International, April, 1977.

Goodman, E.I. "Status of small and medium power reactors."
Nuclear Engineering International, July, 1978.

Joskow, Paul L. "The International Nuclear Industry Today."
Foreign Affairs, Summer, 1977.

Knox, Richard. "The good and bad news for Canadian industry."
Nuclear Engineering International, August, 1978.

Maclean's, 14 June, 1976.

Mandel, Heinrich. "Nuclear Energy in the next 12 years - a
European utility outlook." Nuclear Engineering Inter-
national, April, 1977.

Marshall, Pearl. "Romania plans to build CANDU next year."
Nuclear Engineering International, June, 1977.

Masters, Richard. "Co-operation and concentration pay dividends
in Canada." Nuclear Engineering International, June, 1976.

_____. "Problems of exporting to developing
countries." Nuclear Engineering International, May, 1978.

Mooradian, A.J. "Nuclear research and development in Canada."
Nuclear Engineering International, June, 1974.

Nuclear Engineering International, Dec., 1977, p. 6;
April, 1978, p. 7; May, 1978, p. 11; June, 1978, p. 4;
and August, 1978, p. 6.

Rippon, Simon. "Nuclear Exports: Nothing but problems."
Nuclear News, May, 1978.

Sabato, Jorge A. "Atomic energy in Argentina: a case history."
World Development, I, August, 1973.

Stewart, Walter. "Lorne Gray's Gamble to Make Canada a Nuclear
Great Power." Maclean's, September, 1970.

_____. "How We Learned To Stop Worrying And Sell
The Bomb." Maclean's, November, 1974.

Strasser, Steven and Nater, Timothy. "Nukes Nein!" Newsweek,
10 July, 1978.

Urquhart, Ian. "A scandal revisited." Maclean's, 28 November,
1977.

Weller, James A. "What nuclear power means to Canadian
Industry." Nuclear Engineering International, June, 1974.

Woite, George. "Can nuclear power be competitive in developing
countries?" Nuclear Engineering International, July, 1978.

B) Newspapers

Anderson, Ian. "Boyd: Nuclear Energy is Quebec's Only Option."
The Gazette (Montreal, 10 November, 1977.

_____. "Ottawa planning to link up with industry to
market CANDU." The Gazette (Montreal, 10 March, 1978.

Best, John. "Romania-Canada nuclear deal nearing completion."
Ottawa Journal, 9 November, 1977.

Blair, Allan. "The case for nuclear." Financial Post,
28 January, 1978.

Calamai, Peter. "India may pass Canada in nuclear field."
The Citizen (Ottawa), 12 May, 1977.

Carruthers, Jeff. "Eight firms form nuclear consortium."
Globe and Mail, 8 January, 1977.

_____. "AECL authorizations tightened by Ottawa."
Globe and Mail, 12 October, 1977.

_____. "Romanis likely to buy CANDU reactors."
Winnipeg Free Press, 3 November, 1977.

_____. "AECL customers may be looking elsewhere."
Ottawa Journal, 16 December, 1977.

_____. "Japan to install CANDUs." Ottawa Journal,
27 April, 1978.

_____. "Major reorganization at AECL will involve
setting up four quasi-autonomous subsidiaries."
Globe and Mail, 29 July, 1978.

_____. "Romanian CANDU deal clears second stage."
Globe and Mail, 29 July, 1978.

_____. "Credit line is arranged for Romania."
Globe and Mail, 22 November, 1978.

_____. "Four CANDU response credited to financing."
Globe and Mail, 21 December, 1978.

_____. "AECL to try changing methods by selling
complete 'CANDU kits'." Globe and Mail, 1 February, 1979.

_____. "AECL offers first total package in bid to
secure Argentina sales." Globe and Mail, 4 April, 1979.

_____. "AECL official warns CANDU hurt by Ottawa's
waffling." Globe and Mail, 3 October, 1979.

Claridge, Thomas. "Hydro to mothball one plant, study a slow-
down for 3 others." Globe and Mail, 14 February, 1979.

Clifford, Edward. "Argentina may favor Canada on reactors."
Globe and Mail, 14 February, 1979.

Cohen, Joan. "AECL: government control that never was."
The Citizen (Ottawa), 3 March, 1978.

Financial Post, 16 December, 1978.

Fox, Michael, "Ottawa hesitant over second reactor for
Argentina." Financial Post, 21 January, 1978.

Globe and Mail, 15 March, 1977; 22 August, 1978; and 4 October,
1979.

Henry, Sarah. "New AECL chief promises agency's overhaul."
The Citizen (Ottawa), 13 January, 1978.

Kipling, Bogdan. "Made-in-Japan CANDUs hinge on license
agreement." The Citizen (Ottawa), 12 October, 1976.

Long, Doug. "We can do." The Citizen (Ottawa), 4 October, 1979.

Nossiter, Bernard. "Strong opposition, rising costs blamed for nuclear slowdown." The Citizen (Ottawa), 7 February, 1977.

Ottawa Journal, 4 January, 1978.

Steklasa, Robert. "Scarce sales worry industry." Financial Post, 28 January, 1978.

Taylor, Marsha. "Italian politics could put CANDU out." The Citizen (Ottawa), 6 December, 1978.

Teasdale, Philip. "AECL's Lessons." Financial Post, 22 January, 1978.

The Citizen (Ottawa), 3 May, 1977 and 4 October, 1979.

The Gazette (Montreal), 25 October, 1977.

Vinocur, John. "Outlook Held Bleak for Manufacturers of Atomic Reactors." New York Times, 21 September, 1977.

CONFERENCE PROCEEDINGS

Amyot, L. "Nuclear Power in Quebec." Paper presented to the Conference on Canadian Nuclear Policy, Mont Ste. Marie, Quebec, 9 November, 1978.

Anderson, D.E. "Comparative Electrical Generation Costs." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Toronto, June, 1976.

Blair, A. "AECL/CANDU Towards a Rational Role and National Policy." Paper submitted to the Science Council of Canada, May, 1977.

DeLeon, Peter. "A Cross-National Comparison of Nuclear Reactor Development Strategies." Paper prepared for the nuclear energy panel of the Second International Congress on Technology Assessment, Ann Arbor, Michigan, October, 1976.

Doern, Bruce G. "The Politics of Canadian Nuclear Policy." Paper presented to the Conference on Canadian Nuclear Policy, Mont Ste. Marie, Quebec, 9 November, 1978.

Douglas, J.M. "The Economic Viability of Nuclear Exports." Paper presented to the IX Conference on International Relations, Quebec City, Quebec, October, 1977.

_____. "Nuclear Manufacturing - A Year For Decisions." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Ottawa, June, 1978.

Duret, M.F.; Phillips, G.J.; Veeder, J.I.; Wolfe, W.A.; and Williams, R.M. "Report on Nuclear to the Conservation Commission of the World Energy Conference." Ottawa: July, 1977.

Fogarty, John. "Manufacturing Components for the Nuclear Industry." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Ottawa, 1975.

Foster, J.S. "Marketing the CANDU - An Overview." Paper presented to the Canadian Nuclear Association International Marketing Seminar, Ottawa, 29 March, 1977.

_____. "CANDU - Future Developments." Paper presented to the Nuclear Power Seminar, Calgary Power Limited, Calgary, Alberta, September, 1977.

Graham, R.J. and Stevens, J.E.S. "Experience with CANDU Reactors Outside of Canada." Paper presented at the Annual International Conference of the Canadian Nuclear Association, Montreal, June, 1974.

Gray, J.L. "Canadian Industry and Atomic Energy." Paper presented to House of Commons Committee on Research, Minutes of Proceedings and Evidence, No. 9, Appendix II June, 1956.

Guard, Robin F.W. "Prospects For Reorganizing the Canadian Nuclear Industry." Paper presented to the Conference on Canadian Nuclear Policy, Mont Ste. Marie, Quebec, 9 November, 1978.

Leaist, G.T. "AECL Nuclear Power Marketing." Paper presented to Annual Conference of the Canadian Nuclear Association, Toronto, June, 1974.

Merlin, H.B. "Nuclear Energy: Its Growth and Impact." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Montreal, June, 1971.

Parfitt, A.W. and Robinson, J. "A Review of Problems in Nuclear Expansion." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Toronto, June, 1976.

Perryman, E.C.W. "Canadian Power Reactor Program - Present and Future." Paper presented to the 27th Annual Congress of the Canadian Association of Physicists, Edmonton, Alberta, 27 June, 1972. (AECL-4265).

- Reny, J.P. "Manufacturing Opportunities in the Canadian 'CANDU' and Heavy Water Programs." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Ottawa, June, 1975.
- Rowan, Malcolm. "Canadian Nuclear Policy and Federal-Provincial Relations." Paper presented to the Conference on Canadian Nuclear Policy, Mont Ste. Marie, Quebec, 9 November, 1978.
- Schofield, L.J. "The Effect of Inflation on Nuclear Energy." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Ottawa, June, 1975.
- Shepherd, J.J. "The Structure of the Canadian Nuclear Industry." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Montreal, June, 1977.
- Skjoeldebrand, R. and Roberts, J.T. "The IAEA Nuclear Power Forecast for Developing Countries." Paper presented to the Annual International Conference of the Canadian Nuclear Association, Toronto, June, 1976.

DOCUMENTS

Atomic Energy of Canada Limited. AECL Review Ottawa: Atomic Energy of Canada Limited, December, 1977.

Annual Report 1976-1977
and 1977-1978.

- Barber, R.J. and Associates. "LDC Nuclear Power Prospects, 1975-1990: Commercial, Economic and Security Implications." Report to ERDA, Washington, February, 1975. (ERDA-52).
- Canada. Department of Energy, Mines and Resources. An Energy Strategy for Canada: Policies For Self-Reliance. Ottawa: Supply and Services, 1976.
- Canada. Department of Industry, Trade and Commerce. Canadian Nuclear Industry Study. Ottawa: March, 1975.
- Canada. Parliament. House of Commons. Official Report of Debates. 11 March, 1971; 25 May, 1972; 13 December and 20 December, 1974; 23 June, 1975; 22 December, 1976.
- Canada. Parliament. House of Commons. Standing Committee on National Resources and Public Works. Proceedings. No. 1, November, 1977.
- Canada. Parliament. House of Commons. Standing Committee on Public Accounts. First Report, 27 February, 1978.

- Canada. Parliament. House of Commons, Standing Committee on Public Accounts. Proceedings. No. 8, 21 December, 1976 to No. 10, 27 January, 1977; No. 12, 3 February, 1977; No. 3, 15 November, 1977 to No. 5, 22 November, 1977.
- Canada. Parliament. Senate. Special Committee on Science Policy (The Lamontagne Committee). A Science Policy for Canada, Vol. 1 Ottawa: Queen's Printer, 1970.
- Canada. Parliament. Senate. Special Committee on Science Policy (The Lamontagne Committee). Proceedings. No. 5, 30 October, 1968 and No. 17, 11 August, 1976.
- Canadian Nuclear Association. The Role of Nuclear Power in Ontario. Toronto: Canadian Nuclear Association, 1976. Submission to the Royal Commission on Electrical Power Planning, August, 1976.
- Export Development Corporation. Annual Report 1969 and 1975
- International Atomic Energy Agency. Market Survey For Nuclear Power in Developing Countries, 1974 Edition. IAEA-165. Vienna: International Atomic Energy Agency, 1974.
- OECD Nuclear Energy Agency and International Atomic Energy Agency. Uranium: Resources, Production and Demand. Paris: OECD, 1975.
- Taiwan Statistical Data Book, 1977. Republic of China: Economic Planning Council, June, 1977.
- Task Force Hydro. H. Crothers, Chairman, Nuclear Power in Ontario. Report submitted to the Province of Ontario's Committee on Government Productivity, February, 1973.
- Trudeau, P.E. "Canada's Obligations as a Nuclear Power." Address to Canadian Nuclear Association, Ottawa, 17 June, 1975. Statements and Speeches, No. 75/22.
- United Nations. World Energy Supplies 1972-1976. Statistical Papers, Series J. No. 16. New York: United Nations, 1978.

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