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**The Energy Crisis, Canada,
and
CANDU Reactors
by**

Anne Elizabeth Evans, B.A.

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**A thesis submitted to the Faculty of Graduate
Studies and Research in partial fulfillment of
the requirements for the degree of
Master of Arts
in International Affairs**

**The Norman Paterson School of International Affairs
Carleton University
Ottawa, Ontario
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I

ANNE ELIZABETH EVANS

1976

The undersigned hereby recommend to the Faculty of Graduate Studies and Research acceptance of this thesis, submitted by Anne E. Evans, in partial fulfilment of the requirements for the degree of Master of Arts.

Michael S. Fry, Acting Director,
Norman Paterson School of International Affairs

Robert Morrison, Supervisor

The basic contention of this thesis is that the decision taken by the Government to sell CANDU reactors to Third World nations, if they accept strict bilateral and IAEA safeguards, and agree to sign the NPT, is the only practical decision given current attitudes and experiences. This contention is supported by an analysis of three factors: (1) the energy crisis, and its effect on Third World and industrialized nations; (2) the Canadian attitude to control of nuclear technology, and how this attitude is often in conflict with the desire to export Canadian nuclear expertise; (3) the role of safeguards and the NPT and their ability to halt the uncontrolled spread of nuclear technology. The final chapters summarize the attitude toward nuclear sales now being exhibited by the Government, and draw some conclusions and recommendations on this policy.

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CHAPTER I INTRODUCTION

In May, 1974 when India detonated her first "nuclear device", Canada became the target of much criticism, both at home and abroad. This criticism centered mainly on the low-key safeguards on nuclear material and technology that Canada had supplied to India, and the refusal of the Canadian Government to pay attention to warnings by such people as Prime Minister Bhutto of Pakistan that India was determined to explode a nuclear device. Canadian nuclear policy underwent an extensive review after May, 1974 and more rigorous bilateral safeguards and more encompassing commitments not to use nuclear material and technology for any military purpose or in any explosive device were demanded of purchasing nations. The fact, however, that the Government has decided to continue its nuclear sales abroad has raised much opposition, both in the House of Commons itself, and among non-political groups outside.

This paper proposes to analyse the background of the decision to continue sales from three viewpoints: (1) the energy crisis - what it is, (chapter two), and how it is affecting Third World and industrialized nations; (chapter three), (2) the Canadian attitude to nuclear

technology, both in the past and now, and the place that CANBU occupies in this attitude; (chapter four), and finally, (3) the role that safeguards and the NPT play in the regulation and control of the spread of Canadian and other nuclear technologies - what are safeguards, and how do they operate under the NPT?; are nations satisfied with controls, and if not, why not?; will safeguards be really effective in preventing a nation from taking the nuclear option? (chapter five).

Chapter six will look at the reasons why Canada has refused to withdraw from the nuclear market, and the effect this decision has had on the Opposition in the House of Commons. Chapter seven will offer some observations and recommendations on government policy.

II Energy Crisis

A 1945-1960

The world-wide reconstruction effort which took place after the Second World War began the trend towards the use of oil as the primary source of industrial and transportation energy. Though world coal production between the years 1945 and 1954 rose, industrial nations such as the United States and Canada showed a decline in coal production, and a definite preference for petroleum as an energy base. (See tables 2^D and 2^E at end of chapter.) The low price of petroleum on the international market, plus the ease with which it could be found and shipped from the Persian Gulf area, began a cycle in which the availability of petroleum encouraged higher consumption rates, which, in turn, increased demand, thereby increasing production. The result was that oil and natural gas production rates rose much faster than the rate of coal production. (See tables 2^F, 2^G, 2^H.) The trend was also encouraged as the rate of world energy consumption increased from 3.8 billion toe (tons of coal equivalent) in 1950 to 7.5 billion toe in 1970, with most experts predicting that consumption would continue to rise to between 23 and 27 billion toe by the year 2000 (three to five times the 1970 total).¹

B Increase in Energy Use in the United States

The marked rise in world fossil-fuel consumption was due greatly to an increase in the rate at which the United States used petroleum and natural gas. Between 1940 and 1960 the total production of mineral fuel resources jumped from 25,088 trillion BTUs (See Appendix A) to 41,552 trillion BTUs (See Appendix A), with the share of crude petroleum in this total rising from 31.3% to 35.3%. On the other hand, the percentage share of coal declined from 53.3% in 1940, to 26.8% in 1960, while the percentage of natural gas rose from 11.9% in 1940, to 34.0% in 1960.² (See table below)

As the production of fossil fuels rose, so did the rate of consumption. In 1940, the percentage share of coal in energy consumption was 53.4; by 1960 this share had dropped to 22.8, while the percentage share of crude petroleum had risen from 31.4 to 41.8. (Natural gas showed an even more remarkable increase, going from 12.4% in 1940 to 31.7% in 1960.)³ Between 1961 and 1973 the production and consumption rates of fossil fuels continued to rise, and by 1974, the United States was consuming 16.8 million barrels of oil per day.⁴ This high rate of consumption necessitated a doubling of the import rates for petroleum and petroleum products to the point where, by 1973, the U.S. was importing 6.2 million barrels a day (507.6 million tons per year).⁵

The importation of natural gas also increased after 1960, and by 1970 the U.S. was importing four per cent of all natural gas used by the country. (All imports came from Canadian sources.)⁶

Table 2A

MINERAL FUEL RESOURCES PRODUCTION AND CONSUMPTION 1940-1973

In the U.S.

**Production
(percent of total)**

Year	Total (trillions of BTUs)	Coal	Crude Petroleum	Natural Gas
1940	25,088	53	31	12
1950	34,510	42	33	20
1960	41,552	27	35	34
1965	49,074	27	32	36
1966	51,831	28	33	37
1967	54,839	26	33	37
1968	56,575	25	33	38
1969	58,741	24	32	39
1970	61,882	24	32	39
1971	61,929	22	32	41
1972	63,164	23	31	40
1973	62,841	22	30	41

Consumption
(percent of total)

Year	Total (trillions of BTUs)	Coal	Crude Petroleum	Natural Gas
1940	23,908	52	31	12
1950	34,153	38	37	20
1960	44,569	23	42	32
1965	53,343	22	40	34
1966	56,379	22	40	34
1967	58,265	21	40	35
1968	61,763	20	40	36
1969	64,979	20	40	37
1970	67,143	19	40	36
1971	68,728	18	41	37
1972	72,108	17	42	36
1973	75,561	18	42	36

(Table taken from Statistical Abstract of the United States, 1974, #852, p. 514.)

C Inequalities of Usage

This sharp increase in world energy use, especially in North America, was characterized by a definite inequality of per capita energy use between the industrialized countries and the Third World. In 1970 the energy

consumption per inhabitant of major world areas, measured in tons of coal equivalent, was: North America - 13.6 toe, Eastern Europe, Western Europe and Japan - 4 to 5 toe, the Rest of the World - 0.4 toe, with the world average being 2 toe.⁷ These statistics indicate that while the industrialized countries possess only 20 per cent of world population, they consume 85 per cent of total world energy production. Once again, the United States appears to be the nation which must bear the greatest share of responsibility for the situation, as it uses over one-third of world energy production, while supporting only six per cent of total world population. This situation shows little sign of improving, even though American energy consumption is predicted to decline to 25 per cent of the world total by the year 2000,⁸ as the base from which Third World energy consumption must start to catch up with present American levels is very low. Under these conditions, it would be a century before less developed countries reach current American standards,⁹ and by then U.S. consumption will have risen from contemporary levels.

A second aspect of the inequalities of world oil consumption is the wasteful and careless energy practices which have come to be common-place in western industrialized nations. The low price, relative to the value that petroleum held for the Western world, paid to oil-producing

nations for their petroleum and the ease with which oil could be removed from the Persian Gulf, did little to halt such inefficient practices as the poor insulation of houses in colder climates, or the abundance of private vehicles which utilized vast amounts of oil.* Neither were manufacturing nations able to conceive of a situation in which oil supplies would be limited; instead, these nations predicted that global energy production and consumption would grow at a rate similar to that of the G.N.P., which was forecast to move steadily upwards until the end of the century.¹⁰

Table 2B

WORLD ENERGY CONSUMPTION, COMMERCIAL FUELS
(Orders of Magnitude)

	million metric tons coal equivalent				forecast
	1929	1937	1950	1960	1970
Solid Fuels	1367	1361	1569	2263	3060
Hydro-electricity	14	22	41	82	150
Natural Gas	76	115	273	596	1340
Oil	255	328	636	1492	2680
TOTAL	1712	1826	2519	4433	7230

(From: Oil Companies and Governments An Account of the International Oil Industry and Its Political Environment, J. E. Hartshorn, Faber and Faber, 1962, p. 351.)

* According to F. K. North in a paper entitled Domination of Energy Consumption By the United States, (Geology 67.202 handout, Carleton University, March, 1973), American consumption of oil and oil products in 1973 was 40 times that of India, which had 2½ times as large a population. Furthermore, the U.S., with its 210 million population, used as much energy for air-conditioning as China used for all purposes with its population of 800 million.

D Post-1967

These wasteful and unequal energy practices continued relatively unabated in the Western world until the latter half of the 1960's when increasing tension and instability in the Middle East threatened the steady flow of petroleum from the Persian Gulf area to Western Europe and North America. In addition, the concession system in the Middle East, by which foreign companies, (usually British or American), had operated the oil wells, while the national government had maintained control of the subsoil and mineral rights, had come under growing criticism from nationalist elements as being politically and economically discriminatory in favor of the oil companies. During the years 1967 to 1969 the political instability of the Middle East, combined with the increasingly critical stand of nationalist groups in the area, showed the degree to which excessive dependence upon the Persian Gulf for petroleum supplies had allowed the West to place itself in a very vulnerable position.

The dangers of this vulnerability became obvious just after the Arab-Israeli War of 1967. Israeli possession of the East Bank of the Suez Canal, (which prevented the Canal from being opened to ships from any nation), and the shortage of tanker facilities which became evident at the close

of the 1967 war, forced Western Europe to depend upon Libyan oil fields to fill its industrial needs. This sudden interest in the Libyan oil fields stimulated production in the area to such an extent that production totals jumped from 1.5 million barrels a day in 1966 to over 3.1 million barrels a day by 1969.¹¹ Further European dependence upon Libya became necessary when Syria cut the Trans-Arabian Pipeline bringing oil from Saudi Arabia to the Mediterranean.

The growing European demands for Libyan oil had an immediate effect upon the Libyan government. In order to make the most of the situation, the Qaddafi regime forced the oil companies to cut back on production, demanded a higher price for oil, and a higher tax rate for concession companies, all backed up by threats of oil embargo if the terms were not met.¹² Fearful that their supplies of petroleum would be cut off, these companies operating within Libya agreed to Qaddafi's terms, and raised the posted price of oil by thirty cents a barrel, as well as announcing an increase in the tax rate. Soon other oil-producing nations were demanding new price and tax agreements with the oil companies. The Tehran and Tripoli Agreements of 1971 and the Geneva Agreements of 1972, between oil-producing and oil-consuming nations, not only assured an annual increase in the posted price of oil to compensate

for rapid world inflation, they also made provision for further negotiations to take account of changes in the value of major world currency.¹³ The new agreements opened the way for "participation" schemes by which the governments of oil-producing nations were slowly to assume majority control of the oil companies' holdings, leaving the oil companies free to produce and sell the oil, and to pay the taxes demanded by the new agreements of 1971 and 1972.

II Effects

1 West

The uneasy atmosphere caused in the West by the concerted and determined campaign of the oil-producing countries to limit the power of the oil companies and to dictate, to a greater degree, the price at which their natural resources were to be sold, was worsened by the Yom Kippur War of October, 1973. Frustrated by the amount of support that Israel was enjoying in the western world, the Arab nations imposed an oil embargo against those nations sympathetic to Israel, coupled with a general cut-back in production. These actions caused immediate fears of petroleum shortages in the oil-importing countries, which were exacerbated by the further boost in oil prices by the OPEC nations.

11 LDC's

In many ways the decrease in oil reserves and the steady rise in oil prices since the end of the 1960's presents a greater problem to the less developed countries, (LDC's), than to the industrialized nations. The LDC's have increased their consumption of energy greatly in the last fifteen years, (see Table 2^F at end of chapter), as they have intensified their efforts to develop their economies and improve their living standards. Furthermore, a large proportion of this energy has been in the form of petroleum.* These increasing energy requirements, plus the upward trend in oil prices, have forced the Third World nations to closely examine their energy needs and attempt to strike an even balance between fossil fuels and other energy sources. This same problem is faced by industrialized nations too, but, in the case of LDC's the situation is complicated by the increased demand for energy that development entails. In the early phases of economic development, Third World nations have tended to de-

* In 1960 the LDC group was responsible for about 1/10 of the non-Communist world's total energy use. Between 1960 and 1966 the use of oil in the LDC's jumped from 20 per cent of total energy consumption to 40 per cent of total consumption. Coal, however, declined from a total of 35 per cent to 24 per cent. In general, the use of natural gas rose in South America, Asia, and Africa. (Taken from ENERGY and U.S. FOREIGN POLICY, J. A. Vager and E. B. Steinberg, pp. 100-101.)

emphasize agriculture, (with sometimes debatable results, e.g., Thailand after World War II), which uses little energy in relationship to the money invested, and concentrate upon manufacturing, which is much more energy intensive. In order to continually augment G.N.P. through manufacturing, energy consumption must constantly grow. It has been estimated that a 10 per cent increase in G.N.P. for a less developed country would produce a rise in energy demand which may be as high as 13 to 16 per cent.¹⁴ In an industrialized nation, however, the same percentage rise in G.N.P. would only need an increase of 9 per cent in energy requirements due to the fact that these countries no longer have to make the change from an agricultural-based economy to a manufacturing-based economy. Instead, they are moving toward an economy founded upon the service sectors which do not demand as large an energy supply as the manufacturing-dependent economies.¹⁵

TABLE 2C

NATURAL GAS PRODUCTION IN SELECTED AREAS
1945-1954 (Millions of cubic metres)

	U.S.	CANADA	JAPAN	GERMANY
1945	114457	1371	40.9	59.4
1950	177889	1921	69.1	67.6
1954	247563	3425	141	150.2

TABLE 2D

PETROLEUM PRODUCTION IN SELECTED AREAS
1945-1954 (Thousands of metric tons)

	WORLD (without U.S.S.R.)	U.S.	CANADA	JAPAN	BRITAIN	GERMANY
1945	333000	231575	1091	220	72.7	543
	(with U.S.S.R.)					
1950	523000	266708	3878	293	160	1119
1954	690000	313027	12903	300	161	2666

TABLE 2E

COAL PRODUCTION IN SELECTED AREAS
1945-1954 (Thousands of metric tons)

	WORLD (without U.S.S.R.)	U.S.	CANADA	JAPAN	BRITAIN	GERMANY
1945	1,021,000	571420	13584	22371	185717	35484
	(with U.S.S.R.)					
1950	1,470,000	505319	15364	38459	219796	111,137
1954	1,495,000	377675	11609	42718	227686	129,072

(Tables 2A, 2B, 2C taken from the United Nations Statistical Yearbook 1949-1950 and 1955)

TABLE 2F

**World Production, Trade and Consumption of Energy
for Selected Third World Nations.**

(PART A)

CONSUMPTION
(thousands of Barrels of Oil equivalent)

Country		Total Energy	Liquid Fuels	Natural & Imported Gas	Hydro, Nuclear & Imported Electricity
Mexico	1962	168,893	108,707	50,798	3,695
	1971	316,349	177,880	117,228	9,006
India	1962	358,391	56,453	-	7,051
	1971	503,294	127,003	3,655	16,949
Indonesia	1962	52,954	32,463	17,655	436
	1971	76,518	52,396	22,295	784
Nigeria	1962	8,056	5,037	-	69
	1971	16,337	13,622	730	965
Mainland China	1962	1,398,279	67,228	245	15,239
	1971	2,341,965	208,730	7,120	30,792

(PART B)

PRODUCTION
(thousands of Barrels of Oil equivalent)

Country		Total Energy	Crude Petroleum	Natural Gas	Hydro & Nuclear Electricity
Mexico	1962	176,356	109,211	58,349	3,371
	1971	290,060	152,400	118,918	8,894
India	1962	314,967	6,860	-	7,051
	1971	416,069	45,766	3,655	16,949
Indonesia	1962	166,429	146,025	17,655	436
	1971	365,546	281,496	22,295	784
Nigeria	1962	24,373	21,197	-	69
	1971	489,147	486,501	730	965
Mainland China	1962	1,381,163	43,473	245	15,239
	1971	2,297,968	163,072	7,120	30,792

(Table taken from Yager & Steinberg, Table A-1, pp. 443-445.)

III Reaction to the Energy Crisis

A Third World

In order to sustain a program of economic growth and development, most LDC's must import the bulk of the petroleum they use, though some LDC's are more or less self-sufficient in oil production and a few are important oil producers. Once again, the effects of the ongoing and intensive campaign of the Third World to develop a manufacturing economy and raise its G.N.P. can be seen in a comparison of oil importation figures from 1960 to 1970. Collectively, the LDC's imported 2.4 million barrels of oil per day in 1970, more than double the amount they had imported in 1960; this figure comprised about 67 per cent of total oil consumption of the petroleum-importing Third World nations. Furthermore, there are nearly 80 under-developed countries that are oil-importers, including those nations with large populations such as India, Pakistan, and Brazil. In such a situation the rapid increase in petroleum prices that has been evident since 1973 has meant that the total oil-import bill of these nations for 1974 is nearly six times greater than that of 1970,¹ which has put a severe strain upon the shaky balance of payments structure of many Third World nations.

The situation facing the oil-importing LDC's can clearly be seen when the problems of India, Bangladesh and Brazil are examined. India has a population of 600 million and consumes about 400,000 barrels of oil per day (approximately $\frac{1}{2}$ of Canadian consumption).² Though the country does produce 150,000 b/d, India must import about 250,000 b/d of oil from Iran to make up the quota needed.³ In 1973 these imports cost India between \$400 and \$500 million, but the price was forecast to double in 1974 which would mean 30 to 50 per cent of Indian export earnings would be spent in oil payments. There is little that can be done to alter this state of affairs as there is not much scope for the development of alternate energy sources due to the poor quality of Indian coal, and the fact that production could not be undertaken fast enough to make it a true competitor of oil in the short term.⁴

Bangladesh is confronted with a problem similar to India's, but in this case the outlook is worsened by the fact that the country has no proven oil reserves of significant value, though it does have considerable reserves of natural gas. The population of over 60 million uses about 20,000 barrels of oil per day, and the price increase of 1973 means that 30 per cent of foreign exchange earnings must go to pay for oil imports, whereas 5 per cent was sufficient in 1972.⁵

For Brazil, on the other hand, the question is one of trying to balance rapid economic growth against the need to import two-thirds of annual oil requirements. Yearly consumption in 1973 reached 700,000 b/d, of which only 165,000 b/d⁶ was produced by Brazil itself. The continuing economic growth in Brazil during 1974 caused economists to predict that the import bill for that year would be \$2 billion, (twice the 1973 amount), and equivalent to $\frac{1}{4}$ of the country's foreign exchange earnings.⁷

Secondly, there are some countries in the Third World whose energy problems are superficially less serious than those of the ^{above} ~~substantive~~ nations. In this second group are such countries as Korea, Malaysia, or Taiwan which either possess reasonably strong economies and vigorous export sectors, or which can pass on their increased oil costs to those developed nations purchasing their manufactured goods. This solution is vulnerable to the economic whims and trends in the industrialized nations which are customers of the LDC's, however, and if a recession or inflation spiral becomes evident in developed countries, LDC's such as Korea or Taiwan, which depend heavily on Western markets, could find themselves in as precarious a position as India or Pakistan.

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There is another aspect of the oil crisis which is very relevant to the future of the Third World. Petroleum is an important feedstock for many types of fertilizer and the steep rise in oil prices, combined with a shortage of fertilizer products, has resulted in rapid price increases in fertilizer costs. Those nations, such as India and the Philippines, that have been undertaking food-production experiments dependent on petroleum-based fertilizers, are faced with the grave possibility of food shortages due to the inability to obtain needed fertilizers because of scarcity or expense.

B Western Europe

The situation of urgency which has been prevalent in the Third World since the beginning of the energy crisis has been felt in a different manner in Western Europe. Europeans were not really affected by any oil shortages until the Arab embargo of October, 1973, but when the embargo came into effect Western Europe quickly learned that the policies of the oil-producing states in the Persian Gulf area wielded considerable indirect power over the economic future of the large manufacturing nations. Though the cut-backs in Arab shipments of oil to the West never reached the levels which were originally threatened, the experience of the embargo, plus the sharp and steady rise in petroleum prices, prompted West European oil consumers

to consider ways and means of reducing their dependency on the Persian Gulf and North African oil fields. This dependency cannot be easily cured, however. Western Europe is the world's second-largest oil-consuming area; in 1973 requirements were set at 15.2 million b/d, which accounted for 27 per cent of total world usage.⁸ Of this total, Western Europe produces only 0.4 million b/d, with West Germany contributing the largest share (130,000 b/d). In order to overcome this deficiency, Western Europe imports more than its daily requirement, (15.3 million b/d), and re-exports the balance in the form of petroleum products. This program leaves the region with a 98 per cent "net" dependence upon imports.⁹ There are few alternative energy resources to develop as most reserves have been worked out and oil shale deposits are limited. Recently, there has been increasing interest in the North Sea as a temporary source of petroleum reserves, but this supply of fossil fuel is not considered to be a solution to the question of European self-sufficiency, or even of lessened dependency on the Middle East. Though North Sea oil reserves have been estimated to be between 11.5 and 13 billion barrels of recoverable petroleum (total production in 1974 was announced to be 180,000 b/d, with production forecast to rise to 4 million b/d by the early 1980's), only two per cent of world oil reserves are found in the North Sea,

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which will have only limited importance to western European energy needs. ¹⁰

With the long-term prospect of continued oil shortage before the region, the EEC has put forward plans to lessen over-all energy requirements by 10 per cent for 1985. Three major schemes are currently under consideration. The first plan is the increased use of indigenous reserves of natural gas as an energy source. At present, the consumption of natural gas represents only 10 per cent of total energy use in Western Europe, and, in order to raise the share of natural gas to 25 per cent in the over-all energy budget by 1985, the EEC has proposed that all sources of the fuel be used and a conscious effort be made to reduce the rate of oil consumption in EEC nations.¹¹

The second and third plans advanced by the EEC to extend Europe's available ^{energy} reserves for as long as possible, thereby lessening dependence on the Persian Gulf and North African oil fields, are, respectively, to increase the share of coal in the total West European energy budget, and to begin an intensive program of nuclear power station development which would eventually supply 17 per cent of the region's power needs. (At present, nuclear energy accounts for less than one per cent of West European energy use.) However, all these possible alternatives depend upon political and economic co-operation in

Western Europe so that both funds and technological ability to develop new sources of energy can be found and exchanged.

C Japan

The need to find reliable areas for petroleum supplies assumes major proportions when the case of Japan is examined. Japan is almost totally dependent upon the main oil companies operating in the Middle East for the ^{bulk} majority of its oil shipments, as it has no production of its own and the prospects of finding any substantial deposits are remote. In 1973 Japan was the world's fourth-ranking energy consumer, using 5.4 million b/d of oil, or 9.6 per cent of the world's total energy production.¹³ Japan has recently undertaken a policy of stockpiling oil, but Japanese oil needs are still growing by 18 per cent a year. The OECD has estimated that Japan's oil requirements will reach 9.4 million b/d by 1990.¹⁵

These growing oil needs have been due to the phenomenal growth of the Japanese economy between 1960 and 1973. During the 1960's the economy grew by an average of 11 per cent a year, and from 1945 until 1973 the country had not suffered a decline in its gross national product.¹⁴ Though the economic recession visible during the current

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financial year has caused a 3.2 per cent decline in the economy, (though export earnings partially off-set this decline), Japan's oil import bill is expected to reach 2 billion dollars.¹⁵ Such large import costs place a heavy burden on Japan's economy as Japanese industry depends on oil for more than 63 per cent of its total fuel requirements. This figure is four times as high as that for the United States.¹⁶

When these factors are examined the total reliance that Japan places upon the major oil companies in the oil-producing nations can be seen to put the country in a very vulnerable position. In 1971 the leading oil companies provided 69.9 per cent of Japan's crude oil imports,¹⁷ while in 1973 the Arab/Persian Gulf countries supplied 76 per cent of total Japanese oil imports, Indonesia 17 per cent,¹⁸ and the Soviet Union, one per cent.¹⁹ The need for imported energy shows every sign of becoming greater even though nuclear power and liquified natural gas are predicted to play a larger part in the Japanese energy supply. With these considerations in mind, Japan has always been sensitive to political and military unrest in the Middle East, and has harboured fears that the long and exposed supply route from the Middle East could be easily cut during hostilities. In addition, the Japanese

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government has always been concerned that, even if Japan were not directly involved in any oil crisis, the major oil companies would assign a lower priority to Japan's needs than to those of the United States or Britain when it became necessary to allot the reduced supplies of petroleum.²⁰ To counter-act any possible attempts by the large oil companies to undercut Japanese interests, Japan has begun a program designed to increase its use of atomic power as an energy source, to diversify its sources of oil supply, and to remain as neutral as possible in the Arab-Israeli dispute. In addition, four basic plans are presently directed toward the goal of developing a reduced reliance on overseas oil sources: greater national control over oil supplies through increased economic participation of the Japanese Petroleum Development Corporation, (JPDC); development and operation of a synthetic natural gas power plant; co-operation with the United States to develop solar energy; and extensive discussions with the U.S.S.R. on the possibility of exploiting the oil reserves of Western Siberia. Transport facilities would be built from the Tyumen Fields to the Pacific Ocean, either as a pipeline, a railway, or both combined.²¹

D Canada

The fourth important area to be affected by the worsening energy crisis is North America. As this paper is primarily concerned with Canadian attitudes and policies, the major emphasis will be placed upon the effect that the events of the last few years have had on Canada's energy priorities and goals, and the potential that Canada has for finding enough energy to meet its needs.

1 Resources

One of the first things which becomes apparent when Canada's energy resources are examined is that there is a gap between potential Canadian energy reserves (those reserves that are thought to be potentially available, but are not available at present), and growing Canadian energy demand. As of 1973 Canada's proven reserves of oil were stated, in An Energy Policy For Canada, to be about 9 to 10 billion barrels, with another 5 billion barrels possible being available by 1985.²² However, under close examination this reserve of petroleum is shown to be insufficient for future Canadian needs. Speaking at a conference on energy alternatives in December, 1974, J. G. Stabback said that of the 15 billion barrels of conventional oil-in-place available to Canadians with current technology, 7 billion barrels had already been produced. The 8 billion barrels that were

left, under current production rates of 1.7 million barrels per day, were not expected to last more than ten years.²³

The outlook for natural gas is not much better. Of the 135 trillion cubic feet of raw gas-in-place in Canada, (including that found in the Arctic), Stabback estimated that 80 trillion cubic feet are recoverable with present technology, with cumulative production equaling approximately 30 trillion cubic feet. The current production rate is $3\frac{1}{2}$ trillion cubic feet per year,²⁴ which means that proven reserves will last about twenty-five years.²⁵

As the end of the twentieth century draws near, the prospects of a fossil fuel shortage in Canada increase. Canadian demand is expected to rise steadily and steeply between 1975 and the year 2000, (see chart number one at end of chapter), and since 1969 Canadian gas and oil reserves have been declining in the established fields.²⁶ (Stabback has forecast that by 1977 the production of oil will fall below the present levels and will continue to decline. By 1980 productivity will be 1.5 million barrels per day and by the late 1980's production will have dropped to $\frac{1}{2}$ million barrels per day.)²⁷ The only solution to this problem that has been considered so far is to take the possible productive capabilities of "frontier areas" into account when calculating the supply needed to meet future

demands. The regions commonly designated "frontier areas" are the Atlantic Continental Shelf, the Arctic, and the Mackenzie Delta, but the method used for calculating "potential reserves", (these reserves not accurately measured, but assumed to be in existence), is the same as that used to estimate supplies in the highly developed oil areas of the United States. When applied to the "frontier areas" of Canada these methods lose their validity as the productive capabilities of Canadian oil fields in the north or on the Atlantic Shelf have never been tested.²⁸ According to some authorities, notably F. E. North, in his paper The Future of Canada's Fossil Fuels, there is a very distinct possibility that Canada has over-estimated the potential oil supply in the north, especially when it is realized that the Mackenzie River Delta geological formation favors natural gas deposits rather than petroleum deposits.²⁹

Even the potential value of a large deposit of natural gas in the Canadian Arctic or the Continental shelf is diminished when the problems of transportation are regarded. These discoveries which have been made off the mainland to date have necessitated the construction of undersea pipelines which have been expensive to build and maintain. Furthermore, the gas must be liquified before it can be safely transported, which involves the further expense of refrigeration which can cost as much as \$100 million³⁰ for each refrigerated tanker truck,

The natural gas deposits in the Arctic face not only the problem of pipeline transportation, (which opens complicated environmental questions), but also the related challenges of the best possible use of the fuel which does come to the populated areas. The most optimistic estimate of natural gas reserves in the Mackenzie Delta has been set at 18 trillion cubic feet. Under some schemes that have been suggested for pipeline construction in the area, the bulk of this rather small amount of natural gas would go to service American needs, rather than Canadian industries, and would last for a period of about nine years.³¹ Canadians would thus benefit very little from these northern reserves.

Neither is the outlook for the much-publicized Athabasca Tar Sands much more optimistic for the present, though as more is learnt about mining this type of deposit, future estimates look brighter. For the present, however, the Alberta Energy Conservation Board only considers as "proved recoverable" those oil deposits which lie between zero and 180 feet of overburden, and which "are at least as deep as the overburden to be removed and which contain 8 per cent or more crude bitumen by weight."³² Under these limitations, and if current mining methods recover 90 per cent of available oil, the Alberta Energy Conservation Board estimates that 28 billion barrels of crude bitumen

are "proved recoverable" from the Athabasca Tar Sands. This "raw material" will eventually yield about 26.5 billion barrels of synthetic crude oil,³³ which is a considerable amount, but recovery is much more expensive than conventional oil, and the lead time required to construct a plant capable of recovering the 100,000 barrels a day to make the venture pay, is between 5 and 7 years.³⁴ In order to exploit the Tar Sands to their greatest extent, twenty or more processing plants with a capacity of 100,000 barrels a day must be built, but each installation costs in the neighborhood of \$600 million.³⁵ So far only one plant has been built, and though it has a capacity of 100,000 barrels a day, it has only reached a peak of 50,000 barrels per day.³⁶

A third resource which does not show much scope for further development in Canada is hydro electrical power. At present, Canada does export some hydro-power to the United States, but this small amount is to be cut off by 1989 in response to the increasing demand in Canada itself for hydro power.³⁷ Furthermore, little scope is left for future developments of new hydro-electric sites.

Canada has two other mineral resources, however, which do not face the bleak future of the petroleum and natural gas reserves, nor the mediocre future of the hydro-

* This figure was a 1973 estimate. Present estimates run as high as 2 billion dollars.

electric resources. The most important of these is uranium which is estimated to be 400,000 tons at a price of between \$15.00 and \$20.00 a pound. If a concerted exploration program once again becomes possible, a further 700,000 tons could become available. As the expansion of the CANDU program takes place within Canada, the domestic needs for uranium are forecast to rise, reaching a cumulative total of 100,000 tons by the year 2000.³⁸

The second "secure" mineral resource found in Canada is coal. The demand for coal within this country has been increasing, but at a much slower rate than that of oil, natural gas, or electricity. (See table 2A and 2B at end of chapter.) In addition, major Canadian coal deposits are found in British Columbia, (with smaller deposits in Alberta), and most exports go west to Japan. However, reserves in these provinces may be as high as 120 billion tons.³⁹

ii Self Sufficiency

The decisions taken in the Middle East since the beginning of the 1970's, the rising demand within Canada for energy, and the realization that any future reserves of Canadian fossil fuels are going to be costly and difficult to develop, (with the possible exception of coal), have led to a growing concern with Canadian fuel requirements in the

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government. It has been realized that a method of consumption must be found which will provide the most effective usage and rationing of Canada's considerable but far from unlimited, energy reserves. An answer must be found for the question "How can technology be utilized so that the energy stored in the oil, coal, natural gas, and uranium resources be used to the greatest potential, thus stretching the life of these reserves to the greatest degree?"⁴⁰

One way in which the Trudeau government has attempted to answer this question is to place a limit upon the amount of crude oil exports from Canada into the United States. In February, 1973, the government declared that crude oil exports from Western Canada would be "controlled" in order to conserve supplies for Canadian refineries. In the same month the National Energy Board of Canada stated that the export of energy resources would take place only to the degree that supplies were in "excess" of Canadian requirements. The existence of this "excess" was to be determined by a set formula involving an estimation of domestic demand four years in the future. Since domestic requirements are increasing yearly, it is expected that Canadian oil exports to the United States will show a steady decline. This trend will probably be encouraged through a system of high export taxes on oil from Western Canada and attempts

to build an "all Canadian" oil pipeline from the west to Montreal.

I Effects of the Energy Crisis on World Attitudes

As can be seen from the above paragraphs, the challenges presented by the energy crisis are being met in varying ways by different nations. While Canada, for example, is attempting to formulate a policy of self-sufficiency within the limitations imposed by the fossil-fuel resources that she possesses, Japan is trying to diversify her dependence on overseas oil fields, and Western Europe is turning to a collective approach to the energy problem by looking for ways in which the fuel resources that exist elsewhere can be most effectively used for the longest period of time. However, in spite of the different routes taken by nations to deal with the restrictions imposed by the scarcity of fossil fuels, two facts are recognized by every government: the need to develop energy sources that are alternatives to fossil fuels is becoming more and more acute; and secondly, there are many difficulties involved in finding a satisfactory alternative for fossil fuels. The alternative must be economical, easily available, and dependable, and to date, most attempts at fossil fuel replacements have not been able to satisfy all three of these requirements.

1 Energy Alternatives

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One of the most daunting aspects of the search for alternative energy sources is the fact that, in many cases, there are serious scientific and/or technological problems to be overcome. This drawback can be clearly seen when such energy sources as geothermal power are discussed. This energy source, which is basically the use of the Earth's internal heat, depends upon the efficient flow of pressurized water from one subterranean well to another. The most widely known process of producing geothermal power is the "Hot Rock Method" developed at the U.S. Atomic Energy Commission's Los Alamos Scientific Laboratory. Wide cracks are created in a bed of hard rock, through a series of explosions, and a large area of hot rock is exposed. Pressurized water is then pumped down one well and up the other, extracting the heat from the rocks as it flows past.

Though the "Hot Rock Method" may be workable theoretically, in reality, the lack of hot rock near the surface severely restricts the use of this energy source as a major contributor to Man's power store. The U.S. Department of the Interior has stated that geothermal energy could supply between one per cent and 20 per cent of American electrical generating capacity by the year 2000,

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but the majority of the estimates are in the lower half of that range.⁴¹

A second alternative source of energy is wind energy. The principle underlying the use of wind energy is that variations in the rate at which sunlight warms the air causes the air to move, and the energy of this moving air can be made to do work. However, wind energy is much too diffuse to be considered on any scale greater than a very local level.⁴² Variations in wind speed and direction cause fluctuations in electrical output, which increase capital cost, as wind generators must either be employed with other generating systems or have access to storage facilities in order to match supply with demand. The unreliability of wind energy raises the capital cost of such systems to a level between two and five times as high as conventional generating plants.⁴³

In contrast to geothermal and wind power, solar energy has a much more promising future as an alternative energy source to fossil fuels. Theoretically, solar energy is a good, clean source of power for the world's electrical, industrial and domestic needs as each square kilometer of the Earth's surface receives about 200 megawatts from the sun,⁴⁴ but the heat is clean and inexhaustible. Furthermore, solar energy does not dissipate to the same degree as wind energy, but yet is diffuse enough to

be easily gathered for use domestically and by small industries. This factor may have major implications for LDC's, as solar power could be used, with little technological innovation or expense, for such jobs as cooking or heating, in remote areas, while nuclear power installations or sea-water distillation plants could be concentrated in more populated and industrialized regions. This possibility has been realized by American scientists; in a joint report issued by the National Space Foundation and NASA in 1973, it was stated that by the year 2020, solar energy may fuel 35 per cent of the heating and cooling systems found in American buildings, as well as providing 20 per cent of the nation's electrical needs.⁴⁵

Though the expense involved in developing solar technology in a major way is still very great, some ideas have been put forward which may become practical as technology advances. One of the more interesting suggestions has been put forward by Melvin Calvin in his paper "Solar Energy by Photosynthesis" (Science, Volume 184, April 1974, pp. 375-381). Calvin suggests that the photosynthetic cycle of plants be used to convert the sun's energy into a form which would be useful to man. Two processes are suggested, one which would produce energy in a "storable" form, (as hydrogen), and the other which would use the structure of plant membranes to convert solar energy to

a form which could be easily turned into electrical energy.⁴⁶

There is a second method which can be used to harness solar energy, although the technology is not yet fully developed. This idea proposes the use of inexpensive lenses, (which do not need to be cleaned constantly), arranged in banks to gather the sun's rays which fall on a given area of desert. Each bank would focus these rays onto a small furnace which would be able to chemically transform the heat into fuel.⁴⁷

Fusion energy (the creation of energy from the "pushing together" of atoms, rather than the "pulling apart" of atoms as in the fission process), also presents a possible alternative to fossil fuels, but once again the process has not been proven scientifically feasible. Fusion depends mainly upon two elements: deuterium, found in all types of water, and tritium which is made from lithium. Though the chemical basis of both materials is easily obtained, (lithium is about four times as plentiful in the Earth's crust as uranium, and is found in large quantities in both North America and Africa, as well as in sea water),⁴⁸ it is the use of tritium which presents one of the greatest technical problems in the fusion process. The apparent abundance of lithium is deceiving as it requires about

four times as much lithium to generate a given amount of electricity as it does uranium or thorium.⁴⁹ Secondly, tritium is highly radio-active, with a half-life of about 12.3 years, and tends to interact with the structural materials of the reactor, producing new radio-active nuclides.⁵⁰ The control of these new radio-active substances adds to the technological problems of fusion development.

One major barrier to proving the scientific feasibility of fusion power is the control of the plasma which is used in the fusion reaction. In order for fusion to take place, very high temperatures must be reached, (about 10^8 degrees),⁵¹ which precludes the use of any solid container to handle the reaction. The material undergoing fusion is in the form of plasma at such temperatures, and is contained in a "magnetic bottle" made from wires carrying an electric current, which creates a magnetic field. This magnetic field contains the plasma and prevents the material from leaking or escaping.⁵² However, there are many technological difficulties to be overcome in this field of research, (notably how to prevent instabilities leading to leakage at the edge of the plasma), before the practical generation of fusion power can be started upon. For this reason the feasibility of fusion power is not yet scientifically proven and ^{the technology} will not be ready in the immediate future.

11 Attraction of Nuclear Power

When the technical problems of finding energy alternatives to fossil fuels are examined by developing and industrialized nations, they appear not only to be very costly to solve, but also appear to present little hope of solution within the near future. Wind energy and geothermal power are just too impractical for serious consideration as fossil fuel alternatives, and fusion energy does not hold any promise of being scientifically workable within the next decade when substitutes for oil and natural gas must be found. In addition, there is some doubt that the development of fusion technology will be seriously undertaken before the year 2000 as it represents competition with the breeder reactor, thereby coming into conflict with the interests backing this development.⁵⁸ Nuclear energy, therefore, represents, for most nations, both industrialized and developing, the most reliable alternative to conventional energy sources as it is a technology which has reached a high stage of development and shows little sign of being overcome by insurmountable technological difficulties. It can be obtained and put "on line" within a relatively short period of time; (e.g., the base of India's nuclear power was laid with Canadian and British help between 1955 and 1960), and, once installed, can operate at a lower overall cost than a conventional power-

plant.* Furthermore, there is little visible pollution from a reactor site, (if safety systems are adhered to and pollution controls are installed), and the use of nuclear reactors as a power source opens the door to new types of technology and scientific knowledge.

Closely tied to the technical advantages of nuclear power over other forms of energy, is the large yield of power that nuclear fuel gives in relationship to its size and bulk. When one gram of uranium or plutonium is fissioned, it produces the same amount of heat as the combustion of three tons of coal or 700 gallons of fuel oil. The uranium pellets used in a reactor produce the same amount of electric power as 85 tons of coal, 15,000 gallons of fuel oil, or 2 million cubic feet of natural gas.⁵⁴ Because nuclear fuels are very compact, they can be transported throughout the world at a relatively low, uniform transportation cost.

There are certain disadvantages, both for LDC's and for industrialized nations in the choice of nuclear energy as a substitution or alternative to a fossil fuel

* S. E. Hunt, in his book Fission, Fusion, and the Energy Crisis, (Pergamon Press, Oxford, 1974), states that, in round terms, the cost of building a natural uranium nuclear power station is about twice that needed to build a conventional station of comparable output. However, once built, natural uranium nuclear stations can operate at about one-half the costs of conventional stations, including fuel and labor costs. (pp. 77-78)

economy. One of the most important of these disadvantages is the fact that the demand for low and medium-priced uranium is rising steadily, (see figures 1 and 2), while resources may be unable to keep up with this demand. (see figures 3, 4, 5). Though, as of August, 1972, uranium demand had not overtaken production, (23,000 short tons were produced in the West in 1970, while the annual demand was 15,000 short tons),⁵⁵ demand is expected to rise very steeply during the rest of the 1970's, reaching a cumulative demand of one million tons by 1985.⁵⁶ (figure 2).^{*} In order to satisfy this demand, new uranium reserves will have to be found at a steady rate and breeder technology will have to be given serious consideration.

A second constraint on the use of nuclear power as an energy source in many LDC's, and in those areas of industrialized nations that are isolated or under-populated, is the small amount of electricity used by these areas. Nuclear reactors as power sources are economical only if the electricity that they produce can be fed onto a large power grid system, thereby lowering the price per kilowatt. With this factor in mind, it has been determined that the minimum size of an economic nuclear power plant in nations other than the United States is 800 to 900 megawatts, (depending on the costs of fossil fuels), and 300 to 500 megawatts in the United States itself. In

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order to use the electricity provided by such plants, the national, or regional, electrical supply system's capacity must be at least 2,000 megawatts, which is much greater than that needed by the majority of LDC's.⁵⁷ (See tables 3C and 3D).

However, military prestige and security also play a large role, especially for LDC's, when the decision to install a nuclear reactor is taken. Though the majority of nations that have already achieved nuclear sophistication are opposed to the further indiscriminate spread of nuclear technology, many less developed countries feel that their negotiating and bargaining positions would be enhanced if they could acquire nuclear expertise. An example of this viewpoint was the reaction of African and Asian nations to China's entrance into the nuclear club in 1964. There was a definite attitude of respect for China's achievement among these LDC's, and many leaders, especially those of the right-wing factions in the Indian government, advocated the procurement of a nuclear option on the grounds that any relations with China must be relations between equals. The ability to produce nuclear weapons, even in a minimal way, was felt by some Indian officials to give India the needed psychological support in her dealings with China.⁵⁸

FIGURE 3A

Taken From: An Energy Policy for Canada, Volume I
Analysis, p. 75

TABLE 2A

STANDARD FORECAST OF CANADA'S PRIMARY ENERGY CONSUMPTION
(10¹⁵ Btu)

	1970	%	1980	1990	2000	%
Petroleum	3.1	48	4.8- 5.4	8.7- 10.3	9.4- 14.6	63
Natural Gas	1.2	18	3.1- 3.5	6.0- 8.5	8.2- 9.0	
Coal	0.7	11	1.1	1.6	1.9	7
Hydro* Electricity	1.5	23	2.3	3.1	3.4	12
Nuclear and Other	-	-	0.5	2.0	5.1	18
Total	6.5	100	11.9	19.4	28.0	100

*Hydro Electricity at 10,000 Btu per kWh.

NATURAL UNITS

	1970	1980	1990	2000
Petroleum (mill. bbls/day)	1.5	2.3- 2.5	3.2- 4.5	4.4- 6.9
Natural gas (billions Mcf)	1.2	3.1- 3.5	6.0- 8.5	8.2- 9.0
Coal (mill. of tons)	26	40	54	100
Hydro Electricity (bill. kWh)	187	235	310	344
Nuclear (billions kWh)	1	45	120	503

TABLE 22

STANDARD FORECAST OF CANADA'S SECONDARY ENERGY CONSUMPTION*
(10¹⁵ Btu)

	1970	%	1980	1990	2000	%
Petroleum Products	2.9	58	4.6- 5.1	6.0- 9.4	8.2- 13.5	79
Natural Gas	1.1	22	2.5- 2.0	5.4- 2.0	7.7 2.4	
Coal**	0.3	6	0.3	0.3	0.4	2
Electricity	0.7	14	1.4	2.4	3.9	19
Total	5.0	100	8.8	14.2	20.2	100

*Secondary consumption equals consumption of petroleum products, natural gas, coal & electricity minus conversion losses.

** Includes petroleum coke.

TABLE 3C

**ELECTRIC ENERGY: INSTALLED CAPACITY
(Thousand Kw)**

	1967	1968	1970	1971
Argentina	8553	8820	8691	7103
Burma	261	286	258	-
Chad	1569	1730	295	295
India	13153	14313	16136	-
Lebanon	374	432	431	-
Libya	79.8	168.5	140	168
Brazil	8042	8555	11233	12070
Nepal	31.3	37.7	-	-
Pakistan	1471	1741	2398	-

(Taken from U.N. Statistical Yearbook, Statistical Office
of the United Nations, New York, 1971 and 1973.)

TABLE 3D

POWER REQUIREMENTS OF INDIVIDUAL COUNTRIES
NW(e)

Country or Area	Existing as of end of 1968		Planned for Implementation for year 1969- 1973		Additional Requirements for years 1974-1980	
	Hydro	Thermal	Hydro	Thermal	Hydro	Thermal
Malaysia	264	274	nil	430	252	270
Singapore	nil	464	nil	550	nil	400
Sumatra	1.5	90.5	100	80	a	a
South Thailand	nil	70	nil	60	37	30

a - undecided expansion of power

(Taken from Peaceful Uses of Atomic Energy, Volume 6, p. 382)

FIGURE 3 B1. Projected cumulative uranium demand

Taken from: Boxer, Häussermann, Cameron, Roberts, "Uranium Resources, Production, and Demand", Peaceful Uses of Atomic Energy, Volume 8, p. 14

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FIGURE

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BOXER et al.

Taken from: Boxer et al. "Uranium Resources Production, and Demand"

TABLE 3E

RESERVES & PRODUCTION OF URANIUM U_3O_8
(metric tons)

Country	Reserves as of April, 1970	Production		
		1963	1966	1971
Canada	210,500	7577	3567	4514
South Africa	181,400	4111	2981	3800
United States	226,800	12898	8697	11,158
Australia	19,700	9	23	50

Taken from: The U.N. Statistical Yearbook, 1972.

TABLE 3F

ESTIMATED RESOURCES OF URANIUM MID-1971
(10³ tonnes)

PRICE RANGES

Country	< \$10/lb U ₃ O ₈		\$10-15/lb U ₃ O ₈	
	Reasonably Assured Resources (Reserves)	Estimated Additional Resources	Reasonably Assured Resources	Estimated Additional Resources
USA	230	520	130	275
USA (by-product)	70	-	15	-
Canada	178	177	100	130
South Africa (includ. by-product)	230	11	50	27
Australia	100	5	7	5
France	35	19	7	12
Niger	20	29	10	10
Others	49	45	296	67
Approximate Totals	910	805	615	525

Taken From: Boxer, Haussermann, Cameron, Roberts,
"Uranium Resources, Production, and Demand",
Peaceful Uses of Atomic Energy, Volume 8.

Taken from : Boxer, Häussermann, Cameron, Roberts, P.16

IV CANADA AND NUCLEAR ENERGY

A Actions and Attitudes 1945 to 1974

1 1945 - 1959

The concern over the proliferation of nuclear weapons and the debate on the merits and demerits of nuclear energy as a source of the world's power is not new to Canada. Canadian participation in the Manhattan Project began in June, 1942 and from that time until 1945, when the U.S. Atomic Energy Act limited the exchange of nuclear information between the U.S., Canada, and Britain, Canada remained in close co-operation with her two allies, supplying both raw materials and research facilities. However, in 1945 a cross-roads was reached when Canada decided to forego nuclear ^{weapons} development and to concentrate instead upon a program of civilian nuclear research, and investigation of the peaceful aspects of nuclear technology.

One of the major reasons for this decision was that Canadian leaders, both civilian and military, felt that Canada faced no overwhelming threat from outside. The United States was fully capable and willing to undertake the greatest share of North American defence, and, in any case, a plan of American defence would have to include Canada, as an attack upon the latter would be virtually the same as the early stages of an attack upon the United

States itself.¹ This idea was stated concisely by James
Hayre in "Canada, NATO, and Nuclear Weapons", RCAP Staff
College Journal 1960:

The construction of our own nuclear weapons system, costly and difficult as it would be, is not beyond our financial and technological capacity, as it is clearly beyond the capacity of any other presently non-nuclear NATO member excepting West Germany. But, altogether fortunately, our occupancy of the northern half of the North American continent makes such expense and effort wholly unnecessary. Any atomic attack upon North America would bring about United States retaliation. The Soviet Union, therefore, cannot under imaginable circumstances contemplate a nuclear strike directed specifically against Canada. The American apparatus for massive retaliation serves to deter attack on Canada precisely to the same extent that it serves to deter attack on the United States itself. We are the sole ally of the United States of which this can be said.²

The security brought about by the American commitment to North American defense left Canada free to concentrate not only upon the peaceful development of atomic energy but also upon attempts to limit the spread of nuclear arms and to persuade the United States and the USSR to undertake policies of general arms control. This campaign began as early as November 15, 1945 when Prime Minister Mackenzie King joined with President Truman and the British Prime Minister C. R. Attlee in issuing a Joint Declaration on Atomic Energy. The declaration spoke of the untold potential that atomic power had for both military and civilian uses and the need; "(a) to prevent

the use of atomic energy for destructive purposes,

(b) to promote the use of recent and future advances in scientific knowledge, particularly in the utilization of atomic energy, for peaceful and humanitarian ends."³ In order to accomplish these tasks the destructive use of scientific knowledge, notably in war, had to be prevented, while the beneficial results of the peaceful uses of atomic energy should be shared among all nations. The three signatory nations recommended that a Commission be set up under the United Nations to study "the most effective means of entirely eliminating the use of atomic energy for destructive purposes and promoting its widest use for industrial and humanitarian purposes,...."⁴ Specific proposals were to be made by the Commission in four areas: (1) the extension to all nations of "the exchange of basic scientific information for peaceful ends"; (2) the control of atomic energy to the point where it would be used only for peaceful purposes; (3) the elimination of atomic weaponry from national armaments, as well as the elimination of all other weapons used for mass destruction; and (4) the establishment of an effective inspection-safeguards system to "protect states against the hazards of violations and evasions".⁵ On January 24, 1946, the Atomic Energy Commission was established by the United Nations General Assembly; it consisted of all the members of the Security

Council at any given time, plus Canada as a permanent member.

During the early post-World War II era, Canada was also very active in the area of arms control. The greatest Canadian effort in this field was centered upon formulation of a veritable arms control policy which would be acceptable to both the superpowers, while increasing Canadian security through arms limitation, and, if possible, abolition of nuclear arms. (Little concern appeared to be expressed at this time over the proliferation of civilian nuclear power.) The method of "quiet diplomacy" was employed to put forward the Canadian viewpoint in Washington, while a more vocal campaign was employed to convince the USSR that compromise and co-operation were the only ways to achieve lasting arms control agreements. However, these attempts were largely ineffectual and the arms race continued unabated.

ii 1960 - 1967

In 1960 disarmament became a much more prominent part of Canadian foreign policy when the portfolio of Minister of External Affairs went to Howard Green. The new Minister strongly opposed nuclear weapons and felt that Canadian use of atomic weapons in any form would jeopardize the work that the country was doing in the United

Nations with Third World states.⁶ Under Mr. Green's leadership Canada actively participated in such arms limitation meetings as the Ten Nation Disarmament Conference, and the Eighteen Nation Disarmament Conference. Though these arms control measures did not realize the ultimate aim of complete disarmament, they offered excellent opportunities for Canada to state her conviction that the growing arms race should be controlled and, if possible, reversed.

Nevertheless, during the late 1950's and the first half of the 1960's, there was a fundamental ambiguity in the attitude that Canada held towards arms control. Officially, the international position of the government was that if any lasting efforts in the direction of arms control were to be made, a nuclear non-proliferation agreement had to be formulated, followed by a halt to the arms race. Since a non-proliferation agreement was the most likely of the two goals to be reached in the near future, Canada urged acceptance of the idea that if those nations not owning nuclear weapons abstained from their acquisition, they would be in a strong moral position to persuade the nuclear powers to refrain from the further accumulation of atomic weaponry.⁷

The discussions and events that were taking place within Canada itself, however, did not fully match with

attitudes that were expressed on the international scene. For nearly a decade, (1957 to 1964), the Canadian government and public debated the question of whether or not Canada should accept nuclear weapons both for her role in NATO and for her partnership with the United States in North American defence, but paid little attention to the role of civilian nuclear power in the world community. The debate centered upon three questions: "Should Canadian forces have nuclear weapons under their exclusive control, whether acquired by manufacture or international agreement?; In what ways and to what extent should Canada contribute to the U.S. nuclear deterrent by taking measures under its control, such as allowing the storage of American weapons and/or carriers on Canadian territory?; and Should Canadian forces in North America and/or Europe be provided with nuclear weapons which are not under their exclusive control?"⁸ While there was no doubt that Canada would never undertake to produce nuclear weapons, it was not so clear whether or not Canada should seek nuclear weapons from the United States and insist that they be placed under exclusive Canadian control. By 1960 the debate had grown to such proportions that Canadians were questioning their role in NATO and SEATO and both the government and populace were split into "bomb" and "anti-bomb" groups. The "anti-bomb" group, rather shakily represented by the Liberals in Parliament,

based their stand partly on morality, (if Canada possessed such weapons she might have to use them in acts of mass destruction which would be morally unjustifiable),⁹ prestige, (Canada had been one of the first non-nuclear-weapons nations), and anti-Americanism. It was felt that under the scheme proposed by the Americans for nuclear sharing, Canada would not have enough independent control, and "Canadian control is desirable not for reasons of prestige but because divided control weakens the capacity to deter."¹⁰ The Liberals stated at this point that if Canada did obtain nuclear weapons they "should be owned by Canada and should be used under Canadian authority exclusively,"¹¹ but since this condition was unlikely, it was undesirable to have nuclear weapons of any kind on Canadian soil. When, on November 10, 1959, Defence Minister Pearkes stated that, when the Bomarc was ready, bomb storage facilities in Canada would be made ready, with the warheads placed under joint Canadian-American control, the anti-nuclear faction responded vocally with articles in such papers as La Presse and the Toronto Daily Star, criticising the arrangement on the grounds of infringement of national sovereignty.¹²

Arguments were also raised about the effectiveness of the Bomarc as a defensive weapon. At this time estimates of Soviet bomber strength had been lowered, but

American intelligence under the Kennedy regime had indicated that there might be a "missile gap" in favor of the USSR. In order to protect North America from both bombers and missiles, it was felt that a "defense in depth" scheme was needed, whereby anti-aircraft weapons and missile interceptors would be used.¹³ In the United States there was much discussion as to whether the Bomarc was technically capable of fulfilling the role of an interceptor. This doubt was repeated in Canada by the Liberals who questioned the merit of basing an air defence program on the unproven Bomarc and the Semi-Automatic Ground Environment (SAGE) program.¹⁴ In addition, the Opposition Party felt that to agree to accept the missiles before reaching a consensus about equipping them with nuclear warheads was reversing the logical order of events. Furthermore, both Mr. Pearson and Mr. Hellyer (Liberal Defence Critic) stated that the U.S., not Canada, was responsible for maintaining the deterrent, and Canada's role should be to renounce both nuclear weapons and their carriers and concentrate on interceptors.¹⁵

The Conservative Government under Prime Minister Diefenbaker was careful not to take a firm position in the debate. During these years the Conservative Party concentrated upon a policy of national assertion against the United States, while attempting to live up to the demands

and commitments of the NATO Alliance.¹⁶ The result was that a subdued competition with the Liberals evolved; neither party wanted to be the first to agree to nuclear weapons, but it became increasingly clear that nuclear weapons would be stationed in Canada in the near future, due to growing pressure from the United States and rising complaints from the military that they would not be able to fulfill their role in NATO and NORAD without such weapons. Finally, the Cuban Missile Crisis of 1962 brought the matter to a head when accusations from both the Liberal Opposition and the U.S. Government were made, that Canada had not done its utmost to support the United States in the recent crisis. Pressure mounted for Mr. Diefenbaker to make a decision on the nuclear weapons question, but his inability, or unwillingness to do so, finally culminated in the overthrow of the Conservative Government in February, 1963. When the new Liberal Government came to power it wasted little time in allowing the nuclear arming of the warheads which had been in Canada since 1957.

111 1967 - 1970

The presence of nuclear armaments in Canada did not prevent the new Liberal Government under Prime Minister

(1)

Pearson from pursuing a policy of firm support for arms control and disarmament negotiations. Throughout the years 1963 to 1970 the Pearson, and later, Trudeau Governments continued to support such discussions in the Eighteen Nation Disarmament Conference, the agreement on a non-proliferation treaty, and the Seabed Disarmament Treaty of 1970. When serving on committees and participating in discussions, Canadian diplomats continued to put forward two ideas which were felt to be fundamental to arms control: a halt to the arms race between the United States and the Soviet Union, and formulation of agreed procedures which would control the transfer of "nuclear explosive devices" from one party to another, especially if one of the parties was a non-nuclear power.

Canadian insistence that strict controls be placed upon the peaceful use of "nuclear explosive devices" and that the superpowers undertake more extensive disarmament commitments became an important part of Canadian foreign policy under Prime Minister Trudeau. In 1970 this goal was criticised by the United States when Canada pressed for a change in the Seabed Disarmament Treaty. Canadian representatives suggested the inclusion of procedures by which all concerned governments could check that the clauses in the treaty were being implemented and that the rights of coastal states were being protected. Once these measures

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were included, Canada called for a more comprehensive test-ban treaty by requesting a very low limit on the size of underground tests. Canada had always favored a complete ban on testing since the issue was first raised in the U.N. during the 1963 Partial Test Ban negotiations, and in September, 1971, Canada proposed a Test-Ban treaty covering all underground testing.¹⁷

B Official Policy 1971 - 1975

1 General Policy

In recent years (1971-1975), the Canadian government has continued its policy favouring non-proliferation and arms control. This stand has, at times, been complicated by the fact that Canada has had a flourishing civilian nuclear industry since the middle 1950's, and had not hesitated to share the product of this industry, or the country's large reserves of uranium, with both nuclear and non-nuclear nations. There has sometimes been a conflict, as in the case of technological aid to India, between the belief in sharing the benefits of peaceful nuclear technology, and the enunciated Canadian position on the control of nuclear proliferation. As a result, Canada has sometimes been accused of maintaining a double standard. The accusations reached their height in May, 1974, when India exploded a nuclear device after receiving 15 years

of aid from Canada in the form of fuel, reactors and training of personnel. Prime Minister Shatto of Pakistan stated:

We repeatedly warned India would betray its assurances and its bilateral agreement with Canada and explode a nuclear device in order to claim the status of a nuclear weapon power.

These warnings went unheeded. Meanwhile, over two decades, India steadily acquired the nuclear know-how, built the necessary plants and produced the material required for making a plutonium device of the type exploded in Rajasthan yesterday. 11

The Indian detonation induced the Canadian government to formulate a policy of much stricter safeguards on the use of Canadian-supplied fuel and nuclear reactors, plus the attachment of safeguards to nuclear installations built with Canadian aid, as well as future generations of nuclear material coming from these installations.

Canada has also shown increasing interest in the arrangement of bilateral safeguards to prevent, or at least lessen, the opportunities for proliferation of weapons technology when peaceful nuclear technology is supplied to Third World states by more technically advanced nations. Canadian representatives overseas have been asking that the Cabinet instruct them as to exactly what controls are to be put on each type of material, and exactly how many generations of nuclear material coming from a Canadian-

supplied reactor or installation are to be labelled "Canadian".¹⁹ (In essence, if nuclear material can be traced back to a Canadian reactor, installation or fuel originally supplied by Canada, it will be listed as "Canadian" material, and bilateral safeguards will apply.)²⁰

There has also been increased demand in Canada for a revision of existing safeguard arrangements with a view to reducing the ability of Third World nations to divert materials to fabricate bombs or nuclear explosive devices. To this end, Canada took part with five other nuclear-exporting countries in the Nuclear Exporting Talks held in London, England during June, 1975. The object of these discussions, initiated by the United States, was to reach an agreement on an international convention to establish sales controls and safeguards standards for nuclear material.²¹

ii The NPT

Canada has also changed her conception of the basic role of safeguards in the Non-proliferation Treaty. When the safeguard clauses in the NPT were under negotiation between 1968 and 1970, Canadian interest was focused upon the clarification of rules which would define when proliferation took place and which would govern the materials and processes to be included in a safeguards scheme. With the experience of the Indian detonation of May, 1974, however,

the position of the Canadian government changed slightly and emphasis was placed upon enforcement of the NPT safeguards as they applied to the non-military use of atomic power. The first indication of this new emphasis was produced on September 28, 1974, when Mr. MacEachen, Secretary of State for External Affairs, spoke at the United Nations. Reiterating Canada's desire that the arms race be controlled, and that world stability be increased, MacEachen stated that the core of the proliferation problem was the need to devise a "system that will allow the dissemination of the benefits of nuclear energy without at the same time contributing to the spread of nuclear weapons."²³ The Canadian solution to the problem was that Canada would "satisfy itself that any country using Canadian-supplied nuclear technology or material will be subject to binding obligations that the technology or material will not be used in the fabrication of nuclear explosive devices for whatever purpose."²³ In addition, Mr. MacEachen stated that Canada attached special importance to the role of nuclear safeguards applied by the IAEA.

In the second part of the speech Mr. MacEachen listed three aims of the Canadian government which, it was thought, would bring increased control and surveillance over the transfer of nuclear material from one state to

another:

--the institution of international^{al} measures which would halt both the multiplication and further dissemination of nuclear weapons and the spread of the technology leading to nuclear explosive devices, both for "peaceful" and military purposes;

--an undertaking by all states not to transfer nuclear technology or materials, except under international supervision which would insure that the transfer was not used for fabricating nuclear explosive devices;

--all states should place their inventories of nuclear fissile material used for peaceful purposes under international supervision.

As a first step toward achieving these goals, it was suggested that nuclear-weapons states should place their non-military nuclear facilities under international supervision and work toward a halt of their production of fissile material used for weapons fabrication. Mr. MacEachen also declared that increased international supervision of fissile material was considered by the Canadian government to be the best way to assure the international community that such material was used only for peaceful purposes. This type of system would enable the development and distribution of nuclear energy for peaceful uses.²⁴

In December, 1974, the commitment to a policy of much more stringent safeguards on peaceful uses of atomic power was officially put before the House of Commons in a

report issued by Mr. Macdonald. Declaring that the objectives of Canadian insistence on stricter safeguards was to "inhibit importing states from using nuclear supplies to further the production of nuclear explosive devices",²⁵ the then Energy Minister said that the provisions would be in effect for the life of "all nuclear facilities and equipment" supplied by Canada.

Coverage was also applied to all Canadian-supplied technology, nuclear material, (such as uranium, plutonium, thorium, and heavy water), or future generations of fissile material which will be developed from Canadian-supplied material. Finally, Macdonald stated that all nuclear materials produced or processedⁱⁿ Canadian facilities, whatever their origin, would be covered by Canadian safeguards.²⁶

Safeguards were also extended to the export of nuclear material, equipment, and technology by private concerns. Before exporters made offers to supply fissile material to a non-nuclear state, Mr. MacEachen advised them to ascertain from the Department of Industry, Trade, and Commerce and The Atomic Energy Control Board whether there were any safeguard restrictions upon the material. Most importantly, all safeguard arrangements had to contain binding assurances that nuclear material supplied by Canada, as well as all equipment and technology, would not

be used to produce a nuclear explosive device, even if the stated intention of such a device was for "peaceful" purposes.²⁷

C CANDU

The attitudes that have been expressed by the Canadian government since May, 1974, (such as increased emphasis on multi-generation* safeguards for Canadian-supplied material, fuel, and facilities, and more control over the sale of uranium by private companies), have underlined a basic conflict that exists in Canada's attitude toward atomic energy. On one hand, Canada has expressed a fear of the results of further proliferation of nuclear technology and works to eradicate this danger as much as possible through strict safeguards. On the other hand, however, Canada is eager to conclude reactor sales with Third World nations in order to make Canadian technology and expertise known, and to off-set the expense of Canadian nuclear development. The pressing concerns of the energy crisis have only added to this dilemma as many nations are searching for a cheap, efficient power source and are

* Multi-generation, as used in this sense, refers to the attachment of Canadian safeguards to second, third, fourth, etc., generation material, fuel, and facilities that have been developed from, or built with material and knowledge, originally supplied by Canada.

anxious to conclude the best deal possible, paying little heed to the political and military dangers of proliferation. The remaining chapters of this thesis, therefore, will examine the problem which faces Canada, paying special attention to the pressures of the energy crisis as outlined in the second section, and will attempt to put forward some suggestions which may aid in formulating a future plan of action.

1 Basic Principles

Any discussion of the "Canadian dilemma" would be incomplete without an outline of the operation of a CANDU reactor, and the reasons why it is attractive to less developed countries as a source of power. All nuclear reactors rely on fission for their operation. In this process the atoms of certain heavy elements, such as uranium, become unstable when they capture a neutron. The atom then breaks apart, (fission), producing two "fission product" nuclei, two or three neutrons, and a great deal of energy. The two or three neutrons that result from the original fission may then be absorbed by other fissile atoms, which, in turn, break down in the same way as the first, producing two or three neutrons to carry on the chain reaction.

When a fission reaction takes place the neutrons

that emerge travel at very high speeds. In order for a chain reaction to take place, these fission product nuclei must be slowed down to such a degree that they will react properly with the rest of the fissile material. This operation is carried out by a "moderator", a substance whose atoms collide frequently with the fission neutrons, thereby slowing them down, but which do not capture these neutrons. Once the neutrons are slowed down sufficiently, they react with the fertile uranium 238, or the fissile uranium 235, and the chain reaction continues.

A reactor which uses a moderator to slow neutrons down in this way is called a thermal reactor.* In designing such a reactor, three types of selection must be made which will determine the physical characteristics of the reactor: (1) the type of moderator to be used - either solid or liquid, (see Table 4B); (2) the type of coolant desired - the coolant is passed through the reactor core and transfers the heat produced by the fission process to a boiler to create steam. The cooling system must be very efficient in order to prevent over-heating and melting of the reactor

* Thermal in this sense refers to the speed of the neutrons. A thermal neutron is a slow speed neutron, travelling at approximately one mile per second. Since the majority of reactors use slow neutrons to carry on the chain reaction, they are termed "thermal" reactors. Those reactors that do not depend upon thermal neutrons are called "fast" reactors. (See Nuclear Power Plant Technology, J. George Willis, John Wiley & Sons Inc., New York, 1967, pp. 15-16.)

core. Furthermore, it must be inexpensive, non-corrosive, and must not absorb neutrons.²⁹ The third factor which must be taken into consideration is the form of the coolant containment. The coolant and the fuel must be within the same containment system, but the moderator can either be in this system or outside of it.³⁰ If the moderator is within the containment system, the whole reactor core is surrounded by a single large, thick-walled pressure vessel; if the moderator is outside the containment system, many small, thin-walled pressure tubes pass through the moderator.³¹

ii Operation

The basic model of a CANDU reactor, (Canadian Deuterium Uranium), is the pressurized Heavy Water, (PHW), type. This reactor design uses heavy water at atmospheric pressure as a moderator and consists fundamentally of a long, horizontal cylindrical tank. This tank, called a calandria, is filled with many horizontal tubes which are surrounded by the heavy water moderator, kept below boiling point by a special cooling circuit.³² Inside the calandria tubes are zirconium alloy pressure tubes containing the bundles of natural uranium which serve as fuel for the CANDU reactor. Each pressure tube is connected to inlet and outlet feeders and has a heavy water coolant passing through it. When it is time to refuel, machines couple onto either end of a

pressure tube and new fuel is pushed in one end by one machine while the irradiated fuel is pushed out through the other end and into the other machine. This system insures that the reactor can be re-fuelled "on load", without shutting the reactor down and losing power-generation time.

The task of a reactor in a power plant is to serve as a source of heat which will create steam and turn the turbines to produce electricity. In the case of a Pressurized Heavy Water reactor this job is fulfilled by the coolant. After passing through each zirconium alloy pressure tube, the heavy water coolant is fed through heat exchangers and pumps, which, in turn, generate steam to drive the turbines.³³

iii Variations

The Pressurized Heavy Water version of the CANDU reactor, while successful commercially, (as of December, 1972 there were 13 in operation, including two in India and one in Pakistan)³⁴, is not the only possibility for the Heavy water design. Indeed, there are certain variations of this basic model that will have the effect of reducing capital costs once they have gained wider commercial acceptance. By increasing the outlet temperature of the reactor, increasing the power density, and reducing the lattice spacing, (the "frame" around which the nuclear fuel is

arranged), an increase in thermal-to-electrical conversion efficiency is obtained, and less heavy-water is used.³⁵ However, these goals are not easily achieved as the higher outlet temperature, (337° C), can only be implemented if the operating pressure is increased to 145 kg/cm².³⁶ This increased pressure demands thicker walls for the pressure-tubes, smaller fuel divisions, and faster coolant velocity. Furthermore, the tighter lattice spacing, the greater neutron absorption in the pressure tubes, and the increased fuel subdivision raise fuelling costs, though these costs, in turn, can be minimized if the fuel is enriched with either uranium-235 or recycled plutonium.³⁷ (However, this solution negates the basic advantages of using natural uranium as fuel.)

The greatest variations in the basic CANDU model, however, are brought about by varying the coolants in the model. Because the moderator and coolant are separated by the pressure tubes, different coolants can be used in the reactors with very little change in reactor design.³⁸ One example of a variation in coolant choices is the CANDU-Boiling Light Water reactor. The Gentilly reactor in Quebec is a working example of this type. By using light, (ordinary), water as a coolant, capital costs are lowered through a reduction of heavy water in the reactor's inventory. A second advantage of a CANDU-BLW is that the light

water coolant can boil within the reactor channel, allowing steam to go directly to the turbine. (figure 4H). (When a heavy-water coolant is used the unavoidable leaks in the turbine prevent such a direct cycle.) This type of cycle eliminates a heat-exchanger, thereby reducing capital cost to a greater degree and increasing thermal efficiency.³⁹

A second variation of the heavy-water moderated CANDU, is the Organic-cooled model. This reactor type, which has been tested in the VR-1 reactor, uses an oily organic substance called terphenyl as a coolant. Terphenyls do not capture neutrons to any great degree and are stable in hot and radio-active environments.⁴⁰ Capital costs for this type of reactor are also lower than for the Pressurized Heavy Water reactor, due to the decreased amount of heavy water, but the costs of using terphenyls as a coolant are high, and a heat exchanger is still needed. On the other hand, the chemical properties of terphenyls are such that the temperature of the coolant when it comes out of the reactor is often 100°C higher than that of water, yet the pressure is much lower. These factors insure a higher thermal efficiency and a simpler coolant circuit which contributes to a lower capital cost.⁴¹ Furthermore, there is very little corrosion in an organic-cooled reactor, which cuts down appreciably on maintenance costs.

iv Fuel Cycle and Neutron Economy

The different variations of the CANDU reactor, while they give a good idea of the adaptability of the CANDU design, gain their full significance only when a complete picture of their place in the fuel cycle is given. The fundamental aspect of the CANDU fuel cycle is that it depends upon natural uranium as a source for fissile material, unlike Light Water Reactors which depend upon enriched uranium. The difficulty in using natural uranium as a fuel is that there are very few fissile atoms in the mass of natural uranium. At least one neutron from each fission reaction produced in the chain reaction must cause fission in another U-235 nucleus in order for the chain reaction to continue. Therefore, precautions must be taken against these same neutrons being absorbed by the non-fissile atoms in the bulk of natural uranium. In the light water reactor this problem is not as significant because enrichment, (increasing the proportion of fissile U-235 above the normal 0.7% found in U-238), guarantees that there are more fissile atoms in the fuel. For the CANDU reactor, however, the answer lies with the choice and handling of the moderator.

Fission neutrons, when they first appear in a chain reaction, are moving much too quickly to continue the reaction. They must be slowed down to the point where they

can interact effectively with atoms of the fissile material. This condition is reached through a series of collisions with the atoms of certain light elements, (heavy elements cannot be used as they do not absorb enough of the fission neutron's energy upon impact.) The number of collisions required to slow a fission neutron down to the speed where it can carry on a chain reaction varies with each light element, but it has been found that deuterium is the only one which best combines the virtues of low capture rate and a minimum number of collisions. (see chart below). Though hydrogen slows neutrons down with fewer collisions, it absorbs them at a very high rate, and cannot be used as a moderator with natural uranium.⁴²

Table 4B

ELEMENT	NUMBER OF NUCLEONS	NUMBER OF COLLISIONS
Hydrogen	1	18
Deuterium	2	25
Helium	4	43
Lithium	6 or 7	60
Beryllium	9	86
Boron	10 or 11	95
Carbon	12	114

(In addition, deuterium can be obtained in a concentrated form as "heavy water".) The use of "heavy water" as a moderator greatly reduces overall costs in the CANDU system, as

capture levels are so low that atoms of natural uranium can carry on the chain reaction, eliminating enrichment costs.

Since no enrichment procedure is involved, the CANDU fuel cycle is fairly simple, consisting mainly of four steps: mining and milling of the uranium, fuel preparation, (fuel element fabrication), fuel irradiation in a reactor, and spent fuel storage, which can take place on the reactor site.⁴³ The simplicity of the cycle eliminates the present high costs of enrichment facilities, (about one billion dollars per diffusion plant), and of reprocessing plants, (about \$10 to \$100 million per plant),⁴⁴ as well as reducing the danger of a rise in enrichment costs in the future. (Enrichment costs may be lowered if the centrifuge technique of diffusion becomes more available.) In the case of light water reactors, these considerations are very real as the value of the fissile material remaining in spent fuel is so high that it must be recovered. Even if the potential value of this recovered uranium and plutonium is taken into consideration, the net fuelling costs for light water reactors are double the fuelling costs of the CANDU natural uranium cycle.⁴⁵

A second benefit of using a natural uranium cycle

is that the "neutron economy" of the reactor is greatly increased. Neutron economy means that the amount of uranium burned, "expressed as the power produced per unit mass of uranium mined,"⁴⁶ is nearly double the amount for LWRs. In the CANDU's natural uranium cycle about one per cent of the uranium mined is burned; in the light water reactor about 2 per cent of the enriched uranium in the reactor is burned, which means that only about $\frac{1}{2}$ per cent of the uranium mined is burned.⁴⁷ This situation makes the enriched fuel cycle much more sensitive to any rise in the supply cost of natural uranium, as the natural fuel cycle can produce more power from a smaller amount of uranium, so there is less sensitivity to a rise in the cost of uranium.

The ability of the CANDU reactor to achieve this high degree of neutron economy will gain in importance during the last years of the twentieth century. Though Canada will not face any shortage of low-cost uranium during these years, (Canadian installed nuclear capacity is expected to be only 100,000 MW(e) by the year 2000, which will require about 15,200 tons of U_3O_8 per year, out of a currently available total of 400,000 tons "reasonably

assured resource.")*,⁴⁸ world ~~supply~~⁹ demand for low-cost uranium is expected to cause a shortage in world supplies of low-cost, high-grade ore. Installed nuclear power capacity in the United States alone is expected to reach between 260,000 and 330,000 MW(e) by 1985, which will require an annual production of 65,000 tons of uranium.⁴⁹ (compare with Lapp's estimates below) Uranium needs in other nations are also expected to be high, with cumulative demands reaching 5,200,000 tons by 1990, (exclusive of Communist Bloc nations.)⁵⁰ Such a steady rise in nuclear capacity would require greatly increased uranium supplies, but according to many authorities in the United States, such supplies may not be available. Robert Nininger, a uranium expert with the Federal Energy Research and Development Administration, (FERDA), stated: "No new major uranium producing areas or potential producing areas have been identified in this country during the past seventeen years."⁵¹, while Dr. Chauncy Starr, president of the Electric Power Research Institute in Palo Alto, California estimated that during the next 25 years the U.S. will need between four and eight times as much uranium as the present American total of proven reserves.⁵² Ralph E. Lapp in his article

* A reserve is the same as a "reasonably assured resource". It refers to uranium which can be profitably recovered with currently proven mining and processing technology. ("Uranium Resources, Production, and Demand", Bower, Haussermann, Cameron, Roberts, Peaceful Uses of Atomic Energy, Volume 8, U.N., IAEA, Vienna, 1978, p. 8).

"We May Find Ourselves Short of Uranium, Too", (Fortune, October, 1975), concurs with these opinions. Beginning with the assumption that there will be 200 nuclear plants in the U.S. by 1985, 400 by 1990, and 800 by the year 2000, Lapp has drawn up the following schedule of annual uranium oxide requirements for the United States.

1975	1980	1985	1990	2000
11,000 tons	25,000 tons	45,000 tons	68,000 tons	100,000 tons

He estimates that 1.5 million tons of U_3O_8 will be needed to fuel American nuclear plants during the next twenty-five years.⁸³

On a world scale the situation is little better as the costs of uranium production are forecast to rise due to the continuing inflationary spiral which has been in evidence during recent years. Secondly, the increased depths at which uranium deposits are found, and the larger monetary outlays needed to support these mining operations, (see chart below), will add to production costs, as will the greater public demand that mining companies protect and clean up the environment around their operations.⁸⁴

ERDA ESTIMATE OF COST FOR MORE EXPENSIVE
LOWER-GRADE URANIUM RESOURCES

Table 4c

Host Deposit	Tons of U_3O_8 (millions)	Grade (parts of U_3O_8 /million parts host material)	Forward cost per pound of U_3O_8
shale	5	60 to 80	\$100
shale	8	25 to 60	\$150
granite	8	10 to 20	\$200
shale	200	10 to 25	\$200+
granite	1800	4 to 10	\$200+
sea water	4000	0.003	\$500+

(Taken from "We May Find Ourselves Short of Uranium, Too",
Ralph E. Lapp, Fortune, October, 1975, p. 196)

In light of these rising costs, and the growing demand for low-cost uranium ore, the ability of the CANDU reactor to preserve a high level of neutron economy takes on a new importance. Besides using the uranium fuel to its utmost capacity, the CANDU reactor can also be used as a complement to the breeder reactor. The essence of the breeder reactor is that it produces more fissile material than it burns, thereby extending the reserves of uranium far into the future. In the case of the CANDU system, a small amount of fissile plutonium, (plutonium 239), is produced when uranium 238 is burnt in the reactor. Some of this plutonium is burnt in the one per cent burn-up of

natural uranium within the reactor, but the remaining grams of plutonium, found in the spent fuel,⁵⁵ are potentially valuable. This plutonium can be reprocessed and mixed with new natural uranium to be fed into a new cycle, thereby increasing uranium burn-up to two per cent.⁵⁶ If this process is continued, with the amount of uranium in each cycle remaining constant, the plutonium enrichment of each cycle is approximately three grams of fissile plutonium per kilogram of natural uranium, (i.e., 0.3% to add to the 0.7% U235). If however, the level of uranium fed into the cycle is reduced by a factor of two in each successive cycle, the required initial enrichment level of plutonium rises to about six fissile grams per kilogram of uranium,⁵⁷ if the power level remains constant. However, the amount of plutonium fed into the system between each successive cycle depends upon the burn-up, power, and final fuel composition of the previous cycle.⁵⁸ The concept is represented below.

(These cycles may take place in the same reactor, or in different reactors.)

Though the use of the plutonium from a CANDU fuel cycle will require a reprocessing plant, it has been stated by a number of authorities, (notably Atomic Energy of Canada Limited in its report number 4767, p. 15), that a reprocessing plant designed to extract only plutonium can have a simpler design, and therefore a lower cost, than one which is designed to recover both spent uranium and plutonium. A further stimulus to incorporating a plutonium recycle into the CANDU fuel cycle is that the use of fissile material with the natural uranium fuel gives the reactor designer a greater element of freedom through which he can reduce capital costs. Such an example can be found in the case of the CANDU Boiling Light Water reactor, where the use of enriched fuel, (in this case plutonium), reduces the amount of heavy-water moderator needed, thereby lowering capital costs.⁵⁹

A second potential fuel cycle which could become operative under the CANDU heavy-water system, is a fuel cycle based on thorium. There is little difference between a thorium-based fuel cycle and a plutonium-based fuel cycle except that as there is no fissile thorium to be found in nature, the cycle must be begun by using fissile

material from another source, such as a CANDU reactor using natural uranium or an enrichment plant,⁶⁰ to act as a "trigger device". Because a "trigger device" is needed, the thorium cycle is ultimately dependent upon natural uranium, but once the fertile thorium 232 is produced, the cycle no longer has need of natural uranium. Thorium 232 is the fertile material which is irradiated in the reactor to produce the fissile uranium 233.⁶¹ This material is recycled in the same manner as plutonium 239.

Though the thorium cycle does depend upon natural uranium for its initial impetus, the demand that it places upon U 238 is much less than present fuel cycles.⁶² For this reason, plus the fact that a CANDU reactor on a thorium cycle would come very close to producing more fissile material than it consumed, Atomic Energy of Canada Limited has labelled such a reactor a "near breeder" and has stated that it is complementary to fast breeder technology rather than competitive.⁶² (See figures 1, 2, 3, 4)

v Comparison with Other Systems

In any discussion of alternatives to fossil fuels, the question of economics must play a large part. The CANDU system is economical in its use of uranium resources, but for a Third World nation, or for an industrialized one in these days of inflation and shrinking dollars, capital cost considerations become of utmost importance. A second factor which must be considered is whether the reactor system chosen will be efficient enough to significantly and permanently reduce the purchasing nation's dependence upon fossil fuels. With these factors in mind, this section will compare three aspects of Light Water Reactors and CANDU reactors: capital cost per kilowatt, fuel costs per kilowatt, and overall generating costs per kilowatt-hour. An examination of building and generating costs of conventional and nuclear-power plants in Canada, compared to those of nuclear-power plants, will also be undertaken.

Before undertaking a comparison of the capital cost of CANDU and Light Water Reactors certain limitations upon the CANDU design must be noted. Because natural uranium is used as fuel in the CANDU, the reactor must be of heterogeneous design, (the fuel and the moderator must be separated from each other to minimize neutron capture by U238), and the moderator can be only heavy water or graphite,

(in order to reduce capture of valuable fission neutrons). Secondly, the critical size of a natural uranium reactor is much greater than that of an enriched uranium reactor, (200m^3 for a reactor using natural uranium, while a highly enriched reactor has a critical size of 4m^3), and the core shape of a natural uranium reactor should be spherical in order to have the minimum surface area to volume ratio, and therefore, the minimum neutron loss.⁶³ A third design constraint upon a natural uranium reactor is that construction materials must be carefully chosen so that no material which captures neutrons easily is used.⁶⁴

By contrast, the use of enriched uranium as fuel greatly reduces the design restraints for Light Water and Pressurized Water reactors. Because there is not the pre-occupation with neutron economy, the moderator and fuel may be mixed in a homogeneous design, and the critical size of the core becomes much smaller. (See above.) In addition, construction materials in LWRs may be chosen primarily for their mechanical properties rather than their low neutron capture rates, which means that alloys with high melting-points may be used in reactor construction. The higher melting-points of these alloys allow increased operating temperatures in the reactor.⁶⁵ This greater design freedom in the LWRs does lower their capital cost slightly below that of the CANDU type. Hugh C. McIntyre has

published a study in Scientific American, which states that the capital cost for the 500 MWe Pickering station was about \$365 per kilowatt of installed electric-generating capacity, (KWe), (1975 dollars), while the price of an American plant of the same size was 20% less, or about \$300 per KWe.

vi Capital Costs

In order to gain a sense of perspective when discussing the economic merits of CANDU and Light Water reactors, some thought must be given to how money is spent in a nuclear power station. The following sections will break down the costs of these stations, and attempt to show why, in the long run, the CANDU reactor is the more economical of the two systems.

Capital costs in any nuclear power station can be divided into two classes: those belonging to the Nuclear Steam Supply System, (NSSS), and those belonging to the Power Generation System, (PGS). The Nuclear Steam Supply System is comprised of the nuclear reactor which "burns" uranium to produce steam. This steam is then transferred to the PGS where it is fed into turbine-generators. It is the construction of the NSSS which raises the capital cost of a nuclear power station as elaborate equipment, highly

technical engineering, and extensive safety programs must be undertaken. Furthermore, in the case of the CANDU system, a guaranteed supply of heavy water must also be obtained.

In a CANDU reactor the NSSS consists mainly of:

(1) the core of the reactor - the calandria, end shields and tubes; (2) shield plugs, closure plugs and end fittings to provide access to reactor fuel bundles, seal fuel channels, provide shielding against radioactivity, and form the connections between fuel channels and feeder pipes;⁶⁶ (3) nuclear steam generators, which obtain heat from the heavy water coolant to generate steam; (4) reactor headers, feeder pipes, and pressure tubes, which form the connections between the steam generators and the calandria; (5) the fuelling machines and fuel handling equipment; and (6) the reactivity mechanisms which move reactivity elements in and out of the reactor core.⁶⁷ In addition to these main components there are also other mechanisms such as pumps, valves, and motors which are needed for the Nuclear Steam Supply System to function properly. The total cost for the NSSS has been estimated by the Department of Industry, Trade, and Commerce to be between \$40 and \$45 million per reactor. (1974 dollars).⁶⁸ These costs can be broken down as follows: (all estimates in 1974 dollars.)

23

OF/DE

	Calandrias End Shields Tubes	Shield plugs End fitting assemblies	Nuclear steam generators
500- 600 MW	\$4 million	\$2 to \$3 million	\$4 million
	Reactor headers Feeder pipes	Fuelling machines Fuel handling equipment	Reactivity mechanisms
500- 600 MW	\$3.5 million	(2 machines/ reactor plus spares) \$2.5 million per reactor	\$1 million
	Pumps		Instrument- ation Control Systems
500- 600 MW	\$4 million		\$5 million
	Fuel Fabrication ($\frac{1}{3}$ of cost is refined UO_2 used by fuel fabricators.)		
500- 600 MW	\$19 million	*	

*In making these estimates the Department of Industry, Trade, and Commerce assumed that: (1) no major design changes would arise which would significantly affect Canada's ability to cope with the technical needs of nuclear plants; (2) the level of demand for nuclear equipment during the next 20 years would remain at an average of four units per year for domestic requirements and one unit per year for export, and the peak annual demand would be six domestic units plus one unit for export. (The peak year would be 1983); (3) Canadian producers would be able to undertake projected expansion plans with the financial, technical, and physical resources presently available, and there will be no serious shortage of material, manpower, or offshore supplies. 69

The Power Generation System (PGS), must also be included in the capital cost of a nuclear power station. Because this unit is in a separate power house beside the NSSS building, and is isolated from the reactor by a heat exchanger, more conventional equipment and standards may be used. However, capital cost of the unit is still high, ranging from \$40 to \$45 million.⁷⁰ Major components of this section include such items as: the turbine-generator; condensers; feed water heaters and heat exchangers; pumps; valves; and miscellaneous electrical apparatus, (e.g., small motors, process control equipment, etc.). The available cost figures for this section are:

	Turbine generators	Main condensers
600 MW	\$28 million	\$2 million
	Water heaters	Pumps
600 MW	\$1 million	(no estimate)

vii Heavy Water

One of the most important factors in the capital cost of a CANDU nuclear power station is the dependence of the reactor upon heavy water, (D_2O), as a moderator and often as a coolant. Because heavy water occurs very rarely in nature it must be produced synthetically, and the

process is elaborate and expensive. W. Bennet[†] Lewis and John S. Foster have stated that for the 508 MW(e) Pickering Station, operating at 80% net capacity, the capital cost for heavy water in 1969 was \$57.00/Kg, in units one and two, and \$41.00/Kg in units three and four. In addition, there were upkeep and replacement costs totalling \$37.00/Kg. (This figure had declined by \$4.00 since 1967).⁷¹ These costs become very significant when it is realized that one ton of heavy water is needed for each additional megawatt of installed CANDU capacity.⁷²

viii Comparison with Light Water Reactors

When the cost of heavy water, the cost of equipment, interest rates, and operating and maintenance costs are considered, the capital cost per kilowatt of a CANDU reactor is about 20 per cent higher than that of a Light Water reactor. (\$365 per kilowatt for a CANDU station, and \$300 per kilowatt for a Light Water station. See above.) However, the capital costs for a CANDU station cover all construction and operating costs of the station, and, as reactor units become larger, and the price of heavy

* Heavy Water costs are approximately 15% of total capital costs. 1800 Kg - 1 MW. The cost of D₂O - \$57,000/MW or \$57.00/kw. Since the total capital cost of a 500 MW(e) CANDU station is approximately \$365.00/kw, (McIntyre), the percentage of this cost due to D₂O is 15%. (57/365)

water declines, the discrepancy in capital cost between CANDU and LWRs is forecast to decline.⁷³ Furthermore, Light Water reactors, Pressurized Water reactors, and Boiling Water reactors all use enriched uranium as fuel, and enriched fuel is now about five times as expensive as natural uranium fuel.⁷⁴ In a Pressurized Water reactor, fuel conversion and enrichment represent approximately 37 per cent of the fuel cycle cost, which makes this step in the cycle the most expensive. (see chart below)

Table 4D

PWR Fuel Cycle Cost Projection
(1,150 MW(e), 1975 start-up, 80% Capacity Factor)*

	Consumption Costs	Financing Costs	Total	Per Cent of Costs
Fabrication (@ \$70/Kg U)	0.34	0.08	0.42	20
Uranium Ore (@ \$8/lb U ₃ O ₈)	0.56	0.18	0.74	36
Conversion (@ \$2.52/KgU)	0.62	0.16	0.78	37
and Enrichment (@ \$26/Kg SWU)	taken into above costs			
Spent Fuel Shipping and Reprocessing (@ \$45/Kg U)	0.19	-0.04	0.15	7

* Notes---Consumption costs include interest during construction in the first core. Cost of money and interest during construction at 7%/yr and total fixed charge rate on non-depreciable capital at 14%/yr. The first three items include a 4% sales tax. The figures are taken from a 1970 study by the Edison Electric Institute.

	Consumption Costs	Financing Costs	Total	Per Cent of Costs
Plutonium and Uranium Credits (\$7.50/gm Pu)	-0.35	0.08	-0.27	-
Total	1.36	0.46	1.82	100

(Taken from "Overall View of the Nuclear Fuel Cycle",
Edward A. Mason, in Education and Research in the Nuclear
Fuel Cycle, Norman Oklahoma, University of Oklahoma Press,
1972, p. 7)

When the over-all cost of enrichment is taken into
consideration in the capital cost of a LWR, and compared
with the capital cost of a CANDU installation, there is a
distinct saving on the cost of power from a CANDU station.
This fact can be seen in the table below.

2200 MW(e) Estimates

Table 4E

Investment \$/Kw(e)	COAL	BWR	PWR	CANDU
Energy Cost mill/kWh	117	116	121	184
Amortization	0.90	0.89	0.93	1.42
Fuel Cost	1.69	1.25	1.39	0.60
Operation & Maintenance	0.24	0.19	0.18	0.18
Heavy Water	-	-	-	0.08
Nuclear Insurance	-	0.04	0.04	0.04
Total	2.83	2.37	2.54	2.32

(Taken from Economic Relations Between Fast and Heavy
Water Power Reactors, W. Bennett Lewis, Atomic Energy of
Canada Limited, March, 1970, AECL-3066, p. 3)

CANDUs are also very efficient uranium users, requiring only 50% to 70% of the uranium used by other reactors.⁷⁵ Furthermore, steps have now been taken by AECL to upgrade the efficiency of the natural uranium fuel by mixing it with a small amount of enriched fuel. The plan calls for $\frac{1}{2}$ a gram of plutonium 239 to be added to each kilogram of uranium. Since each kilogram of natural uranium contains 7.2 grams of U235, the "spiked" fuel will contain a total of 7.7 grams of fissionable material. Even this minor enrichment will approximately double the total power output of each CANDU fuel pellet before it must be replaced, raising the power output of the fuel from 8,000 megawatt days per ton to 15,000 megawatt days per ton.⁷⁶

ix Safety Features

A major aspect of comparison between Light Water and CANDU reactors is their respective safety features. Light Water Reactors enclose the reactor core within a pressure vessel, which means that the vessel must be very strong and heavy in order to withstand great pressure, but also reasonably compact so that it is not unmanageable.⁷⁷ If a failure occurs in the pressure vessel, the whole reactor complex is threatened.

The CANDU concept, however, uses small, separate pressure tubes. In case of failure in one of these tubes the reactor containment building can easily withstand the increased pressure until the problem is located and repaired. Also, the fuel channels are separated from each other, and surrounded by 500 Mg of cool heavy water. Under these circumstances, even a total failure of all cooling systems for an extended period of many minutes would not seriously damage the fuel as the excess heat would be transferred to the moderator and light water shield.⁷⁸

x Conventional and CANDU Power Stations

A brief comparison of economic and safety factors of the CANDU and Light Water reactors indicates that, if all aspects are taken into consideration, the CANDU system is more economical because of its more efficient use of uranium fuel and its ability to use slightly enriched fuel in order to increase its power output. The question must now be asked: "Do these factors still hold true if a CANDU installation is compared with a conventional power plant?"

The answer to this question centers upon the low cost of the nuclear fuel used in a CANDU reactor. In 1974

the replacement price for the fuel used in the Pickering station, (four 800 MW reactors), was approximately \$50/Kg of uranium. When the larger Bruce and Gentilly-2 reactors are working, the fuel replacement price will be about \$55/Kg uranium. (1974 dollars). These prices work out to a generating cost of about 0.98 mill/kwh⁷⁹ for the Pickering station.

When this cost is compared with the coal-fired station at Lamberton, Ontario, (which is a similar size to Pickering), it can be seen that Pickering generates power at less than half the cost of the coal-fired station.

Table 4F

Comparison of Electric-Power Costs and Nuclear Costs

	Pickering	Lambton 1	Lambton 2
Unit Cost			
Capital	4.60	1.70	1.70
Operation and Maintenance	1.10	.96	.96
Fueling	.98	10.60	13.32
Heavy-Water Upkeep	.35	-	-
Total Unit Energy Cost (Mills per Kilowatt Hour)	7.03	13.26	16.18

(Taken from: "Natural-Uranium Heavy-Water Reactors", Hugh C. McIntyre, Scientific American, October, 1975, Volume 233, Number 4, p. 10)

CANDU nuclear power stations will also be more economical than conventional ones in the future. W. Bennett Lewis has estimated capital, fuelling, and utilization for both conventional and nuclear stations until the year 2018. (Annual maintenance and operating costs are assumed to be about 0.3 million dollars/KWh for both types, excluding fuel.) The costs given are in 1968 dollars, though inflation has obviously increased costs for both nuclear and conventional plants.

CONVENTIONAL Table 4c

Years	Capital \$Kw	Fuelling m\$/KWh	Utilization hr/yr
1968- 2018	120	3.4	6000
1970- 1980	"	"	"
1981- 1984	"	"	"
1985- 1988	"	"	"
1989- 2018	"	"	"

(Both parts of table taken from: Prospect of Very Low Cost Power From Ontario Hydro Based on Large Capacity Nuclear Generating Stations, W. Bennett Lewis, Atomic Energy of Canada, Report #3686, August, 1970, p. 8)

NUCLEAR

Years	Capital \$/Kw	Fuelling m\$/Kwh	Utilization hr/yr
1968- 2018	-	-	-
1970- 1980	250	0.7	7000
1981-18 1984	220	0.5	
1985- 1988	180	"	"
1989- 2018	160	"	"

Though capital costs for the nuclear station are forecast to be higher than the conventional station, fuelling costs for the CANDU station lower the over-all cost of the nuclear plant to a point well below that of the conventional one. Furthermore, capital costs of the nuclear plant are expected to drop substantially which will lower nuclear costs still further.

TABLE 4A
MERIT RATING OF POTENTIAL MODERATORS

<u>Substance</u>	<u>Moderating Ratio</u>
Zirconium Hydride	49
Organic Liquids	60-90
Light Water	72
Beryllium	159
Graphite	160
Beryllium Oxide	190
Heavy Water - pure	12,000
- 99.8 atom %	2,300

Taken from: The Canadian Nuclear Power Program, A Brief to the Science Council of Canada, AECL Report 4767, 1974, p. 8.

FIGURE 1

AEC Report 4062,
page 12

BIW (Boiling Light water Reactor)

1940

1940
ON 11/11
1940

1940
ON 11/11
1940

1940
ON 11/11
1940

FIGURE 2

PLUTONIUM FUEL CYCLE, AS COULD BE USED IN A CANDU REACTOR

Taken from ALCA Report 4762, P/15

FIGURE 4
Taken From: AECL Report
4767, p. 15

ENRICHED-URANIUM FUEL CYCLE USED IN LIGHT WATER REACTORS

V SAFEGUARDS

A Importance

In the previous chapter two aspects of the "Canadian Dilemma" were described: (1) on the one hand there is a growing desire within Canada that proliferation of civilian and military nuclear power be curtailed; (2) on the other hand, there is a strong feeling that Canada has developed an efficient and economical type of nuclear reactor which presents an ideal opportunity to make Canadian expertise and technology known. The present chapter will turn its attention toward the international and legal aspects of this conflict and concentrate upon the role that safeguards, as they exist under the IAEA and the Nonproliferation Treaty, play in the debate.

1 Growing Nuclear Power

In order to evaluate the role of safeguards in the Canadian debate, it is necessary to explore the reasons why they are considered important to the international community. The answer lies in the relationship between the forecast increase in the number of civilian nuclear stations during the next years and the growing dangers of clandestine diversion of plutonium and enriched uranium for

unauthorized weapons programs. Some idea of this problem can be seen when the figures for the growth-rate of civilian nuclear power establishments are examined. Mason Willrich, in his article "Worldwide Nuclear Industry", stated that in 1971 total world nuclear power capacity was less than 20,000 megawatts, with the United States accounting for 8,000 megawatts, the United Kingdom 4,200 megawatts, the Soviet Union 1,500 megawatts, and France 1,600 megawatts. The remaining nuclear power plants were divided between Canada, The Federal Republic of Germany, India, Italy, Japan, Spain, and Switzerland.¹ (see table 5A). By 1980, Willrich forecast that the situation would undergo a vast change; 140,000 megawatts are expected to be in operation, with the major users being the United States, and the Soviet Union.² (see table 5A). The year 1990 will see the total of installed civilian nuclear power capacity jump to 578,000 megawatts, and by the year 2000 the world total will be approximately 1,480 thousand megawatts.³ (see table 5B).

11 Uranium

Most of the reactors which will be used to satisfy the increasing demand for nuclear power will use uranium which has been enriched to between two and five per cent

U235. At the present time the enrichment process is expensive and complicated and most countries using enriched uranium reactors depend upon the United States or another nation with well-developed technology in this field to supply them with the needed fuel. However, as enrichment technology develops and becomes less expensive, it will come more within the grasp of less developed nations and the dangers of clandestine enrichment programs will increase.

Enrichment requirements for weapons-grade uranium are high: approximately 90 per cent U235 for an efficient explosion, though lower enrichment levels will yield a lower performance explosive.⁴ Even though all present diffusion plants were designed for weapons enrichment, the ability of these plants to reach even higher enrichment levels is increasing. As the breeder reactor and the thorium cycle become more common in future reactor technology, "upper stages" will be added to present diffusion plants in order to produce a higher level of enrichment.⁵ This highly-enriched uranium will be intended for power reactors, but can very easily be used for

* Thorium 232 will, upon capture of a neutron, convert into uranium 233, which is also a fissionable material. However, U235 or plutonium must be used to start the thorium cycle. U235 is preferred. (Taken from "Worldwide Nuclear Industry", Mason Willrich, pp. 47-48.)

weapons production. Nations will find it easier to produce efficient nuclear weapons under the guise of peaceful activities.

The second danger of advancing enrichment technology is the increased use of small centrifuge plants to raise the percentage of U235 in natural uranium. Diffusion plants are large and require a great deal of electricity in order to function, and are therefore difficult to hide. The centrifuge method of enrichment, however, enables plants to be constructed in relatively remote areas, making diversion of enriched uranium difficult to detect and halt.⁶

iii Plutonium

The problem of control of nuclear material becomes even more acute when the production of plutonium is discussed. As uranium burns in a reactor, it produces plutonium, which if removed from the reactor after a short irradiation time, is rich in the 239 isotope and is capable of producing high-grade, efficient nuclear weapons material. If the irradiation time of the plutonium is longer, however, the form of the isotope changes, (into Pu-240), and becomes less capable of producing efficient nuclear weapons material. Pu-240 is less stable than Pu-239 and fissions in a spontaneous manner, which can lead to "predetonation" of a nuclear weapon, reducing its reliability and efficiency.⁷ If a non-nuclear-weapon

state ~~was~~^{were} interested in producing plutonium from a power reactor, the fuel would have to be changed frequently in order to avoid the formation of plutonium-240.

In the case of an enriched uranium reactor, any attempt to divert plutonium from a power reactor into an illegal nuclear weapons program would be easily noticed by the international community. Because Pu-239 must be removed quickly from the reactor before it forms Pu-240, the enriched uranium reactor must be shut down frequently, as there is no on-power fuelling technique for this type of reactor. In addition, chemical reprocessing plants and fuel fabrication plants would have to be enlarged in order that more frequent fuel processing could take place.⁸

(This statement is especially true if the state is building a large nuclear-weapons force.) The operation would involve a great deal of expense and technical demand and would be easily noticed by other nations. Suspicion as to the intent of such a program would be quickly aroused, especially if the nation undertaking these alterations was a non-nuclear-weapons state.

The situation with a natural uranium reactor, or a slightly-enriched uranium reactor, is much more serious, however. The amount of plutonium produced by a natural uranium reactor is about double the amount produced in an

enriched-uranium reactor, and there is a much greater concentration of plutonium-239 in this plutonium. Roughly, one kilogram of plutonium can be produced each year for every three to five megawatts of power in an enriched uranium reactor, while one kilogram of plutonium is produced each year for every two or three megawatts of power in a natural uranium reactor. Of the plutonium produced in a natural uranium reactor, or a slightly enriched reactor, 70 to 80 per cent is plutonium-239, and plutonium-241, while 20 to 30 per cent is Pu-240.⁹ Furthermore, a natural uranium reactor, such as the CANDU, in which the fuel can be loaded and unloaded without shutting the reactor down, allows the plutonium to be removed economically more often than does the enriched reactor, thus decreasing the amount of Pu-240 in the irradiated fuel. (However, some opinion is held that the CANDU fuelling system cannot be operated fast enough to remove the early plutonium.)¹⁰ Since a natural uranium cycle does not require a costly enrichment process, a nation with a small civilian nuclear power program can obtain weapons-grade plutonium with very little notice to the outside world that it has done so. These dangers are growing every year as more and more non-nuclear-weapons states obtain a civilian nuclear power capacity and add to the world's plutonium production capacity. (see table 5C).

iv Increasing Instability

The dangers of an unchecked growth of uranium and plutonium stockpiles are obvious to anyone who takes the time to examine the question. The "nuclear club" has grown from one to six during the last thirty years, while the world is still a long way from any effective way of controlling international disputes. The nuclear arms race between the U.S.S.R. and the United States shows very little sign of ending, while friction in such areas as the Middle East and Africa push smaller nations to the brink of war and sometimes over it. In such an atmosphere, the fact that a nation knows it has the capability to "go nuclear" may encourage it to do so in an effort to protect its sovereignty, or prestige, or to prepare for any future military confrontation.

This increasing trend toward nuclear proliferation through the spread of civilian nuclear capability, not only makes the outbreak of nuclear war more likely, (though some Indian strategists might disagree with this opinion), but also makes its effects more dangerous. No longer will a war be confined to a certain geographical area if nuclear weapons are used, but the prevailing winds may blow the resultant fallout over areas which were totally uninvolved.

B Brief History of Safeguards

The attempt to promote international security by regulating the development and spread of nuclear technology has often been hampered in the past by the concept of security as primarily a national concept. The fundamental objective of safeguards on nuclear technology is to increase the security of each state party to the system, with complete nuclear security being achieved when every state is a signatory to the agreement. Over the years, however, differing national views as to what constituted "security" have presented obstacles to the implementation of a safeguards system. The following section will attempt to present a short history of the development of safeguards, highlighting the friction caused by the differing concepts of "security", while later sections will show that, in official thinking at least, these concepts still raise questions in some nations as to the effectiveness of the NPT.

1 Early Years

Soon after the beginning of the nuclear era, the West expressed the desire to formulate a plan whereby nuclear material given by one state to another would be guaranteed to be used only for peaceful purposes. In

November, 1945, the United States, Canada, and Britain issued the "Three Nation Agreed Declaration" which first used the term "safeguards" in conjunction with nuclear development and technology. The term was given more concrete form in January, 1946, when the United Nations General Assembly adopted the Resolution on Atomic Energy which established the United Nations Atomic Energy Commission. Part of the declaration's text stated that the UNAEBC "shall make specific proposals...for control of atomic energy to the extent necessary to ensure its use only for peaceful purposes;...for effective safeguards by way of inspection and other means to protect complying States against the hazards of violations and evasions."¹¹

Though the Soviet Union supported the formation of the United Nations Atomic Energy Commission, and had even been a co-sponsor of the resolution setting up the organization, when it became clear that some degree of national sovereignty would have to be sacrificed to implement the recommendations, the U.S.S.R. became suspicious of Western intentions. At this time the United States was the only nation with a large civilian and weapons technology, and this fact was viewed as a great threat to national and economic security by the U.S.S.R. Accordingly, when the Baruch Plan for the international control of atomic energy was put forward by the United States in June, 1946, the

Soviet Union rejected it completely. The plan suggested total international control over the development of atomic energy, and a system of complete accountability for all nuclear material, which would not only detect the illegal diversion of this material, but would also be able to prevent this diversion. In addition, all major nuclear installations would be under international control.¹²

The U.S.S.R. responded to the proposal in very strong terms. Soviet representatives at the United Nations stated: "The Soviet Union does not intend to make the fate of its national economy dependent on U.S. financiers, industrialists, and their underlings, who seek to bind other countries and in particular the Soviet Union hand and foot."¹³ The Soviet position was that any move toward international control of atomic energy had to be accompanied by the total halt of the "production and employment" of atomic weapons with the destruction of all nuclear stockpiles as the first step. Since the United States was the only nuclear power at that time, what the Soviet Union was advocating amounted to virtual American^{nuclear} disarmament.¹⁴

11 1953 - 1957

This proposal was, of course, completely unacceptable to the United States given its supreme distrust of Soviet actions and motives. The debate between these

nations supporting control of nuclear energy through international means and those who advocated national approaches to the problem continued throughout the 1940's and early 1950's. By 1949, however, it became evident that prevention of nuclear proliferation through an international monopoly was a fading dream. In that year the U.S.S.R. detonated its first nuclear device and the United States was deeply involved in busily adding to its own nuclear stockpile. The hope of international control receded even further in 1952 when Britain also detonated a nuclear device. The United States, even so, decided to try once more to bring nuclear proliferation under international control; this time, however, control over nuclear development was to be vested in an International Atomic Energy Agency instead of the monopolistic "international control" dependent upon American support. Speaking before the U.N. General Assembly on December 8, 1953, President Eisenhower drew attention to the magnitude of the nuclear arms race and proposed that the United States, the Soviet Union, and other nations that had begun to develop a nuclear weapon's industry "begin now and continue to make joint contributions from their stockpiles of normal uranium and fissionable materials to an International Atomic Energy Agency.... The proposal has the great virtue that it can be undertaken without the irritations and mutual suspicions incident to

any attempt to set up a completely acceptable system of world-wide inspection and control."¹⁵ The Atoms for Peace proposal also suggested that the International Atomic Energy Agency be responsible for storage and safekeeping of the nuclear material contributed and that it be the undertaking of the Agency to devise methods whereby fissionable material could be distributed for peaceful purposes and "to provide abundant electrical energy to the power-starved areas of the world."¹⁶

In suggesting the Atoms for Peace plan in December, 1953, Eisenhower had laid the groundwork for the system of safeguards later developed by the International Atomic Energy Agency. Though no plan for international inspection and control had to be negotiated before the proposal could be put into operation, there was the basic outline of the Agency's right to carry out safeguards and to verify the type and amount of nuclear material allotted to states.¹⁷ However, one fatal flaw in the plan was that Eisenhower had committed the United States to a scheme of allowing the world-wide distribution of fissionable nuclear material before an acceptable system of arms control was implemented.¹⁸ This weakness was seized upon by the Soviet Union and used as an excuse for the rejection of the Atoms for Peace proposal. The plan was stated to be incapable of reducing the danger of nuclear war, and served merely

"to relax the vigilance of the peoples against the dangers of nuclear weapons."

Soviet fears and unwillingness to participate in the Atoms for Peace proposal did not stop the United States from persuading other states involved in the production of nuclear energy to undertake the formation of the IAEA. American policy was directed chiefly at reducing Soviet fears of American domination of any international agency and to bringing the Soviet Union into the discussions. Basically three compromises were made to ensure success in this endeavour: (1) control in both the IAEA organization itself, and in the operation of safeguards, was put into the hands of those states "most advanced" in nuclear energy; (2) specific safeguards were enumerated in the IAEA Statute and it was considered that those states applying for IAEA assistance would have to submit to these safeguards. It was also stated that the Statute's safeguards provisions would have to be further developed so that a more adequate system could be formulated;* (3) The

* No effort was made to develop a more intricate safeguards plan at this point because time was limited and the negotiating team's manpower resources were low. Secondly, it was felt that a concerted attempt to formulate a strong safeguards plan would give the Soviet Union a strong propaganda advantage in nations such as India where the whole idea of safeguards was unpopular. (B. G. Hochhoefer, "Historical Evolution of International Safeguards", p. 29)

United States also made some of the safeguards' wording and provisions close to a proposal put forward by the U.S.S.R. in June, 19⁴⁷ as an alternative to the Baruch Plan. In wording the early safeguards in this manner, the question of forcible sanctions was left up to the United Nations, or "a group of states". There was no effort to create an international control organization which would be able "not only to detect violations, but also to prevent and correct them."¹⁹ On October 1, 1955, the U.S.S.R. agreed that "the draft statute with certain amendments could be used as a basis for drawing up the IAEA Charter."²⁰

C IAEA Safeguards and the NPT

1 Early Problems

The Statute of the International Atomic Energy Agency was opened for signature on October 20, 1956. Two articles provided the basis of the safeguards function: the first, Article II, required the Agency to "ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose."²¹ Article III gave the IAEA authority to establish and administer three types of safeguards: (1) those pertaining

to assistance provided by the Agency or at its request,
under its supervision or control; (2) those instituted
at the request of parties to any bilateral or multilateral
agreement; (3) those enforced, at the request of a state,
on any nuclear activity of that state.²² In addition,
article XI, paragraph 4, required that any non-military
nuclear project undertaken with IAEA assistance must not
use such assistance to further any military purpose and
that the project must be subject to Agency safeguards.²³

As the nuclear era progressed, the circumstances
which had given rise to the formation of the IAEA began to
be superseded by a new set of situations. The use of,
and research into, the development of civilian nuclear
power became much more common in non-nuclear-weapons
states as well as nuclear-weapons states. Non-nuclear-
weapons states began to take the attitude that, since both
"categories" of nations, (nuclear and non-nuclear), had
done much to develop the peaceful uses of atomic energy,
it was not just that nuclear-weapons states should have
control over the civilian as well as the military areas
of nuclear energy. In the early years of the 1960's it
became clear to most nations that a well-developed civilian
nuclear technology would aid and stimulate other types of
industrial development. This attitude was especially

evident in nations such as India which felt that a leading position in military nuclear technology was not synonymous with one in civilian nuclear technology. It was said that fear of the dissemination of nuclear weapons should not be used to restrict non-nuclear-weapons states from developing their nuclear technology for peaceful purposes.

24

The greater concern with technology also gave rise to questions about the relationship between different safeguards systems. The uncertainty was clearly evident in the debate over the relationship between Euratom and IAEA safeguards. In the original draft of Article III of the IAEA Statute, IAEA safeguards, or the equivalent, were required to regulate nuclear material. Those nations belonging to Euratom insisted that their safeguard system be considered equivalent to the IAEA system, since it was more comprehensive and established than the Agency scheme. The U.S.S.R. rejected this proposal on the grounds that all the Euratom countries were also members of NATO and that any attempt to make Euratom safeguards equivalent to IAEA safeguards, would be the same as granting a free hand to unrestrained nuclear development within NATO.

The substance of these, and many smaller questions, was examined by a group of consultants who met from

October, 1968 to August, 1969. The consultants established a committee to advise the Board of Directors of the IAEA as to the Agency's safeguard responsibilities under the NPT and to the content of the safeguard agreements formulated under the Treaty. ²⁵ All those states that were members of the IAEA were invited to put forward their ideas of the effects of the NPT on the Agency's safeguard activities, and these views were circulated among the members, together with some comments by the Director General. The committee then met from June 12, 1970 to March 19, 1971 and brought down a series of recommendations to serve as a basis of NPT safeguards agreements. Included in these recommendations was a complete safeguard plan, which was designed to facilitate the application of IAEA safeguards under the new conditions of the NPT. This document, (INFCIRC/153), became the foundation of the present NPT safeguards system in 1971. Its official title is "The Structure and Content of Agreements between the Agency and the States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons", but it is more simply known as the "Negotiating Instructions", or the "Blue Book".

11 IAEA-NPT Safeguards

The Nonproliferation Treaty, as it operates at the present time, has no safeguard system of its own. It uses, instead, the safeguard system of the IAEA, but considerably broadens the concept of this plan. Whereas the IAEA Statute does not demand that an Agency member submit to safeguards, (except if the state requests and receives nuclear aid from the Agency, or through it), the NPT insists that all non-nuclear-weapon states Party to the Treaty begin the negotiation of safeguard agreements with the Agency within 180 days of entry into force of the Treaty, (or no later than upon ratification of the Treaty), and to conclude these negotiations within 18 months of their start. ²⁶ The NPT also forbids any Party to supply certain types of nuclear material for peaceful or weapons purposes to any ^{non-nuclear} state, unless the material is subject to IAEA safeguards. In addition, nuclear-weapon states cannot aid non-nuclear-weapon states to obtain nuclear weapons or explosive devices, nor can non-nuclear-weapon signatory states manufacture these articles on ²⁷ their own, even for peaceful purposes. However, the safeguards established in a signatory state must not hamper peaceful nuclear research and development in non-nuclear-weapon states, nor must they inhibit the economic

and/or technical development of the nation.

In contrast to the tight controls of the NPT, the Statute does not require that any member of the Agency submit to safeguards, unless the member state requests, and receives, nuclear assistance from or through the Agency. Furthermore, member states are not committed to make their transfers of nuclear material or nuclear assistance to other nations subject to IAEA controls²⁹, although parties to such bilateral or multilateral agreements can request that IAEA safeguards be applied.

iii Operation of Safeguards under the NPT

The objective of the safeguard clauses in the Nonproliferation Treaty is "the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection."³⁰ The main instrument for detecting illegal diversion is the IAEA, through its organization of inspectors. If illegal diversion is detected, the IAEA then alerts the world community that diversion has taken place. The IAEA does not have the power to punish offenders; such action is left to the

"proper United Nations organs", though how this punishment is to take place is not specified.

The NPT has given the IAEA the responsibility of controlling all "source" and "special fissionable" material in the signatory non-nuclear-weapon states, except for that material used in legitimate military activities. (Legitimate military activities are those which do not involve "nuclear explosive devices". The development of nuclear-powered submarines could be included in this category.) Since "source" and "special fissionable" material are not defined in the NPT itself, their definitions must be taken from the IAEA Statute: "Special fissionable" material includes plutonium-239 and uranium which has a higher ratio of the fissionable isotopes U-233 and U-235 than ordinarily occurs in natural uranium. The term "source material" includes all other uranium, (either natural or depleted), and thorium which is in the form of metal, alloy, chemical compounds, or concentrates.

In carrying out its responsibilities under the NPT, the IAEA depends upon a system of national as well as international controls to audit the flow of nuclear material through the fuel cycle. The NPT requires that each signatory non-nuclear-weapon state "establish and maintain a system of accounting for and control of all nuclear

material subject to safeguards." In addition, the NPT safeguards clauses specify certain procedures to be followed by the national systems so that they fit easily into the controls that are under the jurisdiction of the IAEA. Though the responsibility to account for all nuclear material used in nuclear projects does not apply to the civilian nuclear programmes of nuclear-weapon states, both the United States and the U.K. have placed certain of their non-military programmes under NPT safeguards, as a gesture of good faith.

The method of control of nuclear material depends upon the delineation of "material balance areas" within each nation. These material balance areas may be of varying sizes, ranging from a part of one nuclear facility to an area composed of two or three facilities. When the state first submits its facilities to international controls, an inventory of all nuclear material in each material balance area, (MBA), is made, recorded, and verified. After this process has been carried out it is the duty of the national government to keep an accurate and up-to-date record of every change in the quantity, type, and form of nuclear material in each MBA which passes through the fuel cycle. All transactions must be recorded whether they result from the transfer of material from one area or

country to another, the production of new nuclear material, the transformation of existing nuclear material, or from the consumption or loss of old material.

The procedure of measuring the flow of nuclear materials in the fuel cycle takes place at certain strategic points defined by the IAEA as "...a location selected during examination of design information where, under normal conditions and when combined with the information from all 'strategic points' taken together, the information necessary and sufficient for the implementation of safeguards measures is obtained and verified; a 'strategic point' may include any location where key measurements related to material balance accountancy are made and where containment and surveillance measures are executed."

As can be seen from the definition of a strategic point, containment and surveillance measures make up two very important aspects of the safeguards function. In order to verify that the national accounting system for each MRA is correct and accurate, the NPT requires that the IAEA prepare and submit a statement "in respect of each material balance area, of the amount of material unaccounted for over a specific period, giving the limits of accuracy of the amounts stated." This verification must be carried out through "the use of instruments and

other techniques" applied at strategic points. This "use of instruments and other techniques" for verification is known as surveillance measures.

Containment measures, which were originally envisioned as physical storage of nuclear material by the IAEA, do not, under the NPT, refer to the actual protection of nuclear material but to a "means of defining material balance areas for accounting purposes".³⁶ With this limitation in mind, nuclear material, after it has been through the inventory process, is stored in a container under the supervision of Agency inspectors and a seal is placed on the container. In this way, as long as the seal is not broken, (as ascertained by periodic inspections), the IAEA is aware of the location of all nuclear material under its jurisdiction. If some of the material must be removed, the Agency is notified and an inspector is sent to be present when the seal is broken.

D Commitments of Nuclear-Weapons States under the NPT

Besides requiring that safeguards be applied to the peaceful aspects of nuclear technology in non-nuclear-weapons states, and prohibiting the transfer of nuclear weapons or explosive devices to any state, the Nonproliferation Treaty names two obligations that the nuclear-

weapons nations have toward the non-nuclear-weapons states. The first of these obligations is described in Article V and is a commitment that, "... under appropriate international observation and through appropriate international procedures, potential benefits from any peaceful applications of nuclear explosions will be made available to non-nuclear-weapon States Party to the Treaty on a non-discriminatory basis and that the charge to such Parties for the explosive devices used will be as low as possible and exclude any charge for research and development." ³⁶ This technology and material must only be used for peaceful purposes and must be subject to observation by "an appropriate international body with adequate representation of non-nuclear-weapon States." However, most nuclear-weapons states, especially the United States, feel that PNE's are not practical and that any benefits from them would be marginal at best. Therefore, there is little enthusiasm to support these programmes in non-nuclear and Third World countries.

Article IV of the Treaty outlines another facet of the obligation to aid non-nuclear powers with the benefits of peaceful nuclear explosions. Each Party to the Treaty has an "inalienable right ... to develop research, production and use of nuclear energy for peaceful purposes

without discrimination and in conformity with Articles I
37
and II of this Treaty." (those which forbid the transfer of nuclear devices to non-nuclear-weapon states). In addition, the second paragraph of this article states that "Parties to the Treaty in a position to do so shall also co-operate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration of the needs of the developing areas of the
38
world."

The second obligation that the nuclear-weapon states have toward the non-nuclear-weapon states is "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control."
39
It is the failure of the nuclear-weapon states to fulfill these two obligations, to make available the material and opportunity for the peaceful nuclear development of non-nuclear weapon states, and the obligation to negotiate an end to the nuclear arms race, that have caused disillusionment and fears of bad faith in non-nuclear-weapon states.

E Suspensions of the Non-nuclear-weapons States

Though most states support the spirit and idea of the Nonproliferation Treaty, namely that, in order to reduce world tension and increase the level of trust among states, some means must be found of regulating the development of nuclear power, many nations do not agree with the duties and obligations laid out in the NPT. Most of these objections center around the subjects of possible commercial restrictions if the Treaty were signed and the possibility that military security would be endangered if NPT obligations were accepted. With these considerations in mind, the objections of four nations have been chosen for study; three of these nations have not signed the Nonproliferation Treaty, and the fourth, Japan, has signed, but not ratified. It must be emphasized that the objections laid out below are the official statements of each nation. No major effort has been made to pass a value judgement on these statements, but a few comments have been included where it was felt that official statements and actions diverge.

India, as is well-known, has had an active nuclear industry since the beginning of the post-World War II era. Though the country has required aid from Canada, the United States, and Britain, India has built up a core of well-trained nuclear scientists and is developing her substantial reserves of uranium and thorium. This active nuclear industry, however, was not considered by the Indian government during the 1950's and 1960's to be the first step towards formation of a nuclear weapons capability. In fact, India was very vocal in her denunciation of nuclear weapons and gave very strong support to attempts to limit further proliferation. In 1968 the Indian government put forward five points which it considered necessary to a non-proliferation program:

- (1) An undertaking by the nuclear Powers not to transfer nuclear weapons or nuclear weapons technology to others;
- (2) An undertaking not to use nuclear weapons against countries who did not possess them;
- (3) An undertaking through the United Nations to safeguard the security of countries which may be threatened by Powers having a nuclear weapons capability or embarking on a nuclear weapons capability;
- (4) Tangible progress towards disarmament, including a comprehensive test ban treaty, a complete freeze on production of nuclear

weapons and means of delivery as well as a substantial reduction in the existing stocks;

(5) An undertaking by non-nuclear Powers not to acquire or manufacture nuclear weapons. 40

In addition to the above points, India was largely responsible for the drafting and presentation to the United Nations General Assembly of the "Principles of Nonproliferation", (Resolution Number 2028), which was put forward in November, 1968:

(1) The treaty should be void of any loop-holes which might permit nuclear or non-nuclear Powers to proliferate, directly or indirectly, nuclear weapons in any form;

(2) The treaty should embody an acceptable balance of mutual responsibilities and obligations to the nuclear and non-nuclear Powers;

(3) The treaty should be a step towards the achievement of general and complete disarmament and, more particularly, nuclear disarmament;

(4) There should be acceptable and workable provisions to ensure the effectiveness of the treaty;

(5) Nothing in the treaty should adversely affect the right of any group of States to conclude regional treaties in order to ensure the total absence of nuclear weapons in their respective territories. 41

When the Nonproliferation Treaty was opened for signature in 1968, however, India refused to add her name to the list of those willing to abide by the document. In

a speech before the Lok Sabha, (lower parliamentary house), in 1969 Prime Minister Gandhi stated that the draft was not acceptable because "it does not fully conform to the principles [of Resolution 2028] enunciated in the General Assembly."⁴² * Three major areas of criticism are officially levelled at the NPT by New Delhi: (1) there is an imbalance of obligations between the nuclear-weapon powers and the non-nuclear-weapon countries; (2) the security guarantees are considered to be inadequate; and (3) there are discriminatory aspects of the development of peaceful nuclear explosives.

In the first case India feels that the NPT has imposed upon the non-nuclear-weapon states the obligation not to accept nuclear weapons, but has done very little, if anything to halt the manufacture, stockpiling, and production of these weapons by the Superpowers. In order to halt horizontal proliferation, (a term first used by Trivedi, the Indian representative at the ENDC), India feels that the Superpowers must halt their vertical proliferation of nuclear weapons by adhering to a comprehensive nuclear test ban treaty, instituting a "cut-off" of production of nuclear weapons material, and reducing

* The credibility of this statement comes into question when the Indian "explosion" of May, 1974 is considered.

the number of their nuclear armaments. The Strategic Arms Limitation Talks, in India's opinion, have done very little to fulfill these requirements or the obligations undertaken by the nuclear-weapons powers in Article VI of the NPT. Five shortcomings of the SALT Agreements have been listed by the Indian government.

(1) The treaty does not ensure the non-proliferation of nuclear warheads, in fact, there is a significant competition between the United States and the Soviet Union to add to their nuclear weapons stockpiles. The agreements do not limit R & D which is designed to increase the sophistication and accuracy of nuclear warheads.

(2) The SALT Agreements confer special status on the U.S.A. and the Soviet Union. The talks were conducted exclusively between the two nuclear Superpowers, thereby underlining their special status as possessors of vast nuclear arsenals. This situation, when taken in combination with the fact that the NPT, already conferred special status on the five nuclear-weapons states, is completely unacceptable.

(3) SALT did not achieve a promise by the U.S. and U.S.S.R. to enter into a "no first strike" agreement. They have not, therefore, accepted obligations and responsibilities equal to their power.

(4) SALT has not instituted an approach to nuclear

disarmament since the direction of the arms race has not been reversed.

(5) The NPT has been designed to last for 25 years, which indicates that the nuclear powers were interested in preserving their pre-eminence over the non-nuclear powers for as long as possible. The limited duration of the SALT Agreements, however, shows the basic distrust existing between the Superpowers.

These criticisms of the Nonproliferation Treaty and the SALT Accords gain even more impact when seen against India's distrust of the security aspects of the NPT. On May 14, 1968 Ambassador Mohammed Azim Hussain of India stated at the 57th meeting of the First Committee of the United Nations that the security assurances of the nuclear states to the non-nuclear-weapons states could not be a quid pro quo for acceptance of the NPT. Security assurances must be given by the nuclear-weapons states to non-nuclear-weapon states whether the NPT existed or not. The reasoning behind this statement is a suspicion of the intentions and power of Communist China. Since the Sino-Indian dispute of 1962 many Indians feel that, if India possessed a nuclear device, she would be in a stronger position in any future altercation with China. If China threatened to use her nuclear potential against

Indian cities, India could counter the threat by making it clear from the start that any Sino-Indian conflict could easily become nuclear.⁴⁶

Though India does not at present have the delivery capability to make this course of action totally credible, events since 1967-1968 have made it more attractive. In 1967 India demanded a security guarantee from the United States and the Soviet Union as a precondition for renouncing nuclear weapons. In April of that year the Indian Foreign Minister, M. C. Chagla, asked for a joint guarantee from the United States and the Soviet Union against nuclear attack or blackmail. (Although the idea was not openly expressed, the guarantee was supposedly directed against China.)⁴⁷ However, at this time neither the Soviet Union nor the United States was willing to give guarantees, the latter because of Johnson's "bridge building" campaign, and the Soviet Union because it did not want to aggravate the already precarious position of Chinese-Soviet relations. Furthermore, the losses in Vietnam had made the U.S. unwilling to accept new commitments in Asia.⁴⁸ When the United States, the Soviet Union, and Britain offered, in the spring of 1968, to put before the Security Council any instances of aggression against non-nuclear signatories of the NPT, India refused the offer

on the grounds that any Security Council action would be ignored by Communist China, or perhaps vetoed by France.⁴⁹ Furthermore, in the Indian view, the fact that the offer was made indicated an implicit discrimination between non-nuclear-weapon states who were signatories of the NPT, and those who were not. Finally, it seemed to India that security guarantees and acceptance of the NPT were unrelated, and therefore a security guarantee could not be made a carrot for the Treaty's signature. The idea was expressed clearly by the Indian representative to the Security Council in June, 1968:

It is in the interest of the international community that non-nuclear-weapon States are encouraged to remain in that category. This can be done only by ensuring the security of all non-nuclear-weapon States in conformity with the Charter, regardless of whether or not they sign the nonproliferation treaty. 50

A final major criticism that India holds against the Nonproliferation Treaty is that it discriminates against those states wishing to undertake a program of peaceful nuclear explosions. Though the government has not begun a comprehensive program using PNE's, India does not want to renounce the right of PNE's altogether. The opinion is that no ban should be placed upon the development, application, and use of nuclear energy for truly peaceful purposes, and that science and technology should

be fully available to all nations without discrimination. The NPT, in the Indian view, does not fulfill these aims. In March, 1970 the Indian Defence Minister stated:

"... Also, even in the development of nuclear energy for peaceful purposes, it [the NPT] puts constraints and restraints which are totally unacceptable to us. For all these reasons, we have taken the attitude that we will not sign it."

52

The arguments of the Indian government before 1974 hid, in many ways, the efforts of a powerful rightist faction within the country to equip India with a nuclear weapons option. Since May, 1974, however, the fact that the Indian government has not rejected the option has become much more evident, casting suspicion upon the stance that India has traditionally taken. Furthermore, the long duration of the Sino-Indian security problem does little to assure other nations that India has no intentions of developing a weapons industry, although whether or not India can successfully develop a delivery capability to go with the weapons industry is still in doubt.

The touchy issue of peaceful nuclear explosions has also played a major role in the Brazilian government's decision not to sign the Nonproliferation Treaty. To the government, the NPT has put too many restrictions on the development of nuclear technology for peaceful purposes. Because it is a developing country, Brazil's leaders are fearful that signature of the NPT would result in the country being too dependent upon the nuclear powers for development aid.⁵³ Since peaceful nuclear explosions are permitted under the Treaty of Tlatelolco, Brazil advocates that they should be permitted under the NPT, especially since the government expects PNE's to be helpful in redirecting rivers and building canals.* Brazil sees a connection between PNE's and industrial-economic development, and feels that to give up the first would retard the second.⁵⁴

A second aspect of Brazil's fear of economic discrimination in the NPT is uncertainty of the position of the

* As stated before, the use of PNE's as efficient instruments of economic-industrial development has all but been completely rejected by developed nuclear nations. Therefore, Brazil's constant emphasis of their value is suspect. Brazil is probably more interested in developing her nuclear industry to the point where it can easily be put on a weapon's footing if an advantageous opportunity presented itself. This supposition gains support when it is remembered that Brazil is led by a military government, which is convinced of the country's future as a great power.

Brazilian nuclear program if the Treaty is signed. At present, Brazil has a small nuclear program* which it hopes will aid the country's future economic development and which will entice Brazilian nuclear scientists to stay in the country. 55 Brazil has stated that it will not use this program to develop nuclear weapons, but it will not renounce the benefits of peaceful nuclear technology.

At the same time, Brazil explains that it is not satisfied that the security assurances given to non-nuclear signatories of the NPT are not respectful of the sovereign equality of United Nations member states. Such security assurances are discriminatory as they do not cover non-nuclear-weapons states which have not signed the Treaty or which have withdrawn from it. Brazil states that the nuclear-weapons nations must disarm under the Nonproliferation Treaty and that a significant portion of the assets freed by nuclear disarmament should be devoted to economic development in LDC's. This program should 56 take place under the auspices of the United Nations. Brazil's attitude was stated in 1971 by the Brazilian Ambassador in Stockholm:

The Brazilian attitude of strong opposition to the Treaty has not changed. Brazil considers the Treaty incompatible with the interests of her economic development and her national security. The restrictions that the Treaty imposes on the development

* This statement was true in 1973, but since the German-Brazilian agreement of 1974 Brazil's nuclear programme has expanded greatly and is no longer small.

of nuclear technology for peaceful purposes by the military "non-nuclear" countries are unacceptable. The Treaty does not provide any guarantee for the security of the non-nuclear countries against an attack or a threat of aggression with nuclear weapons, nor does it create any kind of actual engagement, on the part of the nuclear powers, that they will proceed to their own partial or total disarmament. To sum up, the Treaty does not establish an acceptable balance between the rights and obligations of nuclear and non-nuclear countries.

While commercial and technological considerations are the main reasons why Brazil has refused signature of the NPT, security concerns are the main reasons for Israel's rejection. Since the establishment of a Jewish State in the Middle East in 1948, Israel has managed to defeat the Arab States four times, (1948, 1956, 1967, and 1973), but there is an ever-present fear in the Government that, if the Arab Nations were to solve their unity problem and act in a concerted manner, sheer force of numbers could outweigh any advantage Israel now holds (The possibility of united Arab action would be even greater if the Arab States came under the influence of a charismatic leader.) At present, Israeli conventional

forces are efficient, well-equipped, and technologically superior to those of the Arab nations, but Israel has a length of border disproportionate to her size which leaves the major population and industrial centers close to Arab territory. This fact means that there is the constant danger that an Arab attack could destroy not only Israel's industrial and communications centers, airfields, and military bases, but her major cities and cultural centers as well.

Apart from these strains and tensions brought on by living with the Arab threat, Israel must be constantly aware of the influence of the Superpowers. The most obvious example of this influence has been the "behind-the-scenes" support of the Arab cause by the Soviet Union and the Israeli cause by the Americans in 1967 and 1973. Secondly, Israeli unwillingness to disclose the extent of the country's nuclear power program, and the constant danger that a war in the area will erupt, has induced the American Government to supply Israel with conventional arms, conditional upon continued Israeli renunciation of nuclear weapons, in order to improve Israel's security. The U.S. has also agreed to development of peaceful nuclear technology in the country, if Israel accepts American participation in its nuclear program. One

example of this arrangement was the offer to Israel of a six hundred megawatt reactor in June, 1974, which was designed to produce electric power.* (This offer was the first time that a nuclear NPT signatory had contemplated supplying nuclear equipment to a non-signatory state which was capable of producing nuclear weapons.)⁶⁰

The Dimona reactor plant was built in 1956, and was the first nuclear reactor in the Middle East. It was built with French assistance and was not subject to any safeguards. Though Israel does not possess any plutonium separation plant or uranium enrichment plant, as far as it is known, the plutonium produced in the Dimona reactor is sufficient for 3 to 5 small nuclear weapons.⁶¹ Therefore, it would seem reasonable that Israel does possess some reprocessing capability, even if this capability is not a full-sized plant. Such a fact is disconcerting to other nations when taken in conjunction with the Government's 1961 rejection of a nuclear-free zone in the Middle East. The opinion of Israeli leaders at that time was that such a zone would do nothing to end the real threat which originated from the conventional arms race.

* A similar reactor was also offered to Egypt at the same time.

It was stated by M. K. Hazan in a Knesset debate that:

There are no nuclear weapons in the Middle East and Israel will never be the first to introduce them. But Israel can be destroyed by conventional weapons and therefore the stress should be laid on conventional disarmament in the world and in the region. 62

The idea and tone were repeated by the Israeli delegate

to the United Nations during the May, 1968 debate on the Non-Proliferation Treaty.

For obvious reasons my country has a special sensitivity to the security aspect. We are involved in an unresolved conflict in which our security is being threatened and which has thrice in two decades erupted into armed hostilities. That conflict is marked by a massive and unchecked arms race of conventional weapons which, by our standards, have a vast capacity to kill and destroy. We cannot know what dangers and threats may confront us in the future. It is only natural that we should give earnest scrutiny to the security provisions intended to accompany and compensate for the restrictions that non-nuclear powers would voluntarily assume under the treaty. 63

Israeli refusal to sign the NPT is motivated by regional concerns. The Nonproliferation Treaty has done little to alleviate the dangers of the conventional arms race in the Middle East, and the Government also fears the danger of industrial and military espionage by IAEA officials friendly to the Arab cause. Many Israeli officials feel that by staying out of the NPT the country would gain concessions from the Superpowers in exchange for any

possible signature, though this suggestion is highly debatable. Most analysts feel that a more plausible reason for not signing is that Israel does have a weapons' capability, but prefers to keep it secret. Hypocrisy would surround any signature of the NPT under these conditions, but of course this reasoning could not be given as an excuse for not signing. Officially, Israel supports the principle of the Nonproliferation Treaty, but is engaged in a "deep, thorough, prolonged study to establish its attitude toward the Treaty"⁸⁵. In Israel's opinion there is no separation between the Nonproliferation Treaty and peace in the Middle East area. Negotiations for signature of the NPT must be so arranged that "solution of one facilitates progress in a solution of the other."⁶⁶

iv Japan

In contrast to Israel's over-riding concern with the current security aspects of the NPT, Japanese reluctance to ratify the Treaty, (Japan signed on February 3, 1970, is in keeping with the changing Japanese view of her security needs. After World War II three factors prevented Japan from considering a nuclear industry in any serious way. The most obvious factor was the American occupation of Okinawa and the Home Islands. The second

factor, which sprang from the American occupation of the country, was the "Peace Constitution" introduced by the Americans. Article IX of the Constitution renounced war as the sovereign right of the nation and stated that "land, sea, and air forces, as well as other war potential will never be maintained". Japanese leaders officially declared that Japan had no enemies and that it would not engage in war with any other nation.

The third factor militating against any effort by Japan to build a nuclear industry was the "nuclear allergy" of the nation's citizens. As a result of the shock and trauma experienced when nuclear bombs were dropped on Hiroshima and Nagasaki at the end of World War II, the populace had a revulsion against all aspects of nuclear technology in the early post-war years. No major counter-argument against the allergy ever developed during these years due to the belief that, because of bilateral defence treaties with the United States, Japan would be covered by the American "nuclear umbrella". The Japanese Government developed the "Three-Point Non-nuclear Principle" whereby Japan pledged itself not to possess, produce, or allow the introduction of nuclear weapons into the country. The Government did not allow the United States to station or introduce nuclear weapons into Japanese terri-

tory, except in the case of Okinawa, which continued to be occupied by American forces until the beginning of the 1970's.⁶⁸

With the end of American occupation, however, the LDP governments have claimed that the "Peace Constitution" does not negate the inherent right to self-defense. Though the "Three-Point Non-nuclear Principle" is still maintained, and Japan still states that the country has no official enemies, the LDP feels that a Self-Defense Force must be designed to provide external as well as internal defense. External defense means providing the country with "its own defense power commensurate with ... national strength and national circumstances as much as possible."⁶⁹

In addition to this swing to a conveniently ambiguous definition of external defense, the Japanese Government has undertaken a campaign to eradicate the "nuclear allergy" by informing the public of the benefits of nuclear technology, on the grounds that the extreme position of earlier years gave rise to an unreasonable fear of nuclear technology and to the belief that the American "nuclear umbrella" would protect Japan in any instance.⁷⁰ The Japanese view now is that the days of American-Soviet confrontations, such as Berlin and Cuba, are over and that more danger comes from confrontation along the Soviet-Chinese border.⁷¹

The American withdrawal from Asia during the last few years has added to Japan's worries over Communist China. To many Japanese officials the withdrawal has been too extensive and endangers the Japanese-American Alliance commitments. Many nongovernmental analysts advocate a strong R and D program in the peaceful uses of atomic energy as well as a stepped-up rocketry program because "Communist China's enthusiasm and efforts for nuclear armament . . . may be greater than we suppose. Also the nuclear countries may fail to guarantee the security of non-nuclear countries so effectively as we expect. In that event, both Japan and India will be forced to arm themselves with nuclear weapons by their own efforts." 72

To more official governmental thinking any confrontation along the Sino-Soviet border will have a profound effect on Asian security as a whole because no one can predict what China will do. Japan feels that it cannot foretell whether or not China will use nuclear weapons in any future confrontation, due to the fact that the Chinese nuclear philosophy has never been fully expressed in public, and so no firm "China policy" can be formulated. 73

Given this factor, and the decline in the reliability of the U.S. nuclear guarantee, more pressure can be brought to bear against Japan ratifying the NPT and

reducing its alternatives.

The Japanese Government also feels that nuclear power holds the key to the nation's continued economic growth and hopes that the country can become a leading civilian nuclear power by the end of the 1970's. At present, the country is still dependent upon imported nuclear technology, mainly from Britain and the United States, but the Long Range Atomic Energy Program hopes to produce an "independent fuel cycle", reducing Japanese⁷⁴ dependence on outside fuel and imported technology.

The Nonproliferation Treaty, in Japanese minds, prevents the achievement of this goal. The inspection clauses of the Treaty contain the opportunity for unequal treatment of Euratom States and Japan as the Euratom safeguard system can be easily adapted to the IAEA-NPT system, but⁷⁵ Japan's national controls cannot. Furthermore, if safeguards are applied too stringently, Japan fears that inspection will prevent, or hinder, the development of indigenous technology for peaceful uses of atomic energy⁷⁶ as well as industrial activities in other fields.

Though the Government does not suggest any reduction in IAEA inspections, Japan fears that any expansion beyond the present imported items will place intolerable burdens on Japanese nuclear industry and increase the chance of

nuclear piracy. If an expansion of the inspection scheme is carried out, as much as one-half of the IAEA's system may be devoted to Japan's future nuclear industry, which, unless the inspection methods are simplified and mechanized, will cost the country too much to support. (If the reactors of the Boryo Power Plant are closed down, one reactor will be inspected. It would cost the country \$2.5 million [1.7 billion yen]. Studies indicate that the costs of inspection may amount to one per cent of the total electric power produced in Japan, and many authorities feel that this figure, even though it is small, can affect Japanese bids for large nuclear projects, unless inspections are conducted on a "nondiscriminatory" basis between Euratom and Japan.

In summary, Japan's reluctance to ratify the NPT stems from a fear and uncertainty as to what China will do in the future as well as the desire not to restrict the country's future economic growth. The insecurity that Japan feels vis-à-vis its powerful neighbour can be said to indicate an attitude that is common among nations unwilling to sign the NPT. The opinions and policies of the four case studies included in this chapter point to a belief that solutions to security problems, and to a lesser degree, economic problems, are more pressing than the relatively idealistic concepts of the Nonproliferation Treaty. In this context, the

purchase of a nuclear reactor, ostensibly as a power source, may be viewed by these nations more as a solution to the security-military problem, than as a solution to an energy problem. More specifically, nations facing an uncertain future, such as Israel or India, like to keep their options open; CANDU, with its ability to produce weapon-grade plutonium, leaves the purchasing nation free to take whichever option it chooses.

TABLE 5A

NUCLEAR POWER BY COUNTRY

Country	No. of Power Plants 1974	Installed Capacity (MWe)	No. of Power Plants 1980	Installed Capacity (MWe)
Japan	10	1,756	11	21,636
West Germany	1	1,987	34	4,100
United Kingdom	28	5,335	47	11,111
USSR	10	2,457	23	11,997
Sweden	1	440	13	10,060
France	6	2,481	12	7,281
South Africa	-	-	8	6,898
Canada	5	1,974	9	5,482
Switzerland	3	1,006	6	3,406
Taiwan	-	-	4	2,808
Korea	-	-	4	2,328
Italy	3	597	5	2,163
East Germany	1	70	5	1,830
Czecho-slovakia	-	-	4	1,760
Belgium	-	-	3	1,650
India	3	600	8	1,610
Argentina	-	-	3	1,518

continued

TABLE 5A

Country	No. of Power Plants 1974	Installed Capacity (MWe)	No. of Power Plants 1980	Installed Capacity (MWe)
Finland	-	-	3	1,480
Mexico	-	-	2	1,200
Netherlands	1	55	3	1,105
Spain	3	1,100	3	1,100
Romania	-	-	2	880
Bulgaria	-	-	2	880
Austria	-	-	1	700
Brazil	-	-	1	626
Yugoslavia	-	-	1	600
Thailand	-	-	1	500
Philippines	-	-	1	420
Pakistan	1	125	1	325
Other (Not yet announced)	-	-	-	28,000
Totals	67	20,078	231	161,000

Taken from: Nuclear Theft: Risks and Safeguards, Mason
Willrich, Theodore N. Taylor, p. 197.

TABLE 5B

FORECAST OF INSTALLED NUCLEAR POWER
CAPACITY, EXCLUDING COMMUNIST COUNTRIES
(in thousands of Megawatts)

Year Ending	LWR	AGR + HWR	HTGR	LMFBR	Total
1979	90	25	0	0	115
1980	108	32	0	0	140
1981	130	39	0	0	169
1982	152	46	0	0	198
1983	173	58	0	0	231
1984	202	62	0	0	264
1985	234	69	0	0	304
1986	271	75	0	0	350
1987	315	80	7	3	405
1988	345	82	15	7	451
1989	383	92	23	14	512
1990	424	102	31	21	578
1991	478	112	40	30	660
1992	536	121	49	33	740
1993	543	125	66	66	800
1994	596	145	61	77	880
1995	636	159	68	106	970
1996	671	164	75	149	1,060
1997	703	175	81	190	1,150
1998	738	191	88	221	1,240
1999	766	193	93	297	1,350
2000	803	208	109	337	1,457

Taken from: Nuclear Theft: Risks and Safeguards, Mason
Willrich, Theodore B. Taylor, p. 198.

TABLE 5C

**PROJECTIONS OF PLUTONIUM PRODUCTION CAPACITIES
IN SELECTED NON-NUCLEAR-WEAPON COUNTRIES**

Country	Estimated Nuclear Power Capacity (megawatts)		Estimated Plutonium Production Capacity * (kilograms/year)	
	1975	1980	1975	1980
Federal Republic of Germany	5,000	20,000	1,000	4,000
Japan	5,000	25,000	1,000	5,000
Canada	2,500	6,000	600	1,500
Sweden	2,500	9,000	500	1,800
Italy	1,000	5,000	200	1,000
Spain	1,000	5,000	400	1,000
Switzerland	1,000	3,000	200	600
India	1,000	2,000	200	500
Argentina	300	1,000	100	300
Israel	-	500	10	100
Other	3,000	15,000	3,000	3,000
Rounded total for non- nuclear-weapon countries	22,000	91,000	4,000	18,000

*Approximate production rate of 0.2 kilograms
plutonium per year per megawatt.

Taken from: "Worldwide Nuclear Industry", Mason Willrich,
International Safeguards and Nuclear Industry, p. 67.

CHAPTER VI THE GREAT DEBATE

A Pressures on the Government

The second, third, fourth, and fifth chapters of this paper have been devoted to a presentation of the background and definition of one of the most important problems facing the Canadian government today. The problem can be broken down into three parts: a) there is a growing scarcity of cheap, easily available fossil fuels in an era when developed nations are demanding more power for their industries, and Third World nations are requiring power for their own development; b) Canada has developed a nuclear reactor which, though its initial capital cost is high, is cheaper to operate over the long term than many more common reactor types. Secondly, it places much less demand on uranium resources than the more popular LWR, and this factor is very crucial in calculating the utility of CANDU as a long-range energy option. c) Canada has traditionally supported nonproliferation and arms control agreements, though at times this support has been tempered by commercial considerations. There is growing emphasis within Canada upon IAEA safeguards as they exist under the NPT and governmental criticism of the arguments put forward by nations such as India

and Brazil, that the NPT is discriminatory. However, the desire to present CANDU as an example of Canadian technology to countries abroad influences the stand that the government takes on the nonproliferation issue, often to the point where Canada can be accused of playing a hypocritical role. This chapter will examine the current government position on these problems as well as the arguments that the Opposition and other groups in Canada have put forward as rebuttal.

B Current Government Position in Debate

1 Background to Position

In 1970 when the Canadian Government published the document Foreign Policy for Canadians the booklet on external relations stated that aid programs should be given priority in the department because Canada was committed to the welfare of the individual and Canadians "could not create a truly just society within Canada if we were not prepared to play our part in the creation of a more just world society." Furthermore, aid efforts would increase international support for Canadian interests and policies.¹ In keeping with this stated policy the Prime Minister visited both Pakistan and India in 1971 and increased aid to India to the point where it

represented nearly half of all the bilateral aid provided
by Canada.² The Trudeau Government viewed development as
an area where Canada could set an international example
and follow a policy which would not merely be a reflection
of American trends. Trudeau announced that he wished "to
allocate the major portion [in the order of 80 per cent
of Canadian bilateral funds to selected 'countries of
concentration' and to specialize in assisting particular
sectors within those countries in which Canada has special
competence."³

The Indian detonation of a nuclear device in May,
1974 gave rise to serious and prolonged questioning of
this attitude. Canadian officials in New Delhi had felt
for a long time that Indian ideas of the role of nuclear
technology were changing and that the government was under
strong pressure to explode a nuclear device as notice to
nuclear powers, but particularly Communist China, that
India was capable of joining their elite club. However,
Canadian representatives were unable to say when the
explosion would take place,⁴ but when it did, Canadian
reaction to the event in May was sharp and immediate. The
results of India's action were far-reaching; not only was
nuclear aid to India cut off the day after the explosion,
but the government undertook a complete review of its

nuclear aid policy and the role of safeguards in nuclear development. Many authorities felt that the May detonation had proven that nuclear proliferation had become too big a problem for IAEA safeguards alone. Allan Beesley, the Canadian representative on the IAEA Board of Directors, said in a meeting in June, 1974 that: "It is inevitable that more countries will turn to nuclear power to meet future electricity requirements. Access to this cheap and reliable power source should be facilitated to those countries prepared to deal in a responsible manner with obligations which access to nuclear technology entails, but the progressive spread of nuclear power makes it more essential to prevent the use of fissile material for military use." ⁵ Beesley went on to say that in the current political climate it would be advantageous for Canada to make separate bilateral agreements, in addition to the IAEA safeguards, with nations such as Argentina and South Korea, to prevent any utilization of the material, equipment, and services provided with the sale of a CANDU reactor, to make a nuclear device. ⁶ This suggestion, however, opened the question of the effectiveness of any safeguard program: how could Canada ensure that any extra bilateral agreements with an importer nation would be more effective in preventing the development of a nuclear device than the past agreements had been? ⁷

Furthermore, the intigation of separate bilateral agreements raised the problem of delegation of duties. Would Canada employ its own inspectors and how would inspections take place? How would authority be divided between the two sets of safeguards? The Cabinet, of course, could not guarantee any effects of future nuclear aid policy, but three aspects of the revised program became obvious during the next year: (1) CANDU reactor sales would be continued, (2) there would be more rigorous safeguards on nuclear materials and technology, and (3) more pressure would be exerted on prospective customers to sign the NPT.

11 Continued Sale of CANDU

The first aspect that became clear in the dust caused by the debate over Canada's nuclear aid policy, was that the government was not going to end the sale of CANDU's to overseas buyers. The nuclear embargo against India after May, 1974 had severely strained Canadian companies in the nuclear business. Many companies found themselves with as much as five million dollars in goods on their hands with little chance of payment. The original Canadian-Indian sales agreement called for payment only after the goods left Canada, but with the embargo, no goods were leaving the country. Though there was little

chance that nuclear-supply companies could bring legal action against the government, since special insurance against cancellation of export permits could have been⁹ obtained from the Export Development Corporation, many government officials felt that the nuclear export companies did have a strong moral claim for compensation. The companies were guaranteed payment on shipment of their goods and did not expect the government to "pull the rug out from under their feet". If the feeling of government betrayal persisted among nuclear export companies, many authorities feared that Canada's domestic nuclear program could suffer, as companies would be less willing to enter,¹⁰ or remain in, the nuclear business.

By December, 1974, Canada had settled upon a "middle of the road" policy, whereby nuclear equipment, fuel, and technology would be sold, but only to nations willing to accept stricter bilateral nuclear safeguards with Canada, as well as those safeguards imposed by the IAEA and/or NPT. In a speech to the House of Commons on December 31, 1974, the Energy Minister, Donald Macdonald, stated that the government had decided to offer "the benefits of lower cost nuclear energy" to other countries, while, at the same time, trying to stop the proliferation of nuclear weapons. In the future, no material or tech-

nology sold by Canada would be used for "peaceful" nuclear devices, and Canada would demand much more stringent bilateral safeguards on the material it did sell. ¹¹

Over the next six months the government defended its position and developed the arguments with which it currently buttresses its decision to continue CANDU sales.

On June 17, 1975, Prime Minister Trudeau, in a speech before the Canadian Nuclear Association, listed three obligations that Canada had as a nuclear country:

- (1) to help less developed nations develop a current technology and bridge the gap between rich and poor;
- (2) to ensure that "nuclear devices, materials, or technology from Canadian sources not be used for explosive or illegal purposes", through the application of strict safeguards, and (3) an obligation to the Canadian people to provide safe sources of energy, to preserve the environment, and to foster a competitive Canadian industry. ¹²

On June 20, 1975, in a speech reported by the Vancouver Province, the Prime Minister reiterated his stand by stating that Canadians have an obligation to help "lift poor nations into the twentieth century" by providing them with a cheap and reliable source of power. If Canada did halt CANDU sales to such nations as Brazil and Argentina, the action would have little effect on their determination to develop nuclear weapons, as they could

easily negotiate with other nations for the supplies they need. At present, Trudeau said, "Canadian nuclear export agreements contain the toughest safeguards of any nuclear supplier country."¹³ Donald Macdonald supported this attitude a week later when he replied to a call from Robert Stanfield urging a moratorium on CANDU reactor sales. The Energy Minister said that the government was afraid that, if a moratorium on CANDU sales were declared, other countries, such as West Germany, would sell nuclear material under much easier safeguards than Canada's.¹⁴

iii Increased Emphasis on Bilateral Safeguards

The decision to continue CANDU sales ushered in the second phase of Canada's revised nuclear policy, a much greater emphasis on bilateral safeguards, and increased efforts to lay the foundation for an organization of the nuclear exporting countries. The groundwork for this policy was set out in the end of December, 1974, when, in his speech to the House of Commons defining the role of Canadian bilateral safeguards, Energy Minister Donald Macdonald stated that safeguards would cover all Canadian-supplied equipment and facilities for their life-time; all nuclear facilities and equipment using Canadian-supplied technology; all nuclear materials, including

nuclear fuel, fissionable products derived from such fuel, and heavy water obtained from Canada; and nuclear materials "whatever their origin",¹⁵ produced or processed in facilities supplied by Canada.

This attitude was reinforced in May, 1975 when, at the NPT review Conference, External Affairs Minister Allan J. MacEachen said that: "Canada will provide nuclear material, equipment, and technology to other countries only on the basis of binding commitments that Canadian supplies will not serve the development of any nuclear-explosive device for whatever purpose. This policy will¹⁶ apply equally to all countries."

A second component of Canada's increased concern with safeguards was the rejection of the utility of Peaceful Nuclear Explosions. During his speech to the 1975 NPT Review Conference, Mr. MacEachen stated: it is the Canadian view that, "if there were to be a halt in the experimentation or application of peaceful nuclear explosions at this time, it is unlikely that any country would suffer significant economic disadvantage. We should think it in the interest of the non-proliferation regime and of achieving a comprehensive test-ban to halt experimentation in this area, at least until a thorough re-evaluation of the world's resource and energy needs

presents a more compelling case for the use of peaceful
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nuclear explosions."

The third aspect of the policy of stricter controls and safeguards on the sale of nuclear material and technology was the active Canadian participation in the London Conference which met in June, 1975. On June 18th the United States, Canada, the Soviet Union, Japan, Britain, France, and West Germany met in London, England to discuss possible means of controlling nuclear sales and developing
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safeguards to prevent the spread of nuclear weapons. The meeting was prompted by the fact that the Indian detonation the year before had taken place with materials supplied by Canada, and, that in early June, 1975 West Germany had agreed to export nuclear technology to Brazil, (which did not support the NPT), in exchange for access to
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Brazilian uranium supplies.

Though the progress of the London Talks remained secret, it was revealed in February, 1976 that three "principles" had been reached by the nuclear exporting countries. These principles were "designed to inhibit the spread of nuclear weapons while permitting nuclear exports of equipment to meet the world's growing energy needs", and consisted of: (1) Recipients of any nuclear technology from the seven supplier states must apply

internationally accepted safeguards drawn up by the IAEA, regardless of whether they are members of the Agency or not; (2) Recipients must give assurances that nuclear facility imports will not be used to make nuclear explosives for any purpose, even for peaceful purposes; (3) Nuclear importers will not transfer any materials or duplications of equipment to third countries without obtaining identical assurances. (Canada has upheld this commitment in her agreements with Argentina and South Korea. See below.) The signatory nations also "committed" themselves to control and safeguard efforts including co-operation on physical security, measures for protecting nuclear material in transit, and recovery of stolen nuclear material. Pledges were also given that efforts would be made to help the IAEA improve its international safeguard activities, and to "encourage the designers and makers of sensitive equipment to construct it in a way that will aid safeguards."

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iv Continued Support of the Nonproliferation Treaty

The third aspect of Canada's revised nuclear policy was a more exact interpretation of the Nonproliferation Treaty. The concept was stated very clearly by Mr. MacEachern at the NPT Review Conference in May, 1975.

The Minister for External Affairs emphasized that Canada felt that the Nonproliferation Treaty was the best way by which non-nuclear-weapons states "can develop non-military uses of nuclear energy while providing other nations with effective reassurances concerning their peaceful intentions.... We believe that the treaty can encourage the wider sharing of nuclear resources and technology by ensuring that nuclear co-operation will serve only peaceful purposes. We see the treaty as important to international détente and to encouraging efforts to achieve nuclear disarmament." ²¹ In order to uphold this belief in the NPT, Mr. MacEachen said that Canada was willing to supply increased amounts of aid in the nuclear field to developing countries, either bilaterally or through the IAEA, but only if these countries were party to the Nonproliferation Treaty. Future official bilateral development-assistance commitments for the financing of nuclear projects would be granted only to those states Party to the NPT.* A nation's adherence to the Nonproliferation Treaty would be "an important factor when reaching decisions on the provision of Canadian Government ... financing in the nuclear field." ²²

* Argentina occupies a special position in regards to this statement as contracts to supply nuclear material and technical co-operation were first signed by Canada in 1974.

v Functioning of Revised Policy

Since Canada has revised her nuclear policy, three contracts have been signed for nuclear co-operation with overseas nations. Two of these contracts, with Argentina and South Korea, were for technical nuclear co-operation and upgraded safeguards, while the third, signed with Finland on March 5, 1976, covered upgraded safeguards on uranium sales to that country. All three agreements show the effects of Canada's greater concern with safeguards and control of nuclear material. In the case of Argentina and South Korea, nuclear exports, including technology, shall be authorized only after conclusion of an inter-governmental guarantee that:

- (1) the items supplied, or items produced with these, including subsequent generations, will not be diverted to any non-peaceful or explosive purpose;
- (2) these guarantees are verified through inspection mechanisms of the International Atomic Energy Agency;
- (3) that the retransfer of items supplied and items produced with these including subsequent generations of nuclear material only be done with the consent of the Government of Canada;
- (4) that the enrichment and reprocessing of nuclear material supplied, or nuclear material produced with items supplied, only be done with the consent of the Government of Canada;
- (5) that IAEA safeguards and other mechanisms of bilateral verification for aspects of

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guarantees where the IAEA system is not applicable, be in place for the life of the supplied item or for items susceptible to these guarantees, produced from these items;

(6) that adequate measures for the physical security of materials be in place to protect the supplied items from the threat of sub-national diversion. 23

The agreement with South Korea is designed to remain in force for the life of the CANDU nuclear reactor facilities, or for 10 years, (whichever is longer), while the Argentinian Agreement is for 15 years, with renewals of 10 years thereafter, unless one of the parties objects. In addition, if either South Korea or Argentina is found to be using Canadian-supplied materials, equipment, or technology, or items derived from the originals, for non-peaceful or illegal purposes, Canada may immediately cease nuclear co-operation with the offender. ²⁴ This right is further reinforced in the case of South Korea to the point that, if illegal use or diversion is discovered, Canada has the "right to require ... the immediate return" of all equipment, material, nuclear facilities, nuclear material, and information received under the co-operation agreement, as well as "all material and nuclear material used, produced, processed, reprocessed, enriched, fabricated, or converted from by, in, or with the items obtained from Canada; and any and all subsequent generations

of material and nuclear material derived from the prior
two classes of items." ²⁵ South Korea was also urgently
advised to sign the Nonproliferation Treaty as soon as
possible.

These safeguards are not very inhibiting. In the
first place, the Argentinian agreement states that renewal
can take place only if one of the parties does not
object. What is to prevent Argentina from objecting to
the agreement and refusing to renew it? There is no
action Canada can take in this instance, except to recall
all nuclear material, etc., but, if Argentina is willing
to abrogate the agreement, its nuclear industry is prob-
ably capable of supporting a nuclear weapons program in
any case.

Secondly, there is always the possibility that a
safeguarded nation will gather enough information to pro-
duce, on its own, a reactor that is sufficiently different
from the CANDU to be outside the scope of Canadian safe-
guards, but based on the same principles as the CANDU.
What would be the status of Canadian bilateral safeguards
in such a situation?

The agreement with Finland covers the use of 900
tons of U308, with which Finland hopes to develop a

nuclear power generating program. Though information is not as readily available on the type or extent of safeguards between Canada and Finland, Mr. MacEachen has said that one of the provisions forbids Finland from using the material for "any nuclear explosive device".²⁶

D Arguments Against the Government's Position

Although official, publicised debate on the government's decision to sell CANDU reactors under its upgraded safeguards program has been minimal, there are certain arguments which can be advanced which raise serious doubts as to the wisdom of the government's decision to carry on with the sale of CANDU. The arguments are many and varied but this section proposes to deal with six, grouping them under three general headings, the Nonproliferation Treaty, Government treatment of nuclear policy, and the effect of CANDU sales in the Third World.

1 The Nonproliferation Treaty

In chapter five a short history of safeguards was given along with an outline of how they function in the present environment. Two factors emerge from this survey: (1) Safeguards do not provide absolute protection of nuclear material, nor is there any guarantee that

illegal diversion by a signatory nation will be punished, or even detected, (2) The main concern of nations, when they sign a safeguards agreement, is security. Nations must feel that safeguards, whether under the NPT or the IAEA, are going to improve their internal and international security. Taking these two considerations into account, three criticisms can be levelled against the continued sale of CANDU reactors. The first is simply that a CANDU does produce plutonium at a faster rate than most other commercial reactors, (see figure 6A at end of chapter), and this situation facilitates the task of weapons manufacture, once the plutonium is separated from the reactor's waste material.

After the plutonium is separated, it must be transported and stored. The difficulties of handling such material give rise to the second argument against exportation of CANDU to Third World nations, the dangers of nuclear theft by terrorist or other nongovernmental groups. In his book, The Curve of Binding Energy, John McPhee deals extensively with the problem of nuclear theft by nongovernmental groups. McPhee records an interview he had with William Brobst, the head of an Atomic Energy Corporation department dealing exclusively with the transfer of plutonium and other nuclear material. Mr. Brobst stated

that: "In trucking of [nuclear material] there is constant pilferage, day-to-day theft, 'shortages'. Of all the freight of any kind that is shipped in this country, one to two per cent disappears. ... The nuclear business has vaults, fences, alarms. They have great machines to count atoms. Then they take all these atoms, lump them into a drum, and toss them out into crime." ²⁷

This opinion is supported by Theodore Taylor, president of the International Research and Technology Corporation. He has stated:

The levels of physical security now applied to fissionable materials for civilian use, in the United States and other countries, are considerably lower than those overcome in many successful thefts of other valuables in the past. Many situations now exist where quantities of fissionable materials sufficient for several nuclear explosives are not protected by armed guards, major physical barriers, or intrusion alarms. ²⁸

If this is the view of security precautions taken in the United States, how much less effective would be the security precautions in many Third World countries where technology is not as efficient and trained manpower is scarce?

The problem of terrorist diversion becomes more alarming when viewed in the context of increasing plutonium production. In 1971 world production of plutonium was 13 tons, and by the year 2000 it is expected that 750

tons will be produced annually. The audits that are made of nuclear material at each stage of processing cannot avoid an average plutonium loss of between 0.2 and 0.5 per cent, and cannot detect whether the loss is due to clandestine activities or not. If a 0.2 to 0.5 per

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cent loss is assumed for every 750 tons of plutonium produced, the total amounts to 2.25 tons, or enough plutonium for 350 bombs of the size which destroyed

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Nagasaki. Only six kilograms of plutonium, or 20 kilograms, (13 pounds), of enriched uranium are needed to

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create a nuclear weapon of this size, and though a terrorist group may not be able to achieve the level of enrichment needed to create an "efficient" nuclear device, (about 90 to 95 per cent enrichment is needed), the knowledge of how to construct a nuclear weapon is no longer limited to a few people, and the technology is no longer classified. The fact that a terrorist "bomb" may not be as sophisticated as governmental devices makes little difference once a clandestine group has acquired the technology and materials and is prepared to use them.

The third objection against Canada's sale of CANDU reactors to Third World nations also⁶ revolves around the aspect of security, but in this case it is the security fears of the Third World nations themselves which provide

reasons for withholding sales. The objective of the NPT and IAEA safeguards is to provide enough internal and international security, through the system of inspections, surveillance, and accounting of nuclear material, that nations will agree to forego the development of nuclear weapons. The NPT, however, has not been successful in overcoming the feelings of insecurity springing from regional hostilities based upon conventional weapons. In reality, the NPT offers little relief to nations such as India and Israel which are faced with major conventional threats to their security, and which are therefore more likely to develop nuclear weapons than nations like Canada or Sweden, which are not faced with external security threats. To nations in an insecure position, IAEA safeguards merely narrow their options and prevent them from increasing their security through the development of nuclear weapons. Even if these nations did accept safeguards, they would abrogate these safeguards at the earliest opportunity if they felt it to be advantageous. The point of controls would then be lost.

Taking the security fears of Third World states into consideration, even the more encompassing bilateral safeguards that Canada has developed and implemented during the last year are not enough to prevent a customer

from "going nuclear" if it so desired. Safeguards are strong only up to the point where they don't conflict with national interest, and if the immediate military protection of territory or way of life becomes the national interest, safeguards and assurances will be sacrificed to the greater need. This idea was expressed by President Park of South Korea in June, 1975 when he said: "If the U.S. nuclear umbrella were to be removed, we would have to start developing our own nuclear capabilities to save ourselves."

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ii Government Treatment of Nuclear Policy

The objections to Canada's nuclear policy that are raised in this section center upon the Opposition's dislike of the Government's attitude toward nuclear sharing, and the Government's disinclination to talk about nuclear policy. The matter came to a head in June and July, 1975 when the government announced its decision to sell nuclear reactors to South Korea and Argentina. When Prime Minister Trudeau stated that Canada's refusal to sell CANDU reactors wouldn't stop nations such as Argentina and Brazil from developing nuclear weapons if they were determined to do so, Conservative leader Robert Stanfield and N.D.P. Energy Critic T. C. Douglas demanded that the government submit its nuclear sales agreements to the

Commons before they were signed. Stanfield then called
for a moratorium on reactor sales while Canada persuaded
other exporter nations to instigate firmer controls. 34
A week later Mr. Stanfield repeated his demand for a
moratorium on CANDU sales, on the grounds that a mora-
torium would give the international community time to
develop stricter safeguards, but was opposed by Mr.
Macdonald. The Energy Minister expressed the fear that,
if a moratorium were held, other countries such as West
Germany would step into the breach and sell reactors
under easier safeguards. 35

In July, Flora MacDonald, the Conservative M.P.
for Kingston and the Islands, joined Mr. Stanfield in
protesting the Government's nuclear policy. On July 19,
1975 ^{Miss} ~~Ms.~~ MacDonald told the annual Belleville Peace
Festival that: "Assuredly as Canadians we should not
allow ourselves to be in that position where we add to
the dangers of nuclear war. We, as Canadians in the cause
of peace, should be saying to our government 'Let's put a
moratorium on all of this.' It's time we spoke out very
strongly that we don't want to see Canada adding to the
world's potential for danger." 36

Opposition complaints have also been supported by
some opinion outside of Parliament. In early July, 1975
Dr. Bernard Feld, the Secretary-General of the Pugwash

Organization, said that plutonium could be diverted from Canadian nuclear power stations, despite strict international safeguards. Dr. Feld admitted that Canadian safeguards were tougher than most, but that could not prevent one per cent of all plutonium produced in a power reactor being diverted without detection. In a standard 500 megawatt CANDU reactor, which operates regularly, 500 pounds of plutonium are produced annually. A one per cent diversion of this total would provide any group with five pounds of high-grade plutonium each year. Dr. Feld estimated that a crude nuclear device can be built with only ten pounds of plutonium, and since most Canadian nuclear projects will involve two to four 500 MW reactors grouped in a power station, it would not be too difficult to obtain the needed plutonium.

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In answering the Government's claim that nuclear technology is one of the best ways for developing nations "to leap frog the industrial revolution" and that it would be "irresponsible" for Canada to withhold advantages like power reactors, isotope therapy, and cobalt therapy units, Dr. Feld stated: "That's a tremendous rationalization. To sell nuclear energy as the hope for the future of the developing world is a vast delusion. Many developing nations would be better served by smaller-scale solar energy or hydroelectric power plants."

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One criticism of Dr. Feld's position is that it is a patronizing one; Third World nations are perfectly capable of deciding for themselves what energy source best serves their power needs, and many are quite highly developed, with industrial bases nearly as big as Canada's. (e.g., Brazil, Argentina, or India). A more serious criticism of government policy than Dr. Feld's is the fact that the Trudeau Government is not confident enough in its own policy to expose it to a full-scale debate in the House of Commons. On February 26th and 27th, 1976 the question of what controls and obligations would be put upon Pakistan if a CANDU reactor were sold to that country, was laid before Mr. MacEachen. In each instance, the External Affairs Minister declined to give a straightforward answer to the questions asked by Mr. Broadbent and by Mr. T. C. Douglas. Excerpts from the exchanges are given below:

Mr. Edward Broadbent (Oshawa-Whitby): With direct reference to those standards to which the minister has referred and following questions put to the Prime Minister yesterday, can the minister assure the House that the standards unilaterally imposed by Canada in terms of its sale of nuclear equipment and supplies will apply in the case of Pakistan, not only to nuclear equipment made in Canada and used in Pakistan but also to equipment that has been purchased by Pakistan from other countries, more specifically France?

Hon. Allan J. MacEachen (Secretary of State for External Affairs): We are presently engaged in negotiations with Pakistan with the object in mind of increasing the level of safeguards on the reactor that is presently in Pakistan. ... That [reprocessing] plant which is to be supplied by France ... would be covered by safeguards negotiated between Pakistan and France as certified by the International Atomic Agency. We certainly cannot negotiate with Pakistan with respect to a facility provided by a third country. We are at present engaged in discussions with Pakistan with respect to this, what happens and under what conditions material coming out of the Canadian reactor may be subsequently used.

Mr. Broadbent: I have a final supplementary question, Mr. Speaker. Once again the minister did not answer the question. Will he assure the House that as a precondition laid down by the government of Canada for sale of uranium to Pakistan, Plutonium, which can be produced by the Canadian reactor, in Pakistan, could not be used by Pakistan on the French reprocessing equipment?

Mr. MacEachen: As I understand it, the plutonium itself would be the end product of a reprocessing facility supplied by France, if and when it goes into production. What is of concern to Canada of course is the spent fuel that comes out of the Canadian reactor which may subsequently be reprocessed in the facility provided by France. It is with respect to this spent fuel that we are presently negotiating with Pakistan, with which country we already have a safeguard provision with respect to the use of that spent fuel. We are attempting to arrange new safeguards or additional safeguards with respect to that spent fuel, but not for plutonium, which is a separate process. 39

There is some doubt here as to whether Mr.

MacEachen understood where the plutonium in question came from. Mr. Broadbent asked if the plutonium that comes from Pakistan's CANDU reactor would be allowed to be

used on the reprocessing equipment supplied to Pakistan by France. In his reply to the question Mr. MacEachen seemed to indicate that he felt the plutonium was produced by the reprocessing plant itself, ("As I understand it, the plutonium itself would be the end product of a reprocessing facility ..."), which is not correct and points out a grave lack of understanding of plutonium production. It is the production of plutonium and its treatment when it comes out of the reactor that is one of the major causes of debate, both within Canada, and in other countries.

On the other hand, Mr. MacEachen's answer may have been deliberately vague and cloudy in order to delay any firm decision being taken. If so, the action was an excellent debating tactic, but added little to efforts to reassure the Opposition that safeguards would be closely followed and applied.

The debate continued a little later:

Mr. T. C. Douglas (Nanaimo-Cowichan-The Islands):
Mr. Speaker, I have a question for the Secretary of State for External Affairs. Since the Canadian government and the government of Pakistan are discussing the sale of a nuclear reactor and in view of the fact that two things concern a great many people in Canada - first, the fact that Pakistan has not signed a non-proliferation treaty and second, that it has not cancelled its order to purchase a reprocessing plant as South Korea did - I want to ask the minister if the government can assure

this House that the signing of the non-proliferation treaty and the cancellation of the contract to purchase a reprocessing plant will be conditions which Canada will impose before it will agree to sign any such agreement with Pakistan?

Hon. Allan J. MacEachen (Secretary of State for External Affairs): Mr. Speaker, the Hon. Member's question is based upon a mistaken premise. We are not discussing the sale of a nuclear reactor with Pakistan; we are not discussing at all the sale of a reactor or any other facility.

Mr. Douglas (Nanaimo-Cowichan-The Islands): Mr. Speaker, we are discussing with them the sale of nuclear technology and uranium; they already have a reactor. I am perfectly aware of that. I ask the minister the question with respect to these two things: is the Canadian government prepared to impose the two conditions I have suggested?

Mr. MacEachen: Mr. Speaker, the premise of the second question is also mistaken. 40

February 27th, 1976:

Mr. Edward Broadbent (Oshawa-Whitby): Mr. Speaker, I have a question for the Secretary of State for External Affairs. In the House yesterday with reference to negotiations that are going on between Canada and Pakistan concerning nuclear safeguards, the minister said: 'What is of concern to Canada ... is the spent fuel that comes out of the Canadian reactor and that may subsequently be reprocessed in the facility provided by France.'

I should like to ask the minister now whether he will assure the House that no further shipments of uranium from Canada to Pakistan will take place unless Pakistan accepts the point that Canadian safeguards apply not merely to the CANDU reactor provided by Canada but also to the use of spent fuel from the Canadian reactor now in Pakistan.

Hon. Allan J. MacEachen (Secretary of State for External Affairs): Mr. Speaker, the negotiations between the Canadian team and the Pakistani team are still underway. ... The hon. member is suggesting that Canada withhold its supplies of uranium or fuel to Pakistan in order ... to bring Pakistan to the point of cancelling a contract which, I understand, has been entered into with the French government. That is a possibility, but I think the hon. member should understand the implications for Pakistan if Canada at this point withdrew its fuel from the CANDU power reactor and cut off the supply of electricity for the city of Karachi.

(This threat is actually a good leverage point to make Pakistan adhere to Canadian safeguards whole-heartedly.)

Mr. Broadbent: ... I should like to ask the minister the following question. Given ... the equal concern from the point of view of everyone in the world to stop the development of nuclear weapons, would the minister not agree that unless we get the most stringent guarantees from the government of Pakistan which would totally inhibit the use of Canadian-provided material for the development of nuclear weapons, we should not proceed in any way with further shipments of uranium material to that country?

Mr. MacEachen: ... I believe the hon. member should bear in mind as well that, as I understand it, there has been a safeguards agreement negotiated between France and Pakistan relating to the processing plant. These safeguards are of London Club quality and have been approved by the International Atomic Energy Agency, so that processing plant is actually safeguarded under internationally approved standards.

.....

Mr. Broadbent: Considering that the minister has been quoted as saying that the safeguards agreed to by a number of countries in London were in fact lower than the safeguards expected

by the Government of Canada, I should like to ask the minister whether he is now saying that the Government of Canada is prepared to accept what I understand to be the Pakistani position, namely, that the safeguards expected by the Government of Canada for Canadian-provided facilities will not be applied to facilities provided by another country, even if that means that those facilities are going to be using spent fuel provided originally by Canada and processed on the Canadian reactor in Pakistan.

Mr. MacEachen: The hon. member has rather ambitious plans for Canada in that he expects Canada to direct the nature of an agreement between two other countries, in this case between Pakistan and France. I believe that is quite a silly proposal made by the leader of the New Democratic Party.

...

Mr. MacEachen: The question which is relevant, ... is the safeguards with respect to the Canadian reactor which is presently in Pakistan. It is with respect to that reactor ... that negotiations are currently under way, and at the moment we are considering what our total approach will be depending upon the results of these negotiations. With regard to Pakistan, we are insisting on the highest possible safeguards. However, please do not ask Canada to determine what arrangements ought to exist between Pakistan and France. Surely, the French government has something to say about that. 41

Mr. MacEachen's statement that Canada does not have the right to "determine what arrangements ought to exist between Pakistan and France" for reprocessing of Canadian-supplied material, is at best, slap-dash. Canada has given Pakistan a nuclear reactor on the

condition that the material from the reactor be governed by Canadian safeguards. Therefore, Canada has the right to demand that these safeguards are adhered to, and, in this respect, what Pakistan does with spent fuel is of a very great interest to Canada.

The refusal to debate CANDU sales in Parliament raises the question of whether the government really has faith in its own policy. This is not the place to explore the problem in detail, but it should be pointed out that the waffling attitude of Mr. MacEachen contributes little to a picture of decisive, coherent policy.

FIGURE 6A

ANNUAL RATE OF PRODUCTION OF FISSIONABLE PLUTONIUM IN
DIFFERENT TYPES OF POWER REACTOR

Taken From: B.M. Jasani, "Fast Breeder Reactors",
Nuclear Proliferation Problems, P.49

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CHAPTER VII SUMMARY AND CONCLUSIONS

A Summary

The objective of this paper has been to look at the Canadian decision to sell CANDU reactors overseas against the background of five considerations: (1) the energy crisis and its effect on Third World and industrialized states; (2) the traditional and current Canadian attitudes to control of nuclear technology; (3) the appropriateness of CANDU as a partial solution to the energy needs of the Third World; (4) the objective of IAEA safeguards to control the spread of nuclear technology, thereby increasing the security of signatory states; (5) the operation of these safeguards under the NPT, and their failure, in the opinion of many strategically important Third World states, to provide the necessary security to warrant an abrogation of the right to produce nuclear weapons. In the sixth chapter an attempt was made to show how concern with these five aspects was brought together in the Government's "middle of the road" decision to continue the sale of CANDU, but only under much stricter bilateral safeguards, and with greater emphasis placed upon co-ordinated safeguards by the London Group. Some of the arguments which have been

advanced against this position were then discussed. The present chapter will concern itself, by way of conclusion, with some observations and recommendations on government policy in an effort to suggest some means by which greater control over nuclear energy may be formulated.

*** Conclusions and Recommendations**

1 Points of Consideration

The first point of consideration is that, at present, there are no ready alternatives to nuclear energy and fossil fuels as sources of electrical power. Chapter three examined a variety of alternatives and concluded that, for the current decade, solar energy was the only alternative which showed promise of being practical. For nations such as Brazil, Argentina, Japan, or India which have large populations and which are industrializing quickly, a power source must be made available to them now, even if it is used only until solar energy is more fully developed.

A second aspect is a moral question. Does Canada, or any other country, have the right to deny nuclear power to developing Third World nations, while using such power itself? If Canada were willing to forego the use of nuclear power within its own borders such a

policy might be more feasible, but this course is impractical and unworkable. Canada is too firmly entrenched in the nuclear business itself to demand that other nations refrain from taking the same course. Furthermore, the CANDU reactor is a practical source of power for those nations which have a power grid large enough to accommodate the large blocks of power available from nuclear reactors. The CANDU uses uranium efficiently, can be run on either the uranium or thorium cycle, and has minimal fueling costs, thus lowering the over-all cost of the electricity well below that from a LWR.

The third point is Canada's attitude to the peaceful uses of atomic energy. Canada has always supported the belief that the peaceful application of nuclear energy should be shared among those nations without a nuclear technology of their own, as long as these nations are willing to accept safeguards and controls upon the material and facilities supplied. Unless the government is willing to countenance a complete about-face at this juncture, this policy will have to be continued. Furthermore, the Nonproliferation Treaty, a document which Canada helped to draft and now firmly supports, encourages the sharing of peaceful nuclear technology under adequate safeguards. To deny industrializing Third World nations the use of nuclear energy as a power source, would be to

undermine one of the basic concepts of the NPT. What must be guaranteed is that: (1) Third World nations using nuclear energy as a source of electrical power must be signatories of the NPT, and (2) there must be adequate safeguards so that the nuclear material, equipment, and facilities supplied will not be used for any other purpose than for electrical power.

11 Recommendations

An examination of the points listed above leads the writer to conclude that the decision by the government to continue nuclear sales to developing Third World nations, who are signatories of the NPT, and who are willing to accept bilateral safeguards with Canada, is the most practical solution to the "Canadian Dilemma". However, there are certain recommendations that can be put forward.

The major recommendation is that a moratorium should be held on further CANDU sales to Third World nations until greater international control of the fuel cycle is realized.

Secondly, firmer support should be given to the demands put forward by the Group of 77 at the 1975 NPT Review Conference. This group of Third World non-nuclear

states is not under the direct nuclear protection of
 1
 either Superpower, and therefore, has an over-riding
 concern with security and how it functions under the NPT.
 In 1975 the group put six main demands before the nuclear
 powers:

- (1) an end to underground nuclear tests.
- (2) a substantial reduction in nuclear
 arsenals;
- (3) a pledge not to use or threaten to use
 nuclear weapons against non-nuclear parties
 to the Treaty;
- (4) concrete measures of substantial aid
 to the developing countries in the peaceful
 uses of nuclear energy;
- (5) creation of a special international
 regime for conducting peaceful nuclear
 explosions; and
- (6) an undertaking to respect all nuclear-
 free zones. 2

All of these demands, except for the fifth, have been
 repeatedly proposed by Canada since the Second World
 War. If nuclear nonproliferation were as important to
 the government as is claimed, continued active support
 of these claims, (apart from number 5 which is generally
 felt to be unworkable), would be in keeping with Canadian
 policy.

The Government must also be more prepared to
 defend its nuclear policy in Parliament. The policy of
 evasion now being followed does little to indicate that

the Government really has confidence in its policy or that it can provide the necessary leadership to implement it. In order to forge a strong nuclear policy, all facets of the issue must be brought out into the open, which will mean of course, full debate over the pros and cons of nuclear policy

The recommendations suggested above may appear to be insufficient and brief when compared with the many pages devoted beforehand to the energy crisis, its effect upon developed and developing nations, and the potential that Canada possesses for partially alleviating this crisis. However, the central task of this paper was to analyze the choice facing Canada. In fulfilling this task four points have been made: (1) there is a growing scarcity of easily available, inexpensive fossil fuels and this scarcity is not going to be overcome; (2) the CANDU is an efficient nuclear reactor and is practical for use in many Third World nations; (3) Canada has a history of support for controls on nuclear technology, and nuclear arms, which sometimes clashes with the desire to export Canadian nuclear technology abroad in an effort to make our expertise in this area known; and (4) the Nonproliferation Treaty, as it now operates, is not strong enough, in its guarantees of security for non-nuclear signatories, to entice these near-nuclear

states with security problems, and who for this reason should be NPT signatories, into signing the NPT. Furthermore, safeguards, as they now exist, can be easily circumvented by those states with the will and the technical knowledge to do so. What confronts the Canadian Government, therefore, is a two-fold problem: it possesses the nuclear "know-how" to reduce the severity of the energy crisis, but if it transfers this technology to Third World nations, the ideal of safeguards will be in danger of being lost and the chances of proliferation will rise. Furthermore, the suggestion not to sell nuclear technology is not satisfactory either as developing nations can then accuse Canada of flaunting a double standard, using the benefits of nuclear technology herself, yet denying them to others and assigning them to a permanent status of underdevelopment. Such a decision would also be a complete break from the Canadian policy of sharing the benefits of nuclear technology with non-nuclear countries willing to accept safeguards. The decision of the Government to continue nuclear sales in conjunction with a policy of much stricter safeguards is, therefore, the best compromise between these two extremes.

This policy, however, would gain strength if a moratorium were declared on CANDU sales until greater

international control of the fuel cycle has been achieved. The greater the number of nations involved in seeing that the safeguards placed upon the fuel cycle are not ignored, the lesser the chances that such safeguards will be ignored. There is no guarantee that nuclear power facilities designed for production of electricity will not be used for military purposes; all that Canada, or any other nation, can do is to reduce the number of opportunities available to nations to convert peaceful nuclear installations into weapons-producing facilities.

EQUIVALENT ENERGY CONTENT OF DIFFERENT KINDS OF FUELS

	Energy Content	Energy Content /Mass Million BTU /tonne	Energy Content /Mass Relative to Coal
Oil	5.8 M Btu/ barrel	42.9	1.44
Coal	13,500 Btu/ pound	29.8	1.00
Gas	10^6 Btu/ 1000 ft ³	56	1.86
U235	9400 MW-days (thermal)/ tonne	77×10^6	2.6×10^6
Natural Uranium (Contain- ing 0.7% U235)		550,000	18,500

tonne - metric tonne

1 metric tonne = 1000 kg = 10^6 gm = 2200 lb

Rough Equivalents for Energy Content

5 barrels of crude oil equals 1 tonne coal (NTCE)

6 M ft³ of gas equals 1 barrel crude oil

or 30 M ft³ of gas equals 1 tonne coal (NTCE)

and 0.38 gm of U235 (in 53 gm [about 2 ounces] of natural uranium equals) 1 tonne of coal.

Based on G. C. Lawrence, Royal Society of Canada Symposium
on Energy Resources, Ottawa, October, 1973.

APPENDIX B

**TYPICAL CAPITAL COST BREAKDOWN
(CANDU Nuclear Power Station)**

DIRECT COSTS	Per Cent
Site, buildings and structures	10.0
Reactor boiler and auxiliaries	15.0
Turbine generator and auxiliaries	9.0
Electrical power systems	4.5
Common processes and services	4.5
Instrumentation and control	3.5
Initial fuel (half first charge)	1.5
Heavy Water	15.0
	<hr/>
	63.0
 OTHER COSTS	
Design engineering	8.0
Construction and field engineering	9.0
Commission	3.0
Administration and miscellaneous	2.0
Interest during construction and escalation	15.0
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	37.0
 Total	 100

Taken from: As Energy Policy for Canada, Volume 2, p. 301.

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