INIS-mf--6164 CA8004749

Canadian Nuclear Association Association Nucléaire Canadienne
Suite 1120, 65 Queen St. W., Toronto, Ont. M5H 2M5

NUCLEAR POWER IN CANADA

SUBMISSION TO THE

NEW BRUNSWICK LEGISLATURE STANDING COMMITTEE
ON ENERGY

FREDERICTON

January 29, 1980

CANADIAN NUCLEAR ASSOCIATION

SUBMISSION ON NUCLEAR POWER

To:

THE NEW BRUNSWICK LEGISLATURE STANDING COMMITTEE ON ENERGY

January 29, 1980

1. CANADIAN NUCLEAR ASSOCIATION (CNA)

The Canadian Nuclear Association (CNA) was founded in 1960 to promote the orderly and sound development of nuclear energy for peaceful use. Today the Canadian nuclear industry directly employs over 35,000 Canadians and has annual expenditures now running at over 1½ billion dollars.

The CNA consists of over 230 corporate member organizations, approximately one third from the public sector and the remainder from the private sector. Our members' interests range from fundamental research to nuclear power plant operation; from mining of uranium to storage of spent fuel; and from the production of radioisotopes for medical use to manufacture and construction of some of the largest nuclear power stations in the world.

2. CNA VIEWS ON NUCLEAR POWER

The CNA firmly believes that nuclear power has a major role to play in meeting the electrical power needs of many parts of Canada well into the next century at least. In making this statement the CNA wishes to make it abundantly clear that it is not recommending an exclusive reliance on nuclear power. Although it has been clearly demonstrated in Ontario that nuclear power is now economic at load factors below 50 per cent, there will still be a need for fossil (principally coal) generation as well as continued use of hydro-electric generation. Other forms of generation will assume increasing importance as they demonstrate their economic competitiveness. In fact, the wisest strategic course would be to use a variety of generation types, with the greatest emphasis placed on those types that use resources located within Canada. The reasons for CNA's support of nuclear power are:

1. It is clean and safe and causes the least disturbance to the environment compared with other developed sources of electrical power production.

2. It has been demonstrated to be cheaper. The decision to make Pickering a nuclear power station instead of an equivalent fossil fuel station has already resulted in a saving from importing over $800 million worth of U.S. coal. Pickering's total energy cost per kilowatt-hour in 1978 was 10.4 mills, including all capital, operating and fuelling costs, compared with the current fuelling cost alone of about 13.9 mills at Lambton G.S., Hydro's most efficient coal fired station. Since the net energy cost is low, primarily because of very low operating fuel cost, very high standards of safety can be afforded. The cost of these is reflected in the capital cost. The result is a lower accident probability than from other forms of generation.

3. It reduces transportation requirements when generating centres are distant from fuel sources since, to generate the same amount of electricity with bituminous coal requires twenty thousand times the weight of the equivalent natural fuel bundle. Fatalities at grade crossings are a hazard in the rail transportation of large amounts of coal.

4. It can make Canada more "self-sufficient" in electrical energy production for many decades. By the year 1995, without further nuclear power after the commissioning of the Bruce B nuclear generating station, Ontario Hydro alone would be importing 65 per cent of its fuel requirements for electricity generation from outside the Province of Ontario. Much of this fuel would consist of U.S. coal. With the planned nuclear installation program of Ontario Hydro only 25 per cent of its fuel requirements would be so imported. In the Maritimes there is great dependence on imported oil with all the uncertainties that entails. Each 600 MWe CANDU unti, similar to Point Lepreau, when operating at 80 per cent capacity factor saves nearly seven million barrels of oil per year.

5. Canada has the manufacturing capacity, heavy water production capacity and skilled manpower to design, construct and operate nuclear power plants. This capability would also permit the design and construction of nuclear stations dedicated to the export of electricity (the highest Canadian value-added form of exporting uranium as an energy source) or nuclear stations to serve as the energy core of future combined energy centres.

6. Its excellence of performance has been amply demonstrated by the Pickering and Bruce Nuclear Generating Stations.

The need for nuclear power depends on the growth in electrical demand and the availability, economics and environmental impact of alternative forms of electrical generation. All forms of power generation will require large amounts of capital and hence financial factors need to be considered. In the case of those power sources that depend on non-renewable fuel sources - coal, gas, oil, uranium and thorium - their future availability, cost, and alternative use by society are also important.

3. DEMAND FOR ELECTRICITY

In assessing future growth in electrical demand the following factors will have a significant influence:

3.1 Conservation. The CNA strongly endorses the goal of reducing the waste of energy by increasing the efficiency of end use util -ization relative to energy input. Such a goal would have minimal adverse effect on employment. Higher efficiency steam and process cycles, cogeneration of steam and electric power, district heating, etc. will become more likely to be economically attractive at energy costs rise. The speedier advent of such systems could be encouraged by tax and other incentives.

The reduction of waste is in itself a socially desirable goal. If energy shortages should occur in years to come, voluntary conservation may be insufficient to fill the gap. If shortages are to be avoided then the public, business and government must become more conscious of the need for genuine conservation.

It is, however, difficult to assess quantitatively the effect of conservation on electrical demand since electricity use is characterized so often by its convenience.

3.2 Growth in Population. Over the 25 year period 1976-2001, the population of Canada is projected to grow from 23 million to somewhere between 28.4 and 36 million,[2] an increase of from 23 to 57 per cent. Even a zero per capita growth rate in electricity consumption would lead to demand increases paralleling population increases.

3.3 Growth in Living Standards. Even if it is assumed that there will be no growth in living standards of those at present at the upper end of the standards scale, which is a debatable assumption, there will be significant growth in levelling up the standards of the much larger number of people at present below the upper levels. Attempts to freeze people at their present relative standard of living is not likely to be acceptable and could only be implemented by socially disruptive coercive measures alien to the great majority of the people.

3.4 Growth in Pollution Control. Society is rightly concerned about controlling and reducing levels of pollution in all fields of activity. Most pollution control equipment requires energy input, often in the form of motorized drives or electrostatic or electromagnetic devices, all of which consume electricity.

3.5 Growth in Manufacturing. Most people favour growth in the manufacturing sector to process any province's natural resources to more finished levels. This creates more employment, at higher skill levels, and improves overall balance of payments by reducing imports of finished products worth more than the reduced exports of raw materials. This would lead to growth in electricity demand in this sector.

3.6 Substitution of Electricity Use for Other Forms of Energy.

This is very difficult to forecast in quantitative terms. However, oil and gas are so valuable in chemical terms that their mere burning is being increasingly questioned. Electrification of railways and mass transit systems, followed by increasing electrification of other modes of surface transport, is very probable. Heat pumps may prove to be an economic means of space heating and cooling. Since oil and gas account for nearly two-thirds of total energy consumption, and electricity for less than one-third, any shift from oil and gas to electricity has a relatively greater effect on increased electrical demand. On a national scale substituting electricity for the expected maximum importation of 600,000 barrels per day of oil in the late 1980's would require an additional 60,000 MWe of electric generating capacity.

3.7 Price. In many parts of Canada the price of electricity and of electrical appliances has risen at a lower rate than the Consumer Price Index and average weekly wages and salaries. In relative terms, electricity has thus got significantly cheaper and, in accordance with the classic laws of economics, use has increased. As long as this trend continues electricity demand will continue to increase.

It is very stongly suggested by the CNA that the social consequences of inadequate energy supplies and particularly electricity, which is used in so many areas vital to our health and well-being, are far more serious than the possibility of an occasional small excess reserve margin in some years where, for example, economic recession might have temporarily reduced load growth. The consequences of gas shortages were dramatically shown in recent winters in many parts of the north-east and mid-west in the U.S.A., with schools closed, mass layoffs and severe restrictions even on home heating.

4. CONVENTIONAL GENERATION TECHNOLOGY

It is becoming increasingly clear that CANDU nuclear generation is the preferred conventional method of power generation in Ontario for the next several decades. Towards the end of this century nuclear generation will become increasingly important in New Brunswick and other parts of Canada.

Indigenous uranium fuel and the local availability of almost all the material and human skills required to construct and operate CANDU stations suggest that this mode of generation can meet most future base load requirements with economy and security of supply. The successful operation of CANDU stations in Ontario for many years now has fully demonstrated their overall excellence and suitability for this purpose.

Hydro and fossil-fuelled generation will continue to play an important role in many parts of Canada. Tidal power may prove economic in the Bay of Fundy. However, many major hydroelectric developments pose serious environmental concerns.

Large quantities of coal and some oil and gas are required to fuel plants which are existing, under construction or committed. Some percentage of all these modes of generation will be required far into the future to provide an adequate generation mix for optimum system operation. It may well be decided by society in the not too distant future that oil and gas are too valuable as lubricants, petrochemical feedstock and for transportation needs to be merely burned.

A "Consumer Society" scenario, advocated[3] as an alternative to building any further nuclear plants in Canada, envisions the consumption of 238 million tons of coal in Canada by the year 2000. This would involve an order of magnitude increase in Canada's coal consumption. The capital and labour requirements, the effect on the transportation infrastructure, and the health impacts of such an increase need to be fully evaluated.

Health impacts occur in both the occupational and public health areas. A major data base study[4] for the MERES (Matrix of Environmental Residuals for/Energy Systems) program contains a great deal of statistical information on pollution effects, occupational health effects, costs and many other requirements. Their figures for occupational health effects alone for electrical power production (including extraction, processing, transportation, generation and transmission) are shown in Table 1.

TABLE 1

OCCUPATIONAL HEALTH EFFECTS
(MERES DATA)*

(Per 10^{12} Btu)

	Deaths*	Injuries	Man-days Lost
Coal	.0227	.778	101.8
Oil	.00125	.107	4.86
Nuclear	.00112	.043	1.99

*Coal and oil data probable error < 50 percent
Nuclear data probable error < 25 percent

This twenty times higher death rate in coal mining compared to uranium mining is borne out by the direct uranium mining death rate in Ontario uranium mines and by British coal mining death statistics,[5] which is reputed to be the safest coal mining industry in the world. The Ontario and British figures do not include delayed health effects from lung cancer and black-lung disease, though preliminary data indicates a similarly favourable relative pattern for uranium.

Data for the public health effects of different types of fossil and nuclear electric generation are difficult to quantify because of the wide range of permissible emissions from fossil-fired power plants. A study by Comar and Sagan also provides data on this subject. They estimate that the premature deaths in the general population per year per 1,000-MWe power plant are in the range of 2 - 100 for coal and oil and 0.01 - 0.2 for nuclear.[6] Becker (Rensselaer Polytechnic Institute, N.Y.) and Kaufman (Director, Office of Research, New York State Department of Public Service)[7] indicate much higher deaths with coal generation if the same conservative threshold assumptions are used for both coal and nuclear. Jan Doderlein[8] estimates that the deaths to the public from additional coal-fired generation, in the period 1975-2000 in U.S.A., might be over two hundred times higher than from the same amount of additional nuclear generation. Another major U.S. study (WASH-1224)[9] reached the same conclusion, namely that the human health and injury effects, both occupational and public, are least with nuclear power, greater with oil, and greatest with coal. In the study they assigned a value of $50 man-day lost, leading to a life value of $300,000 if one assumes 6,000 man-days lost per death. They then assessed the costs of health, injury and environmental impacts and showed that they were small compared to capital, fuel and operating costs (3 percent for coal, 1 percent for oil, and 0.9 percent for nuclear). This favourable comparison for nuclear is shown in spite of excluding the public health effects of airborne fossil pollutants--SO_2, NO_x, particulates, trace metals--which could not be quantified. If higher values should be assigned to a man-day lost, then nuclear power would appear even more favourable. In this study all impacts were assessed for the energy production system, from the mining or pumping state through fuel processing, upgrading and transportation, power generation to recovery and waste disposal.

A recent paper by Burnett showed the significant adverse public health effects of substituting fossil for nuclear generation, even allowing for the hypothetical risk of a core meltdown.[10]

A study[11] by Dr. Herbert Inhaber, published early in 1978, assessed the total risk per unit net energy output of ten energy systems - coal, oil, natural gas, nuclear, wind, methanol, ocean thermal, solar heating, solar thermal - electric and photovoltaic. It assessed the risks involved in material and fuel production; component fabrication; plant construction; operation and maintenance; transportation and waste disposition. The study also included the occupational and public health risks not only in normal operation but also the risks from potential catastrophes in the case of nuclear. Natural gas came out as the least hazardous in total impact, followed by nuclear power and then solar heating with coal and oil over a hundred times more hazardous. Publication of this study by the Atomic Energy Control Board in Canada sparked worldwide interest in the subject of total energy system risk assessment - an interest welcomed by the nuclear industry.

It should be no cause for surprise that the public health hazard from nuclear plant emission is so much lower than the corresponding hazards from coal fired plants. The maximum permissible additional radiation from operating power reactors is less than five per cent of natural background radiation, and actual levels are very much lower than this. The permissible standard for sulphur dioxide in the air is more than one hundred times the natural background level of this gas and is very close to the level that causes damage to human health.

In addition there are small amounts of heavy elements (including mercury) and radioactivity (from uranium and radium in coal) discharged from coal plants either via their stacks or in their ashes.

5. ALTERNATE GENERATION TECHNOLOGY

The CNA recognizes the importance of research and development into alternate generation technologies. For the purposes of this submission, and for convenience of discussion, these future technologies are classified into three stages of evolution in new technology, namely, "research", "development" and commercialization".

Much attention is presently focused on research and development of alternate renewable technologies such as solar energy, biomass, wind power and "watts from waste". The CNA fully supports the various research and development programs now being proposed and getting underway. It must be emphasized, however, that these technologies are mostly still in the research and development stages, while none has yet grown past the small-scale stage. During the next several decades none is likely to become available as a commercial-scale operating scheme to meet or displace a significant fraction of the overall electrical energy demand anywhere in Canada.

Nuclear fusion is a particularly attractive alternate technology which is currently under study in several countries. It also must be regarded as being within the research and development phase and it is not yet clear how it will be employed on a utility scale.

Because of the early state of the art of many of the newest technologies, the CNA would urge that the development of alternate approaches derived from the existing technologies be given suitable priority. In many instances this involves continued development of non-renewable resource use, with maximum conservation of the most scarce resources.

It is clearly desirable to develop further the technologies of coal utilization, whether by burning it in a furnace or by converting it into gaseous and liquid products. It is also desirable to continue the development of mining and reclamation techniques along with improved methods of emission control and waste disposal.

For meeting our needs from 1985 to 2000 the most promising technologies appear to be those based upon the alternate versions of the present CANDU nuclear generator. The existing CANDU uses very small amounts of uranium fuel by comparison with our resources. New fuel cycles can be developed to use even less uranium, or to use no uranium at all if it becomes desirable to use another fuel.

The CNA wishes to emphasize the importance of investing, and of continuing to invest, adequate funds for the development of electricity generating technologies which are sufficiently close to full scale commercial development to be realistically adopted by Canadian utilities, or which can displace a significant amount of utility generation. The CNA fully supports R & D funding of research and development of alternate technologies, but it trusts that the public recognizes the enormous gap which exists in technology, economics and time between the conduct of such experiments and their practical application as multi-megawatt (or equivalent) sources of supply.

Furthermore, care must be taken to ensure that Canada's energy research and development effort is not spread too thinly. This would result in the chances of making a major contribution in any one specific technology--such as is occurring with nuclear fission to considerable national advantage--being lost. It is clearly undesirable and impractical to change the direction because a program gathers strength as it develops--Canada has now built a nuclear program which many believe to be the best in the world by pursuing a steady course. It is impractical to change direction because of the investment in careers and equipment which cannot readily be reallocated.

It seems to take about twenty-five years to develop a new power generation concept from completion of the research stage to full-scale utility operation. Canada should build upon its present strengths to produce the bulk power required in the next several decades, while creating an environment which encourages the orderly development of dramatically alternate technologies.

In assessing energy generation technologies it is important that they all be assessed, on a total system basis, for their requirements of non-renewable materials, capital, labour, transportation, distribution and energy consumption. Compared to fossil and nuclear generation, relatively little work has been done in these areas for the so-called 'renewable' technologies. A U.S. Study,[12] for U.S. conditions, calculated the energy payback times for different systems (Table 2) in terms of the number of years output required to generate (payback) the energy consumed in fabricating the equipment; building the generating plant; mining, processing and transporting the fuel (if any) and disposing of the wastes.

TABLE 2

ENERGY SYSTEM PAYBACK TIMES

System	Payback Times (Years)
Oil-fired	0.2
Coal-fired	0.2
Synthetic Natural Gas from Coal	0.4
Synthetic Liquid Fuel from Minemouth Coal	0.5
Light Water Reactor	0.4
Fast Breeder Reactor	0.4
Fusion	0.4
Solar collector (thermal)	8.3
Solar cell (electric)	48.0

The very high internal energy consumption for solar cells is due to the large energy requirements to process sand to polycrystalline silicon. The figures in the table are of interest mainly in relative rather than absolute terms for one system compared with another.

6. POWER ECONOMICS

The construction of a base load electricity generating station - whatever mode of generation is employed - costs a lot of money. For example, a new CANDU station ordered now to come into service in ten years' time costs about $1400 per installed kilowatt. That is to say - it would cost nearly three billion dollars including escalation to build another 2-million kilowatt station equal in size to the 4-unit Pickering A station starting today. Many billions of dollars will be spent for new nuclear stations between now and the year 2000.

It must be recognized that one person's expenditure is another's receipt. Each dollar spent on nuclear power construction in Canada largely ends up as a dollar of income to Canadian citizens. There is also a well-known multiplier effect in capital expenditure of this type which creates additional activity throughout the economy as the man who makes a good wage installing the reactor uses this money to purchase commodities and services. Furthermore, the result of this productive endeavor is a dependable long-term supply of electricity which is essential to "downstream" economic activity of every type.

Expenditures of this type represent an allocation of Canada's manpower resources to productive employment and the creation of real wealth. As such, these expenditures must be distinguished from many other classes of government expenditure which re-distribute wealth from one segment of society to another without adding to the total wealth. Each 600 MWe nuclear unit built generates about 30,000 man-years[13] of work or an average, over a ten year period, of about 3,000 additional jobs.

6.1 Economic and Industrial Capacity

The CANDU technology is Canadian, the fuel is Canadian and all of the equipment is, or can be, produced in Canada. In fact, the Canadian nuclear power program is the most significant and successful activity in the field of high technology ever undertaken and brought to commercial fruition in Canada. The success of the program is due to the skills of people engaged in design, equipment fabrication, construction, operation and mining. Stringent safety criteria have been evolved in Canada for the unique CANDU reactor system.

To develop a new CANDU station from early planning to in-service requires 10-15 years. Nuclear power cannot be a stop-and-go programme if high efficiency and economy is to be achieved by the industry.

The development of the CANDU power reactor is an excellent example of partnership between governmental agencies and the private sector in Canada. This partnership takes place in every phase of the nuclear industry from research and development through plant design and construction to the commissioning of the power plant. This partnership must not be allowed to stagnate due to any breakdown in long-range planning.

Concern has been expressed regarding the ability of the economy to devote a sufficient portion of its resources to an expanding nuclear program. The Canadian Nuclear Association would point out that in many areas the nuclear program has essentially carved its own niche in the economy. For example, those who design, weld, test and install pressure vessels tend to have specialized skills, and use equipment reserved for that special purpose, and which cannot readily be deployed to some unrelated activity, such as searching for oil. If you ask these companies whether they are overloaded at present or whether they foresee an inability to meet the requirements, the answer is a resounding "NO".[14]

Backing up this specialized labor and manufacturing capacity there is a very large segment of general construction activity associated with the construction of a CANDU nuclear plant. This provides a large and steady basis of economic activity in the community.

A most important requirement is to plan and carry out these works on a steady schedule, without sudden changes in the rate of development which can result in massive lay-offs and dislocations.

6.2 Nuclear Power Costs

Nuclear power is seen to have a key role to play in the economies of advanced industrial nations, including Canada, in disengaging electricity costs from the effects of possible increases in fossil fuel prices.

A comparison of total unit energy costs (TUEC) expectations for plants recently installed (Lambton/coal and Pickering A/nuclear) shows fossil generation to be twice as expensive in the first year of operation and four times as expensive after 15 years. The nuclear costs are almost level with time because the decreasing capital component of TUEC nearly offsets the forecast escalation in the fuel and operation and maintenance components.

The kilowatt-hour cost from Pickering B and Bruce B in the mid to late 1980's is forecast to be less than that from Lambton, which started generation in 1969; and it is estimated that Lennox (oil fired) will cost 50 percent more per kilowatt-hour than Pickering B and Bruce B.

6.3 Impact on the Canadian Economy

The highly productive nature of the nuclear industry in Canada relates not only to its employment of a large proportion of professionals, skilled operators and trained construction personnel, but also to its efficient use of capital in installing manufacturing facilities and in the upgrading of indigenous natural uranium into a useful and valuable form of energy. This combination of factors is a significant component in a vitally important activity promoting industrial growth in Canada, with the potential for export of manufactured products, electricity and technology.

6.3.1 Number of Employees

There are at present over 35,000 Canadians employed in the nuclear industry. Over 21,000 employees are hourly paid, over 5,000 are professionals and 8,500 are other salaried staff.[14] These numbers include those engaged in all aspects of nuclear energy related work - uranium mining, fuel manufacture, R & D, design, manufacture, construction, commissioning, operation and maintenance of nuclear power and heavy water production plants. With a nuclear building program, geared to a national energy self-sufficiency policy, manpower requirements in Canada could rise to about 130,000 by the year 2000.

6.3.2 Dollar Value

The total annual dollar value of Canadian nuclear-oriented projects, is now running close to one and half billion dollars.[14]

6.3.3 Upgrading of Resources

Canada must upgrade more of its primary resource production prior to export, for two significant reasons. The first is to overcome the unfavorable effect on Canada's trade imbalance of net oil imports. The second reason is to bring about a more balanced regional and industrial development in Canada.

The provision of large amounts of electrical power is necessary for resource upgrading; e.g., for the manufacture of pulp and paper and smelting and refining materials. Complete CANDU stations, fuel and engineering services, can be very attractive export commodities and represent an appreciable upgrading of indigenous material with the utilization of local manufacturing facilities and skilled manpower.

6.4 Export of Electricity

It has been suggested that an opportunity may now exist for New Brunswick, Ontario and for other Provinces in the future, to construct one or more CANDU plants to generate electricity for export sale to customers in the United States. This proposal is being examined by various agencies.

In economic terms the construction and operation of such stations would have all the advantages of similar stations constructed for domestic purposes.
In financial terms these stations would have the additional benefit of earning revenue in U.S. dollars, thus making a material contribution to Canada's balance of payments. Whatever borrowing is necessary to finance the plants could readily be undertaken. Since it will be repaid by offshore earnings, the borrowing is of an entirely different character to that made for purposes of domestic expenditure.

The CNA would welcome such projects which would provide an important amount of work at this time when employment and capital investment projects are below what the economy can support.

6.5 Ability to Finance

"...anything which makes economic and political sense is financially possible." This statement was made and reiterated several times in a presentation by Wood Gundy Limited[15] to the CNA Annual Conference in June 1977.

In making this statement the speaker was simply restating the circumstances under which Canadian electric utilities have been expanding for many years. The construction of CANDU stations is financially possible because it allocates the productive resources of Canada to purposes economically and politically desirable to a large majority of its citizens.

Various authorities[15,16] have estimated that total Canadian spending on energy products may rise from the current level of 3.5% of GNP to 5.5 - 6.5% of GNP after 1980. They state that such growth can be accommodated readily, provided the economic and financial justifications exist.

The CNA believes that price is a most important aspect of sound economic justification. Price is the basic yardstick for determining the correct level of economic activity within each appropriate sphere of endeavor. Power does not have to be sold cheaply. It is very important that, through an appropriate rate structure, a utility has the necessary excess of revenue over costs each year to maintain a proper equity to debt ratio and meet other sound financial criteria.

7. URANIUM SUPPLY

The domestic requirement for uranium depends on the amount of CANDU nuclear plants in Canada. There is, at present, 5,600 MWe of nuclear generating capacity operating in Canada, all on the Ontario Hydro system, with an additional 9,800 MWe under construction, for a total of 15,400 MWe. Population growth, economic growth, electricity substitution for oil and changes in both the relative and absolute prices of different forms of energy will all affect load forecasts, as will the decisions taken to implement any policies of energy self-sufficiency. Further additional nuclear plant construction beyond the 15,400 MWe level, during the rest of this century in Canada could be in the range of 10,000 to 60,000 MWe.[17] Such a wide range in forecasts gives rise to considerable uncertainties for both the Canadian nuclear power and uranium mining industries.

For the CANDU units in service and under construction the 30 year lifetime requirement for uranium, operating at an 80 per cent capacity factor, is 69,000 tonnes U.[18] This figure should be compared to Canada's present reasonably assured reserves of 235,000 tonnes U with an estimated additional amount of 728,000 tonnes, mineable at prices up to $175 per Kg U.[18]

The lead times faced in developing new uranium mines from start of exploration to full production could be in excess of 10 years. Increased exploration effort for uranium must continue to be encouraged to ensure the security and economy of fuel supplies, and domestic uranium requirements should continue to provide the basis for such efforts.

Resources are only one part of the supply picture and represent potential supply, not actual supply. Actual supply is determined by mining and milling capacity, and estimated annual Canadian uranium production over the next 12 years is shown in Table 3.

TABLE 3

ESTIMATED ANNUAL CANADIAN URANIUM PRODUCTION[18]

Year	Tonnes U
1978	6,803 (actual)
1979	6,900
1980	7,200
1981	9,000
1982	9,900
1983	11,000
1984	13,500
1985	14,400
1986	14,500
1987	14,500
1988	14,700
1989	15,400
1990	15,500

In assigning the domestic allocation among producers, measured, indicated and inferred resources were included with weighting factors of 1.0, 0.8, and 0.7 respectively. The lower values for the last two categories reflect a lesser degree of reliability than measured resources. Each uranium producer is allocated its share of the domestic requirements in accordance with its adjusted reserve to the total adjusted reserve for all the Canadian uranium producers marketing uranium. This amounts to about 23.5 percent of the total recoverable adjusted reserve for all Canadian uranium producers marketing uranium.

World demand is very much larger. The Conservation Commission of the World Energy Conference has estimated that world uranium requirements would increase to about 200,000 tones U per year by the year 2000,[19] and 350,000 tonnes U per year by 2020 even if fast breeder reactors were developed successfully by the end of this century.

Demands of this magnitude can only be met or modified by any or all of,

(a) New discoveries of economic orebodies recovered by established techniques.

(b) Development of advanced fuel cycles - plutonium recycle, thorium/U_{233} cycle - for the CANDU system.

(c) Development and commercialisation of the fast breeder reactor.

(d) Development of economic means of extraction of low concentrations of uranium from seawater, granites and shales.

Methods (a) and (b) are the most likely routes for Canada, but the discovery of new economic deposits of ore depend firstly on the deposits actually being there and secondly on the incentives and exploration efforts to find them. The latter is very much dependent on the economic health of the domestic uranium mining industry, which in turn is very much dependent, in a heavily regulated industry, on sensible government policies. A proper level of support for R & D agencies on research in the field of advanced fuel cycles will provide valuable insurance for the future by leading to Canada's energy self-sufficiency.

7.1 Uranium Pricing

Uranium prices increased from levels as low as $5/lb U_3O_8 in 1972 to prices close to $45/lb for immediate delivery. There are many reasons for this.

(a) The uranium mining industry went through a prolonged slump with many mines forced to close, only the richest ore seams being profitable, and artificially low selling prices at distress levels.

(b) The worldwide uranium industry has been hit by the general cost inflation of the past few years.

(c) Progressively lower grade and more difficult access ores are being worked.

(d) More stringent environmental and safety requirements are necessary, including much more stringent ventilation regulations in underground mines and future monitoring and management of waste dumps after the deposit has been mined and the mine operator has left the scene. The execution of these requirements represent a direct added cost, which is reflected in a higher cost for uranium fuel and ultimately a higher cost for the electricity consumed.

(e) Higher costs of exploration.

A governmental view on future uranium prices was given by E.M.R. Deputy Minister MacNabb at the 1976 Uranium Institute meeting in London: "...foreign utilities and their governments should not expect producers and producer governments to react favorably to a demand for prices based on costs plus a 'reasonable' profit. This utility approach to pricing has little relevance when dealing with an evasive, depleting and finite mineral commodity. The purchasers must expect, and respect, producer requests for prices that move well ahead of inflating costs. Without that, the supplies necessary for future needs will not be forthcoming."[25]

Over the past few years prices have in fact risen sharply, due in part to the strong probability that the demand for uranium could double every 6 or 7 years, fears of future shortages, and the relative value of uranium compared with the value of alternative fuels.

7.2 Uranium Exploration

Since uranium is such a concentrated energy source and occurs as an ore (with typical concentrations in the range of 1 to 5 pounds per ton of ore) and occurs in comparatively few deposits of these concentrations, compared to coal or oil, it is a relatively difficult material to find. During the industry slump in the 1960's there was little incentive or financing for exploration. This situation has changed considerably and exploration has increased substantially in Canada, U.S.A., Australia and many other parts of the world in recent years. In Canada $71.7 million was spent on uranium exploration in 1977 and $90 million in 1978.[18]

It has been estimated that exploration costs are approximately $2 - $3 per pound located. At current money values this could mean a total investment, for exploration alone on a worldwide basis, of $10 billion over the next 25 years. This in turn implies building up to an exploration force comparable with that of the entire uranium mining industry at the present time.[21]

A number of utilities including Ontario Hydro in Canada, and in other countries such as U.S.A., Japan, U.K., Germany, France, Spain and Italy, have formed, either directly or indirectly, joint ventures with mining exploration companies to seek out reserves for the future. In the light of the nature of the product being sought, this is a prudent move on the part of those utilities.

7.3 Uranium Stockpiling

The IAEA/OECD estimate puts the overall world level of stocks as the equivalent of over 80,000 tonnes U, a figure which is four times the world production level in 1975.[22] Stocks are not likely to remain at this level for long. However, again because of its concentrated energy nature, uranium is a much easier fuel to stockpile than any of the fossil fuels. A 12 month supply for the 15,400 - MWe probable installed capacity in Canada in 1990 would require only 2,200 tonnes U to operate this capacity at 80 percent load factor. At $110/Kg U and 10 percent interest charge this stockpile would represent an annual carrying charge of $24 million plus very minor storage costs. This is a modest charge for a significant degree of "self-reliance" that would provide protection against any sudden changes in uranium supply. A similar capacity coal stockpile would require 38 million tons of bituminous coal with an annual carrying charge (for coal at $45/ton) of $170 million, plus significant storage costs.

8. DECOMMISSIONING AND WASTE MANAGEMENT

An assessment has been made[23] of the cost of the complete dismantling and removal of a 600 MWe CANDU reactor and the site returned to a state where no surveillance inspection or tests are subsequently required. The cost (in 1976 dollars) is thirty million dollars. This amount is probably considerably less than the salvage value of the heavy water inventory in the reactor. Even if the heavy water has zero value and it was decided to treat this cost as part of the annual operating cost (and not as part of the utility operating costs in the years when the decommissioning work was actually done) it would add less than 0.2 mill/KWh to the cost of the electricity produced. This amount is approximately 2 per cent of the present total unit energy cost (annual charges on capital, including depreciation, plus fuel plus operating and maintenance costs).

There is a great deal of work going on, in the numerous countries with nuclear power programs, into further development and refinement of long term waste management techniques. Work is proceeding in Canada on the necessary geological studies. However, general public concerns in this area are unlikely to be resolved until an actual site for the first long term waste storage facility is selected and the actual storage and disposal methods implemented.

9. CONCLUSIONS

The CANDU nuclear-electric generating system can play a major role in helping to achieve energy self-sufficiency in Canada. It is one of the very few successful all-Canadian ventures in a high technology area. Skilled manpower and surplus manufacturing capacity is available for both domestic and export business. However, what has taken so long to build up can quickly be destroyed and action by the decision-makers are required to maintain a viable nuclear industry in Canada that can quickly respond to crucial energy needs in the years ahead.

REFERENCES

1. B. Greer - Wooten and L. Mitson. Nuclear Power and the Canadian Public. Research Report. Institute for Behavioural Research, York University. 401 pages. June, 1976.

2. Population Projections for Canada and the Provinces, 1972 - 2001. Statcan Catalogue 91 - 514. June, 1974

3. F. H. Knelman. Nuclear Energy - The Unforgiving Technology. Hurtig Publishers, Edmonton, 1976. Pages 214 - 217.

4. Hittman Associates, Inc. Environmental Impacts. Efficiency and Cost of Energy Supply and End Use. N.T.I.S., U.S. Department of Commerce, November, 1974. Vol. 1. Tables 2, 16 and 26.

5. Report of Her Majesty's Chief Inspector of Mines and Quarries for 1974. London. H.M.S.O. Table 1.

6. G. L. Comar and L. A. Sagan. Health Effects of Energy Production and Conversion. Annual Review of Energy. Vol. 1. p. 596. Table 7. 1976.

7. Martin Becker and Alvin Kaufman. Electric Energy Alternatives Appraisal for New York State. IEEE Paper F 76 618-9. September, 1976.

8. Quoted by David Smith in More Black Death than Black Gold. Nuclear Engineering International, February, 1977. P. 25.

9. U.S. Atomic Energy Commission. Comparative Risk-Cost-Benefit Study of Alternative Sources of Electrical Energy. WASH-1224. Chapter 1 - Introduction and Summary - reprinted in Nuclear Safety, March - April, 1975. pp. 171 - 182.

10. T.W.T. Burnett. The Human Cost of Regulatory Delays. American Nuclear Society. Transactions. Vol. 23. pp. 452 - 454.

11. H. Inhaber. Risk of Energy Production. AECB-1119/Rev-2 (Third Ed.) Ottawa. November, 1978.

12. Seymour Baron. Energy Cycles: Their Cost Interrelationship for Power Generation. Mechanical Engineering. pp. 22 - 30. June, 1976.

13. Electrical and Electronic Manufacturers Association of Canada. Impact of 3 different Forms of Energy on Provincial Economies. Toronto. May, 1979.

14. Leonard & Partners. Economic Impact of Nuclear Energy Industry in Canada. Ottawa. August, 1978.

15. P.A.T. Campbell and P.L. Jones. Nuclear Energy - The Material Constraints - Limitations on Money. Wood Gundy Limited. CNA Annual Conferences, Montreal June, 1977.

16. Ralph G.M. Sultan. Energy Industry Finance: The Next 50 Years. (Chief Economist, The Royal Bank of Canada). Third Canadian National Forum. Halifax, Nova Scotia. April, 1977.

17. H. E. Thexton and A. R. Scott. Domestic CANDU Program Including Opportunities for Electricity Export. 19th Canadian Nuclear Association Annual Conference. Toronto. June, 1979.

18. Energy, Mines and Resources Canada. 1978 Assessment of Canada's Uranium Supply and Demand. (Report EP79-3). June, 1979.

19. M. F. Duret, R. M. Williams, et al. The Contribution of Nuclear Power to World Energy Supply, 1975 - 2020; Volume 2 - Nuclear Resources; in World Energy Resources 1985 - 2020. IPC Science and Technology Press. July 1978.

20. G. M. MacNabb. North American Uranium Resources, Policies, Prospects and Pricing. International Symposium on Uranium Supply and Demand. The Uranium Institute, London. June, 1976. p. 10.

21. John Kostuik. Key Issues Affecting the Future Development of the Uranium Industry. International Symposium on Uranium Supply and Demand. The Uranium Institute, London. June, 1976.

22. IAEA/OECD. Uranium: Resources, Production and Demand. December, 1975.

23. G. N. Unsworth. Decommissioning of CANDU Nuclear Stations. AECL - 5800. April, 1977. pp. 49 - 67.