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THE POLITICS OF NUCLEAR ENERGY
IN CANADA: A CRITICAL ANALYSIS

by

© Babar Mirza

A thesis submitted to Carleton University in partial
fulfillment of the requirements for the degree of

Master of Arts
in
Political Science

Department of Political Science

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ABSTRACT

This thesis is basically concerned with the politics of nuclear energy in Canada. The analysis attempts to provide a clear picture of the current problems facing nuclear energy development in the country. A comparative assessment of other energy options has also been made, as no discussion about the merits of nuclear energy is complete unless extensive comparisons are made with other energy forms.

Since nuclear energy has become an extremely controversial issue in recent times, the problems discussed in the thesis mainly relate to the nature of those controversies and the political complexities of decision-making. Considering the nature of the Canadian federal system and the division of jurisdiction between the federal and provincial governments over energy policy, the various issues involved in nuclear policy processes are naturally examined from a decision-making perspective.

The thesis is that no current theory of public policy can fully explain the various processes involved in decision-making at the governmental level. The decisions reached are obviously the result of the interplay of environmental conditions and socio-political factors. As the number of possible influences is considerable, and there are also limits imposed by technology on the decision processes involving such a complex field as nuclear energy, no one theory can be expected to serve as a wholly satisfactory framework for such an analysis of public policy.

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Some of the information concerning nuclear energy was also obtained by personal visits to a number of local offices, such as the offices of the AECL, the Pollution Probe, the Atomic Energy Control Board and the Department of Energy, Mines and Resources. The staff at all these offices were most co-operative and helpful for which the writer is indeed very thankful.

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CHAPTER I

INTRODUCTION

Basic Issues

Although this thesis is essentially concerned with the politics of nuclear energy in Canada, we propose to examine nuclear energy issues within the framework of a broader energy perspective. This approach is expected to provide a more useful analysis, since nuclear energy cannot be insulated against the impact of economic factors which affect other energy forms. We have seen this happen in the oil crisis of 1973 when the pricing and supply position of oil was affected, causing a chain reaction in the pricing and supply position of all other energy forms, including of course nuclear energy. It will therefore seem desirable to examine, at least briefly, the various options open to Canada for developing her entire energy potential, and not just confine our examination to nuclear energy alone. We will thus have to go into the problems which affect the development of various energy forms, particularly the limitations imposed by economic and environmental factors on their development.

However, insofar as nuclear energy is concerned we find that the nuclear power industry in Canada has been beset by uncertainties which

have seriously limited its growth potential. Events in recent years have tended to increase rather than diminish the problems adversely affecting the interests of the industry, and to damage its claims as a comparatively economical, reliable and safe source of energy. There is as yet little likelihood of an early reversal of these anti-nuclear trends which first gained momentum in the United States and then spread to Canada. The net effect of these trends has been to impede the pace of nuclear expansion.

A major uncertainty afflicting the industry is of course public concern about the possible environmental dangers from the operation of nuclear power plants. These concerns continue to grow. They have added a new dimension to the debate over the suitability of nuclear energy as a viable alternative to the more conventional forms of energy dependent on oil, gas and coal which, at some point in time, may be so exhausted as to be economically unattractive to produce.

But the issue of energy shortages and the need for measures to find acceptable solutions cannot be examined in isolation and have to be considered in the light of the overall needs and aspirations of a society. While the whole question boils down to what kind of life one expects to live in terms of material benefits, we cannot obviously go into this question here, as it also raises moral and ethical issues with which this thesis is hardly concerned. Nevertheless, one thing is clear. The economic growth of a nation is dependent on a high degree of industrialization. No country can hope to achieve this without adequate supplies of energy at costs compatible with the need of the industry in a

competitive world situation. Canada is fortunate in that she is richly endowed with a vast array of natural resources with which to develop her industrial potential. She is, however, not immune to the effects of fluctuating world prices, particularly for commodities such as oil which she still imports, though only to a limited extent.

Although Canada has the oil supply potential to phase out oil imports, dependence on hydrocarbon energy will ultimately have to give way to more durable forms of energy. There is little doubt that the energy crisis of the early seventies has lent credence to the view that physical shortages of energy resources, such as oil, must now be regarded as a fact of life. The present oil glut in world markets should not, however, blind us to the fact that oil is still very much a political weapon, as no reliance whatsoever can be placed on continued supplies of imported oil, so long as future policies relating to oil production, pricing and distribution from the Middle-east sources remain in unpredictable hands.

Keeping these factors in mind, no issue will perhaps have a greater impact on Canada over the next several decades than the country's decisions on energy. These decisions will naturally be concerned with such issues as the priority that may be given to energy conservation, the pricing of energy, and the particular energy sources which should be developed first. Decisions of this magnitude will certainly have an enormous effect on the total economy of the country.

While seeking solutions to their energy problems, many countries,

including of course Canada, have considered the development of nuclear power to generate electricity. Speaking primarily about nuclear energy development in the United States, one writer emphasizes the importance of electricity

...as the best way to reduce dependence on foreign oil, as well as to ensure a limitless and economic supply of energy for the future. A growing number of countries have built nuclear power plants or made plans to acquire them.¹

Despite the need for more electricity, opposition to continued nuclear power development has been growing in recent years both in the United States and Canada. The critics have thus begun to question the need for more nuclear power plants, their safety, and the arrangements for nuclear waste disposal. Questions have also been raised about the long-term effects of nuclear radiation. Moreover, the opposition has been able to mobilize a certain amount of popular support which has enabled it to raise the level of the debate to the status of a political issue of some magnitude.

The fact that this subject became a matter of general public debate in Canada only in the seventies and not earlier when civil nuclear power first got underway, or in the sixties when opposition to nuclear weapons prompted major demonstrations in the United States but without attracting much attention in Canada, can perhaps be explained by what Bruce Doern, a notable writer and a leading analyst of Canadian nuclear energy policies, considers to be the reason:

During the 1950s and 1960s public opinion in Canada about nuclear policy could be said to consist of a high degree of deference, awe and mystery. While there has always been a strong concern about nuclear weapons, the domestic power program operated largely in an environment of benevolent deference to scientific authority and expertise.²

Although opposition to nuclear power in Canada was considerably slower to become mobilized than was the case in the United States, by 1975 the debate had assumed a wider perspective and a political character. The new issues that began to be discussed concerned the fundamental attractions of nuclear power, particularly bearing in mind the doubts objectors had about the safety of nuclear facilities and their wider concern that civil nuclear power development could not but promote nuclear proliferation.

It seems paradoxical that only two years earlier, with the outbreak of the Middle-east war and the energy crisis which hovered so ominously, the need for the development of nuclear energy was brought into sharp focus. Those who had always regarded nuclear energy as the only long-term solution to the world's energy needs, began to feel the case for its rapid development to be even more urgent than they had previously maintained.

Today, the position has become complex and perhaps confused. The mere mention of the word "nuclear" evokes all kinds of concerns, especially in the minds of those who are opposed to nuclear energy.

It was some thirty-seven years ago that the Zeep nuclear reactor at Chalk River, Ontario, first achieved criticality. During the intervening years, a great many nuclear-related scientific and

technological advances were made. But these seem to have been forgotten or overshadowed by the persistent outcry during recent years against nuclear technology and the issues connected with its development.

The issues raised by the debate over nuclear power development are certainly very important for a number of reasons. For example, industry and government will be allocating large sums of money to projects connected with energy development. Decisions of policy-makers and investors about different energy strategies will have important implications for Canada. Even though there are many uncertainties concerning the social and environmental impacts associated with various energy options, experts in their respective fields of specialization will certainly be able to delineate the nature of the risks posed by each system. More importantly, increased public concern about problems associated with nuclear energy has led to the need for greater government involvement in decisions concerning nuclear industry. This has however not been a problem as nuclear industry in Canada from the very beginning of its development has been a public sector industry:

...it is perhaps the classic Canadian example of a state-dominated industry since its most powerful organizations, Atomic Energy of Canada, Ltd., Eldorado Nuclear Ltd., Ontario Hydro, and Hydro Quebec are all owned by governments.³

As this thesis is mainly concerned with the politics of nuclear energy in Canada, it will naturally concentrate on the issues and

ramifications of the debate over nuclear power development. It is, however, important to go over the historical background of the debate first, as it relates to the growing popularity of electricity and electric power which had begun to replace other forms of energy.

The Increasing Role of Electricity:
An Historical Background:

From the early stages of its development, nuclear power began to be recognized as an important source of electricity which had already been accepted as perhaps the most versatile and convenient form of energy. Some industrial and residential consumers of energy had accordingly moved away from coal, oil and natural gas to electricity. With the increase in the demand for electricity, interest in nuclear power began to increase too.

On an average, the consumption of electricity in Canada for the years 1960 to 1975, increased at the rate of 6.1 per cent. In 1976, a 7.1 percent increase was recorded over the figure for 1975. But there was a decline in 1977 when the use of electricity increased by only 5.4 per cent over the figure for 1976, thus reflecting a high correlation between electricity consumption and economic activity. In that year, real gross national product increased by only 2.6 per cent when compared with 4.9 per cent recorded in 1976. In 1978, however, electricity consumption increased by 5.5 per cent. Although this was a very slight increase over

the 1977 figure, it was considerably below the 1960-1975 growth rate of 6.1 per cent a year.⁴

In terms of actual production figures, the total generation of electricity in Canada in 1980 was 366 033 GWh as compared with 352 375 GWh generated in 1979 - a four per cent increase. The estimated figures for 1981 however show that the total electricity produced in that year increased by only 2.8 per cent over the 1980 production figures. Despite this decline in electricity growth rate, net exports for 1981 amounted to 33 875 GWh as compared with 27 237 GWh in 1980. There has also been no appreciable change in consumption patterns by sector. The industrial sector of course consumes the greatest share of the electrical demand, followed by the residential and commercial sectors.⁵

In terms of installed electrical generating capacity, Canada had a total of 23,049 MW capacity in 1960, of which 4,392 MW were conventional thermal and 18,657 MW hydroelectric. The figure for 1975 was 61,352 MW which represented the total installed electrical generating capacity for that year.⁶ But by the end of 1980, Canada's total net installed electrical generating capability had increased to approximately 78,000 MW, i.e. more than twice that of 1960. Of this, hydroelectric plants accounted for about 46,430 MW, conventional thermal stations 26,517 MW and nuclear power 5,064 MW. If we look at the figure for total generation of electricity, 366,033 GWh was generated in Canada in 1980 as already mentioned. The breakdown of this figure shows that approximately 68

per cent was supplied from hydroelectric generation, 22 per cent from conventional thermal generation and 10 per cent from nuclear generation.⁷ Interestingly enough, the federal government's forecast for the year 2000 shows that the component of nuclear energy, which was a mere 5 per cent in 1975, will grow to 33 per cent by the end of the century.⁸

Following the successful operation of the first full-scale nuclear reactor in Canada for the production of electrical energy in 1966, there arose a great deal of optimism in government and business circles about the peaceful use of the atom to create an unlimited source of cheap energy. But this optimistic view was not shared by many of those who later became vehement critics of nuclear power.

In the summer of 1975 a coalition of anti-nuclear groups was formed. It sought to stir up public concern over nuclear policy and programs.⁹ The debate, which has gone on since, has seriously jeopardized the prospects of nuclear energy development on any substantial scale.

Although current government forecasts project that nuclear reactors will provide 33 per cent of all electricity generated by the year 2000, there are some who view these forecasts as too optimistic. With a greater emphasis on energy conservation policies and soft-energy options, it is quite possible that the rate of growth initially predicted for electrical energy, may have to be reduced to a more realistic level.

While the present uncertain phase of nuclear energy development in Canada can, to some extent, be attributed to the apprehensions expressed by anti-nuclear interests on the harmful effects of any large-scale use of nuclear energy, it is also partly the result of a changed economic situation. Thus the demand for electricity has been adversely affected by higher electricity prices as a result of the rise in coal, oil and uranium prices.

Scope of the Inquiry and
an Overview of the Debate:

Apart from the changed economic situation, the pace of nuclear power development has also been affected by changes in the political and regulatory aspects of nuclear energy. The great enthusiasm within the federal government that had earlier been responsible for boosting nuclear development in collaboration with Ontario Hydro, has since mellowed down considerably. Moreover, increasing public concern about hazards associated with nuclear power has resulted in stricter regulation of the industry by federal and provincial authorities.

Those opposed to nuclear energy obviously felt happy and encouraged with the slowdown in nuclear development. This gave them a new opportunity to question the advisability of the government supporting any further development of nuclear energy. The Three Mile Island accident in Harrisburgh, Pennsylvania has since provided the opponents of nuclear energy a more potent argument with which to oppose nuclear energy development in Canada. The Harrisburgh accident is of course considered

to have been the most serious accident known to have taken place in a commercial nuclear plant. Following the accident, the Atomic Energy Control Board launched an intensive inquiry to assess the implications of the accident for Candu plants and their operation, and has since laid down more stringent requirements.

The future of nuclear power in Canada thus appears to rest on how those responsible for its development react to this new and more hostile public concern. Many of the elements in the debate about nuclear power naturally involve highly technical questions, such as what constitutes an acceptable level of exposure to radiological emissions. Then there is the question of the assessment of the likelihood of a serious accident, and the level of risk that will be acceptable.

It should, however, be obvious that no discussion about the merits of nuclear energy or any other energy source is complete unless it makes extensive comparisons of various energy options. This thesis has therefore attempted to discuss nuclear power within the context of possible alternatives. Nevertheless, the focus of the discussion will be on nuclear power itself and the debate concerning its suitability as a source of electricity. This will carry us into the field of nuclear policies and the ongoing debate about the extent to which nuclear energy production and utilization should be subjected to governmental control and authority.

While the public mood affects every government policy to some

extent, it has already encouraged a protracted debate over the proper priorities and policy options in regard to the nation's energy resources. Therefore, in the changed environment of public opinion about nuclear energy, a decision on its future will have to be taken only after a thorough discussion in a political forum has taken place. This would provide an opportunity for a balancing of technical judgements against less-technical social concerns.

While in this introductory chapter we have briefly touched upon some of the issues concerning nuclear energy development in Canada, in chapter II we will be discussing some of the theories of public policy with a view to see if various factors which influence public policy and the processes involved in decision-making can at all be explained within the framework of those theories.

Chapter III examines the world energy situation, as well as the current energy problems which Canada is facing today. The National Energy Program is also discussed in that chapter. Although chapter IV deals with the development of nuclear energy in Canada, including of course the economics of nuclear power, it is chapter V which contains a comprehensive analysis of some of the most important nuclear energy issues in Canada. These include issues of such public controversy as for example, the debate between the proponents and opponents of nuclear energy over the suitability of nuclear power, nuclear policy as a federal lever in federal-provincial relations, and of course environmental safety and social costs.

Chapter VI contains a case study which provides information on

some of the important aspects of Ontario Hydro's nuclear energy program. It also provides a brief comparison with the Three Mile Island nuclear plant in Pennsylvania in order to enable us to determine if the problems which afflicted the U.S. plant have any implications for the safety of Candu reactors used in Canada.

And finally, chapter VII contains a summary and conclusions. However, it needs to be emphasized that the conclusions reached are based strictly on the facts presented in this thesis.

CHAPTER II

THEORIES OF PUBLIC POLICY: THEIR UTILITY AND LIMITATIONS

Background to the Policy Process

This chapter attempts to explain briefly some major theories of public policy to see if the various factors which influence public policy and the political complexities of decision-making on such a sensitive issue as nuclear energy, can be analyzed within the framework of any of those theories. Government intervention in the energy sector is, of course not a new phenomenon. In recent years, government authority over the energy sector has so expanded that practically no area of energy management has remained unaffected. This expansion of authority and government involvement in the industry was spurred by the growing recognition of a national need, not only to conserve the rapidly dwindling energy resources but also to develop conventional and new energy sources.

The introduction of the National Energy Program in 1980 was thus considered as a milestone in Canadian economic history:

It marks an abrupt reversal of the policy thrust, established in the last months of the former Liberal government and continued by the Conservative government, toward more reliance on private initiative as a principal driving force in the Canadian economy. It is also a harbinger of a return to a policy climate so familiar in the mid-1970s, wherein private sector undertakings were regarded with suspicion and their vilification used as the new raw material for crafting political strategems.

Energy has of course become one of the leading economic and social issues of this century. Obviously, energy issues are no longer restricted to questions of economics or the security of supply. They now encompass a much wider field, involving considerations of life-styles and social organization. Perhaps no energy issue is today as important for maintaining a proper balance between public and private benefits than the current debate over policies concerning nuclear energy. Moreover, energy planning requires decisions regarding the "mix" between public and private benefits that result from a particular policy. Nuclear issues are thus highly contentious, and as Doern points out, they are influenced by contending values about the policy process itself:

Nuclear policies are multivalued, as are so many fields of public policy. That is, they invoke a range of ideologies, values, and objectives whose rankings are different among different participants.²

Nuclear Policy Paradigms:

Public policy, as noted above, is subject to influences exerted by "paradigms", which are really nothing more than sets of socially co-ordinated views about how in general policy options may be approached. The debate over "hard" and "soft" energy policies could thus be identified in terms of two different paradigms. While these two paradigms may reflect different rankings of values, it must be pointed out that:

'hard' and 'soft' energy paradigms are not always stark opposites.... Such simple categorizations defy the close interdependence of energy, economic and social issues.³

Though simple, such paradigms of contending ideas constitute an important factor for understanding such actions or policies as, for example, government intervention in a particular field of economic activity. However, an understanding of intervention is only possible within a framework that comprehends the technical realities under which a particular enterprise or industry functions: "In the nuclear industry this begins with an appreciation of nuclear fuel cycles."⁴

Theories of Public Policy:

In view of the characteristics of the nuclear fuel cycle and its critical nature, it is important to understand that there is no single policy process involved in dealing with nuclear issues, but rather a number of policy processes that have to be considered. As already indicated above, nuclear policies are also influenced by contending values about the policy process itself. We have seen that nuclear policies are especially susceptible to conflict because they arouse concern about the proper role of the government which has the responsibility to consider how public decision processes should be designed to ensure public participation and acceptance.

Therefore, the various issues with which we are concerned in this thesis will be examined in terms of the decision-making process. The making of energy policy is of course a cycle of governmental decisions made within the constraints imposed by the character of available energy resource and technologies. But energy has often been highly sectoral, in

the sense that policy evolves in response to the economic and political peculiarities of different energy sectors. This sometimes creates problems and can even lead to mutually inconsistent approaches to energy utilization. Thus, laying down a policy for the nation's energy resources has now become so complex that energy management is perhaps the most controversial and difficult of all domestic policy areas.

For this reason, it is difficult to claim that any particular theory of public policy will be able to encompass all aspects of the decision-making processes in the area of nuclear energy. With this reservation in mind, it is proposed here to examine a limited number of theories of decision-making which have been advanced to shed light upon public policy processes. It is however to be noted that we will confine our analysis of the current nuclear energy debate to the following five political issues:⁵

1. The high-technology aspect of the nuclear industry.
2. The debate between the proponents (including the government) and the opponents of nuclear industry.
3. The state-ownership aspect of nuclear industry.
4. Manifestations of nuclear policy that touch upon federal-provincial relations.
5. Inter-departmental aspects of nuclear policy within the federal bureaucracy.

Canadian public policy has been described as a plurality of closely interlocked processes. Moreover, public policy includes not only the actual activities undertaken by a government, but also the resulting impacts. A number of concepts and models have been developed over time for describing and explaining various political processes. Thomas R. Dye, for example, has provided us with a description of eight such analytical models as noted below:

1. An Institutional Model
2. A Process Model
3. A Rational Model
4. An Incremental Model
5. A Group Model
6. An Elite Model
7. A Game Theory Model
8. A Systems Model

Each of these models, however, focuses on separate elements of political activity. Particular aspects of public policy can thus be described and explained by the use of these various models in a variety of key domestic policy areas, subject of course to the limitation that each theoretical model can only explain specific elements of public policy. Dye elaborates this further:

Most public policies are a combination of rational planning, incrementalism, competition among groups, elite preferences, systematic forces, political processes, and institutional influences. Throughout this volume we employ these models, both singly and in combination, to describe and explain public policy.⁶

While it is true that none of these models was derived especially to study public policy, each seems to provide not only a different way of thinking about policy, but also suggests some of the general causes and consequences of public policy. However, a brief description of some of these models will clearly show their limited utility in offering an analysis of the impact of social, economic, and political forces on the content of public policy.⁷

Institutional Model

Governmental institutions are really structured patterns of behaviour of individuals and groups. They naturally affect the content of public policy. But both structure and policy are largely determined by environmental forces. Therefore, by changing the existing institutional arrangements, it is quite unlikely that there will be any direct impact on public policy, unless the underlying environmental forces, i.e., social, economic, and political factors, also change.

Process Model:

Policy processes can be described as a series of political activities, such as the identification of problems, formulation of policies, their legitimation, implementation and evaluation. The process model can thus explain the various activities involved in making policy. Its focus is however limited since it is not concerned with analyzing the substance of public policy.

Elite Theory:

In this theory, public policy is viewed as being the result of the preferences and values of the governing elite. The masses may however have an indirect influence. Since the elite model is comparatively closed and non-competitive, its utility for analyzing public policy in a highly democratic system of government is limited.

Rational Model:

A rational policy is one that is considered to be most efficient. Efficiency in this sense implies that the ratio between the values achieved and the values sacrificed is positive and higher than any other policy alternative. There are however many obstacles to such rational decision making. Because of the many conflicting values which cannot be objectively compared or weighted, rational policy-making does not often take place in government.

Game Theory:

Game theory can be applied to rational decisions in a competitive situation in which the outcome depends upon what others do. As a key concept in game theory is strategy, its utility is generally limited to serious conflict situations in which two or more parties may try to outmanoeuvre each other over a sensitive issue, such as the Cuban missile crisis of the early sixties.

Systems Theory:

This theory simply explains how a political system functions and how it responds to forces in the environment. Public policy is thus viewed as an output of the political system. The value of the systems model to policy analysis is however limited, inasmuch as it does not explain what particular forces dominate and are really responsible in shaping public policy.

We have briefly described above the limited utility of six analytic models out of the eight suggested by Dye. Before we discuss the remaining two models, it needs to be pointed out that there are many other theoretical models which have been developed over time to explain how decision-makers select one of several alternatives. But this does not mean that any one of these models can fully explain the various influences which are brought to bear in shaping public policy. According to Peter Aucoin, "there has not yet emerged a general theory that has been accepted as the framework for the analysis of public policy." Aucoin then goes on to point out that there still remains a marked disjunction of theories and models: "This disjunction is due not only to the different foci but also the different levels of analysis of the several approaches which have been developed."⁸

Despite the limited utility of these models, it will perhaps be useful to examine some of them in greater detail. We have therefore selected three well-known theoretical models for this purpose, as they appear to be of some importance for analyzing some of the public policy processes. Two of the models to be discussed in greater detail are those from the list of eight which Dye had suggested, namely: the Incremental Model and the Group Model. It must nevertheless be emphasized that such formal decision-making models are of little utility for examining the complex nature of policy-making, except perhaps in the most exploratory way.

The first model to be considered here is the "incrementalist" theory of policy-making advanced by Charles Lindblom. In this model, policy-making activities are described as involving "disjointed incremental" decisions. As Lindblom explains, this means that decision-makers "muddle through," primarily by considering policy alternatives which are only marginally different from each other. In other words, no radical changes are sought, nor usually serious attempts made to evaluate the possible consequences of the proposed policy.

It is, therefore, obvious that an incremental type of policy-making must look back to the past as a guide for making choices for the present. Elaborating the theory, Lindblom thus explains:

Policy-making typically is part of a political process in which the only feasible political change is that which changes social states only by relatively small steps. Hence, decisionmakers typically consider, among all the alternative policies that might be imagined to consider, only those relatively few alternatives that represent small or incremental changes from existing policies.⁹

The chief advantage of this type of policy is that it minimizes the risks generally associated with radical changes which cannot easily be reversed. Moreover, "incrementalism accomodates bargaining and compromise among multiple political interests demanding a voice in policy decisions."¹⁰

A frequent criticism concerning this theory is that it tends to bolster the status quo and hence is contrary to the liberal-democratic ideal, which encourages changes directed at improving existing social conditions.¹¹ Furthermore, incrementalism is incapable of dealing with policy innovations or larger issues which require radical solutions. It would, therefore, appear to represent a typical but often too much of a cautious approach to decision-making to be generally applicable to an area so fraught with fundamental value conflict as nuclear energy.

The second theory to be considered here is Public Choice theory. This tries to explain public policy by focussing attention on individuals who participate in the collective policy decisions. The assumption behind this theory is that these individuals while performing their respective roles, make choices to maximize their own self-interests. According to Auccoin, who quotes Maslove, "the novelty and the promise of this approach is its emphasis on individuals rather than institutions as the primary actors in the system."¹²

It will be seen that in this respect Public Choice Theory is quite consistent with the traditional economic models of decision-making in its emphasis on individuals. A typical traditional economic theory as advanced by Downs for example, explains the economic theory of democracy through the construction of a model which tends to define political rationality from an economic point of view. The model rests basically on the assumption that every government seeks to maximize political support. While introducing the notion of rationality, Downs questions the role of government in the achievement of its conscious goals.¹³ He, therefore, concludes that politicians do not seek office merely in order to carry out particular policies but rather to secure an official position of authority with a view to satisfying their own personal interests. Thus, for elected politicians, policies essentially constitute a means of attaining private ends. From this it follows that government's social function is at variance with its private motive, which is the maximization of votes instead of utility or welfare. As the emphasis in the Public Choice theory is on individuals rather than on institutions which inevitably play an extremely important role in policy processes, its utility for explaining the complexities of decisions on issues of public policy is also limited.

And finally, the third theory we propose to examine here is the Group theory which explains political behaviour as stemming from some form of group conflict. The explicit conflict model maintains that public policy is formed as a result of competing pressures. The group approach

thus minimizes the importance of the autonomous individual and gives support to the doctrine that social change is wholly the product of social groups.¹⁴

Since Group theory begins with the proposition that interaction among groups is the central fact of politics, it obviously applies more to the American political system than to Canada. Explaining this difference, Van Loon and Whittington point out that the influence of organized interests in Canada is significantly less than it is in the United States:

The overwhelming importance of Canada's federal structure and her deep environmental cleavages suggest that other factors than interest group activity may be more important in the minds of Canadian decision-makers.... There does exist, however, a vast array of organized interests in Canada which seek to influence Government decision.¹⁵

In whatever way we may look at Group Theory, there is no doubt that it is just as much limited in its scope as the other two theories we have described above. Even in the United States where group pressures dominate the political system, it has failed to reflect its utility in certain areas of public policy, as for example in energy and the environment. This is how Dye describes the limitations of Group theory:

Group theory suggests that public policy reflects the balance of group interests. But the group struggle over energy and the environment has resulted in a virtual stalemate over policy direction and a paralysis of government action. The result is a failure of government to develop reasoned, consistent, and coherent energy policy.¹⁶

While concluding this brief discussion of the theories of public policy, all that need be said for the present is that public policies are obviously determined by the interplay of environmental conditions and socio-economic interests. The conjunction of interests and institutions involves the relationship between these two sets of determinants. Thus, in Western democratic traditions, public policy is generally expected to be in keeping with the principles and values inherent in the political system. But, at the present time, there is no recognized theory which deals with the importance of ideas in public policy. A number of studies have, however, been done which point to an initial understanding of this factor. Manzer for example, has applied Thomas Kuhn's concept of "paradigms" to the question of knowledge and ideas in public policy. A policy paradigm thus represents a set of principles and mind-sets from which specific policy-making can proceed. Policy paradigms therefore tend to be restricted to specific fields of public policy or to dimensions of public policy that cut across policy fields but are not the entire substance of public policy.¹⁷

Thus, public policy on such a sensitive issue as nuclear energy is so susceptible to a variety of influences that no one of the existing theoretical models can completely explain how and why decisions are made. We will, therefore, examine this further in the final chapter of this thesis in order to determine why the different processes involved in decision-making on nuclear energy issues cannot be fully explained in terms of the theories of public policy which we have already described.

CHAPTER III

THE ENERGY CRISIS

The World Energy Situation: An Overview

The sudden and unexpected fourfold rise in world oil prices in 1973-74 was a clear warning of a radical change in the world energy situation. This inevitably created serious long-term problems throughout the world, particularly for countries dependent on oil imports.

The initial shock of higher oil prices stimulated substantial increases in the price of other forms of energy. Balance-of-payments problems became more acute in international trading, and inflationary pressures began to be felt.¹ Thus, the Middle-east oil embargo has been able to deliver a powerful economic and political blow to the whole world. It has not only led to a drastic shift in wealth among nations, but has also slowed down the high level of postwar economic growth.

The world energy problem is a problem of oil supply and the abnormally high prices which have now to be paid for it. Because of the changed situation, the world has been witnessing an enormous energy transition which continues to cause a great deal of uncertainty in the

energy supply position throughout the world. The recent oil glut in world markets should not, however, be allowed to mislead us into believing that the OPEC cartel has been effectively broken and no longer poses a threat to future oil supplies from the Middle-east sources.

Amongst the measures which were considered necessary to meet the energy crisis, a great deal of hope was initially pinned on the early development of renewable energy sources. But it has now become quite clear that the provision and development of renewable sources of energy on any large scale is not economically feasible with the limited technology that we possess at the present time. However, the most successful public response so far made to the world energy problem is now partly reflected in the efforts that are continuing for promoting policies of energy conservation.² While these conservation efforts are extremely useful, we still have to find additional sources of energy to meet future world demand. A variety of forecasts is of course available for assessing world energy reserves, but no reliable estimates can perhaps be made with any degree of certainty. One thing, however, seems to be quite clear:

World supplies of oil and fuelwood are being depleted more rapidly than alternative fuels are developed to replace them....Among the non-renewable sources of energy, oil had the highest rate of consumption and by far the largest use relative to existing reserves of any of the fossil fuels.³

The chart reproduced at Appendix A shows the distribution of world energy consumption and production, as well as the population in percentages for each region. It will be seen that North America has the

highest energy consumption, followed by other industrialized regions. On a per capita basis, energy consumption of the industrialized countries taken together is almost ten times that of the developing countries. Thus, per capita energy consumption in North America alone is fifty times more than it is in South Asia.⁴ These high rates of consumption by the industrialized regions of the world will certainly result in the rapid depletion of resources. Moreover, the increases in world energy demand and the forecast decline in energy production will make the situation very critical, particularly for countries dependent on imported supplies of energy.

According to a study prepared for the Canadian government, the total world energy requirements are expected to be the equivalent of more than 300 million barrels of oil a day (MMboed) by the year 2000. This has been worked out at a rate of growth of about 3.5 per cent a year. Assuming that one-half of these requirements are to be met by oil, 150 million barrels of oil per day would be needed to meet the demand. The anticipated oil production, on the other hand, is less than half this figure.⁵

However, if we look at the total energy situation and not confine ourselves to oil alone, then a more encouraging assessment is contained in a study commissioned by the Ford Foundation in 1978. This study concludes that the world is not running out of energy sources, but that the use of these energy sources "may become constrained by political or environmental factors..."⁶ While it may be true that the world is not just yet

running out of conventional energy sources, a time will certainly come when non-renewable energy sources will have become depleted to a point where energy shortages will really become critical.

With continuous increases in the world population, which is estimated to double within the next fifty years, and greater industrialization to cope with the increased demand for products, the effects of energy shortages are bound to be felt more acutely as time goes on. It is apparent that the supply of many conventional energy sources will be effectively exhausted at some point in time. New technology and advanced methods of production may add to the supply somewhat, but this may ultimately prove to be too expensive. Thus, the increases in world energy demand and the subsequent decline in the production of oil and other conventional energy forms, would create an extremely precarious situation. Even allowing for new discoveries of oil and for the development of oil sands and shales using enhanced recovery techniques, "...major adjustments in world energy systems away from such heavy reliance on oil..."⁷ will have to be made before the end of the present century.

Along with the many technological and economic factors that will determine how the energy shortages are to be overcome, a strong role will naturally be played by public perceptions of the energy problem, and the policies which are adopted in keeping with those concerns. Therefore, if we take a more philosophic view of the situation, we find that there are some who believe that the world needs a technology of behaviour "comparable in power and precision to physical and biological technology",⁸ in order to control the excessive and sometimes

inappropriate use of modern technical advances such as have promoted the affluent private pursuit of happiness in a continually deteriorating human environment.

While we shall be discussing elsewhere the questions pertaining to ecological and environmental crisis, the point to be made here is that the OPEC countries of the Middle-east, which control the world's largest oil reserves, are in a position to make use of oil as a political and economic weapon to achieve their own narrow interests. We have seen how an oil embargo imposed by them in the winter of 1973-74 caused panic among nations dependent on oil imports. Under the existing conditions of virtual OPEC monopoly, the oil market is no longer a free market. OPEC being the largest producer of oil in the world, it can normally be expected to manipulate both production and prices.⁹ The use of oil power to raise prices to an unrealistic level has obviously created serious economic problems throughout the world.

However, as the market for oil is essentially a world market, oil supplies once loaded in the ships have a degree of freedom to be moved around and sent to any destination. Because of this flexibility, the producing country's control over the final disposition of the shipment is considerably weakened. Moreover, since the establishment of the International Energy Agency in 1974, competitive scrambling among shipping and marketing agencies has been controlled.¹⁰

While a certain amount of uncertainty will always remain with regard to supplies of oil from the Middle-east sources, the world energy situation on the whole does not appear to be very gloomy, at least in the

immediate future. A study conducted by the Ford Foundation to determine world energy reserves, shows that conventional oil and gas resources will be adequate to meet the energy demands of a growing world economy for several decades. Potential reserves of coal, oil shale, tar sands and other sources of fossil fuel would also perhaps be adequate for another hundred years or so.

Although these estimates of potential reserves may appear to be encouraging, the obvious abundance of these resources does not necessarily imply that they can all be used without certain serious limitations. Apart from the excessive costs of extraction and transportation from remote areas, there are other considerations too which will make it impractical to make use of many of the potential reserves:

The need to go further and deeper to get energy and the high environmental and social costs associated with the lower grade energy resources will tend to offset improvements in the technology of extraction and use that are sure to occur and that have traditionally resulted in declining real energy costs.¹¹

For the reasons indicated above, some energy forms may never be used in quantities that can physically be developed. For example, nuclear fission power development may be limited in certain countries by concerns about operating safety, waste-disposal problems, or the fear of nuclear fuel shortages.

Although the rise in demand for all forms of energy during the past few decades has cut into the existing resources at an unprecedented

rate, the figures of potential world energy production up to the year 2020, show enormous increases in all forms of energy. These figures have been taken from the proceedings of the Canadian National Energy Forum convened in Calgary in november 1979 and may be seen at Appendix B.¹² They represent the projections made by the Conservation Commission of the World Energy Conference.

But these forecasts of a high growth rate in energy demand are not shared by everyone. Some energy analysts expect the world's energy economy "to shrink in the foreseeable future."¹³ It will therefore be useful to look at both the high and the low growth projections and then make our own independent judgements.

The studies conducted by the Conservation Commission of the World Energy Conference in 1978 show that on the basis of a high growth projection, there will be a five-fold increase in energy consumption in the next four decades. This is based on an average economic growth rate of 4.2 per cent per annum. On the other hand, a low growth projection based on only 3 per cent economic growth rate shows that energy demand will rise just about two and a half times above current levels by the year 2020 as against the five-fold increase projected on the basis of a high growth scenario.¹⁴ The supply pattern that emerges from the various World Energy Conference studies is summarized and depicted in the two charts at Appendices C and D respectively.

Briefly, these projections show that all resources, except oil, will increase over the present levels by the year 2020. While oil and gas are expected to peak by the year 2000, twenty years later, i.e. by the year 2020, they will represent only 23 per cent of the primary energy production. This reflects a considerable drop when compared with 60 per cent in the 1960s and 68 percent in the 1970s. The position of coal is, however, fairly stable inasmuch as it is expected to represent 25 per cent of the total global supply of energy. As regards unconventional oil and gas, they will only increase from 0 to 4 per cent of the total. But hydro power, together with a few other renewable energy forms, are expected collectively to maintain a level of 16 per cent of the total energy supply. Thus, by the year 2020, a gap of almost one-third in the total energy supply will have to be made good, and this is expected to be done by nuclear energy.¹⁵

In 1979, nuclear power reactors provided about 1 per cent of the world's commercial energy, i.e., 8 per cent of all electricity produced.

Twenty-three countries, including seven developing, depended on nuclear energy for part of their electricity requirements. This number will increase as plants now under construction begin operating.¹⁶

The predictions made by the World Energy Conference in 1978 suggest that over one-tenth of the global energy needs by the year 2000 and as much as one-third by 2020, could be met from nuclear power. These forecasts are of course very tentative as nuclear power seems to be generating growing public opposition, and has become the most controversial of all energy issues.

In concluding this overview of the world energy situation, it is important to bear in mind that energy problems by their very nature are such that no country can afford to ignore the impact of the world market forces on their own national policies. Conversely, energy-related events of importance anywhere in the world have direct consequences for the entire world oil market. For this reason, we have to maintain a world perspective of the energy situation when deciding our own national energy policies.

Canada's Energy Problems

While Canada, like any other country, is affected by changes in the world energy situation, the national impact of such changes is cushioned-off by the fact that Canada is richly endowed with substantial oil, natural gas and other energy resources. She is thus relatively less vulnerable to the vagaries of the OPEC cartel than most countries, as she produces more energy than she consumes. But this does not mean that Canada has no energy problem. For example, at the time of the energy crisis of the early seventies, Canada was probably passing from a period of apparent abundance in energy to one that was considered at the time as a period of serious shortages. Of course in terms of her ability to obtain oil, Canada was not suffering from real shortages; not was she paying extraordinarily high prices compared with most of the other countries of the world. Presently, Canada has no serious energy problem insofar as resource availability is concerned. But limitations of one kind or another could prevent her energy economy from continuing to grow

at the same pace as in the past. This is how David Brooks, the author of Zero Energy Growth for Canada, describes Canada's energy self-sufficiency:

Actually, if abundance is defined as the ability to export energy, the period of energy abundance was very short: essentially the 1960 to 1975 period, which also witnessed an enormous growth in per capita energy consumption in Canada. However, if abundance is measured by the presence of a general perception of Canada as 'energy rich' the period extends over a much longer time.¹⁷

No matter how we look at the situation, there is little doubt that Canada is amongst those few countries which have adequate energy sources to meet all reasonable requirements in the immediate future. However, the only problem in Canada at the moment is the uncertainty which exists in deciding which of our substantial domestic resources will be developed first and how the cost of those developments will be shared between the federal government, the producing provinces and industry.

While the development and utilization of various energy resources with which Canada is well-endowed is necessary for meeting the country's future energy needs, there is another school of thought in Canada which argues that a satisfactory solution to soaring prices and dwindling resources will never be found in increased production but rather in finding ways to control consumption. David Brooks, for example, recommends the adoption of policies which would lead to zero energy growth. A demand-based energy policy for Canada is expected to encourage conservation techniques to such an extent that the annual rate of energy consumption would not change from one year to the next:

Canada might be better off with a slightly negative growth rate in energy consumption.... The concept of zero energy growth is defined in terms of the absolute (not per capita) level of total primary (not secondary) energy.¹⁸

Brooks then goes on to explain that during the period between the last two wars, energy consumption in Canada grew by less than 3 per cent per year. Thereafter, it averaged 4.5 per cent and increased to about 6 per cent per year between 1960 and 1974. Pointing out that this high growth rate is undesirable, he quotes Bill Daniel, president of Shell Canada, who had been urging rates of growth in energy demand to be maintained between 2 to 3 per cent per year. Similarly, in 1979 the Progressive Conservative Party too had urged a target of only 2 per cent. Brooks also refers to Alastair Gillespie, former Minister of Energy, Mines and Resources, who had often spoken out in favour of zero-per-capita energy growth as a target for Canadians. Zero energy growth as used by Brooks of course means zero absolutely, whereas the former Minister's suggestion refers to energy consumption growth to be equal to the population growth. Brooks thus points out that on the basis of current projections, this would work out to an annual increase of 1.3 per cent for both.¹⁹ However, Barry Beale, another energy analyst, while referring to the National Energy Board's most recent estimates, maintains that a growth rate of 3.4 per cent in primary energy consumption over the next decade or roughly 25 per cent lower than the average for the previous thirty years, may be expected.²⁰

Notwithstanding these two different assessments of energy growth

rates, the Board's forecast for total energy demand based on selected economic and population indicators and on anticipated energy prices over the period 1980-2000, shows that energy demand in Canada is expected to increase from 10.4 exajoules in 1980 to 12.9 exajoules in 1990, and to 16.2 exajoules by the year 2000. These primary energy demand figures are summarized in the table at Appendix E. These increases in energy demand represent an overall growth rate of 2.3 per cent per year. However, the rate of population growth is expected to decline from an annual average of 1.1 per cent during the 1980s to an average rate of 0.9 per cent during the 1990s. On this basis, therefore, Canada's total population by the year 2000 is expected to increase to only 29 million people.²¹

While the NEB forecast for the total energy demand up to the year 2000 shows considerable increases, the share of crude oil is expected to decline from 39 per cent in 1980 to 29 percent in 1990, and 26 per cent by the year 2000. This decline in oil consumption can only be achieved through a considerable national effort to adopt energy conservation practices and to make greater use of other energy forms as substitutes for oil. Improvements in industrial energy efficiency and in automotive fuel economy are amongst the most important factors necessary for achieving a lower oil consumption growth rate in the coming decades. In any case, reducing the demand for oil should not be too difficult a task in Canada because the country has a broad resource base potential, including coal, uranium, wood, hydroelectricity and natural gas. The Department of Energy, Mines and Resources seems to agree that Canada should be able to manage the transition from established conventional oil, "to the new

unconventional and frontier oil which will become available in the late 1980s and 1990."²² Of course this hopeful assessment was made before the current impasse over the Alsands project, which is now reported to be almost a dead issue.

Notwithstanding the apparent setback to the Alsands project in Alberta, the goal of energy self-sufficiency in Canada is, to a large extent, dependent on the successful exploitation of new oil discoveries and the availability of more advanced technology to provide cost-effective and environmentally acceptable processes for the development of unconventional sources of energy. Although the NEB forecast points to the fact that Canada may very well face a serious domestic shortfall of oil as early as 1990, there is some reason for optimism. According to Beale, current information indicates substantial oil finds in the Beaufort Sea, in the High Arctic and off-shore near the East Coast. Together, these reserves may be substantial. However, in spite of these optimistic forecasts, the next few years will probably see a lower overall growth in demand and also a shift in the primary energy mix. With a substantial reduction in the use of oil, an expanded role for gas, coal and primary electricity can be expected. This will be clear from the table at Appendix F.

Beale also predicts that in the absence of any new major proven oil discoveries, a national shortfall of 709,000 barrels of oil a day may be expected to occur by 1990.²³ This is about twice the amount of oil currently being imported. The situation would of course change if new

domestic oil supplies in sufficient quantities could be assured from exploitation in the conventional oil regions of Alberta and Saskatchewan, or in the frontier and offshore areas as already mentioned.²⁴

In its latest projections on undiscovered oil and gas reserves, the Geological Survey of Canada estimates a 50 per cent probability that 0.4 billion cubic metres of conventional oil will be discovered in western Canada during the 1980s. In the offshore and frontier areas, the estimated quantities are 1.9 trillion cubic metres of gas and 826 million cubic metres of oil. Although such optimistic estimates may sound encouraging, we have to guard against placing too much reliance on sources of energy which are still undiscovered.²⁵

Considering the fact that our established conventional crude oil reserves at the end of 1980 were estimated to be only 745 million cubic metres, there would seem to be no alternative but to continue importing oil for a considerably longer period than originally anticipated. With the heavy reliance of our economy on oil, this would seem to be necessary, unless of course steps are taken to substitute other energy forms for some of the oil imported. Presently, Canada imports only about 25 per cent of her oil requirements. But according to the National Energy Board, imported oil will be supplying at least 50 per cent of Canada's oil requirements and perhaps as much as 85 per cent by 1995.²⁶

As regards the heavy oil deposits and the oil sands in Alberta and Saskatchewan, these are estimated to hold possibly one trillion barrels of

oil in place. Of this perhaps only about 20 per cent, or 200 billion barrels of oil might be technically recoverable over the next 50 years. Obviously, no reliance can be placed on the availability of oil from these sources as they are even now proving to be very expensive to exploit. The current production figures show that during 1980 the two oil sands plants already in operation averaged only 20,000 cubic metres a day. Progress on the other heavy oil plants has remained static due to lack of agreement on certain financial aspects of the project between the two levels of the government and the industry.²⁷

While resource availability within the country is a very important aspect of the energy problem, another equally crucial aspect is the matching of demand with the available supply. Unfortunately, Canada happens to be amongst the world's most voracious energy consumers. This should be quite evident from the diagram at Appendix "G" which shows per capita consumption of commercial energy in fifteen selected countries, based upon United Nations data. It will be seen that in 1978 Canada consumed 6,765 kilograms of oil equivalent per capita as compared with 7,775 kilograms consumed by the United States. By way of comparison, the lowest consumption was that of Bangladesh with only 29 kilograms per capita for the year under consideration.

It is important to understand that the degree to which the distribution of energy consumption varies across the world is dependent on numerous factors. For example, the more energy-intensive industries there are in a country, the higher will be the ratio of energy to GDP. In

Canada's case, of course, there are many industries which fall into this category. Moreover, Canada is well-endowed with natural resources, and this comparative advantage has been an important factor in her high social and industrial development. Coupled with these factors, the past advantage of cheap and plentiful energy supplies has contributed to greater energy use in this country.²⁸

While Canadians are amongst the most intensive users of energy in the world, Canada produces enough energy to make herself completely free of foreign supplies of oil in due course. Energy options in Canada are wide enough and there is thus no real danger of any serious shortages of energy occurring in the immediate future. By restraining demand through conservation, these options can be kept open for a longer period, but not for too long. Canada will therefore have to decide very soon which of her existing resources, including of course nuclear energy, should be developed first, and what kind of mix should be planned for.

The National Energy Program
and its Impact

Canada's National Energy Program (NEP) was introduced on October 28, 1980. Its major thrust has been to try to achieve energy self-sufficiency by the end of the decade, and to increase federal government participation in the energy sector. Various measures ranging from price policies to grants and subsidies introduced in the program are

therefore expected to achieve a reasonable balance between supply and demand.

A key element in the NEP is its target that Canada should achieve by 1985 an 11.4 percent reduction below the 1979 level in the total use of crude oil. One way of achieving this target would be by substituting natural gas for some of the crude oil consumed. But the program lacks credibility as conservation policies are obviously based on inadequate criteria. For example, the price of crude oil has not "escalated quickly enough to take advantage of the natural conservation effects which are induced by rising prices."²⁹

While the national goal of Canada's energy policy has been self-sufficiency and greater independence from the world oil market by the end of the decade, this cannot be achieved without either increasing the supply of domestic oil or switching over to alternative forms of energy to the extent feasible.

The optimistic projection of oil supply contained in the NEP is of course based on an expected surge in oil output from unconventional sources. In this assessment a great deal of reliance seems to have been placed on the availability of frontier oil and increased supply from synthetic fuels.³⁰

However, despite doubts about the feasibility of these projections, Canada is not likely to have an energy deficit in total

terms. The difficulty arises from a mismatch between the pattern of energy demand and the pattern of energy supply. Even though Canada is a net exporter of energy because of her large exports of natural gas and electricity, she is very much dependent on imported oil. According to the requirements envisaged in the NEP, Canada's oil imports were projected to be 425,000 barrels a day (about 215,000 barrels a day on a net basis), or about 25 percent of Canadian oil consumption.³¹ But in actual fact, net imports were only 163,000 barrels a day during 1980 as there has been a general decline of 2.2 percent in domestic oil consumption over the 1979 level. This decline is attributed to increased conservation, substitution of other energy sources for oil and an economic downturn. The net import figure for 1980 thus compares well with the net petroleum import target of 150,000 barrels a day agreed to between Canada and the International Energy Agency.³²

However, in spite of an overall reduction in domestic oil consumption as indicated above, Canada will continue to have a substantial deficit of liquid petroleum supplies relative to current consumption in the short run. Because of the impact of large oil imports on Canada's balance of trade, and the uncertainty concerning the continuance of enhanced supplies from traditional sources to meet growing energy requirements, it is obvious that the energy problems in Canada are now essentially those of encouraging greater conservation, shifting to alternative energy sources, and developing more reliable and perhaps higher-cost domestic supplies.³³ But in view of the fact that Canada has the highest per capita energy consumption in the world after the

United States, it may not be possible for her to achieve substantial reductions in the demand for petroleum products in the immediate future, unless more stringent and extensive conservation and substitution measures can be found and pursued.

In the circumstances explained above, Canada will have to continue importing oil for some time to come. Production figures for 1980 show that Canada produced 103 million cubic metres of oil (including liquid petroleum gases) as against 106 million cubic metres in 1979 - a reduction of 3 million cubic metres. Although the figures for consumption also declined from 111 million cubic metres in 1979 to 109 million cubic metres in 1980, the net imports increased from 4 million cubic metres to 7 million cubic metres in the same period.³⁴

This large oil deficit is of course partly the result of having to import oil for the Atlantic Provinces, which do not as yet have access to natural gas. The problem will be resolved once the proposed Trans Quebec and Maritimes Pipeline is completed. At the moment, however, the total energy supplied by crude petroleum to the Atlantic Provinces is 78 per cent of their total energy requirements, as against the Canadian average of only 45 per cent. Figures showing Regional Gross Domestic Energy Consumption for 1978 are reproduced at Appendix H. These show that the percentage of total energy supplied by crude petroleum ranges from a low of 34 per cent in Alberta to a high of 78 per cent in the Atlantic Region.³⁵

As a result of increased shortages of oil, our dependence on hydrocarbon energy sources will soon have to give way to sources which hold the promise of greater abundance. Although the most obvious of such sources would be nuclear energy, its opponents are generally strong advocates of renewable forms of energy. Unfortunately, however, renewable energy technologies such as those involving solar energy or energy from biomass, are still very much in experimental stages and not yet sufficiently developed to be used on any wide scale. With the exception of hydro-electric power, the same is true of other forms of renewable energy, including geothermal, wind power and ocean energy. These energy sources can hardly be considered viable substitutes to fill the gap that may be caused by future oil shortages. Nevertheless, indicative planning targets for renewable energy use have been set at 5 per cent of Canada's primary energy demand by the year 2000, and 10 percent by 2020. These are however very ambitious targets.³⁶ Similarly, conservation efforts, though very necessary and important, are not likely to result in any substantial savings of energy to balance the shortages which may occur in the future. Moreover, policies which advocate substituting a resource like coal for oil for the purposes of generating electricity are likely to prove far too expensive if environmental considerations are not to be lost sight of. For example, the existing oil-fired plants would have to be modified considerably to accommodate the use of coal-oil mixture or the fluidized-bed combustion technology so as to reduce the air pollution that would result from using coal. In any case, industrial structures based on the availability of cheap oil will need not only time but also a great

deal of expenditure to be modified so as to adjust to any such change-over.

Although government is providing financial and other incentives for the development and use of new energy sources and for measures to conserve energy, it is not possible to predict how effective these efforts will ultimately prove. But purely from a financial point of view, the premature replacement of lower-cost hydro-carbon energy by higher-cost alternative forms of energy, such as solar energy or the wind-power, which may prove to be most expensive for any large-scale replacement program, does not appear reasonable.

The oil sands project on which so much hope was initially pinned (as it was expected to supply oil for another 400 years), is no longer considered a dominant contributor to domestic energy supplies in the coming decades:

In 1980 dollars, the estimated cost of the next tar sands plant has passed \$10 billion and the impact on Alberta's economy of establishing a series of such plants in rapid succession could be devastating.³⁷

Apart from these high costs of development of the tar sands, there are certain serious environmental dangers associated with such a development. The tar sands facilities use large quantities of water which become contaminated with bitumen and cannot be returned directly to the

source of supply. Significant quantities of sulphur dioxide are also released into the atmosphere during processing of the high sulphur bitumen. It will thus be seen that development of the tar sands is by no means free from complications. As things stand at present, any further move to revive the project will depend on the settlement of financial issues between the federal government and the producing provinces. This will have to take into account the benefits which can be offered to the industry so as to make the project sufficiently attractive.

While there is not much hope of obtaining significant oil supplies from the tar sands in the immediate future, our conventional proved reserves of crude oil and natural gas liquids, which are mainly concentrated in Alberta, are estimated to provide for a total yield of 1,288 million cubic metres. At a consumption rate of 300,000 cubic metres a day, they are expected to last for about 10 to 11 years. But if we look at the conventional oil resources which include the remaining reserves, discovered reserves, and undiscovered potential at a 50 per cent probability level (1976 estimates), the total comes to 4,194 million cubic metres of conventional oil resources.

Natural gas reserves, which are also mainly concentrated in Alberta, are estimated at 2,127.5 billion cubic metres. At an annual consumption rate of 45 billion cubic metres, these reserves should last for about 50 years. Estimates of total natural gas resources, on the other hand, are three times the estimated reserves. Thus, even though

plenty of gas is available, the problem of transporting it to destinations not yet connected with pipelines will be a major drawback.³⁸

Another extremely important source of energy in Canada is of course hydro-power. At the present moment, about 69 percent of the electricity produced in Canada comes from hydro sources, 22 percent from fossil fuels and 9 percent from nuclear power. Although there are abundant resources in the country for future development of hydro-electric power, only a few are considered economically feasible. Moreover, the selection of a site for any new hydroelectric project requires careful study and investigation to ensure that there will be no adverse effect on nearby farms and on inland fisheries.

Insofar as the existing installations are concerned, Canada's total hydro-generating capacity in 1979 was 43,990 MW as against 27,216 MW conventional thermal and 5,866 MW nuclear. In 1980 the total installed hydro-generating capacity had increased to 46,430 MW. Hydro-electric power potential, including plants under construction, comes to 59,013 MW. However, the total developable potential which is economically and technically feasible is estimated at only 63,440 MW.

Coal is another plentiful resource in Canada, but some of it is located in areas from where its extraction and transportation may be too expensive. The existing reserves of coal are considered adequate to meet domestic demand for centuries.³⁹ In 1979, 33.2 million tonnes of coal

were produced in Canada. A good deal of it is exported. Because of the difficulty of transportation, higher grades of thermal and metallurgical coal have traditionally been imported into Ontario from the eastern United States.

While the greatest potential for an increased use of coal would be for thermal generation of electricity, conversion of the existing oil-fired plants will be necessary if it is decided to substitute coal for oil. However, the greater use of coal in the generation of electricity could add further to the already serious pollution problem and the acid rain controversy which this has generated. Research is therefore continuing on new technologies, such as for manufacturing gas from coal, or reducing oil consumption in power plants by burning oil and pulverized coal together.

It will be seen that coal at present supplies about 9.3 per cent of Canada's total primary energy consumption, and accounts for about 15 per cent of the nation's total electricity supply. According to the NEB forecast, about one-quarter of Canada's total electricity is expected to be generated by using coal.⁴⁰ Such technologies as the fluidized-bed system which eliminates 90 per cent of sulphur dioxide emissions and substantially reduces emissions of nitrogen oxides, will naturally encourage greater use of coal for the generation of electricity. However, all such projects using a completely new technology will not only need massive capital investment, but some of them may not even prove to be

economically competitive for many years. An outstanding example of such a financially disastrous situation occurring would be if the production of substitute natural gas from coal were undertaken while plentiful supplies of natural gas from normal sources were still available in the market. We must therefore guard against accepting any new technology, without first investigating the full consequences of its use.

After examining the various options concerning different forms of energy sources that are available to us for utilization and further development, we find that a substantial portion of the existing and future oil shortages will have to continue to be made good by imported oil, despite attempts at conservation and substitution of other forms of energy. The important role of nuclear energy in possibly changing this situation has so far not been discussed. A separate chapter has therefore been devoted to that discussion.

An Analysis and Summary
of the Current Energy
Issues in Canada

The evolution of Canadian energy policy since 1973 can be seen to involve three distinct phases. Beginning with confident assurances of plentiful supplies of petroleum and natural gas, the second phase (1976) marked the uneasy hopes of self-reliance. The third phase in this

evolutionary process arrived with the introduction in 1980 of the National Energy Program. It initially led to renewed optimism for the early achievement of total self-sufficiency.

With a view to freeing Canada from reliance on foreign petroleum supplies by 1990, the following three approaches have been adopted by the federal government:⁴¹

- (1) To force a reduction in demand for oil by price increases.
- (2) To develop domestic conventional and non-conventional petroleum sources through price increases, tax incentives, and grants.
- (3) To encourage interfuel substitution away from petroleum to natural gas, electricity, coal, and renewable energy sources.

While a reduction in the demand for oil through pricing and conservation policies can perhaps be achieved, it is not certain how far the development and substitution of unconventional sources of energy will really prove to be a viable solution for meeting the future oil shortages.

In a critique of current Canadian plans for the expanded development of the tar sands and frontier petroleum, Fred Knelman, who considers such a development much too costly to be worth the attention that is now being paid to it, thus explains:

Conventional wisdom, unfortunately, is tied to conventional sources. Bad energy, like bad money, drives out the good. Moreover, bad energy is both costly and uncertain. The billions of dollars required for tar sands, pipelines, and frontier and offshore sources will surely cut into the money we desperately require for necessary social services, let alone for conservation. Thus bad energy drives out both good energy and good money.⁴²

Despite the fact that interfuel substitution is an important element of any national energy policy, the concept unfortunately is rather broad inasmuch as it includes fuels and technologies from both the "hard" and the "soft" energy options. One of the most controversial aspects of interfuel substitution relates to the role of electricity and the part it can play in meeting future energy needs. A complicating and controversial factor in this debate has been the association of electricity with nuclear power and the hostility which this has generated.

Hostility in certain sections of the public to nuclear energy is not a new phenomenon. What is new in the energy debate is the hostile reaction from industry and the oil producing provinces to the National Energy Program introduced in October 1980. The most important oil producing province, namely Alberta, has actually gone so far as to retaliate against the federal government by such actions as cutting back on oil supplies.

A central thrust of the NEP, apart from its emphasis on the need for achieving energy self-sufficiency, has been the objective to Canadianize the petroleum industry. It is believed by the Program's critics that this objective is likely to hinder technology transfer, which has important implications for the "crucial heavy oil and tar sands development."⁴³ Critics argue that in the past access to foreign technology and foreign expertise has proved to be essential in the development of Canadian projects. This does not necessarily imply that foreign ownership should be considered as a pre-requisite for the transfer of technology. There are many ways in which foreign technology can be

acquired. Special arrangements can be made that do not allow ownership of ~~the~~ industry to remain in the hands of foreign interests. Such special arrangements could ultimately lead to the development of indigenous technology, which could have a long-term beneficial effect on Canada's future industrial development. An outstanding example of a high-technology industry in which indigenous technology was used is that of the Candu reactor industry, a wholly Canadian enterprise.

So far we have discussed two primary objectives of the National Energy Program, namely: self-sufficiency and Canadianization of the industry. The third objective concerns the pricing and revenue-sharing aspect of the program. There are obviously many ways in which one may interpret the notion of revenue-sharing and the effect which pricing has on it. Price increases could very well lead to substantial income redistribution within Canada. For example, the producing provinces, primarily Alberta, could receive large windfall gains by virtue of their ownership of the resources.

As seven of the ten provinces produce no oil or gas, they are economically in a disadvantageous position when compared with the producing provinces. In their case, the additional burden of energy price increases can seriously affect their financial position. But in the case of the producing provinces, notably Alberta, the story is different. Let us therefore first look at the negative effect of not raising the prices: "for each dollar the Canadian price is below world prices, Alberta is foregoing nearly \$400 million in revenues per year."⁴⁴

Conversely of course, a dollar rise in price would give Alberta a windfall profit of \$400 million.

To offset part of the price increases, six out of the seven non-producing provinces receive equalization payments. These increased equalization grants are paid out of the general revenues, causing budgetary deterioration at great public costs: "more than anything else perhaps, it is this problem of the internal distribution of the revenues that has prevented the move to a more rational pricing system."⁴⁵

Although the National Energy Program has introduced major changes to the previous incentive structure for exploitation and development of new energy sources, the introduction of major new energy taxes has created considerable controversy. Moreover, the policy in respect of domestic pricing and revenue sharing of crude oil production, partially aimed at reducing federal deficits, has created a situation in which federal and provincial governments concerned have found themselves at loggerheads.⁴⁶ Here it is important to understand that under the Canadian Constitution, control over energy resources within provincial boundaries is vested in the provincial governments. Similarly, many aspects of the energy program, including conservation programs, are within provincial jurisdiction. The recent disagreement over offshore resources is yet another aspect of the federal-provincial controversy over the energy issue.

♥ Apart from the producing provinces' concern for pricing policies

over which the federal government had unilaterally acquired control through the Petroleum Administrative Act, the rent-sharing problem has also become a critical issue. Under the old arrangements, the federal government's share was only 10 per cent; the rest was divided equally between the industry and the producing provinces. But the arrangements made for the period 1980-1983 required an allocation of 33 per cent for the industry, 43 per cent for the provinces and 23 per cent for the federal government.⁴⁷

While dissatisfaction over pricing and the revenue-sharing aspects of the National Energy Program is certainly a major bone of contention between the federal government and the producing provinces, the impact of the program on the capital market is also of crucial importance because of its far-reaching consequences. Already high energy investment levels will likely accelerate further as development of more costly conventional and non-conventional energy sources, including frontier sources, are undertaken:

In current dollar terms, our estimate is for energy spending in the order of \$1.4 trillion over the next 20 years...Electrical generation and the petroleum sectors account for nearly 89 percent of investment needs while pipelines account for the remainder.⁴⁸

Compared with the average investment of \$2.5 billion per year between 1960 and 1974, the annual average in the decades ahead is likely to be more than ten times larger. These are certainly overwhelming sums for any economy, but their effect will be more pronounced for a country like Canada whose energy investment is expected to be well over 9 per cent of her GNP, i.e., more than double that of the late 1970s.⁴⁹

In concluding this summary it will perhaps be useful to explain very briefly the effect of the National Energy Program on Canada's international commitments. As a member of the International Energy Agency and also as a signatory of the International Energy Agreement, Canada has an obligation to follow the guidelines of the International Energy Program. However, there have been some deviations on Canada's part. For example, since 1973, Canada has controlled the price of oil and this has been criticized by IEA for its negative effect on conservation. Similarly, on the question of foreign ownership, the announced intention of the federal government to Canadianize the industry is viewed as discriminatory by the international oil community. Although Canada has not signed the non-discriminatory clause in the International Energy Agreement, the new policy of Canadianization to be implemented under the Foreign Investment Review Act seems to have prompted many foreign-owned companies to cut back substantially on their Canadian investments.⁵⁰

While it may be too early to determine the impact of the NEP on other objectives of the program, it is certainly a major departure from past policy, representing as it does an intrusion into the private sector.

CHAPTER IV

THE DEVELOPMENT OF NUCLEAR ENERGY IN CANADA

An Historical Perspective

Canada's contribution to the development of nuclear energy, and its application for peaceful uses can perhaps best be understood from the following excerpts taken from Wilfrid Eggleston's book entitled Canada's Nuclear Story:

The fundamental scientific break-through which made the exploitation of nuclear energy possible occurred, unhappily, during a period of war psychosis which quickly led to a dark blanket of censorship and a frantic, secret concentration on the manufacture of a super-explosive One of the incidental effects of this abnormal wartime programme was the early involvement of Canada on a scale highly improbable under other circumstances. The greatest scientific project of research and development in Canada's history followed.¹

Canadian participation in the application of nuclear energy began during the wartime period when at Britain's suggestion early in 1942, a joint program was launched in Canada. It is, however, interesting to

recall that some of the basic experiments in nuclear physics were carried out at McGill University in Montreal as early as 1898 by Ernest Rutherford, a New Zealander who had studied at Cambridge's famous Cavendish laboratory, and by Fredrick Soddy, a chemist from Oxford University:

Two of the major figures in the early twentieth century development of atomic theory, Rutherford and Soddy, although neither of them were Canadian, did much of their important work in Canada. They left this country with a legacy in nuclear research which served as an inspiration to subsequent workers.²

While credit is certainly due to the two scientists mentioned above for their basic experiments in nuclear physics, the discovery of radioactivity by Henri Becquerel of France two years earlier, i.e., in 1896, followed by G.S. Schmidt of Germany and Madame Curie of France is regarded by many historians as the starting point in the understanding of the atomic and subatomic phenomena.³

In the years which followed, there began to develop a greater understanding of the atomic potential, but up to 1938 interest had remained purely at a theoretical level. However, with the outbreak of the war in September 1939, atomic research assumed a new dimension. The outbreak of the war provided the needed stimulus for the development of technology to enable the testing of atomic theories. A veil of secrecy was naturally drawn over further experiments and discoveries. It was in these circumstances that late in 1942, the first self-sustaining chain

reaction in nuclear fission was attained in the United States at the University of Chicago under the direction of Enrico Fermi, an Italian Physicist and a refugee in US from Fascism. This ultimately led to the development of the atom bomb, the first one being exploded as a weapon of destruction over Hiroshima on August 6, 1945, followed by a second atomic bomb dropped over Nagasaki three days later.

It is, however, noteworthy that during the very early stages of the war, a small-scale nuclear research project had already been established and was being carried on in utmost secrecy at the National Research Council's laboratories in Ottawa under the overall direction of its new president, Dr. C.J. Mackenzie. While the pioneer work on uranium fission was being done in France, England, Germany and the United States, in Canada the possibility of building a successful nuclear pile, or reactor, using natural uranium moderated by carbon was being investigated.⁴ The senior member of the group carrying out this research in Canada was Dr. George C. Laurence, a native of Charlottetown who had studied under Rutherford at the Cavendish laboratory. He is credited with building Canada's first atomic pile in the Ottawa laboratories of the NRC. Although useful results were obtained from this pile, the work on nuclear fission proceeded rather slowly because of the high priority given to other projects within the NRC at the time.

In spite of the fact that Canada was proceeding rather slowly with research on nuclear fission, this work was of crucial interest to the authorities directing nuclear research in the United Kingdom. As a member of the British Commonwealth, Canada provided an ideal location for a major

British atomic energy project, far away from the dangers of German aerial attacks to which Britain was then exposed. Moreover, Canada had the additional advantage of being a major source of uranium. The mine at Great Bear Lake owned by Eldorado Gold Mines Limited was, until the outbreak of the war, used for producing radium. Thus, large stocks of uranium which had been produced as an unwanted byproduct of the radium extraction had accumulated. To meet the increasing demand for uranium from the UK and the USA, the mine which had remained closed from the start of the war was reopened in 1942. It was only a couple of years earlier that the possibilities of using uranium for making a bomb had first begun to be explored in the United States by President Roosevelt's "Advisory Committee on Uranium" and in the United Kingdom by the "Maude" Committee.

In France, experiments using heavy water as neutron moderator had to be cut short and transferred to Britain due to the German invasion of the country. Two French scientists, Von Halban and Kowarski, who were associated with the French project, managed to escape to Britain where they were offered facilities at the Cavendish laboratory for continuing their experiments.

Subsequently, attempts at coordinating the work of the two projects mentioned above with the work being carried on in the United States failed, when the Americans declined to accept a British proposal to transfer the group working under Von Halban to the United States. The US refusal to accept the British offer was apparently based on grounds of security, as the Von Halban group included some scientists who were born

in Nazi territory. The proposal to send the von Halban group to the United States arose because the work the group had been doing with slow neutrons using heavy water was expected to complement similar work being done in Chicago using graphite.

Having failed to get the United States to accept the von Halban group, Britain then decided to approach Canada with the same offer. Canada welcomed the opportunity afforded by this arrangement. The group arrived in Canada towards the end of 1942 and began working in Montreal. Its assigned task was to produce design data for a heavy water reactor. The group already had in its possession a small quantity of heavy water which it had purchased in Norway while still working in France. It was hoped by the group that larger quantities of heavy water would be available by 1943. Through a remarkable coincidence, the US had also been looking for a source of heavy water and had already entered into an arrangement with a Canadian company to set up a heavy water plant at its synthetic ammonia fertilizer factory in B.C. Although construction on the project was started in September 1942, only small quantities of heavy water were delivered the following year. By 1944, production had only reached half a ton per month. It was therefore agreed that the first six tons of heavy water would be made available to von Halban's group in Montreal. However, as there was no firm commitment to the construction of a heavy water reactor, the design work undertaken by the group proved to be no more than a theoretical exercise.

With so much uncertainty surrounding the project, morale at the Montreal laboratory was at its lowest ebb, particularly as rumors from

Washington about Anglo-American cooperation were not too encouraging. The group was also facing internal problems of its own. To add to this confusion, there was also some difficulty in getting adequate supplies of uranium. The situation was becoming very discouraging, and there seemed to be no clear objective in sight in relation to the program. Canada thus had no alternative but to turn to the Combined Policy Committee created by President Roosevelt and Prime Minister Churchill at the Quebec conference in 1943. That committee had been formed to coordinate British-American collaboration in nuclear research. Accordingly, at a meeting of the committee held in Washington on April 13, 1944, Canada stressed the importance of constructing a heavy water reactor in Canada to help the Allied nuclear war effort. The proposal was accepted and the committee decided that Canada should go ahead and build a heavy water reactor for the production of plutonium from uranium:

This momentous decision marked the beginning of the nuclear age in Canada. It also provided an immediate focus for the activities of the Montreal group and to lead them, Dr. J.D. Cockroft was sent over from the UK to supervise the program.

Work was therefore soon started for the design of a 10 megawatt reactor. Defence Industries Ltd. (DIL), a crown corporation organized in the early years of the war, was given the task of constructing the new plant on the site which had already been selected for the establishment of the new laboratory and the reactor complex. While originally only one reactor had been proposed, it was later decided to build two reactors and two separation plants. The first reactor, a zero energy experimental pile

(ZEEP), was to be used for research. Experience gained from ZEEP was to help in the design and construction of the second and much larger reactor to be known as NRX. The design for ZEEP was completed in the Ottawa laboratories of the National Research Council and that for the NRX in the Montreal laboratories. The reason for building the NRX reactor was to demonstrate the feasibility of making fissionable material in a heavy water reactor for atomic bombs. As two different methods were to be tried, one for producing plutonium and the other for irradiating natural thorium to produce uranium-233, two separation plants were needed.

It was in these circumstances, therefore, that the foundations for a research reactor complex were laid at the Chalk River site. Chalk River thus became the base for the world's second reactor (the first outside the USA). It went critical on September 5, 1945. ZEEP provided basic data on the use of natural uranium fuel and heavy water as a moderator.

However, when the war ended in August 1945, the Chalk River site was only partially completed. With the end of hostilities, the prospects of completing the project looked bleak as most of the British and other foreign scientists were returning to their homes, including Dr. Cockcroft who had originally been sent to Canada to supervise the Montreal group. Apparently, he was needed in Britain to take charge of the British atomic energy program. As a replacement, Britain offered the services of Dr. W.B. Lewis, who arrived in Canada in September 1946 and took over as Technical Director of the Chalk River establishment.⁶

This transitional period proved to be one of great uncertainty for

the Canadian program. The gap caused by the loss of foreign scientists and the increasing aloofness which the United States was now exhibiting in relation to the Canadian nuclear research program convinced Canada that it was time to consider more seriously the commercial possibilities of developing nuclear energy for peaceful purposes. In this effort, it was naturally expected that each country would pursue its own program independently for the further development of nuclear technology for commercial use.

As Canada was closely associated with the USA and the UK, with whom she had shared many of the war-time secret decisions that contributed to the development of the atom bomb, she naturally emerged from the war as one of the few countries which had the know-how in advanced nuclear technology. Canada also had the needed resources for nuclear energy development as she possessed substantial uranium deposits at Port Radium and there were reasonable prospects of finding more in the mineral-rich Canadian Shield. In addition to this important advantage of having a plentiful supply of uranium, the small heavy water plant originally established to serve American needs was already functioning in B.C. at the time. Canada was also fortunate to have the services of "...Dr. W.B. Lewis who was destined to direct Canadian efforts to forge heavy water and uranium into a uniquely Canadian and uniquely successful power reactor system."⁷

It was in these circumstances that the Chalk River Project began to produce more fruitful results as work continued under Dr. Lewis. However, when the project was nearing completion, Defence Industries Ltd.,

which had originally contracted not only to build the facilities but also to operate them, declined to continue with the operational responsibility. It was therefore decided to transfer industrial operations, as well as the research laboratories at Chalk River, to the NRC in February 1947.⁸ The NRC in this case was acting as an agent of the Atomic Energy Control Board (AECB) which had been established in 1946 under an Act of Parliament.

Apart from the ZEEP reactor which was completed in 1945, the construction of NRX, a more powerful research reactor, was completed in 1947. This was followed by NRU, a third experimental reactor completed in 1957. These three reactors, all located at Chalk River, were handed over for operation to Atomic Energy of Canada Ltd. (AECL), a Crown corporation which had been created in 1952.

The experience gained in the operation of these research reactors finally led to the construction of Canada's first nuclear power station at Rolphton, Ontario. It had a capacity of 25 MW and was named Nuclear Power Demonstration (NPD) plant. It began to produce electricity in 1962, thus demonstrating the technical feasibility of employing natural uranium and a heavy water system for power generation.⁹ This was a joint project of AECL, Ontario Hydro and Canadian General Electric.

Five years later, i.e., in 1967, Canada's first full-scale prototype Candu station with a capacity of 200 MW was completed and began operating at Douglas Point on Lake Huron. The next development saw the construction by Ontario Hydro of one of the world's largest nuclear power

stations at Pickering on Lake Ontario. The Pickering station produced its first electricity in February 1971, just five and a half years after construction began. Known as Pickering A, it consists of four 500 MW units, "which have established many records in the international field of nuclear power plant construction, consumption and operation."¹⁰ At the full output of 2000 MW, the plant generates enough power to supply electric current to more than 1.5 million homes.¹¹ A second power station of the same capacity, known as Pickering B, whose construction was started in 1974, was expected to be in operation by 1983.

In addition to the Pickering complex, a much larger generating station located at Tiverton and known as Bruce A, with a total capacity of 3000 MW, was first started in 1976. An identical four-unit station, Bruce B, is also expected to be fully operational by 1987. The construction of yet another nuclear power station of a still larger capacity is proposed to be completed by 1990. This station, located at Darlington, near Bowmanville on Lake Huron, will have a capacity of 3400 MW.

It will be seen that while Ontario has pursued nuclear power development with considerable speed, most of the other provinces have shown little active interest. Apart from Ontario, the only other provinces operationally concerned with nuclear energy development in their provinces have been Quebec and New Brunswick.

As a result of agreement between the federal and Quebec governments, a small nuclear power station of 250 MW capacity, known as Gentilly 1, was established and was started up in 1970. This reactor

uses boiling water instead of pressurized heavy water as used in Ontario Hydro's reactors. But Gentilly 1 has been a source of trouble due to frequent malfunctioning and has been shut off at the request of the Quebec government. Hydro Quebec has since become engaged in the construction of Gentilly 2, a 600 MW Candu reactor of conventional design, whose start-up date was expected to be sometime in 1982-83. A similar power station at Point Lepreau in New Brunswick owned by the New Brunswick Electric Commission (NBEPC) was also expected to be started up at about the same time.

The present position in regard to nuclear reactors in Canada can perhaps be summed up as follows:

At present 25 nuclear power reactors with a total capacity of over 15,000 megawatts are operating or under construction in Canada.¹²

A detailed list of power reactors licensed and planned in Canada will be found at Appendix I. The list does not include the research reactors used by various universities and research institutions. A list of heavy water plants licensed as of 31st March, 1981, may also be seen at Appendix J. The list contains information as to the location of these plants, their capacity and present status.

Atomic Energy of Canada Limited
(AECL) and The Nuclear Industry

In the preceding section, we traced the growth of Canada's nuclear

research program from about the time of the outbreak of World War II. Initially, the program was funded and controlled by the government through its Crown Agency, the National Research Council (NRC). In addition to the research at the NRC, a small amount of research was also being carried out in the universities.

As already mentioned, the program was first operated by Defence Industries Ltd. (DIL) on behalf of the National Research Council. With the establishment of the Atomic Energy Control Board under the authority of the Atomic Energy Control Act of 1946, the overall responsibility for the program was transferred to the Board on December 1, 1946. It was in these circumstances that the NRC took over direct control of the project from Defence Industries Ltd. on behalf of the AECB on February 1, 1947. DIL was, however, to continue with the completion of the construction works already authorized or in hand. All new works were thereafter to be the responsibility of the NRC. As Dr. C.J. Mackenzie, who was already the president of the NRC, also took over as the president of the AECB, cooperation between the two organizations was expected to be very close.

However, in the early 1950s, it became quite evident that the increasing involvement of the Chalk River establishment in commercial activities such as the sale of plutonium to the USA, would justify the creation of a separate organization to assume responsibility for the control and management of the facilities at Chalk River. Accordingly, a Crown corporation to be known as Atomic Energy of Canada Limited (AECL) was set up under the provisions of the Atomic Energy Control Act of 1946.

It took over the Chalk River Project on 1st April, 1952.

Although the operations at Chalk River were transferred from the NRC to the AECL, the administrative control remained with the AECB. Dr. Mackenzie, who had become the president of both the AECB and the NRC, took over as president of the AECL, but only after resigning the presidency of the NRC. However, by 1954, it became clear that the AECB could not effectively control the day-to-day activities of the AECL, which had grown enormously in size. Accordingly, through an amendment to the Atomic Energy Control Act of 1946, responsibility for the AECB's research and production functions was taken away from the Board and placed directly under a minister responsible for both the AECL and the AECB.¹³

While the various functions and responsibilities that the Atomic Energy of Canada Limited is required to undertake basically relate to the development and utilization of atomic energy for the benefit of Canadians, in more specific terms the efforts of the corporation are concentrated in the following three areas:¹⁴

1. Nuclear-electric power, including research and development in waste management and safeguards.
2. Medical and industrial applications of radioactive isotopes and, more recently, particle accelerators.
3. Underlying research in selected fields necessary to support the applied development work.

Funds are provided by government for the AECL's research and development activities. In 1978-79, \$112 million were provided for this purpose. The cumulative total since 1952 amounts to \$1.5 billion, mostly in support of R&D activities that are concentrated at the Chalk River nuclear laboratories in Ontario and at the Whiteshell Nuclear Research Establishment at Pinawa in Manitoba.

Cooperation with the provinces is normally maintained by AECL through working arrangements with the electric utilities that have nuclear power. At the present time, the three AECL-owned prototype reactors known as NPD, Douglas Point and Gentilly-1 are all operated by utilities under contract. These three units serve as test-beds for a variety of experiments. AECL also maintains active liaison with the provinces that do not yet appear to have a need for nuclear power but are prepared to consider it as a future option.

As regards AECL's relationship with Canada's nuclear industry, the corporation naturally adopts procurement policies beneficial to the industry. At present, 80 per cent of the Candu reactor system is supplied by Canadian industry. The very substantial results achieved by Canada's nuclear industry can certainly be attributed in large part to the "unique package of funding, technology and research management furnished by the laboratories through R&D contracts."¹⁵

Cooperation with the universities is another important aspect of AECL's activities. Visiting scientists and collaborators from universities are involved in most areas of research. R&D contracts with

Canadian universities, currently about \$400,000 per year, provide AECL with special skills or facilities the universities are able to offer.

In the international field, AECL maintains close contacts with various organizations, including the International Atomic Energy Agency (IAEA) through collaborative research programs and other special arrangements. These contacts have been further strengthened since the formation of a fifth semi-autonomous unit, Atomic Energy of Canada International Company in June, 1979. Each of the five units of AECL, namely Research, Engineering, Chemical, Radiochemical (formerly known as Commercial Products Division), and the new International Company, has full financial and operational control subject to performance monitoring. The creation of the new company has thus strengthened AECL's international marketing and overseas project organization. This new organization has assumed a leading role in all AECL marketing activities with the exception of those undertaken by the Radiochemical Company, which concentrates on high technology products such as medical accelerator units, irradiators, Cobalt-60 and a range of other isotopes.¹⁶

Some idea can perhaps be had about the extent of commercial activities of the corporation from its revenues. AECL's total revenues from its commercial operations during 1980-81 totalled \$570.2 million, an increase of 14.7 per cent over the previous year. Included in this total are \$185.3 million for activities related to the export of materials and services for the construction of nuclear plants, \$101.2 million for the Company's Candu engineering expertise for domestic and international projects in support of nine Candu nuclear power reactors in operation and

an additional seventeen under construction, \$120.2 million for heavy water and \$55.2 million for radiation equipment and isotopes. The remaining revenue of \$108.1 million represents investment and interest income. After deducting the cost of sales, marketing and administrative expenses, and interest charges, the operating profit for the year amounted to \$28.8 million. However, prototype reactor operations continued to require support both from the Company and the government. The financial reorganization of the Company in 1980 proved to be an additional burden to the government as it primarily consisted of the forgiveness of the loans and advances due to the government with respect to the purchase, rehabilitation and construction of heavy water plants in the amount of \$816.9 million.¹⁷

Other important aspects concerning the extent of AECL's operations can be judged from the number of its full-time staff, which totalled 7,512 at the end of 1980. During the period under consideration, the engineering design of eight major nuclear station construction projects totalling 12,000 MW of electrical capacity was underway. Moreover, the Company provided continuous support services for the 5,000 MW of Candu capacity already in operation in Canada. Its two operating heavy water plants at Port Hawkesbury and Glace Bay in Cape Breton also continued to perform at record production levels.

In order to meet its commitments, the corporation also paid special attention to the following projects:

1. Design and support for commissioning activities on two 600 MW domestic projects, Gentilly-2 and Point Lepreau.

2. Cooperation and support in the final stages of construction of two 600 MW projects in Argentina and the Republic of Korea.
3. Design work in support of site construction at Ontario Hydro's Pickering "B", Bruce "B" and Darlington stations.
4. A review of the engineering of Candu reactors in the 900-1100 MW range based on Bruce and Darlington designs in order to develop design programs suitable for the export market.

A major portion of Canada's nuclear industry is of course based on the Candu reactor system, which is continually undergoing refinement in the various development laboratories of the AECL and industry. In order to be able to fulfill this role, AECL has been pursuing numerous activities ranging from basic scientific exploration to commercial operations.

Nuclear industry in Canada is a good current example of Canadian manufacturers successfully entering and supplying the needs of a high-technology energy sector. The number of manufacturing firms committed in various degrees to supplying the nuclear steam supply system for nuclear power plants is about one hundred. These firms directly employ an estimated 6,000 people in the manufacture and supply of the various components of the nuclear system. As the Candu nuclear system is uniquely Canadian in concept, design and execution, the industry has been structured to stimulate Canadian participation. Today it represents a "blend of efforts involving government, electric utilities and private

industry."¹⁸ All construction and design engineering is carried out by Canadian firms, or by the personnel employed by AECL, or by the utilities themselves. Close cooperation between these three has encouraged the supply of roughly 75-85 per cent of the components required both for the nuclear power stations and the heavy water plants. Table 2-7 reproduced at Appendix K, shows the structure of the Canadian nuclear industry, including uranium mining and refining.¹⁹

While the foregoing account of AECL's activities shows the importance and usefulness of this organization, the nuclear industry as a whole has unfortunately become an example of the potentially disastrous effects of production facilities expanding to meet forecast equipment requirements that seem to have failed to materialize. The only hope for the continued good health of the industry in Canada lies in greater expansion of the export market to serve foreign needs for additional nuclear plants. Although discussions have been going on with various countries in an attempt to attract their business, so far prospects do not appear to be very encouraging.

The Need For
Nuclear Energy:
Some Basic Considerations

From the figures of potential world energy production up to the year 2020 as shown in the table at Appendix B, it will be seen that in the view of the World Energy Conference, nuclear energy "will grow dramatically as a contributor to world energy."²⁰ However, following

the Three Mile Island reactor accident in the U.S. in March 1979, forecasts for future installed nuclear capacity have been revised downwards many times. The accident has spurred the demand for stiffer environmental and regulatory controls. But the situation now seems to be changing. Confidence in nuclear energy is again building up and there is now a tendency to upgrade these forecasts. Nevertheless, insofar as Canada is concerned, our nuclear energy requirements will have to be kept to the minimum, in keeping with the two key elements of the National Energy Program: (i) a substantial reduction in the rate of growth in total energy demand (especially demand for oil), and (ii) replacement of imported oil by Canadian energy resources.²¹ This latter requirement would imply greater use of nuclear energy if other substitutes for oil are not found suitable.

Although we have shown elsewhere in this thesis that a substantial energy potential exists in Canada from a variety of resources, the existence of a potential in no way could imply that an adequate supply of any combination of the energy resources will actually be available at any given time. There is of course no way that all supply options can be fully developed at the same time. We have, therefore, to consider which combinations of resources are most appropriate for maintaining sustainable energy balances for the next 20 to 30 years. For the purposes of this thesis, however, we will restrict our examination to the total requirements of electrical energy, and not go into any detailed requirements of other energy forms. In this way, we will be able to focus attention on nuclear energy and assess its suitability as a promising source of energy for meeting our future needs for electrical power. This

assessment is necessary not only because of the Three Mile Island accident, but also because of the few minor incidents since then in our own nuclear plants which have raised the question of nuclear reactor safety. Although a large number of countries, including Canada, have made a commitment to nuclear power, the reaction amongst a section of the public and the media has been to question "the safety and the need for nuclear reactors."²² It is therefore obvious that since nuclear reactors are not completely foolproof, there have to be certain limitations on their use and further expansion. In other words, we must develop nuclear energy only if other forms of energy are either environmentally worse or considerably more expensive.

Although these two aspects of nuclear energy will have to be carefully examined in relation to the overall energy situation in Canada, in the global context, according to the experts of the World Energy Conference, nuclear energy will grow dramatically as a contributor to world energy production within the next few decades. Conventional oil and gas, as already noted, will be on the decline. Coal will therefore become a major contributor, along with some renewable resources, provided there is a greater interest and investment in research for their development.²³

The position in Canada today, insofar as electrical energy is concerned, is more hopeful in that hydro-electric power dominates the scene. In 1978, it contributed 70% of electricity production, as against 22% electric generation using fossil fuels and 8% nuclear. It is however predicted that by the year 2000,

...each of these sources will be providing roughly a third of production, with coal having taken over the shares now carried by oil and natural gas. The role of nuclear power will increase dramatically as Canadian utilities run out of new hydro-electric sites to harness... By the year 2025, nuclear will likely dominate the electricity picture.²⁴

Similar views are also shared by the Department of Energy, Mines and Resources. While acknowledging the uncertainty created by public opposition to nuclear power, the Department maintains that by the year 2025, 60% of all electricity might be generated by nuclear power. Thus, nuclear power and hydro-power are expected to supply virtually all of the base load electric power.²⁵

In 1978, Canada had 4,800 MW installed nuclear capacity. Nuclear-generated electricity grew from 0.1% of Canada's primary energy supply to 3% in 1977. But as a percentage of electricity supply, it has grown from 1.0% to 8.0% in the same period. By 1988, however, nuclear power is expected to grow to 15,190 MW.²⁶ But this growth is likely to be confined to Ontario, as the two other provinces, interested in nuclear energy, namely Quebec and New Brunswick, have only a limited interest. We will, therefore, concentrate our discussion on Ontario's nuclear energy program and then try and determine the possible impact it will have in generating a more positive response to nuclear energy from other provinces.

According to the Interim Report of the Royal Commission on Nuclear Energy (Porter Commission), demand for electricity is expected to grow at

an average rate of 4% to the year 2000:

We have concluded that nuclear power has a role to play in this expansion programme....The absolute safety of any industrial process, or human activity, including the generation of electricity, cannot be guaranteed. In the case of the Candu reactor we have concluded that within reasonable limits, the reactor is safe....On economic grounds Candu reactor and coal generation are the major realistic options for new large scale base load supply of electricity in Ontario in the late 1980s and 1990s.²⁷

In its final report, however, the Commission warns:

No further development of the 1,250 MW Candu reactor, even in the concept stage, should be undertaken by Ontario Hydro. Any additional nuclear base-load power stations in the post-Darlington period should be based on 850 MW Candu reactors. We believe that such standardization will facilitate reactor safety as well as optimizing the average capacity factors of these stations.²⁸

It will be seen from Appendix I that the present capacity of all reactors is 850 MW or below. This situation may, however, change when more research has been completed in developing reactors of greater capacity. Other pertinent aspects of the Porter Commission Report are summarized below:²⁹

1. The capital cost for the development of nuclear power plants is estimated at \$2000/KW. On this basis, by the year 2000, a total capital expenditure of the order of \$25-60 billion will be needed.
2. The cost of decommissioning a nuclear reactor at the end of its life is estimated to be 1 to 5 per cent of the initial plant cost. This could work out to as much as \$36 million for a 600 MW plant.

3. The federal Nuclear Liability Act requires the operator to carry \$75 million in third party liability insurance per installation. Ontario Hydro is at present spending \$815,000 per year as premium for this insurance.
4. Nuclear R&D costs are a hidden factor. The total historical cost is estimated to be about \$1.2 billion, i.e., \$70/KW on reactors now operating.
5. Eldorado Nuclear Ltd., and Atomic Energy of Canada Ltd., the two federal Crown Corporations: "currently dominate much of the front-end of the fuel cycle and potentially the back-end as well".
6. The proposed Nuclear Control and Administration Act (which died on the order paper), would have allowed the federal government to become more involved in the commercial aspect of nuclear power.

Although we have already discussed the activities of the AECL in a separate section, it needs to be emphasized here that federal government policy has been based on maintaining close cooperation between the corporation, the electrical utilities (notably Ontario Hydro), and the private sector. AECL provides support, information and data to Canadian utilities and manufacturers in the nuclear sector. Representatives of AECL, Ontario Hydro, and the private sector form an important part of the Canadian Nuclear Association (CNA), an organization founded in 1960. It "coordinates and represents the interests of governments, utilities, consulting firms, producers of essential materials, and manufacturing firms who are or expect to be engaged in some phase of development and/or utilization of nuclear energy."³⁰ Unfortunately, however, the Candu

nuclear industry has developed rather slowly, but this has been largely due to the very small domestic market. Moreover, demand for these reactors from abroad has been very limited. Nevertheless, the Candu reactor is the only commercially available reactor which uses heavy water as its moderator, natural uranium as the fuel, and pressurized heavy water as the coolant. In consequence, it is claimed to be the most economical and efficient to use. For example, the operations and maintenance costs of a candu reactor when compared with a coal station show that the fuel cost ratio of nuclear to coal per kWh generated is roughly 1 to 9. This means that \$6.5 billion worth of uranium will generate as much electricity as \$50-65 billion coal. Furthermore, higher rates of increases in uranium prices would not significantly increase the total cost of nuclear power relative to coal.³¹

Another important consideration in support of nuclear energy is the fact that the industry directly employs over 31,000 persons in various sectors. According to a recent study, it also has a positive balance of payments of \$335 million. By 1988, the positive balance of payments contribution is expected to grow to \$1.5 billion for fuel replacement alone. The figure of \$335 million was arrived at after taking into consideration the savings on coal imports, and includes overseas orders, as well as nuclear service and equipment exports in 1977.³²

Therefore, while comparing the economic impact of using nuclear power we find that nuclear generating stations are substantially more attractive than coal-fired generating stations. According to the Porter Commission:

Costs on a system basis depend on the rate of system growth and the mix of generating plants. Ontario Hydro has pointed out, for example, that Pickering A has "saved" the power consumer of Ontario millions of dollars as compared with the cost to build or operate an equivalent coal-fired station.³³

THE ECONOMICS OF NUCLEAR POWER

The importance of nuclear power to Canada's energy future, and indeed to the rest of the world, is closely related to the growth in the demand for electricity and the need for meeting part of that demand by the development of nuclear power. Predictions of future growth in electricity demand are therefore important to any discussion of nuclear power. It is a well-recognized fact that there are significant constraints on the amount of energy that can be supplied from fossil fuels, as these sources are not limitless. Therefore, if the demand for electricity should increase substantially, some of that increase will have to be met by employing other sources of energy, such as nuclear power. It follows from this that the smaller the growth in demand for electricity, the more flexibility there will be in determining the extent to which nuclear energy may be employed. The question of how much electricity Canada will need over the next few decades is however not easy to answer. Such controversies as relate to conservation ethics, or to problems of environmental pollution have complicated the issue further.

In the past, a steady growth in the demand for electricity has resulted from (i) increasing population, (ii) declining electricity prices as a result of technological advances, and (iii) the adaptability of electricity to a variety of uses. The demand for electricity is therefore closely correlated with economic activity as measured by real gross national product (GNP).

Canada's annual rate of growth in electricity demand from 1948 to 1973 was stable at about 6 to 7 per cent. During this period the rate of growth of real GNP was about 5 per cent. However, as a result of sharp increases in the world price of oil in 1973, economic activity in Canada and elsewhere was adversely affected, and this necessitated a change in the way energy was used. Thus, the annual growth rate of electricity has fluctuated considerably since 1973. As a result of these fluctuations, the compound growth rate in electricity demand for the period 1974 to 1978, declined to 4.2 per cent. The rate of economic growth as measured by real GNP also declined to 3.2 per cent. The reduction in the rate of electricity demand growth was obviously caused by the relatively low rates of economic growth, higher electricity prices, and to some extent, by conservation measures.³⁴

Apart from the slowdown in electricity sales growth, there has also been an accompanying slowdown in peak demand growth, a major determinant of utilities' need for new generating capacity. Overestimating the growth rate of peak demand can easily result in excess generating capacity. How damaging such an incorrect forecast could be was clearly brought out in the Report of the Royal Commission on Electric

Power Planning, while discussing problems faced by Ontario Hydro.

According to the Commission, the 1977 and 1978 load forecasts to the year 1985, were predicted on growth rates of 6.4 and 5.5 per cent respectively.

On this basis, the additional peak load for the period 1975-1985 worked out to 35 per cent (i.e. 4940 MW) lower than was actually predicted in 1976:

Since Ontario Hydro attempts to maintain a reserve capacity margin of approximately 25 per cent over peak load, this reduced load forecast implies a corresponding capacity reduction of 6200 MW; this is the equivalent of more than three Pickering A stations.³⁵

Noting that the effect of changing forecast growth rates can be "exponential" and "dramatic", the Commission points out that at an average growth rate of 6.2 per cent forecast by Ontario Hydro in 1977, the peak demand would grow from 15,700 MW in 1977 to 95,400 MW in the year 2007. On the other hand, if Ontario Hydro's 1978 forecast of 5.1 per cent growth rate was made the basis for future projections, then the peak demand in the year 2007 would only be 69,800 MW, a colossal reduction of 25,600 MW over the previous forecast figure.³⁶ Extreme care in forecasting is therefore of prime importance. In spite of sophisticated computerized techniques for evaluating data on the economy and other related factors, such forecasts still remain highly uncertain.

One major element in the uncertainty surrounding utility forecasting is of course the degree to which demand is affected by price. Although in the past, falling electricity prices encouraged the use of electric heating and cooling in new homes and led to a growing demand for electric power by industry, one school of thought holds that further electrification of the country's energy economy would be inefficient, uneconomic and socially divisive. Increased use of utility-generated electric power, it is argued, will only increase the amount of energy being wasted, as electricity is inherently inefficient at tasks such as space and water heating. Some environmentalists have therefore suggested that the trend toward cogeneration of electricity and steam by industry will go a long way to help the situation. A strong advocate of a "soft" energy path, physicist Amory Lovins, for example, goes so far as to recommend that decentralized, non-electrical energy technologies should be encouraged:

...two main policy paths for the rich countries are now rapidly diverging, and we must jump for one or the other. The first is high-energy, nuclear, centralized, electric; the second is lower-energy, fission-free, decentralized, less electrified, softer-technology based on energy income.³⁷

In many respects therefore the debate over future electricity demand is part of a larger debate over electric energy futures, i.e., the so-called "hard" and "soft" technology debate. Energy analysts who anticipate continued high growth in energy consumption⁴ tend to stress the need for increasing energy supplies and making greater use of electricity

to offset the limited resources of oil and gas. But those analysts who foresee lower energy growth, generally emphasize the role that conservation and renewable resources can play. Under these circumstances, future electricity demand and therefore the need for additional nuclear generating capacity, will greatly depend on the outcome of the struggle between these two alternative energy paradigms for public policy dominance. Although the country is currently closer to the high-energy, hard-technology path, support for the low-energy, soft-technology path appears to be growing. Consequently, long-term estimates of future electricity demand will continue to have an element of uncertainty.

While there may be uncertainty as to the actual growth in Canada's electricity demand, the continued development of nuclear power in the country is primarily dependent on the extent to which nuclear-generated power is economically competitive with other electric power generation systems, particularly with coal-fired power plants. Factors such as the capacity at which plants are able to operate and the cost and efficiency of the equipment required to meet safety and environmental regulations will play an important role in determining the relative competitiveness of coal and nuclear power plants.

Apart from these two sources of energy, there is also the remote possibility that in some parts of the country, alternative generating sources such as geothermal energy, co-generation and low-head hydro-electric facilities may ultimately become competitive, with both coal and nuclear power for a share of new generating capacity. Thus, there is

widespread debate over the relative economics of nuclear, coal and other generating systems. Nevertheless, predicting the costs of energy generation is fraught with both technical and political uncertainties.

Supporters of nuclear energy argue that it provides considerable savings to consumers. According to Sanjay Banerjee for example, there are many energy technologies that are being developed and may become competitive sometime in the future. Banerjee, however, notes that it would be pointless and unfair to compare nuclear or coal power with an infant technology such as that of solar energy. The main economic comparisons will therefore be confined to nuclear and coal generating systems. Speculating on alternatives to nuclear power, Banerjee thus explains:

In regions of the country where nuclear generating stations are being operated or built, the main base, or intermediate, load alternative is coal, since most of the available hydroelectric resources have been used. It is unlikely that oil or gas fired units would be used for base or intermediate load because of high fuel costs. Fluidized bed combustion units are being developed that may allow the economic use of high sulfur coals and somewhat smaller units. However, the capital costs, taking into account transmission and generation, do not appear to be significantly different from the coal units considered here. Most of the nuclear generating stations are, and will be, in Ontario. Therefore, the first step in evaluating the economic impact of Canadian nuclear policy is to study coal and nuclear station life-cycle costs in Ontario. We do not consider transmission and distribution costs explicitly because they are similar for coal and nuclear.³⁸

The results of Banerjee's study, which was directed at estimating life-cycle costs in Ontario for coal and nuclear generating stations and for determining the sensitivity of these costs to various economic factors, such as fuel costs, etc., show that nuclear generating stations have a higher capital cost than coal fired generating stations, but they have generally far lower fuel costs. Banerjee therefore concludes that in terms of economic costs, nuclear generating stations are substantially more attractive than coal fired stations:

...electrical energy from nuclear generating stations will be 64 per cent cheaper than from coal generating stations over a thirty-year lifetime. Note that this reference cost includes imputed research and development costs for a nuclear plant as well as security, decommissioning, and irradiated fuel management costs. Coal fired stations are not, however, required to incorporate scrubbers to reduce environmental degradation. Accounting for extraordinary operating and maintenance costs (retubing of a nuclear unit, for example) has little effect on the relative cost of power from the two main sources.³⁹

Similar conclusions seem to flow from studies and surveys conducted in the United States. For example, the survey of utilities conducted by the Atomic Industrial Forum in 1978, demonstrated that nuclear power was the lowest-cost producer of electricity. Nuclear plant operations during 1978 thus resulted in savings of more than \$3 billion. The use of nuclear energy "offset consumption of the equivalent of 135 million tons of coal, or 2.9 trillion cubic feet of natural gas, or 470 million barrels of oil." As an example of savings to consumers, the Forum points out that customers at Baltimore Gas and Electric saved \$188.1 million by having electricity generated by nuclear rather than coal and

oil-fired power plants.⁴⁰ Similar claims have been made by Ontario Hydro with respect to its nuclear plants. It is therefore obvious that the development of nuclear energy is supported on grounds of economic benefits it offers. One of the most convincing arguments in favour of nuclear energy is perhaps what Premier William Davis of Ontario had once expressed in a letter. Claiming that in 1977, nuclear energy provided 27 per cent of Ontario's electricity at a total unit cost of about half that of coal, he provided figures to show how competitive nuclear energy is. To quote his own words: "In 1980, over a 30 year period, it will cost \$24 billion for nuclear energy...for coal it will be \$44 billion..."⁴¹

However, proponents of nuclear energy concede that the economic advantage held by nuclear power has narrowed in recent years. Nevertheless, it is maintained by them that nuclear energy will continue to hold a cost advantage over alternative fuel sources in the future. Opponents of nuclear power, on the other hand, do not accept these claims; and point out that in the past nuclear power appeared to be cheaper because of huge government subsidies and because many of the true costs associated with the nuclear fuel cycle remained hidden.

Notwithstanding these contradictory views, a critical determinant of the economic costs in the operation of nuclear plants is the efficiency at which a plant is able to operate. Estimates of generating costs usually assume operation of a plant for 30 years at an estimated capacity level which varies from 60 to 80 per cent. These assumptions have

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of course been made from an extremely limited data base, as the operating histories of large nuclear and coal-fired plants are both short. The available data has therefore to be viewed with reserve. However, insofar as Ontario Hydro's Candu reactor efficiency is concerned, the data made available by Atomic Energy of Canada Limited indicates that in 1979, Pickering Generating Station A continued to set international records with an 85 per cent capacity factor and a lifetime production of electricity "far in excess of any other nuclear power station in the world."⁴²

It will be noted that the reliability of a power station is judged by its net capacity factor, which is the ratio of the energy actually produced to the amount that would have been produced if the plant had operated at its maximum output for the whole period. Because of the inevitable shut-downs for inspection and maintenance, no plant can achieve 100 per cent reliability. Eighty per cent is therefore regarded as a practical goal, and even this is a challenging target.

According to a document on nuclear energy published under the auspices of AECL, an independent survey of the performance of power reactors has established that heavy water reactors, notably of the Candu type, are rated amongst the best in the world.⁴³ Moreover, Ontario Hydro's operating experience using reactors of comparable size, clearly shows that nuclear energy in Ontario is providing electricity at just over half the cost of that from coal-fired plants. Plants fuelled by oil or

natural gas will obviously be still more expensive. Cost comparison figures for coal-fired and nuclear generated electricity for 1978 and Ontario Hydro's projected cost of electricity from three different fuels to the year 1995 are reproduced at Appendices L and M respectively.

It should, however, be noted that nuclear energy is most efficient and economic when used in combination with generation from fossil-fired stations. The reason for this is obviously the fact that nuclear plants operate most economically when run continuously. In this way, they most adequately supply the constant or "base-load" electricity demand from consumers. Fossil-fuelled plants, on the other hand, can be turned on or off more readily to meet what is called "peak-demand." Thus, both types of plants are needed to provide a reliable and economic supply of electricity to meet fluctuating needs.⁴⁴

There is one last point that needs to be clarified before we end this discussion on the economics of nuclear power. Going back to Banerjee's conclusions about the economics of nuclear power, it will perhaps be interesting and useful to see what one of his critics has to say. While agreeing that Banerjee's analysis is well done and that under most circumstances the cost comparison favours nuclear development, David Brooks notes as follows:

I do wish that Professor Banerjee had stated more forcefully that his paper deals with the generation stage. A great deal of needless confusion has arisen because of the lack of attention to whether it is the cost at the busbar (generating plant) or as delivered to the consumer that is in question. I emphasize this in part because coal plants, being smaller than nuclear ones, tend to have lower distribution costs, but even more because conservation and those renewable energy technologies effected on site have negligible distribution costs.⁴⁵

The point raised by Brooks about Banerjee's failure to clarify in his analysis whether he was referring to busbar costs, i.e. costs at the generating plant, or costs at the delivery point, is hardly significant, inasmuch as Banerjee could not have been more clear when he said, "we do not consider transmission and distribution costs explicitly because they are similar for coal and nuclear."⁴⁶ It should be obvious from this that Banerjee was referring to busbar costs only.

While concluding this section concerning the economics of nuclear power, we can perhaps do no better than quote relevant extracts from the Interim Report of the Royal Commission on Electric Power Planning:

Fuel costs, by contrast, vary with level of operation and are consequently less per unit with lower output. Generating stations with high capital costs and low fuelling costs will therefore be most economic at high capacity factors, and those with low capital cost and high fuelling cost at low capacity factors. This is well illustrated by the following frequently cited comparison. In the late 60s and early 70s Ontario brought into operation two 4X500 MW unit stations - Pickering A, which was nuclear, and Lambton which was coal-fired. If each had been operated at 87 per cent of theoretical capacity, appropriate for base load (and the rate achieved by pickering), a comparison of total unit energy costs in 1976 would have favoured nuclear generation by a wide margin....⁴⁷

The Commission, however, cautions that a similar comparison may be found less favourable to nuclear power in later years because of a predicted high increase in capital costs and a "slowing in the rate of increase in fuel costs."⁴⁸ Tables 7.2 and 7.3 appearing in the Commissions' Report and reproduced at Appendix N may be found useful for the purposes of comparison of the costs involved.

CHAPTER V
THE NUCLEAR DEBATE

Basic Issues:

Energy has today, as never before, become one of the most crucial economic and social issues of our time. This is so because all energy issues now go beyond questions of economics, security of supply, and health and safety to encompass questions of life-style and social organization. Perhaps no energy issue brings more clearly into sharp focus this tendency than the debate that has been going on over nuclear energy.

Over the last few years, nuclear power development in Canada has begun to be viewed with some apprehension and has become a political issue, though certainly far less prominently than has been the case in the United States. At first, only a few concerned citizens and environmental groups began to question the advisability of developing nuclear power in Canada to meet future energy shortages. Since then, opposition has become more pronounced. In this chapter, therefore, we will try to identify and characterize the issues of present public controversy, including federal-provincial conflict over certain aspects of energy policy.

Not too long ago, a conference on Canadian Nuclear Policies brought to the forefront some of the crucial aspects of the debate and the controversies which have been generated over the issues concerning the development of nuclear energy in Canada. The conference was sponsored by the schools of Public Administration and International Affairs of Carleton University and the Science Council of Canada, and was held in November, 1978, at Mont Ste. Marie, Quebec. According to Bruce Doern, the conference was convened "... because of the view (the existence of the Porter Commission and the Cluff Lake Inquiry notwithstanding) that this important field of Canadian public policy has not received a sufficiently focussed or systematic public analysis."¹ Doern then goes on to suggest that there are five political issues which will likely have a cumulative impact on Canadian nuclear policy in the 1980s. He has summarized them under the following sub-section titles:

1. The High-Technology "Last Chance" Argument and the Canadian Staple Theory of Economic Development.
2. The Maturing of the Debate Between Pro- and Anti-nuclear Interests.
3. Nuclear State Enterprises and Leverage Over the Private Sector.
4. Nuclear Policy as a Federal Lever in Federal-Provincial Bargaining.
5. Nuclear Policy and Federal Inter-departmental Bargaining.

While discussing the above five issues, we will naturally take into account not only some of the views contained in the various papers presented at the conference, but also any other pertinent material that may be found useful for a proper analysis of the issues involved in the

Canadian debate over the development of nuclear energy. The discussion will focus attention on each of the five issues in the order in which their sub-section titles have been enumerated.

1. The High-Technology "Last Chance" Argument and the Canadian Staple Theory of Economic Development.

Although nuclear technology in Canada is not a major employer among Canadian industries, its importance as a "symbolic lead sector in high-technology industry" can hardly be doubted. The argument that Candu nuclear technology is Canada's best chance or last chance for developing a high-technology industry is certainly one that is not as frivolous as it may first appear to be, especially in the face of unsuccessful attempts over the last decade to find major new technological lead sectors.

It is no secret that Canada's manufacturing industries are today facing serious problems, particularly in the low-technology labour-intensive sectors. This is how Morrison and Wonder, in a paper presented to the conference, describe the situation:

The balance-of-payments deficit on fully manufactured goods is large and increasing. Canadians are highly sensitive to the difficulties faced by their manufacturing industry in international competition, especially the high-technology sector, and to the economic and political vulnerability which their dependence on foreign-controlled resource extraction entails....Other industrial countries already compete fiercely in the high-technology arena, often from a far better base than Canada's....Whatever the obstacles, innovation should remain an essential component of Canada's industrial strategy....Foreign competition is necessary to provide the feedback required for further technical advances.²

More successful foreign competition might have of course been possible had the international nuclear market not been so bleak. The large-scale demand for nuclear power forecast just after the oil embargo of 1973 has failed to materialize. Nevertheless, the national nuclear power programs to meet domestic demand will likely continue to grow for the rest of the present century. But it is important to recognize that exports are necessary to support the domestic industry. On the other hand, no country can expect to sustain a reactor export program that is not based on a strong domestic program.

Most of the industrialized countries which either have or are committed to developing their own nuclear manufacturing industry will ultimately have to find their principal export market for reactor sales in those few developing countries which have already embarked on ambitious industrialization programs. Some of these developing countries may even desire to develop their own nuclear manufacturing industry. Export of reactors to such countries may therefore have to be made under a license to facilitate the development of their own nuclear industry.

In the last few years, Canada's determination to develop and promote nuclear power has gained momentum. While Canada has already sold power reactors to India, Pakistan, Argentina, South Korea and Romania, the Argentinian deal has suffered a financial loss, and there have been problems with the Romanian deal too. Despite these setbacks, Canada is now trying to attract new customers for her Candu reactor system. As an

example of this effort, a recent report appearing in The Citizen, encouragingly suggested the possibility of selling Candu reactors to Mexico, whose businessmen have visited nuclear component plants in Canada:

What was immediately at stake was the opportunity to build four 600-megawatt nuclear reactors, worth an estimated \$5 billion, at Laguna Verde, Mexico. But more than that, the Mexican bid represents the first real test of Canada's latter-day nuclear marketing push in the world's most important reactor competition in 10 years. It will also likely determine what shape the Candu industry will take in the next decade or even, possibly, whether it survives at all.³

Unfortunately, however, the prospects of selling nuclear reactors to Mexico have since diminished as the country now seems to be facing serious financial problems. Nuclear industry in Canada has therefore very little to look forward to in the export market. Moreover, the industry in its export drive seems to be suffering from certain handicaps. These are discussed below.

In a paper presented to the 1982 Annual Meeting of the Canadian Political Science Association, researcher Ted Schrecker has referred to the 1981 EMR review which details a number of handicaps the nuclear industry in Canada has been facing in its export effort. The EMR review has examined a number of policy options, including some relaxation of Canadian safeguards requirements, which are more demanding than those of other countries competing in the nuclear export market. These policy options, according to Schrecker, detail some of the steps necessary to boost Canadian exports, as for example, "...the removal of 'political exclusions' including South Africa, the Middle East and Taiwan; offering

more attractive export financing; and improving the marketing and governmental approval processes for Canadian exports." Schrecker then goes on to explain:

In at least three of the four areas, federal policy has moved in the directions indicated. Though no overt relaxation of safeguards provisions has occurred, the reactor promotions undertaken in Egypt and Kuwait in the winter of 1981-82 clearly indicate the de facto removal of at least one region from 'political exclusion!'

While at the present time the market for nuclear reactor sales abroad is rather limited, it is important to understand that countries buying their first nuclear system will actually be choosing the reactor type on which their future nuclear expansion program will very likely be based. The nuclear market can therefore be said to consist of potentially large sales, even though the number of countries interested in buying nuclear equipment may be comparatively small.

Presently, the principal nuclear equipment suppliers, namely the United States, France, West Germany, and Canada, all have excess capacity in their domestic nuclear manufacturing industry. The need for export contracts is therefore very pressing, especially for Canada, if the industry is to survive. Expansion of the domestic power program would of course also help to stimulate the industry.

The Candu reactor system designed and developed in Canada has many significant design differences from the light water reactor (LWR) developed by the Americans. But both types of reactors operate on the

once-through cycle, in which the fuel is passed once through the reactor and then stored. In this way, the Candu and the LWR use only about one per cent of the energy content of natural uranium. Doern explains this in greater detail:

The Candu uses natural uranium as its fuel and is more efficient in its use of uranium resources than the LWR, which requires enrichment of the U-235 concentration to about 3 per cent. The other 99 per cent of natural uranium consists of the isotope U₂₃₈. This isotope is not fissionable itself....⁵

Moreover, the Candu is a pressurized heavy-water reactor and is the only commercial reactor that has been able to compete in world markets with the American light water reactors. Its main advantage is its ability to operate on natural uranium ore, thus avoiding the need for costly enrichment facilities. The Candu uses roughly 20 per cent less uranium than the LWRs.

Despite this clear advantage, the Candu has not been able to attract the foreign reactor market to any appreciable extent and has been quite unable to penetrate the U.S. market. Presently, the Candu's share of the world market is only about 5 per cent. One reason for this poor performance in the export market may be the relatively higher capital costs associated with the Candu system. Even though rising uranium prices and fuel enrichment costs have generated a new interest in the Candu in the last few years, it is still very doubtful if it will ever penetrate the U.S. market. The reason for this may be the entrenched position of the LWRs in the United States, the licensing problems associated with a new reactor in that country, and the fact that access to

enrichment facilities is no longer a problem for American utilities.

Bearing in mind the problems outlined above, the need for an aggressive nuclear export drive has become very pressing for Canada, especially in view of the fact that there have been substantial cutbacks in recent years with the number of domestic reactors, resulting in overcapacity in the reactor manufacturing industry. However, nuclear export policy has to be oriented in a way that nuclear export activity does not threaten world security by contributing to the proliferation of nuclear weapons. A second objective of the policy and perhaps the most important, would naturally be to secure for Canada economic and political advantages through the sale of uranium and nuclear equipment abroad.

In the fulfillment of these two policy objectives, a third element of some importance has been the desire of the government to contribute to the economic growth of the developing countries by sharing Canada's nuclear power technology with them. This objective is in keeping with the Trudeau government's so-called "third option" foreign policy criteria.

While Canadian policy has involved attempts to gain a special contractual relationship with the European Community, it has also been conducted in recognition of the economic advantage to be had in establishing a more secure relationship with the advanced Third World countries.⁶

Although in the early years of Canada's nuclear export drive, economic factors played a dominating role in setting nuclear export

policy, the Indian explosion of a nuclear device in 1974 brought home the crucial importance of carefully assessing all political and strategic implications of such a policy. The changes since made in the nuclear export policy have obviously imposed restraints on nuclear exports. The possibility that nuclear exports could add to the risk of spreading nuclear weapons has now to be carefully weighed before any export decisions are made. As Canadian reactor sales to such Third World countries as are judged to be politically unstable will always be open to intense political criticism, Doern considers that Canadian sales efforts may have to be concentrated on countries in the West, even though attempts in the past to attract such sales have not proved very successful. He then goes on to speculate:

...the United States may become a more plausible market for Candu or partial Candu sales if the Carter-initiated International Nuclear Fuel Cycle Evaluation (INFCE) study directly or indirectly endorses Candu-based technology....Finally, the probabilities of a continental nuclear energy pact will be influenced by trade-offs in other sectors of Canadian-American relations. There is increased pressure, at least on the Canadian side, to utilize the Candu uranium question strategically in bargaining....If these factors converged there would be very strong pressure to strike a continental nuclear bargain, with the United States benefitting from a reliable and nearby uranium supply and with Canada making just enough Candu or Candu-based sales to sustain and perhaps enlarge its high-technology nuclear industry. For Canada, the combined practice of 'staple' economics and high-technology industry development would be a difficult package for decision-makers to resist.⁷

While there is considerable logic in the scenario of a continental nuclear energy pact between Canada and the United States, it is obviously not very likely that such an arrangement would ever materialize. Firstly, the United States is far more technically advanced than Canada, and is

therefore quite unlikely to need Candu technology to bolster her own nuclear energy development. Secondly, the United States not only has her own substantial uranium resources, but also enjoys an easy access to the world uranium market. Moreover, even though all the nuclear power plants that are operating in the country use "light water" nuclear reactors for the generation of electricity, U.S. research and development effort (despite problems created by strong public opposition) is still placing heavy emphasis on the "breeder" reactor development, as this type of reactor is expected to produce more nuclear fuel than it consumes, thus ensuring an unlimited supply of energy to meet the long-term needs of the country.⁸

As regards the Internal Nuclear Fuel Cycle Evaluation (INFCE) study to which Doern has made a reference, its recent report has basically endorsed the concept of breeder reactors and plutonium reprocessing, while at the same time acknowledging that this would lead to a rapid increase in the availability of plutonium suitable for military use on a world-wide basis.⁹

How far considerations of security will affect the future breeder reactor program in the United States is difficult to predict. One thing though is clear. The support for a breeder reactor program for energy production was primarily based on the grounds that uranium supplies were limited. While concern about the adequacy of uranium supplies still remains high, especially in countries that do not have large uranium

reserves, recent setbacks in the nuclear power industry appear to have lessened the prospects for uranium shortages in the immediate future. The uranium supply position is therefore not as uncertain as it was first made out to be.

Donald Lecraw, in a paper presented to the Canadian Nuclear Policy conference on the policy implications concerning uranium supply and demand, agrees that the future demand for uranium was overestimated. As future uranium prices have been highly uncertain, producers have suffered huge losses in the past due to over-optimistic demand and price expectations. With a view to reducing this uncertainty, many producers have negotiated supply contracts based on a combination of a base price and cost escalation. Whether such contracts will continue to be made in the present situation of over-supply is however questionable.¹⁰

The latest figures showing reserves of uranium at various price levels, and production figures from these reserves are shown in the three Tables presented by Lecraw. Table 1 reproduced at Appendix O shows reasonably assured uranium resources around the world. Table 2 at Appendix P shows potential uranium production from these reserves for the years 1977 to 1990. Actual production figures for the years prior to 1978 are reproduced in Table 3 at Appendix Q.

It will be seen from these three tables that the United States exceeds Canada by a very large margin both in uranium resource

availability and in actual production. This does not of course mean that the United States will not need Canadian uranium. On the contrary, Canadian sales of uranium to the United States are quite substantial and will probably continue to remain high, as the latter country has an extensive nuclear commitment.

The demand for uranium is of course dependent on the number of nuclear reactors in operation throughout the world, as well as on the types of reactors in use. There are other uses for uranium too, particularly in the atomic weapons' program. However, since there has been a general slowdown in the programs for the development of nuclear energy, the demand for uranium has gone down and become very uncertain.

It will be recalled that with the successful operation of the very first nuclear reactor in the United States in 1959, there arose optimistic speculation that by the year 2000 the country would have 1,000 nuclear plants. This optimistic vision was however short lived, as throughout the 1970s concern over nuclear power development began to deepen, causing a slowdown in programs for the construction of additional plants.

In an article published in the Social Science Quarterly, Earl Cook shows the United States to have 75 operating nuclear power plants as of December 1, 1980. In addition, 82 plants were under construction and 15 were in the planning stage. The plants already in operation supplied 10.9 per cent of the electricity generated in the United States in 1980.

Since 1975, however, only a few new reactors have been ordered, and in fact many previous orders have even been cancelled. It will thus be seen that there is a de facto moratorium on ordering new nuclear plants in the United States. This is how Cook explains the situation:

The abandonment of plans for new nuclear power plants appears due more to the virtual certainty of cost overruns related to unanticipated delays, to a decline in the forecast demand for electricity, and to unpredictable government actions than to a revised judgement about the basic economics of nuclear power....Construction costs for nuclear plants in the United States have been rising more steeply since 1970 than those for other types of power plants. There are two reasons: (1) regulatory changes in design criteria to cope with newly identified safety problems, and (2) construction delays caused by faulty performance of contractors and by intervention of concerned individuals and groups in the licensing process.¹¹

Compared with the United States, Canada has only ten operating nuclear power reactors at the present moment. As domestic demand for uranium is hardly 10 per cent of the total annual production, it is in the interest of Canada to promote and encourage the export of uranium surplus to Canadian needs. Obviously, the closest market and one that may ultimately prove to be the most lucrative is the United States.

Canada has about 20 per cent of the world's known and estimated uranium resources. Reserves of uranium in 1977 estimated to be 507,000 metric tons were worth more than \$50 billion Canadian at the world price of \$40 US/lbs. Under the existing government policy, 80 per cent of the uranium can be exported. The uranium industry alone brings in several hundred million dollars a year in foreign exchange and employs 5,000 people. Taxes and royalties on uranium production provide a substantial

revenue to the governments in several provinces. Taken together, the uranium and the reactor industries do one billion dollars of business a year, employing over 35,000 people.¹²

The nuclear industry is also helping Canada in its balance of payments problems. Banerjee, in his paper on the Economics of Canadian Nuclear Policy, elaborates this further:

If the electrical energy were generated by U.S. coal, then about \$1 billion of U.S. coal would have been imported in the period 1971-1977, of which about \$330 million would have been in 1977. For the period 1978-1984, the projected imports would be \$6 billion, if U.S. coal were used instead of nuclear generation....If all the Darlington nuclear units were in service in 1988, then about \$1.5 billion (1977) per year of U.S. coal would have to be used to replace the nuclear component.¹³

As regards the demand for uranium, it is of course related to the demand for electricity and the cost of nuclear power generation in relation to oil, gas, and coal power generation. This is how Lecraw explains it:

In turn, growth in demand for electricity depends on the growth of the world economy, total energy consumption, and the relative price of electricity as an energy source. Since 1973, when energy prices rose so dramatically, the growth of the world economy has slowed and a search for less energy-intensive products and processes has been initiated. Part of the slippage of the demand for uranium is a consequence of the sluggish growth of the world output. Other factors are the drive for energy conservation and the switch away from electricity as an energy source.¹⁴

Referring to the reduction in the percentage of nuclear-powered electrical generating capacity, Lecraw points out that late in 1977 the nuclear share was projected to rise from 16 per cent in 1985 to 45 per cent by the year 2025. However, from 1975 to 1977 these

projections decreased by a factor of two. He then goes on to explain why these projections, which were fairly recent, may again prove to be too optimistic:

For example, in Sweden reactors already constructed have not been put in use pending government approval. In the United States the construction of a reactor in New Hampshire has been halted, and Governor Carey of New York has threatened to withhold licenses for a reactor on Long Island (which is 75 per cent finished) until the problem of waste storage is resolved. Last year no new reactors were ordered in the United States....Orders for three reactors were cancelled and several others postponed, some indefinitely.¹⁵

A situation has therefore arisen which gives a reasonable cause to nuclear suppliers of a possible total collapse of their industry if more and more utilities decide to abandon their plans for nuclear generation of electricity in favour of coal-fired plants.

While the uncertainty in the demand for nuclear power is directly reflected in the demand for uranium, there are many technological factors which introduce further uncertainties in the future projections of uranium demand. For example, the development of recycling technology is still uncertain for technological as well as political reasons. Moreover, the development of the fast-breeder reactor as a long-term possibility, will certainly influence demand for uranium quite dramatically.

From all this it should be clear that the demand for nuclear facilities, including demand for uranium, is now more dependent on political, social and administrative factors than on pure economics. Even though it is generally recognized that nuclear power is cheaper and that

alternative sources are not likely to meet the future demand for energy, political considerations concerning nuclear proliferation, terrorism, and social concern with nuclear waste, reactor melt-down and other possible accidents causing environmental pollution seem to interfere with the normal process of nuclear energy development.

As far as Canada is concerned, it has not only large uranium resources, but additional reserves are likely to be identified in the future as a result of further exploration effort. These valuable resources can make a substantial contribution to Canada's economic well-being, employment, and balance of trade.

In view of Canada's current domestic commitment to nuclear power and the need to ensure a secure supply of domestic uranium, she is likely to remain the most significant exporter of uranium in the world. But, of course, the present federal export policy is restrictive inasmuch as exports are subject to the fulfillment of the following three conditions:

- (1) A thirty-year reserve of nuclear fuel for all existing or planned reactors.
- (2) Canadian uranium to be sold at the "world price" or cost plus escalation, whichever is higher.
- (3) Nuclear safeguards to be embodied in any arrangement for the use of Canadian uranium.

While the effect of these three conditions has been to reduce the amount of Canadian uranium available for export, they have helped to maintain the current price level which would otherwise have fallen.

In concluding this review of the economic benefits to Canada of a high-technology industry, all that need be said here is that the nuclear industry as a whole offers Canada the best chance to meet the challenges posed by future oil shortages, and to develop an important export base using uranium and reactor sales abroad as the basis for further expansion in world markets.

2. The Maturing of the Debate Between
Pro- and Anti-nuclear Interests:

One of the most controversial issues concerning nuclear power has been and continues to be the safety with which nuclear plants can be operated. Public concern about nuclear safety in general, including problems associated with mining, handling of radioactive material, and problems of waste disposal, has prompted strong opposition to nuclear plants in many parts of the world and resulted in increased regulatory activity, which in turn has led to delays in the construction of nuclear plants, and in some cases, even shutdown of operations in the existing plants. The nuclear industry as a whole is thus not only being burdened with increased costs but is also facing a great deal of uncertainty. To add to this climate of uncertainty, a worldwide concern over the safety of nuclear plants reached new heights in 1979 due to the accident at the Three Mile Island plant.

While few people would disagree that the potential for danger exists at nuclear power plants from accidents that could result in an

extensive release of radioactive materials, there continues to be widespread disagreement on the likelihood that major accidents will occur at nuclear plants. It is in the context of these concerns that the debate over nuclear energy has assumed such notoriety and drawn worldwide attention.

Insofar as Canada is concerned, Doern points out that in order to understand the potential role of both the pro- and anti-nuclear interests in future nuclear policy processes, it is necessary to recognize the fact that these two groups are now entering "what I choose to call a more "mature" phase of the development and practice of their political tactics." Although the first phase of their activity in the mid-1970s was characterized by exchanges representing a very stereotyped view of each other, both sides now "seem willing to extend and broaden their debate into a wider realm of economics and political reality, but without conceding the underlying contending values about social consequences of nuclear technology which both staked out in the first phase of their political exchange."¹⁶

The future politics of Canadian nuclear policy, according to Doern, will have to build on this recent process of maturity and link nuclear policies to Canadian economic policy generally, as well as to resource strategies of both the federal and the provincial governments, rather than merely consider the issue a problem exclusively that of science or government.

This analysis obviously suggests that there should be greater public involvement in future nuclear policy decisions. Doern is therefore of the view that as the two previous inquiries, namely the Cluff Lake inquiry and the Porter Commission hearings, did not have sufficient scope in their terms of reference for examining the economics of the industry and the far deeper implications for nuclear power for Canada as a nation, it would now seem essential that a major public inquiry be held. Many of the issues previously left untouched or only perfunctorily dealt with, could thus be properly examined.

An inquiry of this nature, it is claimed, should be able to examine not only the competitive advantages of nuclear over other energy choices, but it should also be able to shed public light on AECL's advanced fuel cycle priorities and future waste management concepts and technologies.

While it would seem doubtful if a major national public inquiry with such extensive terms of reference, will readily be able to throw much more light on the problems of nuclear energy than what we already know, it will perhaps be able to alleviate public concern to some extent. We have therefore no difficulty in agreeing with Doern that even though pluralism does not in itself guarantee that choices will be made in the public interest, Canadians might become somewhat more confident that reasonable choices are being made "if nuclear options are put to the competitive test of both the economic and political market place".¹⁷

3. Nuclear State Enterprises and Leverage Over the Private Sector

By setting up Atomic Energy of Canada Ltd. as a corporation solely responsible for the commercial development of nuclear energy, the federal government created an organization that was to become a powerful influence on energy policy. While it is true that as a Crown corporation, AECL remained fairly isolated from the routine uncertainties of the political processes, it nevertheless enjoyed relatively unrestricted access to policy-makers. Canadian nuclear industry is thus dominated by powerful federal and provincial crown corporations which, apart from AECL, include Eldorado Nuclear, Ontario Hydro, Hydro-Quebec, and the New Brunswick Hydro Electric Commission. These corporations operate within very broad policy guidelines at both the federal and provincial levels.

The federal government's commitment to nuclear power began early in the 1950s when, through AECL, it commenced the development of the Candu reactor for the generation of electricity. AECL, of course, does not manufacture anything for the Candu. It is responsible only for the design and quality of the components made by others.

The Candu was developed by AECL at public expense. Although some of the research and development was carried out by private industry, it was paid for by AECL. AECL today owns the proprietary rights to almost all aspects of the Candu design. But it does not own the right to the manufacturing technology, which is an important part of the total development effort.¹⁸

In building the very first Nuclear Power Demonstration reactor (NPD) which was to prove the Candu concept, an ideal partnership was set up between AECL, the designer of the Candu, Ontario Hydro which had agreed to operate the Candu system, and private industry which helped to manufacture the various components that went into the building of the reactor.

Originally, the idea was that a private organization, if given an opportunity, would learn by building the NPD station, and then be in a better position to exploit the Candu concept commercially by offering it in the market place. Canadian General Electric of Peterborough was selected to fill this role. The company set up an atomic power unit at its own cost, employing some hundreds of people capable of designing and marketing complete nuclear power stations. But after a strenuous export drive, extending over a period of seven years, it had only succeeded in selling one small nuclear power station to Pakistan. Unable to get any more work in Canada, the company was forced to close down its atomic power department in 1968.

The problems which a private nuclear industry has to face in Canada and the way the situation was resolved is thus described by Robin F.W. Guard in his paper presented to the Conference on Canadian Nuclear Policy:

Very few exporters of goods or services can survive on exports alone. Ontario Hydro foresaw that it would need a massive nuclear programme and decided that it could not tie itself to one private company, so it adopted the system it uses today - it hires AECL as its nuclear consultants, buys all the hardware in the open market, and builds stations itself. That it has been successful is an understatement; its achievements in nuclear power are the envy of the world.¹⁹

Guard then goes on to compare Canada with France which, not unlike Canada, has set up an organization based on cooperation between a utility, the manufacturers and the national nuclear energy commission. The crucial difference, however, is that the French organization, known as Framatome, is roughly two-thirds private and one-third government-owned Commissariat d'Énergie Atomique. Moreover, it has a guaranteed monopoly to supply all of the nuclear steam supply system to Électricité de France for a very large national program. In Canada, on the other hand, not only the AECL is a federal organization, but so too is the Export Development Corporation, which arranges financing for nuclear exports. A further complicating factor is that electricity supply in Canada is provincially owned. The federal government is therefore in no position to dictate the development of the Canadian domestic nuclear program.

Explaining why the Canadian export drive has failed, Guard points out that all other countries which have built up a healthy nuclear industry, both for meeting their domestic needs and for export, have used organizations dominated by private industry. In Canada there is no single industrial group strong enough to take the financial risks involved in such a massive enterprise similar to the industrial group in France,

namely Creusot Loire, which holds a majority of the privately-held shares in Framatome. The United States and Germany are two other examples where privately-owned corporations are so large that they can set up independent nuclear corporations without government involvement.

The position in Canada is of course quite the reverse. Even though the recent wave of anti-government criticism, especially by the Conservative opposition, has led to statements about the need to control Crown corporations and to transfer certain functions to the private sector, it is not very likely that nuclear state enterprises will undergo any radical changes that will lead to their ultimate privatization. At least one reason for this is that the federal government now has a direct presence in energy development through Petro-Canada and the tar-sands investment. In view of this, it is hardly likely that it will give up its close involvement in nuclear energy through AECL and Eldorado Nuclear. Obviously, state energy enterprises are viewed by the federal government as an important bargaining tool with the private sector. This leverage is particularly important, since companies such as Gulf and Imperial Oil are also involved in uranium development.²¹

4. Nuclear Policy as a Federal Lever in Federal-Provincial Bargaining

In this section we examine the importance of Canada's nuclear policy as a bargaining tool in federal-provincial negotiations. While it

is true that the federal government has ways of influencing policy in all energy and resource sectors, nuclear power, and uranium are virtually the only resource policy areas where primary authority is in federal rather than provincial hands, and will probably continue to remain so. Doern explains this further:

Thus, in the area of federal-provincial constitutional bargaining, where decentralization pressures arising from the Quebec separatist and western economic challenges are strong, the federal government is unlikely to want to trade away or dissipate its one direct resource bargaining lever.²²

Referring to the formerly proposed Nuclear Control and Administration Act which was tabled in parliament in 1977 as Bill C-14, Doern points out that an important objective of the Bill was to strengthen federal authority more explicitly in the field of health and environment, as well as in matters pertaining to security. The Bill, however, did not go beyond the first reading and died on the order paper when the session of parliament ended.

The existing Atomic Energy Control Act, passed in 1946 and amended in 1954, was largely in response to the need for security and in relation to federal powers over declared undertakings of general benefit to Canada. Had the proposed Act been passed, it would have provided the Atomic Energy Control Board with an explicit and detailed mandate that was lacking in the existing Act.

The first substantive section of Bill C-14 contained two

declarations. The first declaration, though almost identical to the one in the existing Act, confirmed the supremacy of the federal authority over provincial authority in the field of nuclear energy. Obviously, in the contentious area of uranium mining, this would have strengthened federal authority. The use of this declaration to transfer control of all aspects of uranium resource management to the federal government was therefore strongly objected to by the provinces concerned. Gordon H.E. Sims, in his book, A History of the Atomic Control Board, explains this further:

Provincial governments have always jealously insisted on control of their natural resources and a renewed declaration that uranium should be under federal rather than provincial jurisdiction threatened their absolute authority in this area and was seen by some as possible precursor of further federal initiatives to control other energy resources such as coal, oil and natural gas. Several provincial governments continued to be unimpressed by arguments that the special hazards of uranium made uniform standards of health, safety and environmental protection necessary across the country, or that the unique properties of uranium as a potential weapons material made it necessary for the federal authority to control this resource. The dispute between the two levels of government over uranium has not been resolved and it will certainly be raised as an issue at future conferences on federal-provincial relations.

The second declaration as proposed in Bill C-14 would have made the Act binding on the Crown and the provinces. The net effect of this provision would have been to bring the federal agencies, such as AECL and Eldorado Nuclear under the new Act. Other parts of the Bill related to the control of health, safety, security and environmental aspects of nuclear energy, as well as control over commercial and promotional activities.

The provincial objections to the Bill are reflected in some of the criticisms levelled by the western provinces as detailed below;²⁴

- (1) Federal-Provincial consultations which occurred prior to the introduction of the Bill have been inadequate, as the full scope of the proposed legislation was not clarified during those consultations.
- (2) Provisions pertaining to health and environmental legislation duplicate provincial legislation.
- (3) The provisions covering the sale, ~~lease~~, management, exploration, mining, and exploration of nuclear resources are a direct encroachment by the federal government into provincial jurisdiction over the control and management of natural resources.

In addition to these basic objections, concern has also been expressed, as for example by Ontario, over the broader aspects of the public hearing processes outlined in the Bill. Although it is true that the proposed legislation was conceived primarily in response to the widespread public concern expressed in 1975-76 about the Port Hope and Uranium Miners' controversies, Ontario's main objections to some of the Bill's provisions related to the degree of control that the federal government would exercise and the possible duplication of hearings and unnecessary delays that might result from the new hearing processes proposed in the Bill. These objections are clearly reflected in the Ontario Minister of Energy's telex message of November 1977 sent to the federal government. The text of the message, as quoted by Malcolm Rowan in the paper which he presented at the Conference on Canadian Nuclear Policy, is reproduced hereunder.

I can only reiterate Ontario's concern. Ontario is both a major producer of uranium and the major user. Consequently, we are concerned with both the jurisdictional ramifications and economic impact that the Nuclear Control and Administration Act may have on uranium mines and mills, on fuel fabricating, heavy water production, uranium marketing, both domestically and abroad; on nuclear power production, and of course, on the whole spectrum of irradiated fuel management.²⁵

Other provinces, notably Saskatchewan and Quebec, have also taken strong positions in opposing the Bill. It will therefore be seen that the two kinds of leverage which the federal government wanted to strengthen, i.e., the leverage in federal-provincial bargaining and the leverage over the private sector, could reinforce each other and provide nuclear interests in federal policy processes with a useful tool for political bargaining with the provinces. The question however is whether it will be right for the federal government to take a unilateral stand in future nuclear policy without prior consultation with the provinces.

While the federal government firmly believes that it is responsible for determining Canada's energy policy, it also acknowledges that "the generation of electricity has traditionally been a responsibility of provincial governments...." Thus, there is a dichotomy in the federal government's logic, as obviously it cannot pretend to assume total responsibility for Canada's nuclear policy and still maintain that the generation and distribution of electricity is the responsibility of the provinces. Energy policy-making, therefore, cannot legitimately be undertaken single-handedly by any one level of government. Rowan appropriately sums this up:

The active co-operation of every sector of the energy industry and, for that matter, of all consumers is essential. Until the federal government accepts this premise, there is bound to be conflict in federal-provincial relations involving energy and nuclear matters.²⁶

Although there has been a broad agreement on Canada's Candu program, federal-provincial conflict has generally revolved around policies concerning uranium and heavy water, and over the proposed changes in the Atomic Energy Control Act. In other related matters such as the management of radioactive wastes, there now seems to be a greater understanding of the problem, even though the selection of a suitable site for the permanent disposal of wastes may continue to present some difficulty.

On the question of uranium supply and pricing, it will be recalled that in the 1960s when the Canadian uranium industry was experiencing financial difficulties due to a sharp decline in the worldwide demand for uranium, the federal government tried to protect Canadian uranium producers by purchasing and stockpiling uranium. The situation, however, changed early in the 1970s due to an increase in world commitment to nuclear power, resulting in increased demand for uranium.

In view of this turnabout in the demand for uranium, the federal government stopped purchasing uranium, and issued its uranium policy guidelines in 1974, emphasizing the following two aspects:²⁷

- (1) Uranium producers to allocate a portion of their reserves for domestic use, and Canadian utilities to enter into long-term forward supply contracts.
- (2) Uranium to be sold at world prices.

Neither Ontario Hydro nor the Ontario government were satisfied with this arrangement and both wanted a more secure arrangement for the supply of uranium for Canadian utilities, as well as a two-price system, advantageous to the domestic nuclear program. Ontario's main objection was that the guidelines worked in favour of the uranium industry by placing an obligation on the utilities to make long-term contracts for the purchase of uranium. It was contended that the Canadian uranium producers thus had a free hand to export their product without adequate limitations.

A second area of controversy in federal-provincial relations, particularly insofar as Ontario was concerned, has been the issue of heavy water production and supply. Although during the early stages of the Candu program heavy water supplies were obtained from outside the country (mainly from the United States), in subsequent years when the Canadian commitment to the Candu reactor development had grown, it became clear that a Canadian source of heavy water supply would be needed. Therefore, early in the 1960s, construction of the original Glace Bay Heavy Water Plant by Deuterium of Canada Ltd. and of the Port Hawkesbury Heavy Water Plant by Canadian General Electric were approved. A commitment was also obtained from Ontario Hydro that the heavy water for Pickering Nuclear Generating Station "A" would be purchased from AECL.

By 1968, however, the need for additional Canadian heavy water production facilities was felt, particularly as Ontario Hydro began to doubt the production capabilities of the Glace Bay and Port Hawkesbury plants. It was therefore decided that a third plant would be needed to

meet the additional requirements of the Canadian nuclear generation program. Although the proposal for a complex combining nuclear electric and heavy water facilities was originally initiated by Ontario Hydro, which had already entered into an arrangement with a private firm to carry out preliminary engineering studies for the construction of a heavy water plant at Douglas Point, now that AECL had entered into the picture, it was agreed by Ontario Hydro that AECL could take over and complete the construction of the Bruce Heavy Water Plant "A".

In spite of this additional source of heavy water, a shortage of heavy water was again anticipated. As the AECL had undertaken the responsibility for providing heavy water to meet Canadian needs, priorities had to be established for the allocation of heavy water, preference being of course given to the needs of Ontario Hydro. Two agreements were accordingly signed in 1972 between Ontario Hydro and AECL. The Heavy Water Pool Agreement made AECL responsible for negotiating with suppliers to obtain whatever heavy water was needed by Ontario Hydro. The second agreement related to the Bruce Heavy Water Plant and gave Ontario Hydro the option to purchase the plant. It was on the basis of this agreement that Ontario Hydro finally purchased the Bruce Heavy Water Plant from AECL in 1973.

The federal government, no longer agreeable to finance further heavy water plants proposed by Ontario Hydro, decided to construct through

the AECL an additional heavy water plant to meet the requirements of other provinces, and for the export market. It was in these circumstances that the construction of the La Prade Heavy Water Plant was undertaken at Trois Rivières, Quebec.

In the meantime, however, Ontario Hydro's revised forecast figures showed a sharp decline in the likely annual growth in demand for electricity in Ontario from 6.5 per cent forecast for 1977 to 5.5 per cent for the period 1978 to 1986, and 4.5 per cent for the period 1987 to the year 2000. This decline in electricity demand was expected to have a measurable impact on Ontario Hydro's heavy water demand projections.²⁸

Based on these revised projections, Ontario Hydro's original proposal to build three more heavy water plants, namely Bruce "B", "C" and "D" was modified to eliminate one of the heavy water plants. However, with a view to rationalization of the production and marketing of Canadian heavy water, a series of discussions was held between Ontario Hydro, AECL, the Ontario Ministry of Energy, and the federal Department of Energy, Mines and Resources. In these discussions, Ontario Hydro's claim that the heavy water production from Bruce Heavy Water Plant "D" would be in excess of Ontario Hydro's needs, and that this excess would be sufficient to meet the demand that the La Prade plant was expected to supply, seemed to have had its effect. While further discussions were temporarily suspended, it was decided to mothball the La Prade Heavy Water Plant pending discussion of the issue between the federal government and the government of Quebec. The present position of the various heavy water plants licensed in Canada is summarized in Annex VI of the AECB

Annual Report for 1980-81 and may be seen at Appendix J. It will be seen therefrom that not only has the La Prade Heavy Water Plant been mothballed but so too has the Bruce Heavy Water Plant "D". It would thus appear that at present there is no shortage of heavy water production facilities in Canada to meet the needs of the nuclear program for some time to come.

Another important issue requiring federal-provincial agreement has been the question of radioactive waste disposal. In this particular area, both Ontario Hydro and the AECL have cooperated from the very beginning in studies and investigations into the management of radioactive wastes. This has finally led to the establishment of a joint program to assure safe and permanent disposal of radioactive waste from nuclear power reactors. The federal government and its agencies have assumed primary responsibility for the program and for undertaking research and development for the immobilization and disposal of radioactive wastes. The Ontario government and its agencies on their part have assumed responsibility on interim storage and transportation of irradiated fuel. It will therefore be seen that of all the recent initiatives in nuclear energy, the agreement between the federal government and the government of Ontario on the management of irradiated fuel is one of those areas in which full cooperation between the two levels of government has occurred.²⁹

But this does not mean that any long-term solution has been found to the radioactive waste disposal problem as a whole. There are still areas concerning nuclear waste management in which federal-provincial

conflict may arise, particularly as the potential hazards associated with nuclear wastes draw more attention and publicity than any other aspect of the nuclear industry.³⁰ In this connection it will be recalled that a committee was established by the federal government under the chairmanship of Dr. F.K. Hare, Director of the Institute of Environmental Studies, University of Toronto, to review and report on the management of Canada's nuclear wastes. The committee's report was published in August 1977. The House of Commons Standing Committee on National Resources and Public Works was given the task of reviewing the report and its major recommendation which dealt with the need for a national plan concerning the management of nuclear wastes. Some of the observations made in the "Hare Report" appear quite interesting and are quoted below:

The nuclear industry is not alone in finding the public wary of its plans. All high technology industry faces the same problem. Many people now question the wisdom of highly technical solutions to social needs, even when these are urgent and inescapable. the disposal of nuclear wastes, which Canadian society cannot now avoid, is just such a case. It has become surrounded by myths and suspicions. Only wide public consultation can sweep these away.³¹

The basic federal law that applies to the management of radioactive wastes is the Atomic Energy Control Act. Under this Act, the AECB is responsible for regulating and licensing atomic energy facilities, including radioactive waste storage and disposal facilities. However, both the AECB and the provincial environmental authorities are often faced with difficult choices because of the public outcry following any release of radioactivity into the environment.

As already indicated elsewhere, radioactive wastes are produced at different stages of the nuclear fuel cycle. There are thus uranium mining and milling wastes, as well as wastes from the operation of nuclear plants, excluding of course the irradiated fuel which falls in a different category.

Mining and milling wastes alone account for some 100 million tonnes of tailings that have accumulated over time in Canada. By the year 2000, these are expected to increase to 300 million tonnes. Although at present these wastes are under control, a long-term solution to their disposal has yet to be found. As regards reactor wastes, they are generally not considered a long-term hazard. The present methods used in their management are considered safe enough to keep them isolated from the environment. But the storage and ultimate disposal of irradiated fuel is another matter, and seems to have been the main concern of the public in connection with nuclear power. At present there are about 1600 tonnes of irradiated fuel in Canada. The present method of storing irradiated fuel in deep water pools is considered safe and satisfactory for many decades.

However, a significant question that has been raised in connection with irradiated fuel is whether it is to be treated as waste or processed further to recover the plutonium content from it. It would seem that a lack of decision on this issue has been one of the main factors causing delay in the development of a waste disposal site for irradiated fuel which is at present only stored. Moreover, as fuel reprocessing will be necessary once uranium becomes more expensive or in short supply, consideration was being given to determine the best methods and the costs

of recycling the recovered plutonium. Although the Candu system economically burns natural uranium and produces more electrical energy per unit weight of uranium used than any other current commercial nuclear reactor, on a world-wide basis there is just not enough uranium to allow a once-through fuelling system to remain economical for any indefinite period.³²

Apart from the waste management problems, one of the most important questions that needs to be answered is what will be Canada's future nuclear policy vis-a-vis the provincial interests. Obviously, a number of past problems over which disagreement with the provinces continues, will first have to be resolved. The most crucial of all such disputes is of course the federal-provincial jurisdictional dispute over the determination of energy policy generally and nuclear policy in particular. Should this issue be resolved, there is every reason to believe that other matters would not present any serious conflict. It is also important that the public should be taken into the governments' confidence and must be kept better informed on all aspects of Canada's nuclear power program. Rowan, quite aptly, emphasizes this need:

The federal and provincial governments cannot ignore the fact that the public holds them accountable for the costs and problems of the programme and expects them to examine clearly and enunciate the benefits associated with it. This further reinforces the need for a co-operative, complementary, and closely co³³ordinated effort on the part of federal and provincial governments.

5. Nuclear Policy and Federal
Inter-Departmental Bargaining:

Nuclear issues until the early 1970s were, for all intents and purposes, the responsibility of the Atomic Energy of Canada Ltd., which was then the chief guiding force in all nuclear matters, as the concerned department, namely the Department of Energy, Mines and Resources had only limited expertise. During this early period of nuclear energy development, nuclear issues were just beginning to arouse concern and had not yet become too controversial. Other federal agencies in the nuclear field, such as the Atomic Energy Control Board and Eldorado Nuclear confined themselves to limited responsibility in their own spheres of activity.

However, in the mid-1970s and thereafter domestic health and safety issues, and foreign policy concerns became more pronounced, and inevitably began to involve more intensely such departments and agencies as the Atomic Energy Control Board, External Affairs, EMR, and National Health and Welfare. Furthermore, as the political controversy and the economic importance of nuclear issues became more significant, still other departments, notably the Treasury Board, the Privy Council Office and the Department of Finance began to assume important roles concerning problems connected with nuclear energy.

While it may appear from all this that internal nuclear policy processes have become more pluralistic and competitive than they used to be, Doern, referring to the now extinct Bill C-14, warns that although

parts of the Bill represented needed reforms and reflected some internal policy competition, one must not forget that long-term forces make policy pluralism "more illusory than real." He then goes on to suggest that as the monopoly of federal expertise still rests with AECL, the nuclear industry which is now confident about the comparative advantages of nuclear over other energy choices, should not object to a major federal research and development subsidy for selected renewable energy techniques:

The competitive claims of both these energy sources can only be economically and politically refereed if they are put on more of a pluralistic footing.... As I have stressed earlier, pluralism does not in itself guarantee that choices are made in the public interest. Canadians can, however, be somewhat more confident that reasonable choices are being made if nuclear options are put to the competitive test of both the economic and political market-place.³⁴

While Doern has certainly thrown some useful light on the interplay of forces within federal agencies and departments concerned with nuclear energy, it is not quite clear what his grounds are for believing that the nuclear industry is in any position to object to a major federal research and development subsidy for selected renewable techniques. Even though it is true that the nuclear industry, by reason of its close ties with the AECL, has considerable leverage with the concerned government departments, this link by itself does not suggest any logical basis which can be used by it to try to prevent or discourage research and development investment by the federal government in renewable energy programs.

Operational Safety, Environmental
Controls and Social Costs.

The controversy over the safety of nuclear power focuses primarily on concerns about dangers associated with nuclear power plants and the nuclear fuel cycle. These concerns were heightened by the accident in 1979 at the Three Mile Island plant in Pennsylvania.

The potential for danger at nuclear power plants consists of two distinct risks. Both are associated with the release of radiation. The first danger arises from the risks associated with normal emissions of low-level radiation at nuclear plants and at various stages in the nuclear fuel cycle, beginning with the extraction of uranium ores and ending with the disposal of fission products and depleted uranium. While emissions of this nature are an inevitable consequence of operating nuclear facilities, their actual effects on health of workers in the nuclear industry and people living near nuclear plants are the subject of an intense scientific controversy.

A second danger is associated with the possibility of catastrophic accidents at nuclear power plants. If some such serious accident were to occur, it could result in the widespread release of massive amounts of radiation. While experts generally agree about the disastrous health effects of any massive release of radiation, there are sharp differences of opinion amongst them as to the chances of such an accident occurring.³⁵

The main potential hazard in a nuclear reactor, of course, arises from the radioactivity contained in the by-products produced by the fission process. It is, however, impossible for a nuclear reactor to explode like an atomic bomb. This is because the fissile material in an atom bomb has to be brought together very quickly, whereas in a reactor the fissile material is in a dispersed form, "with large amounts of neutron absorbing and moderating material. This makes a bomb-type explosion impossible.³⁶ Moreover, commercial nuclear reactors are designed and constructed for maximum safety. They incorporate a variety of stand-by and fail-safe devices. Nevertheless, the probability of a serious accident, though remote, cannot altogether be discounted, as no human activity can be entirely free of danger. However, the chances of a catastrophic accident occurring are minimal, particularly in the case of the Candu reactors whose safety record has been outstanding:

The Chalk River Laboratories have been in operation for about 30 years, the Whiteshell Nuclear Research Establishment for 14 years, the Nuclear Power Demonstration Station for 16 years, Douglas Point for 11 years, and Pickering for 7 years. During this period, not only have there been no fatalities due to radiation, but also there has never been a lost-time accident due to radiation in operating nuclear power stations.³⁷

The above statement by Alan Wyatt, a strong advocate of Canada's nuclear program, might give an impression that there have been no serious problems with nuclear reactors in Canada. This is of course not entirely true. While it can be reiterated that there has been no serious accident in Canada related to nuclear power production since 1952 when a small demonstration reactor near Chalk River suffered a core melt-down but

without causing any injuries, there have been several cases of malfunctioning and minor accidents in Candu reactors. But none of these has so far caused any injury, radioactive contamination outside the reactor building, or stoppage in the supply of electric power.³⁸

These views on the safety of Candu reactors and the need for Canada to go ahead with its nuclear development program are supported in the findings of the Royal Commission on Electric Power Planning (Porter Commission) established by the Ontario Government in July 1975, in response to public concern about the long-range plans for the development of Ontario Hydro's electric power system. In its Interim Report, the Commission notes:

We have concluded that nuclear power has a role to play in this expansion program.... The absolute safety of any industrial process, or human activity, including the generation of electricity, cannot be guaranteed. In the case of the Candu reactor we have concluded that within reasonable limits, the reactor is safe.³⁹

Any assessment of the acceptability of the risks and benefits of nuclear power will therefore have to include an assessment of the social and political consequences arising therefrom. Nevertheless, it seems obvious that the continued availability of abundant energy is essential to the general well-being of modern societies and an important requirement for the maintenance of a high standard of living.

While there may or may not be a causal relationship between energy consumption and quality of life, in the view of the Porter Commission historical evidence seems to suggest that there is a complex relationship

between per capita energy use and per capita Gross National Product. Moreover, it is a well-recognized fact that technology does play a significant role in enhancing the quality of life, as is so clearly evident from our own personal experiences in daily life. However, the Porter Commission has made it quite clear that not only nuclear energy but all currently available conventional energy systems have social, ethical, economic, environmental and political costs associated with their deployment. This is what the Commission has to say about the risks we encounter in our daily lives:

Paradoxically, living with risks is what makes life possible.... Indeed, the philosopher Alfred North Whitehead once remarked that one manifestation of wisdom was to recognize that major changes in society and culture almost destroy us.... We routinely risk our lives in automobiles, aircraft, and even while participating in sports. Certainly, the risks and the benefits associated with nuclear power have emerged as central issues during our public hearings.⁴⁰

According to the Department of Energy, Mines and Resources, many scientific experts are satisfied that the risks associated with nuclear power can be effectively controlled. Nuclear power has, indeed, received far greater environmental safety and security investigation than any other source of energy. There are multiple back-up and fail-safe devices as already mentioned, and these ensure a reasonable degree of safety. The Porter Commission too has endorsed the use and expansion of nuclear power, subject to certain safeguards. Referring to the Candu reactor, the Commission has drawn attention to the fact that all the stages of the Candu fuel cycle are carried out in Ontario. These include the so-called "front-end" of the cycle, consisting of: (1) mining, milling and refining

uranium, (ii) producing heavy water, and (iii) generating electricity, and the "back-end" of the cycle, i.e., the management of radioactive wastes.

The safety aspects of the fuel cycle will thus be evident from the following observations of the Commission:⁴¹

(1) Candu nuclear power systems use ceramic grade natural uranium dioxide containing 0.7% of the fissionable uranium-235 isotopes. This concentration of uranium is the same as found in nature. It is burnt (in bundles) in Candu reactor without further concentration (enrichment).

(2) The low-level radio-active wastes (protective clothing, etc.) are incinerated and the ash, which is classified as a medium-level waste, is enclosed in heavily shielded containers and then buried in concrete blocks (tile holes).

(3) All Candu spent nuclear fuel is currently stored in large water-filled pools on the plant site.

(4) Transportation of uranium concentrates, fuel elements and bundles, as well as the refining processes have posed no serious problem. But the disposal of mill tailings has caused difficulties in the past. For example, the concentration of uranium oxide (U_3O_8), i.e., the raw material required for nuclear fuel fabrication, is relatively low (0.5 Kg per tonne). This means that for half a kilogram of uranium oxide, one tonne of material is waste "tailings." Approximately 80 million tonnes of these tailings, mostly the result of extensive mining operations in the 1950s and 1960s, lie exposed. These have been treated and neutralized.

(5) The exposure of the general public to radiation caused directly by nuclear power stations is only a small percentage (about 1%) of the recommended maximum levels. For workers in the nuclear industry, the maximum permissible doses are at a level of 10 times those applicable to the general public:

Because each one of us is exposed to between 100 and 150 millirems per year of naturally occurring radiation, it has been argued that, since the radioactive discharge, under normal operating conditions from, say, Pickering G.S. as monitored at the plant perimeter is only 5 millirems/year, this is virtually negligible. Indeed, it has been pointed out that 5 mrem/year is the additional dose received by a person flying from Canada to Europe once a year, or a person living at an altitude of about 3,000 feet above sea level.

The Annual Report of the Atomic Energy Control Board for 1980-81 provides a clear indication that no serious problems of nuclear waste disposal are now encountered.⁴² For example, it shows that the management of mill tailings is required as part of the mine operating license and that tailings are being managed adequately. But a major problem is the storage and disposal of contaminated soil and abandoned radioactive material not associated with activities licensed by the Board, but resulting from activities carried out in the past. To cope with this problem, regional waste management sites are being considered by the Board. As regards spent reactor fuel, the Report points out that as it is produced in relatively small quantities, it is safely stored under water at reactor sites.

Moreover, with a view toward increasing public awareness, the Board has made changes in its regulations so as to permit public access to

licensing information. The Board has also established a process for Regulatory Document Development, which permits the inclusion of a public consultation stage before a document is issued in its final form.

The Report also mentions that the Directorate of Fuel Cycle and Materials Regulation is responsible for various programs for the implementation of safeguards programs, and programs within the responsibility of the Federal-Provincial Task Force on Radioactivity. This Task Force was set up in 1976 to expedite the clean-up of radioactive contamination in Port Hope. It has subsequently expanded its activities to other towns and locations in Canada. Ten federal departments and three provinces are represented on the Task Force.⁴⁶ Moreover, a number of provincial departments and agencies concerned with energy and the environment directly or indirectly, cooperate with the AECB in matters of common interest of jurisdiction.

From the above brief description of environmental safety measures to prevent undue or excessive radiation exposure from nuclear energy production, it will be seen that all reasonable safeguards exist to protect the environment. Coal, which is the only other practical alternative to nuclear-generated electricity, carries with it a much heavier environmental and health cost.

Although the Candu reactor system is different in design from the American light water reactor, the overall safety of different thermal reactor designs is comparable, as the mechanism for dispersal of large amounts of radioactivity is the same.⁴³ Moreover, because of certain

common characteristics of nuclear power plants and the similarity of environmental hazards they pose, the findings of some of the studies conducted in the United States may prove to be a useful guide to be taken note of in connection with the operation of nuclear facilities in Canada. It will, therefore, be useful to review briefly the findings of important studies conducted in the United States that have evaluated the probable effects of a major accident in a nuclear plant.

A major reactor safety study, known as the Rasmussen study, was completed in the United States in 1975. It was directed by Norman Rasmussen, head of the department of nuclear engineering at M.I.T. The aim of the study was to provide a quantitative assessment of the risks to public health and safety from potential accidents at nuclear plants. The study concluded that the probability of direct deaths from a nuclear accident is lower than from many other causes:⁴⁴

The likelihood of reactor accidents is much smaller than that of many non-nuclear accidents having similar consequences. All non-nuclear accidents examined in this study, including fires, explosions, toxic chemical releases, dam failures, airplane crashes, earthquakes, hurricanes, and tornadoes, are much more likely to occur and can have consequences comparable to, or larger than, those of nuclear accidents.

Other important conclusions of the Rasmussen study which may be found interesting are summarized below:

- (1) The probability of a core melt (1 in 20,000) was greater than expected, but the likelihood of a fatality from it was lower than what had been anticipated, i.e. less than 1 in 20,000.
- (2) An accident resulting in more than 10 deaths was likely to occur once in 3 million reactor-years of operation.
- (3) A most serious accident but one that is likely to occur only once in a billion reactor-years, could kill 3,300 people, cause latent cancers in 45,000, and property damage estimated at \$14 billion.
- (4) The fatality risk to members of the public from 100 nuclear plants was lower than that from hurricanes, tornadoes and even falling meteors.

While the Rasmussen report was strongly criticized in the United States by such groups as the Union of Concerned Scientists, it was widely used by the nuclear power industry and the government as an assurance of the safety of nuclear reactors. This optimistic view of nuclear reactor safety was, however, short lived. In July 1977, the U.S. Nuclear Regulatory Commission established a Risk Assessment Review Group to examine the Rasmussen report. The review group, under the chairmanship of Harold W. Lewis of the University of California at Santa Barbara, submitted its findings in September 1978. The group found that even though it was unable to define whether the overall probability of a core melt as given in the Rasmussen report was high or low, it was certain that the error bands were understated. While the extent of this error could not be determined by the review group, the group was critical of the inadequate data base used in the Rasmussen study, as well as of the poor statistical treatment which resulted in "an inconsistent propagation of uncertainties throughout the calculation." The report, however,

acknowledged that the Rasmussen study was an important advance over earlier methodology applied to nuclear risks.

Release of the Lewis report brought immediate response from the Nuclear Regulatory Commission.

In a policy statement issued on Jan. 19, 1979, the N.R.C. accepted the major criticism of the Rasmussen report found in the Lewis report. Specifically it withdrew any explicit or implicit past endorsement of the Rasmussen report's executive summary (it was the executive summary that was most widely quoted by the nuclear industry)....

In the wake of this action by the N.R.C., and only a couple of months later, a presidential special committee reported to the Carter Administration that the problem of safe high-level radioactive waste disposal needed further investigation. On the same day, the N.R.C. ordered five large nuclear plants to shut down due to inadequate protection against earthquakes. Although three of the plants were brought back in service, the remaining two were still out of service some 18 months later.

The year 1979 thus proved to be a time of extreme uncertainty for the U.S. domestic nuclear power industry. The most devastating experience for the nuclear industry, however, occurred on March 28 of that year:

...while industry officials were still reacting against these earlier government moves with interviews criticizing 'excessive government regulation' and 'bureaucratic delays', the newly licensed Three Mile Island reactor in Pennsylvania suffered what is widely considered to be the worst nuclear power plant accident in the country's history. While the environmental and health consequences of the accident appear to be minimal, the political, economic and emotional shockwaves from the Three Mile Island incident are likely to affect the country's nuclear power program for years to come.⁴⁶

According to an informal survey of Wall Street analysts carried out in 1979 by the trade journal Nucleonics Week, there appeared to be a consensus that anywhere from 30 to 53 nuclear plants planned or under construction in the United States will probably be cancelled as an indirect result of the Three Mile Island accident.⁴⁷ Even utilities that remained confident about nuclear power have been forced to examine their projected needs and commitments to build new power plants in the light of financial constraints and reduced demand projections:

Between January 1974 and February 1980, utilities ordered 39 nuclear plants, cancelled orders for 52 nuclear plants, deferred indefinitely orders for at least seven other reactors, and suffered more than 200 delays of more⁴⁸ than a year at nuclear plants planned or under construction.

Thus, the total number of nuclear plants having operating licenses in the United States as of September 1980 was only 74, representing about 9 per cent of the total U.S. electrical generating capacity. While another 108 plants were under construction or had been ordered, a number of these were expected to be cancelled. Government officials projecting the development of nuclear power have accordingly lowered their estimates from 200 plants operating in 1980 to 197 units in 1995. Current U.S.

Energy Department forecasts indicate that nuclear reactors will provide 26 per cent of all central-station electricity generated in the year 2000. By way of comparison, the figures for 1979 show that commercial nuclear reactors generated about 255 billion kilowatt-hours of electricity, accounting for about 11.5 per cent of total U.S. electrical production.⁴⁹

The recent slow-down in nuclear power development in the United States and in many other parts of the world, particularly in Western Europe, has to some extent, been the result of a massive anti-nuclear campaign. The Three Mile Island accident served to focus criticism of nuclear power that had been building up for a decade. The accident has not only hardened the existing attitudes of opponents to nuclear power, but it has also created a problem of credibility for public officials concerned with the implementation of nuclear policy. Dorothy Nelkin, in an article published in the March 1980 issue of the American Political Science Review, explains that President Carter was directly concerned with easing public skepticism about nuclear policy when he appointed the Kemeney Commission:

The problem for Carter was less to evaluate the future of nuclear policy than to assure its public acceptability. He appointed the Kemeney Commission to this end.⁵⁰

Apart from the Kemeney Commission investigation, there were five other major inquiries that were initiated to examine the various implications arising out of the accident. A great deal of confusion seems to have developed amongst the different government agencies involved in

these inquiries, due to their overlapping spheres of influence. Nevertheless, insofar as the Kemeney Commission was concerned, it found the N.R.C. "erring on the side of industry's convenience rather than carrying out its primary mission of assuring safety."⁵¹

The Three Mile Island accident also generated an unprecedented legal battle to establish liability. Despite the existence of the Price-Anderson Act which limited the insurance liability of nuclear facilities in the United States to \$560 million in any one nuclear power accident, suits have been filed claiming damages much beyond this limit. While private insurance covers a maximum of \$125 million, the U.S. government bears the responsibility for the difference. In Canada on the other hand, insurance liability is limited to a maximum of \$75 million.

In contrast to a much larger number of reactors operating in the United States, Canada has only 10 operating nuclear power reactors. They are all located in Ontario and produce about a third of the province's electrical power. This works out to about 10 per cent of Canada's total electrical production. Additional reactors planned for Ontario are in various stages of construction. Apart from Ontario, the only other provinces which have decided to have nuclear power are Quebec and New Brunswick. The construction of a nuclear reactor for each of these two provinces is already in hand. In Quebec, as we have seen, there is already a 250-MW nuclear power station known as Gentilly 1, but it has been in a shut-down state due to malfunctioning.

Canadian public concern about nuclear hazards has been somewhat limited when compared with the United States. These concerns were, however, heightened by press reports highlighting nuclear-related incidents in the United States. The summer of 1975 thus saw the formation of a coalition of anti-nuclear groups, as for example the Canadian Coalition for Nuclear Responsibility (CCNR). These groups sought to stir public concern over nuclear policy and programs in the country. The issues over which attention was focussed included such controversial matters as radiation hazards to the general public, the safe disposal of radioactive wastes, and the proliferation of nuclear weapons due to misuse of nuclear equipment, material and knowhow by unfriendly nations and terrorist groups.

The C.C.N.R., which claims to represent over 100 anti-nuclear organizations across Canada, has been calling for a national inquiry into nuclear energy at the federal level, despite the fact that a number of public inquiries, as indicated below, have already been held to assess some of the dangers associated with the operation of various nuclear facilities:⁵²

- (1) The Ontario Royal Commission on the Health and Safety of Workers in Mines (the Ham Commission).
- (2) The Ontario Royal Commission on Electric Power Planning (the Porter Commission).
- (3) The Cluff Lake Board of Inquiry (Saskatchewan).

- (4) The Energy Committee of the New Brunswick Legislature.
- (5) The British Columbia Royal Commission of Investigation into Uranium Mining (the Bates Commission).

Along with its demand for a public inquiry, the C.C.N.R. has also been urging a two-year moratorium on the licensing, construction and sale of nuclear reactors and related nuclear facilities. By suggesting that the AECL be dissolved and that its staff be relocated in other energy corporations, it seems to have gone well beyond the threshold of normal reasoning. Nuclear industry's reaction to the two-year moratorium suggested by CCNR is thus summed up by Alan Wyatt:

The main concern of the nuclear industry is that a moratorium of this type in essence makes a scapegoat of the entire industry for the real or imagined ills of society, that staff morale would be destroyed, that investor confidence would vanish, and that after the two years were over, it would be very difficult if not impossible to revive the industry.⁵²

Moreover, nuclear power seems to have been linked by its opponents with nuclear weapons, perhaps in order to play on public fears. While it is true that the U.S. nuclear power program grew out of the wartime weapons program, the Canadian development was only very briefly and quite indirectly related to it. It should, however, be recognized that even if all the nuclear power reactors in the world were to close down, the problem of nuclear weapons will still be there, so long as the super-powers continue to rely on atomic power for their military needs and compete with each other in this area. It is nevertheless conceded that the widespread use of nuclear energy for electrical power by nations does give them an opportunity to misuse that technology to develop nuclear

weapons much more easily than would have otherwise been possible.

The way opposition to nuclear power is expressed also differs from country to country. Unlike the United States, opposition to nuclear power in Canada has generally been expressed through normal channels within the political system and not through massive demonstrations or through the law courts, as has been a common feature in the United States. Although opposition to nuclear power in Canada has in recent years taken the form of protest movements, public agitation against nuclear power in this country has been comparatively mild. This is obviously due to the different traditions of government and the different levels of trust in the government which each country enjoys.

Even in such matters as the regulatory control of nuclear facilities and their operation, there soon developed certain marked differences in the philosophy of the two countries. For example, in Canada the Atomic Energy Control Act of 1946 established the Atomic Energy Control Board (AECB), with the dual responsibility of promoting and protecting atomic energy. Therefore, when the Atomic Energy of Canada Ltd. was established as a crown corporation in 1952 to promote the commercial development of nuclear power, its first president also became the president of the AECB.

While in the beginning this arrangement of dual responsibility was in some measure similar to the arrangement existing in the United States where the Atomic Energy Commission (now Nuclear Regulatory Commission) exercised not only the protection responsibility but also the promotion

function, this arrangement of dual responsibility did not for long remain as acceptable in Canada as was the structure of the AEC in the United States. Accordingly, in 1954 the Canadian Atomic Energy Control Act of 1946 was amended to remove from the AECB the responsibility for the promotion function. A similar separation of functions was not effected in the United States until as late as 1975.⁵⁴

In spite of this separation of functions, it is nevertheless true that since government agencies design and build nuclear power plants in Canada, those responsible for the development of Canadian nuclear power enjoy special access to the policy process. Moreover, since nuclear policy in Canada is generally regarded as an important aspect of Canadian economic policy, the Canadian public has probably a less polarized view of nuclear power than the U.S. public. In any case, since nuclear power in Canada is a government enterprise in which the reactors are designed by a federal agency and the plants are built and operated by a provincial utility corporation, with the help of private industry where necessary, a Canadian national consensus has hardly been necessary to go ahead with the nuclear program, as Canadian provinces enjoy far greater autonomy than do the American states.⁵⁵

However, even though under the BNA Act the ownership and control of natural resources rests with the provinces, an exception was made in the case of uranium and other nuclear matters which the federal government wanted to bring under its own control. Therefore, taking advantage of the special exemption clause in the BNA Act, namely: "for the general advantage of Canada," the Atomic Energy Control Act of 1946 placed these powers under the authority of AECB.⁵⁶

Notwithstanding these extensive powers of the AECB, provincial cooperation has been necessary not only as a matter of political expediency but also because of the provinces' responsibility under the BNA Act for health, labour and mineral resources. Moreover, both the promotional and control aspects of nuclear energy and other related facilities involve action by several federal and provincial departments and agencies. A chart showing major nuclear policy organizations in Canada, including international agencies concerned with nuclear energy, is reproduced at Appendix R. It will be seen that a number of government departments and agencies, both at the federal and provincial levels, are involved with nuclear energy. The chart also shows the involvement of the media, the concerned interest groups and the various commissions of inquiries which obviously influence nuclear policy decisions in one way or the other.

It is however the AECB which has specified powers over nuclear energy and associated facilities. Under the Atomic Energy Control Act, the Board is empowered to control the development, application and use of atomic energy. It exercises this control through the Atomic Energy Control Regulations.⁵⁷ These include a comprehensive system of licensing which covers all dealings in prescribed atomic energy substances and equipment. The Board is thus able to ensure that all such substances and equipment are handled and utilized "with proper consideration of health and safety and of national and international security."⁵⁸ As for commitments made in international agreements for complying with prescribed international standards of safety and security, arrangements exist for allowing inspectors from the International Atomic Energy Agency

to carry out checks of nuclear establishments in Canada at prescribed intervals.

Moreover, through its regulations which contain provisions pertaining to the construction and operation of nuclear power plants, the AECB maintains effective control of the safety and environmental aspects of nuclear power stations. However, as the Board is not empowered to hold formal public hearings, public involvement in such matters as site approval is restricted to participation "at public meetings that provincial utilities voluntarily conduct...."59

While the AECB has clear legal jurisdiction to regulate most aspects of nuclear industry, administrative arrangements have to be made with provincial authorities to facilitate interaction and implementation. For example, since a good deal of uranium mining is concentrated in Ontario, it was Ontario's administrative action that has facilitated implementation of necessary controls and safeguards in respect of health and safety of the miners. The responsibility for health and safety of the miners is of course placed on the mine management. It is, however, the provincial Ministry of Natural Resources which has the responsibility for the inspection of mining safety. The standards recommended by the International Commission on Radiological Protection (ICRP) serve as a guide for this purpose.⁶⁰

Following the Ham Commission recommendations which dealt with uranium mining safety, health standards to protect uranium miners have been made more stringent. Current AECB policy permits more

direct involvement of the Board in safety and health measures. To help the Board in these matters, a number of advisory committees has been formed. Members of these committees include individual experts and representatives of federal, provincial and some municipal departments and agencies. It will thus be seen that through its licensing powers, the Board has control over safety, health and environmental hazards associated with the construction and operation of nuclear power plants, mining operations, waste disposal and transportation of nuclear materials. Nuclear facilities are also subject to other federal and provincial environmental and other legislation. Many of the measures of a regulatory nature are therefore increasingly influenced by federal-provincial bargaining.⁶¹

Apart from these domestic concerns, Canada also has certain international commitments concerning its nuclear policy. It has been Canada's policy from the very beginning to adhere to standards internationally recommended as safe for the operations of nuclear facilities. Accordingly, ICRP recommendations form the basis of the AECS's radiation control regulations. The recommendations of the International Atomic Energy Agency (IAEA) have also been included in "Canadian security measures, safety standards, and transportation regulations."⁶² Moreover, Canada has already signed the Non-Proliferation Treaty which requires non-nuclear-weapon parties to submit to IAEA safeguards, and prohibits the supply of certain types of nuclear items to non-nuclear weapon states.

While Canada has not hesitated to cooperate in all such

international agreements, her restrictive policy on foreign ownership of Canadian industry has often been criticized in the foreign press. It was in support of this policy that in 1970, when it was learnt that a foreign-owned company was trying to acquire controlling interest in Denison Mines Ltd., Prime Minister Trudeau voiced his disapproval of the proposed sale. However, government finally agreed to permit foreign owners of uranium companies to retain their holdings as of March 2, 1979, on condition that any future sales of such holdings would be made to Canadian residents until the total foreign ownership was reduced to 33 per cent. This control is presently exercised through the Foreign Investment Review Agency (FIRA).⁶³

Although we have already discussed elsewhere the economic benefits of using nuclear energy and explained briefly in this section the operational safety of nuclear plants and the regulatory mechanism which exists for the protection of the environment, we have so far not discussed the social consequences of nuclear technology and its increasing use not only for the production of electricity but also for application in other fields.

While it is generally recognized that the impact of nuclear power has been greatest in the military and strategic spheres, in the economic field nuclear energy has provided the world with another source of fuel which in one of its forms is self-renewing. Moreover, nuclear technology has been most beneficial for other uses as well, such as in medicine, industry and agriculture. However, from the social standpoint, the consequences of the development of nuclear power will be found more

difficult to assess.

It is a well-known fact of life that economic growth inevitably exerts pressure on environmental quality:

The relationship between economic growth and environmental quality is complex and depends critically upon the nature and stringency of environmental protection programmes adopted by governments and the development of pollution control technology.⁶⁴

Even though many industrial projects have some undesirable environmental effects on health and property, they are generally felt more intensely and directly by people living close to the production centres. These "social costs" can of course be quite significant. Damage to health and property in many industrial centres, particularly in the vicinity of fossil-fuelled plants, is a well-recognized phenomenon of industrial growth. Referring to a study prepared by Professor Hill for the Royal Commission on Electric Power Planning (Porter Commission), Banerjee quotes from some of the findings of the study:

Professor Hill has estimated the 'premature deaths' (public health) and 'injury days' (occupational health) due to mining and extraction, processing, transportation and waste management, and energy conversion for thermal generating stations. His estimates of premature deaths per 1,000 MW(e) plant year is 0.16 to 1.08 for coal, 0.34 for oil, and 0.115 to 0.178 for Candu nuclear. For injury days per 1,000 MW(e) plant year his estimates are 3,000-11,000 for coal, 4,500 for oil, and 1,000 to 2,000 for nuclear. (Professor Hill includes the consequence of major nuclear accidents in his estimates).⁶⁵

On the issue of social risks arising due to nuclear proliferation resulting from power reactor programs, Banerjee points out that a study

conducted at Stanford University in 1978 had concluded that the relationship between nuclear power programs and nuclear weapons was very weak. He thus quotes the example of China which, in spite of its arsenal of nuclear weapons, is continuing to seek the purchase of nuclear power reactors from Western countries.

Concluding that the social costs of nuclear generation of electricity are not qualitatively different from those of other conventional generation concepts, Banerjee refers to the Windscale Inquiry of 1977 which investigated the proposals for building a new nuclear oxide fuel reprocessing plant in the United Kingdom at the Windscale site of the British Nuclear Fuels Ltd.⁶⁶ In this inquiry, Mr. Justice Parker of the British High Court came to the conclusion that alternative generation concepts also involved social costs:

For example, the installation and maintenance of strings of oscillating generators 1½ miles off-shore to the north of Scotland or the erection of 4,800 windmills in the North Sea would create dangers of their own, not only to those who might build and maintain them but also to shipping. Another possibility, the planting of the Lake District with thousands of acres of sugar beet or eucalyptus trees, which was discussed at the Inquiry, would be unlikely to receive much of a welcome from environmentalists. Indeed I find it difficult to understand the process of thought which appears to find it preferable to avoid a death from radiation at the expense of causing more deaths from other causes.⁶⁷

Apart from the Windscale inquiry, two other similar inquiries which were set up to investigate the proposed establishment of uranium mines, namely: the Ranger Inquiry in Australia under Mr. Justice Fox (1975) and the Cluff Lake Inquiry of Saskatchewan under Mr. Justice Bayda (1977) need to be mentioned here, as all these three inquiries have been

subjected to varying degrees of criticism. In his paper to the conference on Canadian Nuclear Policy, Walter C. Patterson, a physicist and energy specialist with the Friends of the Earth Society in London, England, compares the findings of these three inquiries. Some of his observations, though limited in their scope, may be found interesting. Relevant excerpts from his paper are therefore reproduced hereunder:

In contrast to the Ranger exercise, the windscale exercise had precisely the practical effect of rubber-stamping a foregone conclusion.... The Cluff Lake exercise combines elements of Ranger and Windscale. One contrast with the Fox report in their treatment of the issue of nuclear weapons proliferation: The Fox report identified it as an issue of crucial importance.... The Bayda report identifies it as largely irrelevant to the particular question of development of uranium in Saskatchewan.... Once again, albeit for different reasons, the net effect of the Cluff Lake exercise was to rubber-stamp a foregone conclusion.⁶⁸

It will be seen from these reproductions of some of the observations made by Patterson that all the three reports mentioned above have not been quite up to his expectations, except perhaps the Fox report which has explicitly recognized that the final responsibility in all such decisions must rest with the elected representatives of the public in parliament. Although there can be no argument with this stand, the fact remains that reconciling public processes with major industrial developments, especially in the context of civil nuclear programs, is an extremely complicated task. While satisfactory solutions in Canada and elsewhere may not be immediately forthcoming for dealing with a highly controversial issue like nuclear energy and the problems associated with environmental controls, it will perhaps help to reduce public concern if greater public participation in civil nuclear planning can be achieved.

In an article published in Environmental Affairs, the authors point out that while concern over the economic component of environmental regulation is shared in the United States by elite and mass groups alike, the Gallup polls indicate that there is a general unwillingness on their part to accept economic burdens for undertaking pollution abatement measures as a high priority.⁶⁹

In Canada too, the situation does not appear to be very much different. All indications are that neither the government nor the public will be willing to give any higher priority for environmental control measures which may impose a heavy financial burden. In any case, public opinion in Canada seems to have been much milder on environmental issues when compared with the United States. We find that the 1950s and 1960s were characterized by a high degree of faith in government handling of the problems connected with nuclear energy. But this situation had changed radically in 1970s. A number of nuclear critics and public interest groups had begun to emerge. The Canadian Nuclear Association (CNA), began to strengthen its resolve to oppose these groups and defend its own interests, centered in nuclear industries and the utilities, on the grounds that such criticism was unwarranted. Unpublished polls conducted by AECL at the time showed that "opposition increased only marginally after Three Mile Island but increased markedly after media exposure to the Ontario Select Committee on Hydro hearings on reactor safety later in the summer of 1979."⁷⁰ The Canadian Nuclear Association countered its critics by arguing that anti-nuclear interests were being emotional and irrational. It commissioned and published public and elite opinion surveys, in the belief that the more facts and knowledge people had about

nuclear power, the more favourable would be their views. This seems to have worked, as both anti-nuclear and pro-nuclear groups now appear to look at nuclear policy more in terms of Canadian economic policy. Their stand on the social consequences of nuclear energy development, however, remains practically unaltered. It is therefore important that government must recognize that decisions about nuclear power are fundamentally political, and since they also relate to quality of life and the environment, they have to be resolved in a way more acceptable in the climate of the democratic tradition.

CHAPTER VI

A CASE STUDY: ONTARIO HYDRO AND NUCLEAR ENERGY

Ontario Hydro:

This case study attempts to highlight some of the important aspects of Ontario Hydro's involvement in the development of nuclear energy in Ontario. A brief comparison is also made with the Three Mile Island plant in Pennsylvania in order to determine whether the problems that afflicted the U.S. plant and resulted in a serious accident have any implications for the safety of Candu reactors.

While the beginnings of Ontario Hydro can be traced to 1906 when the Ontario Legislature passed an act creating the Hydro Electric Power Commission (HEPC), with responsibility for the supply of electric power to the various municipalities in the province, it was not until 1974 that the Power Commission Amendment Act came into force, making the utility a crown corporation to be known as Ontario Hydro.

Since its formation, Ontario Hydro's growth has been phenomenal, particularly from about the end of the Second World War. Between 1945 and 1972 alone, it brought into service 41 new sources of power which provided

13,000,000 KW of additional capacity - six times more than existed in 1945. The total number of customers served by Hydro and the associated municipal electrical utilities is more than 2.8 million. The extent of Hydro's operations can be gauged from the fact that apart from four nuclear power plants and two heavy water plants, it operates 68 hydro-electric stations and 7 fossil-fuelled stations. Paralleling the development of new power sources, Hydro's transmission system has also been enlarged and extended to deliver electricity from the generating stations to major population areas, as well as to rural areas to meet the needs of most of the farms in the province. Ontario Hydro, along with its municipal partners, is thus meeting more than 95 per cent of the province's requirements for electricity. The remainder is provided by private utilities and companies generating power mainly for their own use.¹

It was in 1951 that Ontario Hydro (then HEPC) began to study the possibility of using atomic energy to generate electricity. Four years later, it began its nuclear research program after entering into an agreement with the Atomic Energy of Canada Ltd. and the Canadian General Electric Company to design and build a small experimental nuclear station at Rolphton, Ontario. A nuclear power plant of 20-MW capacity, known as the Nuclear Power Demonstration (NPD), was accordingly completed and began feeding power into the provincial grid in 1962. It will however be recalled that long before the NPD, Canada's first research reactor (ZEEP) had already become operational in 1945. This was followed by the completion of two more research reactors: NRX in 1947 and NRU in 1957. All these three research reactors are owned and operated by AECL.²

Convinced of the usefulness of nuclear energy for generating electricity, Ontario Hydro entered into an arrangement with AECL in 1959 to build a prototype large-scale station of 200-MW capacity. The construction of a full scale prototype Candu station at Douglas Point on Lake Huron was undertaken and completed in 1967. The station is now part of the Bruce Nuclear Power Development.

The next step in Hydro's nuclear expansion program was to build four 540-MW units at Pickering on Lake Ontario. An announcement to this effect was made in 1964. The first reactor unit was completed and started up in February 1971, about 5½ years after construction had begun.

Pickering "A" generating station was to be one of the world's largest nuclear power stations. Its remaining three units were completed in quick succession, so that by May 1973, all the four units were functioning with full power. The responsibility for completing the project was shared by Ontario Hydro which built the station, and AECL which acted as nuclear designer. At the full output of 2,160,000 KW, the station generates enough power to supply more than 1.5 million homes.³

Another nuclear power station known as Bruce "A", for which an announcement was made by Ontario Hydro as early as in 1968, was also completed subsequently and became operational in January 1979. It has four 750-MW units and is located near the existing Douglas Point 200-MW plant on Lake Huron. In addition to Pickering "A" and Bruce "A" power

stations, two identical stations to be known as Pickering "B" and Bruce "B" are expected to be completed by 1983 and 1987 respectively. However, to meet additional power demands beyond the 1980s, the construction of a 3,600,000 KW station was taken in hand late in 1977 at Darlington, near Bowmanville. The station is scheduled for completion by 1990.

All nuclear reactors used by Ontario Hydro are of the Candu type. Their safety, based on the "defence-in-depth" concept, begins early in the life of a nuclear-electric project. At each and every step of the construction work, precautions are taken to adhere to well-established regulations and procedures to ensure safety. Thus, all of the construction requirements, equipment, safety system and operating procedures have to be first approved by the AECS, which continually updates and monitors the safety requirements of nuclear plants.

For the disposal of irradiated fuel, used fuel bundles are placed in the plant's water-filled storage bays at reactor sites. While the federal government and the AECL have the prime responsibility for the research and development concerning their permanent disposal in deep stable rock formations, Ontario government and Hydro are responsible for studies on interim storage and transportation of irradiated fuel.⁴

In addition to its responsibility for certain aspects of nuclear waste management and radioactive emissions, Hydro also has an extensive program of research and development relating to other pollutants. For example, one of its major goals is to minimize the effect of air pollution from power stations that use fossil fuels such as coal, oil or natural gas.

Potential fuel scarcity has prompted Ontario Hydro to adopt new approaches to the problem of assuring a continued and economic supply of electricity. The fear of conventional fuel shortages in the future is an important factor in Hydro's decision to push ahead its nuclear program. However, in order to conserve energy, Hydro works closely with businesses and industry to help cut back on their electricity use. Energy conservation is promoted through extensive advertising and educational programs.

By providing a reliable supply of low-cost electricity to the homes, farms and factories of the province, Ontario Hydro has assisted the province in its industrial and social progress. Of particular significance are the vast employment opportunities which have been created in the Province. Ontario Hydro's grid system is interconnected with other grid systems so that one utility can help another during power shortages or interruptions. For example, Ontario Hydro's network is interconnected with Manitoba, part of Quebec, and the states of New York and Michigan:

These grids are part of a vast power pool that covers most of the central and eastern portions of the U.S. and the provinces of Saskatchewan, Manitoba, Ontario, New Brunswick, Prince Edward Island, Nova Scotia and parts of Quebec.⁵

Ontario Hydro, as an electrical utility owned by the Province of Ontario, is the largest in the country. The combined assets of the corporation and the municipal utilities served by it, amount to more than \$13 billion.⁶

The Three Mile Island
Nuclear Plant:

Unlike the nuclear power stations in Ontario which are owned and operated by a crown corporation, the ownership of the Three Mile Island nuclear plant is vested in the General Public Utilities Corporation (GPU), which is a holding company. The plant is, however, managed under licence by Metropolitan Edison, a subsidiary of GPU. The reactors at the TMI plant are pressurized-water reactors which use enriched uranium, containing about 3 per cent of the isotope U-235, as their fuel.⁷ The Candu reactors used by Ontario Hydro, on the other hand, are pressurized heavy-water reactors. They use natural uranium which contains only 0.7 per cent U-235.

The reactors at the Three Mile Island plant were manufactured by Babcock and Wilcox (B&W), a subsidiary of J. Ray McDermott & Co. Babcock and Wilcox are now believed to be in a precarious position in their reactor manufacturing business. The company was never even once successful in securing a foreign contract and is now reported to be nearing the end of its work on domestic orders as well.⁸ The bad publicity it had received following the Three Mile Island plant accident of March 1979, has greatly reduced its chances of survival in the reactor manufacturing industry.

Moreover, the accident served to focus the criticism of nuclear power that had been building for a decade. In its extraordinary complexity and far-reaching consequences, the accident has shown that the concept of risk, often narrowly interpreted in terms of health and safety, must be considered in a much broader framework.

A serious accident, like the one at the TMI plant, could create chaotic conditions in the affected area and result in a number of social and psychological problems. In the particular case of the TMI accident, for example, it was found advisable to evacuate pre-school children and pregnant women living within a 5-mile radius of the ill-fated plant. Concern about the possible adverse effects of the accident has thus been expressed quite graphically by the Governor of Pennsylvania. His statement, as quoted by Dorothy Nelkin, is reproduced hereunder:

The movement of elderly persons, people in intensive care units, babies in incubators, the simple traffic on the highways that results from even the best of an orderly evacuation, are going to exert a toll in lives and injuries. Moreover, this type of evacuation had never been carried out before on the face of this earth, and it is an evacuation that was quite different in kind and quality than one undertaken in time of flood or hurricane or tornado.... When you talk about evacuating people within a 5-mile radius of the site of a nuclear reactor, you must recognize that that will have 10-mile consequences, 20-mile consequences, 100-mile consequences.⁹

Purely from a technical point of view, the accident showed that the most serious consequences of a loss-of-coolant accident (LOCA) resulting from the failure of several plant cooling systems, would be to produce a large release of radiation. An accident of this type could result from the rupture of a large pipe in the primary cooling system.

To guard against the possibility of a loss-of-coolant accident, nuclear plants are constructed with what is generally described as three levels of safety in a "defense-in-depth" or multiple-barrier system. This, of course, includes the requirement imposed by the U.S. Nuclear Regulatory Commission that all light-water reactors be equipped with an emergency core-cooling system which should be able to flood the reactor core with water in the event of a failure in the primary system. This precaution is necessary in order to prevent the cladding on the fuel rods from rupturing, as well as for cooling the radioactive materials to safeguard the containment building from damage.

Apart from the TMI accident, no major loss-of-coolant accident had ever before occurred. In fact, the Three Mile Island accident is the most serious accident known to have taken place in a commercial nuclear power plant anywhere in the world. The accident is attributed to operator errors and mechanical failures which led to extensive damage to the reactor's fuel rods. Fortunately, the accident did not breach the plant's containment building, although significant amounts of radioactive gasses did escape into the atmosphere.¹⁰

Considering the severity of damage to the reactor core, the release barriers, particularly the containment, proved to be quite effective in limiting radioactive releases to the environment and exposure of the public to radiation. It has been estimated that the maximum dose that could have been received by an hypothetical individual off-site would be less than 100 mrem. Actual physical checks were also carried out. More than 300 of the people living within 3 miles of the TMI plant were subjected to whole body counting. Scan results did not indicate radiation

levels above normal body levels.¹¹

The TMI accident prompted numerous studies identifying relevant safety issues. Several groups, including the President's Commission (Kemeney Commission), have made recommendations on how nuclear power plants should be licensed and their operations regulated. Although a number of issues relating to light water reactor safety have been raised, we will confine ourselves here to a discussion of only some of the aspects of the TMI accident and the conclusions reached by the President's Commission. These are briefly summarized below:

- (1) The level of operator training at the TMI was inadequate and this contributed significantly to the seriousness of the accident.
- (2) Simulator training did not include training to cope with multiple failure accidents. Nor was there any formally defined program for auxiliary operators.
- (3) In view of the importance of operator actions, the equipment needed for monitoring, warning or for diagnostic purposes should be reviewed to ensure that it can provide information to operators that will enable them to prevent an accident, and also to cope with it, should one occur.
- (4) There is a need to design systems and maintain procedures to mitigate consequences of an accident. Particularly important are systems for isolating filtering, venting, hydrogen recombining, and measuring coolant levels.
- (5) Increased attention should be focussed on measures needed for dealing with accident recovery, clean-up and waste disposal, and the health hazards arising from these operations.

- (6) In-depth studies need to be continued on the probabilities and consequences of nuclear power plant accidents, including the consequences of a melt-down.

Since one of the major issues emerging from the U.S. N.R.C. Task Force investigations concerned the use of design basis accidents (DBA) in the licensing process of nuclear plants, the President's Commission has reiterated the need for considering those accident initiators of lower consequences than DBAs, with particular attention to human failures.¹²

According to the presidential panel's report, excerpts of which have been quoted by the New York Times, the fundamental cause of the TMI accident, following the initial equipment failure, was "operator error." The Panel's Report has also noted as follows:

These shortcomings are attributable to the utility, to suppliers of equipment, and to the Federal Commission that regulates nuclear power.¹³

Implications of the TMI Accident
for Candu Reactors:

A review of the accident and its implications for Candu reactor safety was carried out in Canada by experts assigned for the task by the Atomic Energy Control Board in June 1979. The report of these experts was submitted to the Board in March 1980. Some pertinent aspects of the report are summarized as follows:¹⁴

- (1) The accident occurred to unit 2 of the Three Mile Island Nuclear Generating Station on March 28, 1979, i.e., within about three months of its having been placed in commercial operation.
- (2) At 4 a.m. on March 28, the unit experienced a total interruption of boiler feed-water flow.

- (3) As the boiler contained only a small inventory of water, there was a rapid decrease in the removal of heat from the reactor. This resulted in a rapid increase in primary coolant pressure.
- (4) Under high coolant pressure, the reactor tripped, as it was expected to, but not before a relief valve on the pressurizer had opened, discharging the coolant into a drain tank.
- (5) Although the auxiliary feed-water pumps had started automatically, no feed-water reached the boilers, as isolating valves had been left closed. The valves were finally opened after 8 minutes, but the boilers had already been dry for 6 minutes.
- (6) The operators were unaware that they were faced with a small loss-of-coolant accident (LOCA). They also did not recognize at the time that under these conditions, voids (steam bubbles) could form in the core, even though the pressurizer remained full.
- (7) For some 15 hours from the time of the first interruption of the feedwater flow, the situation remained quite unpredictable. For example, after the first 15 minutes when the tank into which the pressurizer relief valve (PRV) was draining had filled, it began to discharge the coolant to the reactor building sump. The sump pumps then went into action and began pumping the water into the auxiliary building (outside containment). Eventually the sump pumps were stopped by the operators but only after a lapse of 30 minutes.
- (8) Although core cooling was subsequently reestablished through one boiler, cooling was still impaired by an extensive bubble of non-condensable gas (hydrogen) in the reactor coolant system and by coolant flow blockage due to fuel damage.
- (9) In the weeks that followed, hydrogen was degassed from the coolant system. When sufficient degassing had occurred and in-core temperatures had dropped to below saturation, the single operating reactor coolant pump was shut off and the system placed on natural circulation.

The failures which occurred must obviously be attributed to human errors, design deficiencies and equipment failure. TMI 2 was operating with a number of known equipment faults. For example, the non-safety relief valve on the pressurizer was known to be leaking. Among design deficiencies, it should be mentioned that boilers for all B&W reactors are such that the feedwater inventory is very small. This allows only about 30 seconds of full power operation before the boiler goes dry following a total loss-of-feedwater.

Moreover, it seems quite clear that there was insufficient information available to the operators on the condition of the plant during the accident and throughout the recovery phase due to lack of adequate instrumentation. Although the operator actions were the most significant contributors to the severity of the accident, these actions were probably the result of incomplete and misleading information in operating manuals, as well as inadequate training and lack of direct indicators of core cooling conditions. A key factor that contributed to the seriousness of the accident was, of course, the failure on the part of the operators to recognize that the pressure relief valve (PRV), despite its closed indication, had stuck open and that a full pressurizer indication did not necessarily mean that the coolant system was full. All subsequent actions were a natural consequence of these errors.¹⁵

The main purpose of the AECB review as briefly described above, was to determine those aspects of design and operation of Candu reactors which need to be reassessed in the light of the TMI accident. The experts assigned by the AECB for this reassessment, have come to the conclusion

that "the Candu design is more tolerant than that of the B&W to the particular failures which occurred at the Three Mile Island."¹⁶ Nevertheless, since it cannot be claimed that the Candu is immune from serious accidents, many of the lessons learned from TMI, could at least serve as a useful guide for Candu operations. Accordingly, some of the safety aspects of Candu reactors and the measures suggested for improving their safety are noted below:¹⁷

- (1) A plant should not continue to operate with known leaks, or malfunctioning instrumentation or other equipment, unless it has been determined that the degradation is within acceptable limits. It is, however, to be noted that a total loss of feedwater in present Candu plants would not result in the very rapid loss of the boilers as heat sinks. There is approximately 30 minutes of post shutdown feedwater inventory within the Candu boilers. This permits a much longer time to restore feedwater than does the B&W design.
- (2) In the present Candu plants, the shutdown or the maintenance cooling system can withstand full system pressure and can be brought in as an alternate heat sink without cool down or depressurization. However, all future Candu designs should include an alternate heat sink (separate from the boiler and boiler feedwater systems).
- (3) Arrangements should be made for facilitating detection of stuck open relief valves on the reactor cooling system.
- (4) The containment concept for multi-unit Candu stations is quite different from that of the B&W plant at the TMI. For example, the Candu system includes a vacuum building which acts to maintain slightly negative reactor building pressure following an accident. Moreover, containment isolation in Candu plants consists simply of shutting down and isolating the reactor building ventilation system. The only precaution that is necessary is to ensure that the reactor building sump pumps do not start automatically to discharge water outside the containment.

- (5) Operator training programs should be reviewed to ensure that these provide adequate information to enable operators to understand system behaviour under off-normal conditions. The requirement to maintain adequate core cooling under all circumstances should be emphasized.

While the primary purpose of the AECB review was to see if any of the lessons learned from the TMI accident could serve as a useful guide for improving the safety aspects of Candu nuclear plants, it should not be assumed that the particular areas to which attention has now been drawn were being ignored here in Canada prior to the TMI accident. Moreover, as the B&W reactor is substantially different from the Candu design, some of the recommendations made as a result of the investigations carried out in the United States are not directly relevant for Candu operations. However, the most important lesson to be learned from the TMI has been that of the need to ensure that the design of any nuclear power plant must provide a very high level of assurance that equipment and system failures and operator actions will not disrupt the multiple lines of defense and the multiple barriers provided to prevent release of any significant quantities of radioactive fission products. To this end, the recommendations of the AECB experts call for "continued and even greater emphasis on maintaining plant quality in both operation and design, additional safety analyses and plant instrumentation, and improvements in operator training."¹⁸

CHAPTER VII

SUMMARY AND CONCLUSIONS

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Nuclear energy, as part of the broader framework of the national energy policy, has touched on several public issues. As Doern and Morrison have so aptly remarked: "Analyzing Canadian nuclear policies is somewhat akin to examining an elephant...." These two authors in their introductory chapter to Canadian Nuclear Policies have also emphasized the fact that Canadian nuclear policies have become a central issue in the future course of Canadian energy and economic development.

The importance of nuclear industry as a high-technology sector with a vast potential for growth, and the growing economic value of uranium, particularly its role in easing balance-of-payments difficulties which Canada has been facing in recent years, are two of the most crucial aspects of the industry that need to be kept in mind in any discussion involving controversies about the suitability of nuclear power to meet Canada's future energy needs.

The criticism about nuclear policy generally centres around a broad concern about the lack of public involvement in Canadian nuclear policy processes. Concern has also been expressed about Canada's nuclear export policy and whether it provides for adequate safeguards against

Thus, the political problems connected with oil not only exist between countries but also within them. The Canadian election of 1980, for example, found energy at the top of the agenda of issues. Obviously, many Canadians were concerned about future price increases announced by the conservative government then in office. The fate of that government thus clearly hung in the balance, as the election so overwhelmingly proved by bringing the Liberals back to power. The current energy policy conflicts are however not just confined to the two levels of government. Sometimes the provinces have disagreements amongst themselves over energy issues.

Apart from problems and difficulties which have arisen in recent years in federal-provincial relations, Canada is today facing a period of economic transition due to changes in the international economic order, particularly the continuing increases in the world prices for energy and related resource commodities. Regional rates of growth and relative shares of economic activity have also altered quite significantly during the past decade as a result of primary resource development associated with energy production and distribution. This uneven distribution of resources has resulted in massive shifts in income and in greater regional economic disparities which have quite naturally created tensions in federal-provincial relations. It is therefore not surprising that the perceptions of energy policy vary significantly among the different regions of the country and this has given rise to widespread disagreement between the provinces and the federal government over federal energy policy.

Much of the energy debate has focussed on the issue of oil pricing

fuel and made use of the fast-breeder technology for economic or other reasons. The Research and Policy Committee of the Committee for Economic Development has thus noted:

If breeder reactors can be developed as an economic and reliable source of power, they will have two enormously important effects. They will postpone for more than 100 years the prospect of a shortage of fuel for nuclear reactors. And they will ensure the emergence of the plutonium economy with all its dangers.³

Referring to the Candu technology, the Committee has pointed out that for various technical reasons, the Candu is somewhat better for the production of weapons-grade plutonium than the light-water reactor used and exported by the United States. However, one redeeming feature of the Candu system is that the reactor does not need to be shut down when its fuel is replaced. This makes it comparatively easy to extract some fuel that has been burning a short time. Fuel extracted after it has been burning for short periods of time, has less of the undesired plutonium isotopes and hazardous fission products.

As regards public concern about the disposal of nuclear wastes, an intensive program to demonstrate the safe disposal of radioactive fuel wastes in deep geologic formations has been undertaken by the Atomic Energy of Canada Ltd., in cooperation with many government departments, Ontario Hydro, industry and universities. It is however unlikely that the final disposal of these wastes can be undertaken before the year 2000, as further research is needed to verify that the disposal of irradiated fuel waste in deep, stable geologic formations will achieve the overall objective of their safe disposal. A report appearing in the Globe and Mail makes this quite clear:

The federal agency regulating the nuclear industry has ruled out selecting a site in rock to bury high-level radioactive waste until the idea is assessed thoroughly. The AECB also says it wants proof that once the repository is closed and sealed, any radiation doses to the public are likely to be no more than a small fraction of those from natural causes.

In view of these problems of permanent waste disposal, interim storage of irradiated fuel will naturally be needed for several decades. Presently, irradiated fuel bundles are stored quite safely in water-filled bays at the reactor sites.

The safe management of wastes from mining, milling and refining operations is of course the responsibility of the companies involved. Regulations governing the management of these wastes are enforced by the Atomic Energy Control Board and the appropriate provincial authorities. Small quantities of radioactive materials are also released to the environment in the liquid or airborne effluents of a nuclear plant. These releases are monitored and controlled under the existing government regulations.

Although the fear of possible oil shortages, following the Middle-east crisis of 1973, brought home the present reality of the finite nature of hydro-carbon resources, the existing tensions in federal-provincial relations over energy policy have a long history. These relations have now become more strained, not only between the three energy producing provinces and the federal government, but also between the

non-producing provinces. While the conflict had serious constitutional dimensions, in the final analysis it became quite clear that neither the federal government nor the producing provinces had unfettered control over the production and supply of domestic energy sources. The division of jurisdiction between the federal and provincial governments over some aspects of energy has thus given rise to two levels of regulatory activity on the basis of each government's particular jurisdictional competence. But this has sometimes resulted in serious disagreement between federal and provincial authorities.

The evolution of Canada's energy policy since 1973, and the radical transformations which that policy has undergone from time to time, finally resulted in a major policy statement, as embodied in a document entitled The National Energy Program issued by the federal government in October 1980. The three principal approaches of this new policy include: (i) a reduction in the demand for oil by price increases, (ii) the increased development of domestic petroleum supplies, and (iii) the interfuel substitution away from petroleum to natural gas, electricity, coal, and renewable energy sources.

This last aspect of the energy policy is extremely important, as interfuel substitution is essential to the development of any viable national energy policy. But the concept of interfuel substitution is extremely broad, inasmuch as it includes fuels and technologies from both the "hard" and the "soft" energy options. A most controversial aspect of interfuel substitution is the role of electricity in meeting future energy needs. The issue is complicated by the fact that the use of electricity

is invariably associated with the issue of nuclear power. The debate on the future role of electrical energy will therefore not be resolved easily, as it is based on divergent national experiences and perceptions of different energy options.

Obviously, Canada's ability to resolve various energy issues has been dependent not only upon the character of its national resources but also upon the character of its political system. Federalism is of course central to the current debate on many aspects of the energy issue.

Energy policy in Canada has therefore sparked a debate about the nature of the federal system and the conduct of federal-provincial relations. Nuclear energy is part of that debate. This became quite evident, as for example when there was provincial opposition, particularly from Saskatchewan, to the need for continued federal control over the non-strategic aspects of uranium over which the federal government had assumed jurisdiction in the context of World War II.

The concentration of resources such as oil and gas in one region of the country, as also the fact that the provinces have ownership rights and jurisdiction over natural resources within their territory, has meant that energy has become less a debate between the public and private sector of the economy than between different governments and different regions of the country. As both levels of government have the constitutional basis for their involvement in energy policy, rational policy development naturally requires close federal-provincial co-operation.

Thus, the political problems connected with oil not only exist between countries but also within them. The Canadian election of 1980, for example, found energy at the top of the agenda of issues. Obviously, many Canadians were concerned about future price increases announced by the conservative government then in office. The fate of that government thus clearly hung in the balance, as the election so overwhelmingly proved by bringing the Liberals back to power. The current energy policy conflicts are however not just confined to the two levels of government. Sometimes the provinces have disagreements amongst themselves over energy issues.

Apart from problems and difficulties which have arisen in recent years in federal-provincial relations, Canada is today facing a period of economic transition due to changes in the international economic order, particularly the continuing increases in the world prices for energy and related resource commodities. Regional rates of growth and relative shares of economic activity have also altered quite significantly during the past decade as a result of primary resource development associated with energy production and distribution. This uneven distribution of resources has resulted in massive shifts in income and in greater regional economic disparities which have quite naturally created tensions in federal-provincial relations. It is therefore not surprising that the perceptions of energy policy vary significantly among the different regions of the country and this has given rise to widespread disagreement between the provinces and the federal government over federal energy policy.

Much of the energy debate has focussed on the issue of oil pricing

and the sharing of increased revenues. It was, however, not until the international disruption of oil supply and prices in the early seventies that energy policy in Canada became an issue of the utmost importance. A great deal of tension has since developed in federal-provincial relations over energy issues. For example, the eastern provinces which are dependent on international oil supplies, wish to take full advantage of the benefits of resource development. To this end, Newfoundland and Nova Scotia, which have major potential energy resources in their offshore areas, have challenged federal claims to control the development of these resources.

In western Canada, on the other hand, economic development which is primarily based on oil and gas, has been of a boom type, at least until recently. The recent energy and resource boom in that region is therefore seen by the producing provinces as a powerful weapon for forcing a change in historical patterns of national economic development. To ensure this opportunity and take advantage of the situation, the western provinces, notably Alberta, have sought through constitutional debate and legal challenges, an energy policy that fully recognizes their ownership of resources, including rights over management, pricing and revenues.

While much of the debate concerns pricing and revenue sharing aspects of the oil industry, an equally significant issue has been the achievement of an adequate and secure supply of oil to meet future requirements. Achieving national self-sufficiency in crude oil is of course a principal goal of the national energy policy. Although there are many ways of achieving this goal, a reasonable approach would perhaps be

through a combination of different approaches to the problem, as for example suggested in a paper presented by D.W. Stevenson at an international seminar on energy policy held in Alberta in May 1980:⁵

- (1) By increasing supply of oil through the oil sands and heavy oil production, and the development of the frontier sources in the Arctic.
- (2) By reducing oil requirements and substituting other energy forms, such as natural gas, electricity, coal and renewable energy.
- (3) By reducing overall energy requirements through conservation.

The three approaches suggested above are by no means easy to accomplish. For example, the development of the tar sands presents a gloomy picture, as already indicated elsewhere. The difficulty with unconventional oil sources such as the tar sands is that their recovery is technologically complex, economically expensive and environmentally detrimental. There are thus a number of major constraints about too rapid a development of oil sands and heavy oils.

The development of other potential oil supplies from such areas as the Mackenzie Delta, Beaufort Sea and the continental shelf off the east coast, is also not free from difficulties due to the extremely harsh physical environment and the associated high costs of development and transportation.

Since domestic oil is likely to be in short supply to meet long-term future requirements, the choice is limited to finding alternative sources of energy to replace oil wherever possible. Amongst the conventional fossil fuels, only natural gas and coal are suitable substitutes, but their use is subject to a number of constraints.

Although Canada has a surplus of natural gas and a considerable potential for additional supplies, one great obstacle is the enormous cost associated with providing a new pipeline system to carry the surplus gas to new markets from remote areas of the country. Presently, the natural gas transmission system is being extended to meet only the most urgent needs. For example, the construction of a new pipeline to the eastern townships of Quebec, New Brunswick and Nova Scotia is due for completion by the end of 1983. This would allow most major areas in the east, with the exception of Newfoundland, Labrador and Prince Edward Island, to be served by natural gas, thus replacing imported crude oil in those areas. However, because of limited markets for natural gas, Canada continues to use almost two and one-half times more oil than natural gas annually. The situation has to be rectified by making natural gas more accessible to new domestic markets, as there are 50 per cent more reserves of natural gas in the ground than of conventional oil.

Coal is another energy source of which Canada has extensive reserves, but like oil and gas, it is also mainly to be found in western Canada. Transportation costs have therefore limited the Canadian domestic market for Western coal. While any further expansion in the use of coal is dependent on the relative costs of other substitutes, coal continues

to face many of the environmental constraints and concerns faced by oil sands and heavy oil development.

Insofar as electricity is concerned, the current price structure limits the degree to which it can substitute for oil, except possibly in Quebec where hydroelectric power is a major source of energy. But rising oil and gas prices would certainly make electricity a more competitive energy source, especially if it is based on hydroelectric or nuclear development.

The development and supply of electricity in each province is, of course, exclusively within provincial jurisdiction. While interconnections do exist for the transfer of electricity from one jurisdiction to the other to meet particular needs of the area, the concept of a national grid does not appear to have received any positive response. The federal government's role is thus mainly confined to licensing of exports and imports.

As regards the possibility of developing new hydraulic generation sources, not only the distance between markets and potential sources of supply, but also competition between provinces has sometimes inhibited the development of some significant projects, as for example, the Nelson River development in Manitoba and the Gull Island project in the Lower Churchill River basin in Labrador:

In the latter case, the Gull Island project is stalled and Newfoundland's access to hydro-electricity from the Upper Churchill Falls has been thwarted by the inability of Quebec and Newfoundland to reach agreement on the transfer of power across the province of Quebec.

As for nuclear power, provincial government attitudes vary, and these can perhaps be measured by the availability locally of reasonable alternatives to nuclear power as well as by the extent of influence exercised by anti-nuclear forces. The centres of the debate are, however, confined to provinces with a nuclear program. For example, the provinces which have shown interest include not only Ontario which has a massive nuclear program, but also Quebec and New Brunswick which are committed to a limited program of nuclear power development. In the case of Quebec, however, its government's policy has been to go slow with nuclear power development, as it wishes to concentrate more on the development of its remaining hydraulic sources first.

Another province which had been considering a nuclear power development program is British Columbia, but because of political reasons, as well as its desire to make full use of its extensive natural resources first, it has placed a moratorium on uranium mining in the province.

To recapulate, current energy policy in Canada has as its target self-sufficiency in oil by 1990. Out of the three approaches to achieving this goal, namely: conservation, fuel substitution, and the development of alternative indigenous sources, we have already briefly discussed the last two approaches. Therefore, insofar as conservation is concerned, the National Energy Board has estimated (1978) that it would be best to restrain growth of oil demand to 1.3 or 2 per cent per year. However, any serious attempt to place too much reliance on the so-called "soft" energy paths to meet Canada's growing energy needs, is likely to lead to disappointment, as renewable resources such as solar energy or windpower,

have very limited possibilities of further development, particularly to a point where they can compete economically with coal, natural gas or nuclear energy for any large-scale application in industry. Even biomass, which is convertible into gaseous and liquid fuels, has limited use. Nevertheless, residues of forest product mills are at present available on site at some locations, and are being used for many of the energy needs of the forest industries. It is estimated that some 56 pulp mills are displacing 590,000 cubic metres of oil equivalent per year by burning their wood residue.

The federal government has also undertaken programs, known as CREDA (Conservation and Renewable Energy Demonstrations), for developing public awareness of the potential of renewable energy and conservation techniques. Over 300 proposals have so far been approved, with one fifth of the funding from the federal government, one sixth from the provincial-territorial governments, and the rest from the companies, institutions, etc. But these programs are on such a small scale that they are not likely to have any substantial impact on the energy economy of the country as a whole. To use a proverbial phrase, federal funding for these programs is just a drop in the bucket.

Since it is quite unlikely that our energy situation will substantially improve by substituting renewable energy sources or by conservation techniques, we have no alternative but to go ahead with developing nuclear energy so that it can meet part of our future requirements of energy.

While it is impossible to predict, with any degree of certainty, what Canada's future energy demand will be and in what combinations conventional or other sources of supply will meet these demands, it is estimated that between now and the early 1990s, energy consumption in Canada could increase at an annual average compound rates of growth varying between 3.3 and 3.7 per cent. This is a considerable drop when compared with the average annual rates of growth of 5.5 per cent experienced in the recent past. On the basis of these rates of growth, a doubling of energy consumption in Canada by the early 1990s may be expected. The following percentage figures however show the extent to which each energy source in Canada has contributed to the total energy production in 1980:

Oil	42%
Gas	18%
Electricity (Hydro and Nuclear only)	27%
Coal	9%
Renewables	3%
Liquid Petroleum Gases (LPGs)	1%

Since the need for developing nuclear energy arose out of concern for future energy shortages, particularly as a result of dwindling oil supplies and the extraordinarily high prices which have now to be paid for it, it will perhaps be useful to look briefly at the present oil supply situation. While oil production in 1980, including LPGs, amounted to 103 million cubic metres, oil consumption reached a figure of 109 million cubic metres. Oil imports accounted for 35 million cubic metres as against 28 million cubic metres exported during the same period.⁹ By 1990, however, both oil production and consumption are expected to decline substantially. The demand for oil by then is estimated to go down to

85 million cubic metres per year as against the estimated production of 88 million cubic metres. The projected figures for 1990 therefore show not only a substantial decrease both in the demand and supply of oil, but also production somewhat in excess of the demand. This would be a complete reversal from the current situation in which the demand for oil is very much in excess of production. But this does not mean that by adjusting our oil requirements, less energy would be needed. The shortfall has of course to be met by other energy sources.

At present, electricity accounts for some 36 per cent of the energy consumed in Canada. Domestic consumption of electricity in 1980 accounted for 340 TWh, an increase of 5.2 per cent over the 1979 figure. Production had also increased in 1980 by 4.1 per cent over 1979 and accounted for 367 TWh. Exports of electricity, however, declined by 3.8 per cent. They stood at 30 TWh, i.e., about 8.2 per cent of the total national electricity production, as against the import figure of 3 TWh. Of the total electricity produced in the country, about 69 per cent was generated from hydro sources, 22 per cent from fossil fuels (coal, oil and gas), and 9 per cent from nuclear power. However, the share of oil in the production of electricity is estimated to be only 3.4 per cent of the total oil consumption in Canada. The substitution of nuclear energy will therefore not only eliminate the use of oil for the production of electricity, but it will also substantially reduce the consumption of oil in some of the other sectors, except in transportation, which alone accounts for some 44.4 per cent of the total oil consumption in the country.¹⁰

Thus, nuclear power's role as a major source of electrical energy

new hydro-electric sites to harness. According to one analyst, nuclear power will likely dominate the electricity scene by the year 2025.¹¹ The Department of Energy, Mines and Resources, while acknowledging the uncertainty created by public opposition to nuclear power, has also estimated that 60 per cent of all electricity by then may be generated by nuclear power. Accordingly, nuclear power and hydro power are expected to supply virtually all of the base-load electric power.¹²

Nuclear-generated electricity grew from a mere 0.1 per cent of Canada's primary energy supply to 3 per cent in 1977. However, as a percentage of electricity supply, it has grown from 1.0 per cent to 8.0 per cent in the same period. On the basis of predicted figures, nuclear power is expected to grow to 15,190 MW by 1988.¹³

In 1977, nuclear generating capacity was 5,866 MW as against 27,216 MW conventional thermal and 43,990 MW hydro-electric. According to 1980 estimates, current hydro power potential, i.e., actual plus works already committed, is expected to increase the total installed hydro-generating capacity to 59,013 MW. However, the total developable potential which is economically and technically feasible is expected to increase the hydro-generating capacity to a maximum of 63,440 MW. Theoretical potential is of course much higher, but it will be unwise to place any reliance on that possibility. We are thus left with the nuclear option which has practically unlimited potential, particularly if breeder technology had to be made use of to reduce reliance on the availability of uranium resources when they become in short supply. But nuclear power can

only provide base-load electricity. Therefore, in the absence of any large additional hydro sources, more fossil-fuelled back-up plants for generating electricity will be needed. While the use of oil for this purpose will not be possible due to depleting oil resources, the only other alternative for providing back-up generating capacity will be to make increased use of natural gas and coal, provided adequate supplies of these resources can be made available at competitive prices.

It will be seen from the foregoing analysis of the energy situation in Canada that in the coming decades, one factor that will continue to exert pressure over the development of nuclear power will be the rate at which the demand for energy, particularly for electricity, increases. Although in recent years the demand for electricity has grown at a rate considerably below earlier official projections, the rate at which nuclear power will develop in Canada will depend on how effectively new nuclear plants are able to compete with alternative sources of electric power. It is therefore expected that over the next decade, this competition will continue to be mainly between nuclear and coal-fired power plants, in the absence of any other more competitive source of energy.

While the costs of both nuclear and coal fuel cycles are subject to many uncertainties, the following three factors will be most critical in determining their competitive position: (1) capital costs, (2) capacity factor at which coal and nuclear plants will each operate, and (3) the prices of uranium and coal.

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synthetics plants than as boiler fuel. It is therefore far better regarded as a complement to nuclear power than as a substitute.

Solar energy, on the other hand, would seem to offer the preferred long-term alternative to nuclear fission, but it is still in an experimental stage for wider application. Cost projections for solar power have also not been very encouraging. Nuclear power will therefore remain an essential element in Canada's energy supply strategy for some time to come.

At this point, it needs to be emphasized that even if energy growth were held at zero in per capita terms, population growth would imply a rising demand for power. The fact is, then, that Canada needs more energy, especially in the form of electricity. Nuclear power seems to offer the only reasonable alternative.

A transition from predominately coal-fired to fission-based electricity, and then from fission to fusion, would seem to be a logical progression. Nuclear fusion is of course claimed to be potentially far more attractive than the fission technology. Such a claim is, however, still highly speculative. Amongst the advantages claimed for fusion power, it has been pointed out that fusion fuels can easily be extracted from sea water which can be returned to the ocean unharmed. Most fusion fuels and reaction products are non-radioactive: "Thus, no long lived radioactive by-products are created which could result in waste disposal problems."¹⁵ However, the current state of fusion research shows that the "fusion effort is just beginning to scratch the surface in terms of the fundamental principle upon which these fusion systems are based."¹⁶

operation of nuclear plants.

However, one important question that needs to be asked is whether the risk associated with nuclear power is worth the economic benefits. While it is true that there is increased uncertainty about the overall safety of nuclear plants, it is by no means clear that nuclear power involves health and safety risks that are greater than those associated with coal-fired power plants. Even though it is difficult to compare the risks of alternative energy systems, it seems to be generally agreed that the routine health effects associated with the coal fuel cycle are far greater than those associated with the nuclear fuel cycle. Nevertheless, it must be acknowledged that the adverse health impacts of many of the "soft" energy alternatives to nuclear power, such as renewable energy technologies, would seem to be smaller than those of either nuclear or coal technologies. But renewable energy sources, as already explained elsewhere, have yet a long way to go before they can seriously be considered as viable replacements for nuclear plants.

The current concern with environmental problems created by nuclear energy has naturally stimulated public anxiety. This anxiety is perhaps much exaggerated. We have already seen that coal-fired electric plants pose more serious pollutive health hazards than do nuclear plants. Moreover, if we take into account the environmental degradation that results from strip-mining, or the very serious health effects on miners who work in deep coal mines, nuclear energy certainly seems a better choice. Coal is of course more useful and safe to use as a feedstock for

synthetics plants than as boiler fuel. It is therefore far better regarded as a complement to nuclear power than as a substitute.

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But currently there exists no fusion reactor at any stage of development. Nor is there any proven technology capable of leading to a fusion reactor. It is therefore difficult at this stage to provide an estimate of a fusion reactor's commercial availability.¹⁷

As fusion technology is still in an uncertain phase of development, uranium will continue to remain the current reference fuel for the Canadian nuclear power program and is likely to remain so for several decades. Present estimates of Canada's uranium reserves show that there will be adequate uranium to meet domestic consumption and some export into the next century. Nevertheless, keeping in mind the increased future export requirements, Canada needs a dual program of uranium exploitation and development of a new thorium fuel cycle which will provide a much better uranium utilization.

Since fusion power is still far in the future and technologies of renewable resources have not yet developed to a point where they can substitute for fission-based nuclear power, there would appear to be no alternative for Canada but to go ahead with the development and expansion of existing nuclear facilities, on the basis of carefully projected future requirements. Every endeavour is however to be made to improve the existing nuclear technology to make it more acceptable as a safe source of energy. Other precautions to be taken should include the imposition of more rigid controls to ensure proper safety in the design, construction and operation of nuclear plants, so as to minimize the risks associated with accidental release of radioactive pollutants into the environment. Waste management policies and their implementation must also reflect a

deep concern for health and environmental safety.

In spite of dangers associated with nuclear plants and the precautions which have to be taken in their operation, there is little doubt that nuclear industry offers Canada the best chance as a high-technology industry to meet the challenges posed by future energy shortages and for the development of an important export base, using uranium and reactor sales abroad as the basis for the expansion of Canadian exports in world markets.

In a book essentially concerned with nuclear energy in the United States, the author, while comparing U.S. light-water reactors with the Canadian built Candu reactors, explains why the Candu system is preferable:

Another long-term nuclear option suggests a shift from the current light-water reactors to the already established, uranium efficient, heavy water reactors commonly known as CANDU. The heavy water reactors operating on an isotopically denatured uranium-thorium fuel cycle are considered efficient in uranium use. These proliferation-resistant nuclear systems are considered three to five times more efficient than their counterpart light-water reactors on a once-through fuel cycle.¹⁸

Since the principal advantage of the CANDU reactor is its ability to use natural uranium, by-passing the need for costly enrichment facilities, the continued use of these reactors for another twenty years or so, will provide sufficient time for the country to consider the development of long-term nuclear strategies in the growth of the Canadian economy. Rational planning of course requires that all nuclear options

be examined from economic, environmental, and national security considerations. A careful evaluation of the relative merits of each option, taking into account the social benefits and costs, will therefore have to be made when it is decided to change over to any other new type of reactor.

Having finally come to the conclusion that nuclear energy offers Canada the most practical solution for meeting future energy shortages, we can perhaps now end this thesis with a brief discussion of why the various nuclear policy processes with which both levels of the government are involved cannot be fully explained in terms of any of the existing theories of public policy. As already mentioned in Chapter 11, public policy is always subject to influences exerted by what has generally been described as "paradigms." However, government intervention and involvement in the nuclear industry primarily occurred out of considerations for security and in response to the technical realities of the nuclear fuel cycle.

Because of the peculiar characteristics of the nuclear fuel cycle, there is no single policy process, but rather a number of policy processes which are involved in decisions concerning nuclear energy. We have already seen how nuclear policies are highly susceptible to conflict, as they arouse concerns not only about the dangers associated with the nuclear fuel cycle, but also about the proper role of the government which has the responsibility for ensuring adequate public participation in policy processes involving many aspects of nuclear energy. It would therefore seem most appropriate to examine these issues in terms of the decision-making process.

However, in view of the complexities of the nuclear fuel cycle, it is difficult to be very specific about any particular theory of public policy which will be most relevant to the processes of decision-making. The issue is further complicated by the fact that under the Canadian constitution, both the federal and the provincial governments have important powers in the administration of resources. The constitution also sets out federal responsibilities which have the effect of limiting the extent of provincial powers. Obviously, this is an area where most conflicts between the federal government and the provinces occur.

In situations involving federal-provincial conflict, policy decisions are generally the result of bargaining and compromise between the two levels of government. The decisions reached on any particular issue involving federal-provincial conflict, or where there is some public concern, are not really chosen as a solution to a problem but rather result from "compromise, conflict and confusion among officials with diverse interests and unequal influence."¹⁹ Although the above quoted remarks were made by Graham Allison while referring to decisions made in US Congress, the White House, or the federal bureaucracy, they are equally valid when applied to the Canadian political scene.

Moreover, in all matters of a controversial nature, policy decisions are hardly ever considered as final. As new interests gain sufficient strength or power to demand a voice in government policy decisions, policies have to be redesigned to accommodate them to the extent feasible. While this happens all the time, we can see this more clearly at election times when policy decisions are sifted continuously for their individual electoral implications.

A multiplicity of influences therefore acts on the decision-making process. This was clearly brought out in Chapter V while discussing the five political issues. To recapitulate, these five issues relate to (i) the high-technology aspect of the nuclear industry, (ii) the on-going debate between pro-nuclear and anti-nuclear interests, (iii) nuclear state enterprises and the leverage over the private sector, (iv) nuclear policy as a lever in federal-provincial bargaining, and finally, (v) nuclear policy and inter-departmental bargaining. A careful study of Chapter V will reveal that each of the five issues described above is subject to a number of influences which shape nuclear policies. These influences could of course vary from the simple politics of offering electoral support to a more positive demand for a particular policy in return for accommodation in other areas of conflict. Bargaining and compromise are thus a common feature not only between the two levels of government, but also to a limited extent, between the government and other interests, particularly those interests which are strong enough to have their voice heard.

Having briefly discussed some of the factors which affect public policy, we will now try to explain some theoretical implications of how decisions are made. Since a variety of influences affects the shaping of Canadian nuclear policies, no one theory of decision-making can perhaps be expected to explain satisfactorily all the processes which ultimately produce those decisions. Moreover, because of the fact that there are limits imposed by technology on the decision processes involving such a complex field as nuclear energy, it is difficult to see how any single theoretical approach can provide a really useful framework for this purpose. We cannot, for example, say that the "incrementalist" theory

of policy-making to which we have already made a reference in chapter II of this thesis, can explain the decision processes relating to some of the highly controversial nuclear energy issues, as this particular theory is only capable of explaining incremental or small changes from existing policies. It cannot obviously be applied to larger issues or to issues involving policy innovations requiring radical solutions, which are often necessary in most decisions concerning nuclear energy.

As an example of such a policy, we have only to look at the enormous expenditure of \$1.5 billion (cumulative total since 1952) incurred by the federal government, mostly in support of AECL's R&D activities. Another \$816.9 million were lost by government at the time of the reorganization of the AECL in 1980. This additional burden on the government was mainly the result of the forgiveness of the outstanding debt on Quebec and Nova Scotia heavy water plants. Obviously, decisions of this magnitude can hardly be explained in terms of the incrementalist theory of policy-making, or for that matter, in terms of any of the other theoretical approaches we have reviewed.

A second theory to which we have made a reference in chapter II is the Public Choice theory. As in the case of the "incrementalist" theory, the Public Choice theory is also limited in scope and is capable of explaining only certain aspects of the decision-making process. It is not broad enough to encompass a wide range of issues which have to be resolved in policy decisions involving nuclear energy. The assumption behind the Public Choice theory is that decision-makers make choices in order to maximize their self-interest. Since the emphasis in this theory is on

individuals rather than on institutions, it can neither explain the critical nature of technical decisions, nor the impact of institutions which affect those decisions. We obviously cannot ignore the important part played by institutions in making of public policy. Allison makes this quite clear by pointing out that government policy is not made by one individual but rather by a conglomeration of large organizations and political actors.²⁰

A third theory, and the last one to which we have made a reference in chapter 11, is Group theory. This theory too is not entirely relevant to Canadian public policy processes. We have already explained that the influence of organized interests in Canadian policy processes is significantly less than it is in the United States, and therefore Group theory can hardly be applied to policy processes in a political system so different from the American political system where Group theory has received wide recognition. We must therefore conclude that since most policy decisions result from bargaining and compromise, subject of course to limitations imposed by technical factors, a multi-model description of decision-making would seem to be more appropriate for explaining nuclear policies, rather than any single theory of public policy. Thus, Peter Aucoin has quite rightly observed that there is no general theory which can serve as the framework for the analysis of public policy.

A question however arises as to how can we then explain Canadian political processes relating to nuclear energy. While there is no ready answer to this dilemma, it is suggested that we adopt a case-study approach and focus on specific areas of policy. The diversity of

influences which affect public policy, with their broad range of interests and motivations, would seem to support this view. Moreover, when considered in conjunction with limits imposed by technology on the decision process, it is difficult to see how any one theoretical approach can provide a wholly satisfactory framework. Nonetheless, by using a case-study approach, it should be possible to acquire a broader understanding of the policy processes involved in any particular policy area. This is particularly true of policy processes relating to a high-technology field like nuclear energy. As one writer, referring to a theoretical concept which he calls "environmental turbulence," has noted:

Advances in science and technology have proceeded at a pace that dramatically exceeds comparable advances in our political system. One consequence of this constantly expanding gap is the inability of government to respond to - much less to anticipate the technical and logistical spinoffs of scientific advancement.²¹

In recent years, steadily mounting forces of technological, social, and political changes have been so overwhelming that fundamental changes in the nature of the socio-political environment have inevitably occurred. To quote Gawthrop once more:

Less and less can the political behaviour of a phantom public be taken for granted; instability has replaced stability, uncertainty has replaced predictability, and complex patterns of rapid change are becoming institutionalized.²²

In our highly turbulent environment, therefore, no currently existing theory can properly be applied to explain all aspects of public policy. We can only speculate that a concept such as that of "environmental turbulence", while still the embryo of a theory, may hold

some promise for future theoretical elaboration.

And finally, while concluding this thesis, it needs to be emphasized once again that the prospect of continued development of nuclear energy in Canada will largely depend on how government responds to critics of nuclear energy, even if it cannot satisfy them in terms of alternate policy recommendations. The need for greater public involvement in future nuclear policy decisions has also been strongly advocated by Dr. J.E. Hodgetts. We can perhaps do no better than to end this thesis with his warning of some years back:

In the context of democratic state, those who use the levers of control are accountable to the public. If this accountability is to be meaningful, there must be a public with sufficient knowledge of and perceptions about atomic energy matters to carry on an informed public dialogue with policy makers.²³

REFERENCE FOOTNOTES

CHAPTER 1:

¹Scott Fenn, The Nuclear Power Debate: Issues and Choices (New York: Praeger Publishers, 1981), p.1.

²G. Bruce Doern, Government Intervention in the Canadian Nuclear Industry (Montreal: The Institute for Research on Public Policy, 1980), p.39.

³Ibid., p.2.

⁴Canada, Department of Energy, Mines and Resources, Answers to Your Energy Questions (Ottawa: Minister of Supply and Services Canada, 1978), p.28.

⁵Canada, Department of Energy, Mines and Resources, Electric Power in Canada 1981 (Ottawa: Minister of Supply and Services Canada, 1982), pp.6-7.

⁶Canada Year Book 1980-81 (Ottawa: Minister of Supply and Services Canada), p.507.

⁷Canada, National Energy Board, 1980 Annual Report (Ottawa: Minister of Supply and Services Canada, 1981), p.32.

⁸Canada, Department of Energy, Mines and Resources, Energy Futures for Canadians (Summary), Report of a Study Group: Prepared by J.E. Gander and F.W. Belaire (Ottawa: Minister of Supply and Services Canada, 1978), p.41, Fig.11.

⁹R.W. Jackson and J.A. Potworoski, eds. A Nuclear Dialogue (Ottawa: Science Council of Canada, 1976), pp.1-2.

CHAPTER 11:

¹M.A. Walker, "The National Energy Program: An Overview of its Impact and Objectives," in Reaction: The National Energy Program, ed. by G.C. Watkins and M.A. Walker (The Fraser Institute, Canada, 1981), p.3.

⁵⁴Cook, p. 7.

⁵⁵Ibid., pp. 11-12.

⁵⁶Doern, Government Intervention, p. 73.

⁵⁷Canada Gazette, Part 11, Vol. 108, No.12.
SOR/74-335, 4 June 1974.

⁵⁸Canada, Atomic Energy Control Board, Annual Report: 1980-81, p.1.

⁵⁹G.A. Cranker, Nuclear Energy and Environmental Protection:
Canadian Perspectives (Mimeographed)
(Montreal: McGill University, 1974), pp.20-21.

⁶⁰Doern, Government Intervention, pp. 130-135.

⁶¹Ibid., p. 84.

⁶²Cranker, pp.46-47.

⁶³Doern, Government Intervention, pp. 81-82.

⁶⁴Organization for Economic Co-operation and Development,
Environmental Policies for the 1980s
(Paris: 1980), p. 28.

⁶⁵Banerjee, pp. 76-77.

⁶⁶Ibid., p.77; see also Walter C. Patterson, "Nuclear Policy
and the Public Process," in Canadian Nuclear Policies, p.232.

⁶⁷Banerjee, p. 77.

⁶⁸Patterson, p. 237.

⁶⁹B.B. Clary et al, "Environmental Priorities of Opinion-Makers,"
Environmental Affairs, Vol.6 (1977-78), p.46.

⁷⁰Doern, Government Intervention, p. 39.

¹⁶Dye, p.208.

¹⁷Aucoin, pp.14-15. See also Thomas S. Kuhn, The Structure of Scientific Revolutions (Chicago: University of Chicago Press, 1962).

CHAPTER 111:

¹Canada, Department of Energy, Mines and Resources, Energy Futures for Canadians (Summary), Report of a Study Prepared by J.E. Gander and F.W. Belaire (Ottawa: Minister of Supply and Services Canada, 1978), p.14.

²Ruth Leger Sivard, World Energy Survey, 2nd. ed. (The Rockefeller Foundation, 1981), p.3.

³Ibid., pp.5-8.

⁴Ibid., p.10.

⁵Energy Futures for Canadians, p.34.

⁶Hans H. Landsberg et al, Energy: The Next Twenty Years Report by a Study Group Sponsored by the Ford Foundation (Cambridge, Mass.: Bellinger Publishing Co., 1979), p.3.

⁷Energy Futures for Canadians (Summary), p.18.

⁸B.F. Skinner, Beyond Freedom and Dignity (New York: Vintage Books, 1971), p.23.

⁹Canada, Department of Energy, Mines and Resources, An Energy Strategy for Canada (Ottawa: Minister of Supply and Services, 1976), pp.2-4.

¹⁰Energy: The Next Twenty Years, pp.203-206.

¹¹Ibid., pp.8-9.

¹²Canadian National Energy Forum, Proceedings of the Conference (Calgary: November 19-20, 1979), pp.59-60.

¹³World Energy Survey, p.14.

¹⁴Ibid., pp.14-16 and 26.

¹⁵ Ibid., p.26.

¹⁷ David B. Brooks, Zero Energy Growth for Canada
(Toronto: McClelland and Stewart Ltd., 1981), p.10.

¹⁸ Ibid., p.8.

¹⁹ Ibid., p.5.

²⁰ Barry Beale, Energy and Industry
(Toronto: James Lorimer and Co., Publisher, 1980), p.6.

²¹ Canada, National Energy Board, Canadian Energy Supply and Demand 1980-2000 (Ottawa: Minister of Supply and Services Canada, 1981), pp.3 and 10.

²² Canada, Department of Energy, Mines and Resources,
Energy Update (Ottawa: Minister of Supply and Services, 1981), p.3.

²³ Beale, p.6.

²⁴ Energy Futures for Canadians, pp.109-111.

²⁵ Energy Update, p.13.

²⁶ Energy Futures for Canadians, p.109.

²⁷ Energy Update, pp.15-16.

²⁸ Canada, House of Commons. Special Committee on Alternate Energy and Oil Substitution. Report. Energy Alternatives
(Ottawa: Minister of Supply and Services Canada, 1981), pp.23-26.

²⁹ G.C. Watkins and M.A. Walker, Co-eds.,
Reaction: The National Energy Program
(Vancouver: The Fraser Institute, 1981), p.xii.

³⁰ Ibid., p.xiii.

³¹ Canada, Department of Energy, Mines and Resources,
The National Energy Program 1980
(Ottawa: Minister of Supply and Services), pp.7-8.

³² Energy Update, pp.9-10.

- ³³Watkins and Walker, p.7.
- ³⁴Energy Update, p. 10.
- ³⁵Watkins and Walker, pp.7-8.
- ³⁶Energy Futures for Canadians, p.138.
- ³⁷Energy Alternatives, p.29.
- ³⁸Ibid., pp.29 and 34.
- ³⁹Ibid., pp.34-36. See also Answers to Your Energy Questions, p.44.
- ⁴⁰Canadian Energy Supply and Demand 1980-2000, p.94.
- ⁴¹Peter N. Nemetz, ed., Energy Crisis - Policy Response
(Montreal: The Institute for Research on Public Policy, 1981),
pp. xvii-xviii.
- ⁴²Ibid., pp. 50-51.
- ⁴³Watkins and Walker, p.19.
- ⁴⁴Ibid., p.84.
- ⁴⁵Ibid., p. 109.
- ⁴⁶Data Resources of Canada, The National Energy Program:
An Appraisal of a New Policy Initiative
(Mimeographed, 1981), pp.3, 4 and 19.
- ⁴⁷The National Energy Program 1980, p.108.
See also Watkins and Walker, pp.90-91.
- ⁴⁸Watkins and Walker, p.39.
- ⁴⁹Ibid., p.39.
- ⁵⁰The National Energy Program: An Appraisal of a New
Policy Initiative, pp.26-28.

CHAPTER 1V:

- ¹Wilfrid Eggleston, Canada's Nuclear Story (Toronto: Clarke, Irwin and Company Ltd., 1965), p.4.
- ²Canada, Atomic Energy Control Board, A History of the Atomic Energy Control Board, Prepared by Gordon H.E. Sims (Ottawa: Minister of Supply and Services Canada, 1981), p.6.
- ³Eggleston, pp.5-6.
- ⁴Ibid., p.16.
- ⁵Sims, p.17.
- ⁶Ibid., p.13. See also Eggleston, p.146.
- ⁷Sims, p.14.
- ⁸Gordon H.E. Sims, "The Evolution of AECL," (Unpublished Master's Thesis, Carleton University, 1979), pp.36-37.
- ⁹Canadian Nuclear Association, Nuclear Energy: Canada's Resources and Industry (Toronto: Canadian Nuclear Association, 1974), p.4.
- ¹⁰Ibid., p.5.
- ¹¹Ontario Hydro, The Gifts of Nature (Ontario Hydro, 1979), p.20.
- ¹²Sims, A History of the Atomic Energy Control Board, p.117.
- ¹³Sims, "The Evolution of AECL," pp.42-49.
- ¹⁴Atomic Energy of Canada Limited, Activities and Achievements (Mississauga, Ontario: Public Affairs Office, AECL), pp.1-6.
- ¹⁵Ibid., pp.7-8.
- ¹⁶Atomic Energy of Canada Limited, Annual Report: 1979-80 (Ottawa: Minister of Supply and Services, 1980), pp.5-9.

- ¹⁷ Atomic Energy of Canada Limited, Annual Report: 1980-81 (Ottawa: Minister of Supply and Services, 1981), pp.12-13.
- ¹⁸ Beale, p.35.
- ¹⁹ Ibid., p.36.
- ²⁰ Canadian National Energy Forum, p.59.
- ²¹ Energy Futures for Canadians, p.11.
- ²² David Peat, The Nuclear Book (Ottawa: Deneau and Greenberg Publishers Ltd., 1979), p.131.
- ²³ Canadian National Energy Forum, p.73.
- ²⁴ Ibid., p.73.
- ²⁵ Doern, Government Intervention, p.18.
- ²⁶ Ibid., pp.26-28.
- ²⁷ Ontario Royal Commission on Electric Power Planning, A Race Against Time (Toronto: Ontario Queen's Printer, 1978), pp.xii-xiii.
- ²⁸ Ontario Royal Commission on Electric Power Planning, Report. Vol.1 (Toronto: Ontario Queen's Printer, 1980), p.xix.
- ²⁹ A Race Against Time, pp. 111, 116-117, 151 and 171.
- ³⁰ Ibid., pp.38-39.
- ³¹ Ibid., p.112.
- ³² Doern, Government Intervention, p.25.
- ³³ A Race Against Time, pp.119-120.
- ³⁴ Canada Year Book: 1980-81, pp.509-510.

³⁵ A Race Against Time, p.21.

³⁶ Ibid., p.21.

³⁷ Amory B. Lovins, Non-nuclear Futures: The Case for an Ethical Energy Strategy (London: Friends of the Earth, 1975), p. xxvii.

³⁸ Sanjay Banerjee, "The Economics of Nuclear Power," in Canadian Nuclear Policies, p.60.

³⁹ Ibid., p.78.

⁴⁰ See Fenn, p.24.

⁴¹ See letter dated 23 July 1980 from William C. Davis, Premier of Ontario, to Miss D. Bechelt (Pollution Probe).

⁴² Atomic Energy of Canada Limited, Nuclear Responsibility (Mississauga, Ontario: AECL Public Affairs Office), Para.11.

⁴³ Atomic Energy of Canada Limited, Nuclear Energy in Canada: The CANDU System Report Prepared by J.A.L. Robertson (Mississauga, Ontario: AECL Public Affairs Office, 1981), p.7.

⁴⁴ Ontario Hydro, The Gifts of Nature (Ontario Hydro, 1979), p. 27.

⁴⁵ David B. Brooks, "Commentaries on the Political Economy of Canadian Nuclear Policies," in Canadian Nuclear Policies, p. 84.

⁴⁶ Sanjay Banerjee, p. 60.

⁴⁷ A Race Against Time, pp. 105-107.

⁴⁸ Ibid., p. 107.

CHAPTER V:

- ¹G. Bruce Doern, "The Politics of Canadian Nuclear Energy," in Canadian Nuclear Policies, p. 45.
- ²R.W. Morrison and E.F. Wonder, "Canada's Nuclear Export Policy," in Canadian Nuclear Policies, pp. 102-103.
- ³The Citizen, 12 March 1982, p.31.
- ⁴Ted Schrecker, "Strategic Planning Versus Clientele Satisfaction: Nuclear Power in Canadian Energy Policy," (Paper presented to the 1982 Annual Meeting of the Canadian Political Science Association, Ottawa), p.28.
- ⁵Doern, "Canadian Nuclear Policies: Issues and Alternatives," in Canadian Nuclear Policies, p. 12.
- ⁶Doern, "The Politics of Canadian Nuclear Energy," in Canadian Nuclear Policies, p. 48.
- ⁷Ibid., pp. 48-49.
- ⁸Fenn, p. 105.
- ⁹Ibid., p. 197.
- ¹⁰Donald J. Lecraw, "Uranium Supply and Demand: Implications for Policy," in Canadian Nuclear Policies, pp.121-136.
- ¹¹Earle Cook, "The Role of History in the Acceptance of Nuclear Power," Social Science Quarterly, Vol. 63, No.1, March 1982, p.4.
- ¹²Banerjee, pp.68-72 and Lecraw, pp.102 and 121.
- ¹³Banerjee, p. 74.
- ¹⁴Lecraw, p. 129.
- ¹⁵Ibid., p. 129.
- ¹⁶Doern, "The Politics of Canadian Nuclear Energy," pp.49-51.

¹⁷Ibid., p.58.

¹⁸R.F.W. Guard, "Prospects for Reorganizing the Canadian Nuclear Industry," in Canadian Nuclear Policies, p.272.

¹⁹Ibid., p. 272.

²⁰Doern, "The Politics of Canadian Nuclear Energy," p.52.

²¹Ibid.

²²Ibid., p.53.

²³Canada, Atomic Energy Control Board, A History of the Atomic Energy Control Board, Prepared by Gordon H.E. Sims (Ottawa: Minister of Supply and Services Canada, 1981), p.208.

²⁴Doern, p.53.

²⁵Malcolm Rowan, "Nuclear Policy and Federal-Provincial Relations," in Canadian Nuclear Policies, p.257.

²⁶Ibid., pp.248-249.

²⁷Ibid., pp.244-250.

²⁸Ibid., p. 255.

²⁹Ibid., pp.258-261.

³⁰A.M. Aikin, "Nuclear Waste Management," in Canadian Nuclear Policies, p.205.

³¹Alan Wyatt, The Nuclear Challenge: Understanding the Debate (Toronto: The Book Press Ltd., 1978), p.101.

³²Aikin, pp. 209-215.

³³Rowan, pp.260-261.

³⁴Doern, pp. 56 and 57-58.

³⁵Fenn, pp.114-115.

³⁶Wyatt, p. 71.

³⁷Ibid., p. 73.

³⁸Cook, p. 9.

³⁹A Race Against Time, p. xii.

⁴⁰Ibid., pp.5-7.

⁴¹Ibid., pp.37, 40-41, 49-50, 67 and 69.

⁴²Canada, Atomic Energy Control Board, Annual Report: 1980-81
(Ottawa: Minister of Supply and Services Canada, 1981), pp.6-9.

⁴³Wyatt, p. 84.

⁴⁴See Fenn for a summary of the findings of the Rasmussen Study and the Lewis Report which was critical of the Rasmussen Study, pp.136-137.

⁴⁵Ibid., p. 138.

⁴⁶Ibid., pp.5-6.

⁴⁷See Fenn, p.84.

⁴⁸Ibid., p. 84.

⁴⁹Ibid., pp.4-5 and 79.

⁵⁰Dorothy Nelkin, "Some Social and Political Dimensions of Nuclear Power: Examples from Three Mile Island," The American Political Science Review, Vol. 75, No.1, March 1981, p. 137.

⁵¹Ibid., p. 137.

⁵²Cook, p. 5.

⁵³Wyatt, pp. 151-152.

- ⁵⁴Cook, p. 7.
- ⁵⁵Ibid., pp. 11-12.
- ⁵⁶Doern, Government Intervention, p. 73.
- ⁵⁷Canada Gazette, Part 11, Vol. 108, No.12.
SOR/74-335, 4 June 1974.
- ⁵⁸Canada, Atomic Energy Control Board, Annual Report: 1980-81, p.1.
- ⁵⁹G.A. Cranker, Nuclear Energy and Environmental Protection: Canadian Perspectives (Mimeographed)
(Montreal: McGill University, 1974), pp.20-21.
- ⁶⁰Doern, Government Intervention, pp. 130-135.
- ⁶¹Ibid., p. 84.
- ⁶²Cranker, pp.46-47.
- ⁶³Doern, Government Intervention, pp. 81-82.
- ⁶⁴Organization for Economic Co-operation and Development, Environmental Policies for the 1980s
(Paris: 1980), p. 28.
- ⁶⁵Banerjee, pp. 76-77.
- ⁶⁶Ibid., p.77; see also Walter C. Patterson, "Nuclear Policy and the Public Process," in Canadian Nuclear Policies, p.232.
- ⁶⁷Banerjee, p. 77.
- ⁶⁸Patterson, p. 237.
- ⁶⁹B.B. Clary et al, "Environmental Priorities of Opinion-Makers," Environmental Affairs, Vol.6 (1977-78), p.46.
- ⁷⁰Doern, Government Intervention, p. 39.

CHAPTER VI:

¹The Gifts of Nature, pp. 18, 21, 22 and 37.

²Canadian Nuclear Association, Nuclear Energy: Canada's Resources and Industry (Toronto: Canadian Nuclear Association, 1974), p. 4.

³The Gifts of Nature, p.26.

⁴Ibid., p.29.

⁵Ibid., p.14.

⁶Ibid., p.27.

⁷Nelkin, p.133. See also Fenn, pp.105-106.

⁸Fenn, p.87.

⁹Nelkin, p.135

¹⁰Fenn, pp.121-122.

¹¹Canada, Atomic Energy Control Board, Report. Three Mile Island - A Review of the Accident and Its Implications (INFO - 0003, March 1980), pp. 1, 23 and 24.

¹²Kenneth A. Solomon, Some Implications of the Three Mile Island Accident for LMFBR Safety and Licensing: The Design Basis Issue, N-1559-DOE (Prepared for the U.S. Department of Energy, 1980), pp.21-22.

¹³"Excerpts from Presidential Panel's Report on the Three Mile Island Nuclear Accident," The New York Times, October 31, 1979, P.A. 22.

¹⁴Atomic Energy Control Board, Report (INFO-0003), pp.11-1v.

¹⁵Ibid., pp.30-35.

¹⁶Ibid., p.43.

¹⁷Ibid., pp.14-59.

¹⁸Ibid., p.43.

CHAPTER VII:

¹K.S. Shrader-Frechette, Nuclear Power and Public Policy (Boston: D. Reidel Publishing Co., 1980), pp.18-19.

²Ibid., p.26.

³The Research and Policy Committee of the Committee for Economic Development, Nuclear Energy and National Security (New York: The Committee for Economic Development, 1976), p.16.

⁴The Globe and Mail, 11 March 1982, p. 11.

⁵D.W. Stevenson, "Energy Issues Facing Canada: Three Perspectives," in Energy Policy and Federalism, ed. by Livia M. Thur (Toronto: The Institute of Public Administration of Canada, 1981), p.164.

⁶Ibid., p.166.

⁷John J. Berger, Nuclear Power: The Unviable Option (New York: Dell Publishing Co. Inc., 1979), p.27.

⁸Peter Nemetz, ed., Energy Policy: The Global Challenge (Toronto: Institute for Research on Public Policy, 1979), p.212.

⁹Canada, Department of Energy, Mines and Resources, Energy Update (Ottawa: Minister of Supply and Services, 1981), p.10.

¹⁰Ibid., see diagram on p.22, and also pp. 30-33.

¹¹P.G. Campbell, "Canada's Electricity Resources," Canadian National Energy Forum, Proceedings, p.73.

¹²Doern, Government Intervention, p.18.

¹³Ibid., pp.26-28.

¹⁴Banerjee, p.70.

- ¹⁵ M.P. Bachynski, "Controlled Fusion,"
Engineering Journal, Vol.61, No.3 (July 1978), p.15.
- ¹⁶ Charles B. Stevens, "The 1980s: Decade for Fusion Technology,"
Fusion (Annual Review: February 1980), p.40.
- ¹⁷ Walter A. Rosenbaum, Energy, Politics and Public Policy
(Washington, D.C.: Congressional Quarterly Press, 1981), p.49.
- ¹⁸ S. Basheer Ahmed, Nuclear Fuel and Energy Policy
(Toronto: D.C. Heath and Co., 1979), p.145.
- ¹⁹ Graham T. Allison, Essence of Decision: Explaining the
Cuban Missile Crisis
(Boston: Little, Brown and Company, 1971), p.163.
- ²⁰ Ibid., p.3.
- ²¹ Louis C. Gwathrop, Administrative Politics and Social Change
(New York: St. Martin's Press, 1971), p.8.
- ²² Ibid., see preface.
- ²³ J.E. Hodgetts, Administering the Atom for Peace
(Atherton Press, 1964), pp.180-181.

Distribution of World Energy* Consumption and Production, and World Population

percent of world totals, 1979

- Population
- Energy consumption
- Energy production

* includes Alaska

TABLE 1

POTENTIAL WORLD PRIMARY ENERGY PRODUCTION, EXAJOULES ⁽¹⁾

Resources	1972	1985	2000	2020
Coal	66	115	170	259
Oil	115	216	195	106
Gas	46	77	143	125
Nuclear	2	23	88	314
Hydraulic	14	24	34	56
Unconventional oil and gas	0	0	4	40
Renewable, solar, geothermal, biomass	26	33	56	100
Total	269	488	690	1000

The Future Energy World?

Production Projections of the
WEC Conservation Commission

Table 2-2

PRIMARY ENERGY DEMAND - CANADA
NEB Middle Demand Case Forecast

	Petajoules					Av	Annual Increase - %	
	1980	1985	1990	1995	2000	1980-1990	1990-2000	1980-2000
Natural Gas ⁽¹⁾	1 820	2 425	2 799	3 090	3 545	4.4	2.4	3.4
Crude Oil ⁽²⁾	4 068	3 894	3 757	3 904	4 251	-0.8	1.2	0.2
LPG ⁽³⁾	28	39	93	141	150	12.8	4.9	8.8
Hog Fuel & Pulping Liquor	318	381	448	507	568	3.5	2.4	2.9
Other Renewables	8	10	87	164	267	27.0	11.9	19.2
Coal ⁽⁵⁾	1 018	1 144	1 336	1 711	2 051	2.8	4.4	3.6
Hydro & Nuclear ⁽⁵⁾	3 096	3 896	4 338	4 573	5 343	3.4	2.1	2.8
Total Primary Energy ⁽⁴⁾	10 356	11 789	12 858	14 090	16 175	2.2	2.3	2.3

⁽¹⁾ including ethane *

⁽²⁾ including refinery LPG

⁽³⁾ gas plant LPG only

⁽⁴⁾ does not necessarily add up due to rounding

⁽⁵⁾ hydro, nuclear and 74 percent of the coal (in 1990) is used for electricity generation

TABLE 1-2
NATIONAL ENERGY BOARD ENERGY BALANCES IN 1990

	<i>EMR</i> 1978 (actual %)	<i>NEB</i> 1990 (forecast %)	<i>NEB</i> 1990 (forecast Quads)
Oil	44.0	34.8	4.45
Gas and propane	18.5	20.7	2.65
Coal	8.8	9.8	1.25
Primary electricity	28.7	33.9	4.34
Other (from renewable resources)	—	0.8	0.10
Total	100.0	100.0	12.79

Source: National Energy Board, *Canadian Oil and Gas Supply/Demand Overview*, November 1979

Figure 3-1 1978 PER CAPITA CONSUMPTION OF COMMERCIAL ^(a) ENERGY IN 15 SELECTED COUNTRIES

^(a) Commercial energy refers to energy which enters into trade. Data on non-commercial energy use are scarce and imprecise. Source: After United Nations, 1980.

REACTION THE NATIONAL ENERGY PROGRAM

TABLE II
REGIONAL GROSS DOMESTIC ENERGY CONSUMPTION
AND PER CENT DISTRIBUTION BY FUEL SOURCE, 1978

	Atlantic	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	B.C.	Canada*
	(trillion Btu's)							
Total Consumption	680	2267	3061	341	364	932	922	8592
	Fuel Source in Per Cent							
Coal	6	1	15	3	19	16	1	9
Crude Oil & LPG's	78	47	41	38	41	34	41	45
Natural Gas	0	4	22	22	33	48	17	18
Hydro & Nuclear	15	48	22	37	7	2	41	28

*Includes Yukon and Northwest Territories
Source: Statistics Canada Cat. No. 57-003.

POWER REACTORS LICENSED AND PLANNED AS OF 31 MARCH 1981

FACILITY NAME	TYPE AND CAPACITY	STATUS
NPD Generating Station Rolphton (Ontario) (Ontario Hydro & AECL) (1)	CANDU-PHW (2) 25 MW(e) (3)	Started up 1962. Operating under Reactor Operating Licence No. 1/78, Amendment 1, expiring 30 June, 1983.
Douglas Point Generating Station, Tiverton (Ontario Hydro & AECL)	CANDU-PHW 200 MW(e)	Started up 1966. Operating under Reactor Operating Licence No. 5/77, Amendment 1, expiring 30 June, 1982. (Currently restricted to 70% of design power)
Pickering Generating Station "A", Pickering (Ontario Hydro)	CANDU-PHW 4 x 500 MW(e)	Started up 1971. Operating under Reactor Operating Licence No. 3/77, Amendments 1 and 2, expiring 30 June, 1982.
Bruce Generating Station "A", Tiverton (Ontario Hydro)	CANDU-PHW 4 x 750 MW(e)	Started up 1976. Operating under Reactor Operating Licence No. 3/80, expiring 30 September, 1981, allowing operation of units at approx. full electrical power, (88% of design thermal power).
Pickering Generating Station "B", Pickering (Ontario Hydro)	CANDU-PHW 4 x 500 MW(e)	Reactor Construction Licence No. 2/74 in force. Start-up expected 1982.
Bruce Generating Station "B", Tiverton (Ontario Hydro)	CANDU-PHW 4 x 750 MW(e)	Reactor Construction Licence No. 2/75 in force. Start-up expected 1983.
Darlington Generating Station "A" (Ontario Hydro)	CANDU-PHW 4 x 750 MW(e)	Site accepted. Approval of construction requested in 1981.
Gentilly 1 Nuclear Power Station (Quebec) (Hydro-Québec & AECL)	CANDU-BLW (4) 250 MW(e)	Started up 1970. Reactor Operating Licence No. 2/79, amendment 1, expires 30 June, 1981. (Currently restricted to shut-down state)
Gentilly 2 Nuclear Power Station (Hydro Québec)	CANDU-PHW 600 MW(e)	Reactor Construction Licence No. 1/74 in force. Start-up expected 1982.
Point Lepreau Generating Station (New Brunswick) (NBEPC) (5)	CANDU-PHW 600 MW(e)	Reactor Construction Licence No. 1/75 in force. Start-up expected 1982.

- (1) - AECL "Atomic Energy of Canada Limited"
- (2) - PHW "Pressurized Heavy Water"
- (3) - (e) "Nominal electrical power output"
- (4) - BLW "Boiling Light Water"
- (5) - NBEPC "New Brunswick Electric Power Commission"

HEAVY WATER PLANTS LICENSED AS OF 31 MARCH, 1981

FACILITY NAME (LICENSEE)	CAPACITY (TONNES/YEAR)	STATUS
Glace Bay Heavy Water Plant, Nova Scotia (Atomic Energy of Canada Limited)	400	Operating under AECB-HWPOL-403-3 expiring 30 June, 1982.
Port Hawkesbury Heavy Water Plant, Nova Scotia (Atomic Energy of Canada Limited)	400	Operating under AECB-HWPOL-404-2 expiring 30 June, 1982.
Bruce Heavy Water Plant, (Ontario Hydro)		
"A"	800	Operating under AECB-HWPOL-405-1 expiring 30 June, 1981.
"B"	800	
"D"	800	
LaPrade Heavy Water Plant, Quebec (Atomic Energy of Canada Limited)	800	AECB-HWPCA-400-0 - Amendment 1 in effect. Facility mothballed.

HWPOL - Heavy Water Plant Operating Licence
HWPCA - Heavy Water Plant Construction Authorization

TABLE 2-7
STRUCTURE OF THE CANADIAN
NUCLEAR INDUSTRY

<i>Mining and Refining</i>	There are six active uranium mining and associated milling operations in Canada, four located in Ontario and two in Saskatchewan. Eldorado Nuclear Limited, a Crown corporation, operates the only uranium refinery in Canada, located at Port Hope, Ontario. A second refinery is proposed by Eldorado to be located at Blind River in northwestern Ontario and a third to be located in Saskatchewan. Historically, 90% of Canadian-produced uranium has been exported.
<i>Research and Development</i>	Virtually all R and D work is performed by the Atomic Energy of Canada Limited (AECL), funded primarily by the federal government. A proportionately much smaller amount is conducted by universities, the utilities and manufacturing companies.
<i>Engineering and Design</i>	The AECL has been responsible for all nuclear engineering on export reactors and most domestic stations to date. Ontario Hydro continues to develop its capability with the aim of ultimately undertaking most of its work internally. Private engineering and consulting firms are involved in linking the "nuclear steam supply system" to the generating part of the plant.
<i>Manufacturing</i>	Private manufacturing companies are involved in providing equipment and structural materials. Of 100 principal companies, roughly a third can be regarded as having a major commitment to the industry (on the basis of total company sales). Manufacturing activity is concentrated almost entirely in Ontario.
<i>Construction</i>	Overall project management generally is the responsibility of the utilities. The bulk of construction is carried out by both the utilities and construction/contractor companies.
<i>Operations and Maintenance</i>	All procurement and operating decisions are conducted by the utilities.

Figure 9 Cost comparison for coal-fired and nuclear generated electricity — 1978

Figure 10 Projected cost of electricity from three different fuels

RACE AGAINST TIME

Table 7.2 Comparison of Total Unit Energy Costs in a Coal and a Nuclear Generating Station¹

Cost Component	Pickering A: nuclear (1978 mills/kwh)	Lambton coal
Capital	4.4	1.8
Fuelling	1.2	10.8 ²
Operation and maintenance	1.8	1.0
Heavy water upkeep	0.3	
Total unit energy cost	7.7	13.4

Table 7.3 Comparative Costs¹ of Generating Electricity, Fossil, Hydro, and Nuclear Technology, 1976

	Generation cost		Transmission and distribution cost ²		Fuel cost		Total cost	
	(\$/kW installed)	(Mills/kWh)	(\$/kW installed)	(Mills/kWh)	(\$/unit)	(Mills/kWh)	(\$/kW installed)	(Mills/kWh)
James Bay hydroelectric	691	12.47	560	11.02	—	—	1251	23.49
Cull Island hydroelectric	412	7.94	746	15.69	—	—	1158	23.63
Nuclear ³	739	14.17	332	6.11	\$110/kgU	3.55	1071	23.83
Coal-fired	375	7.19	332	6.11	\$35/tonne	12.00	707	25.30
Oil-fired	308	5.90	332	6.11	\$11.85/bbl	16.93	604	28.94
Gas-fired	308	5.90	332	6.11	\$1.50/mcf	13.50	640	25.51

1. Both are assumed to be operating at 87 per cent capacity. 2. Based on 1976 stock of coal at the station.

SOURCE: Ontario Hydro.

1. Costs include interest during construction.

2. Delivered costs assume Ontario loads; unit sizes for fossil and nuclear plants are 750 MW.

3. Nuclear capital cost assumes \$97 per kilogram heavy water; nuclear fuel cost includes 1 mill per kWh for waste management, increased safety and environmental measures, and R & D.

SOURCE: H. Swain, R. Overend, and T. A. Ledwell, *Canadian Renewable Energy Prospects*, (Ottawa: Energy, Mines and Resources, Canada, 1975).

Estimated Additional Resources
(1,000 tonnes)

Table I
Reasonably Assured Resources
(1,000 tonnes)
Data available 1 January 1979

Data Available 1 January 1979

Cost Range

Estimated Additional Resources
(1,000 tonnes)

Reasonably Assured Resources
(1,000 tonnes)
Data available 1 January 1979

Algeria
Argentina
Australia
Austria
Bolivia
Brazil
Canada
Central African Empire
Chile
Denmark (Greenland)
Finland
France
Gabon
Germany F.R.
India
Italy
Japan
Korea
Madagascar
Mexico
Niger
Philippines
Portugal
Somalia
South Africa
Spain
Sweden
Turkey
United Kingdom
United States
Yugoslavia
Zaire

Total (rounded)

The material cost of the resources is based on the source of supply and the method of extraction.

Table 2
Attainable Production Capabilities
(tonnes U)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
Argentina	130	280	360	360	310	310	300	600	600	600
Australia	400	500	500	500	1,800	4,600	8,300	10,600	11,500	20,000
Brazil	n.a.	n.a.	385	385	385	385	385	385	385	385
Canada	6,300	6,450	6,950	7,950	9,750	10,200	11,150	12,500	12,500	11,250
Central African Empire	0	0	0	0	0	0	1,000	1,000	1,000	1,000
France	2,200	2,850	2,850	2,850	3,350	3,600	3,600	3,600	3,700	4,000
Gabon	800	(1,200)	1,200	(1,200)	1,200	1,200	1,200	1,200	(1,200)	1,200
Germany, F.R.	100	100	100	100	150	150	200	200	200	200
India	200	200	200	200	200	200	200	200	200	200
Italy	0	0	0	120	120	120	120	120	120	120
Japan	0	0	0	30	30	30	30	30	30	30
Mexico	0	20	90	170	550	550	550	550	550	550
Niger	1,600	2,400	3,850	4,100	4,300	9,000	9,000	9,000	9,000	9,000
Philippines	0	0	38	38	76	76	76	38	0	0
Portugal	85	86	90	95	100	270	270	270	270	270
South Africa	6,700	8,800	9,700	11,700	11,700	12,000	12,800	12,600	12,500	13,000
Spain	191	191	339	678	678	678	678	678	1,272	1,272
Turkey	0	0	0	100	100	100	100	100	100	100
United States	14,700	19,300	20,300	22,600	26,300	31,200	32,300	34,300	36,000	47,000
Yugoslavia	0	0	0	0	120	120	120	180	180	440
Total (rounded)	33,000	42,000	47,000	53,000	61,000	77,000	82,000	88,000	95,000	110,000

Numbers taken from the 1975 Uranium Report.
Estimated by the Steering Group of the Joint NEA/IAEA Working Party on Uranium Resources.
Source: Uranium Resources, Production and Demand, December 1977, Paris (OECD 1978).

Table 3
Uranium Production
(tonnes t)

Country	Pre 1972	1972	1973	1974	1975	1976	1977 US\$ marked
Argentina	188	25	24	30	23	50	150
Australia	2080	0	0	0	0	0	0
Canada	92500	4000	3710	3420	3510	1850	6100
France	16600	1545	1616	1673	1712	2005	2200
Gabon	1100	210	102	436	800	0	0
Germany, FR	150	0	0	26	57	35	0
Japan	8	8	10	7	3	2	0
Mexico	42	0	0	0	0	0	0
Niger	110	867	948	1117	1106	1100	4600
Portugal	1183	73	73	92	108	85	55
South Africa	61433	3197	2735	2711	2488	3412	6700
Spain	166	55	55	60	136	170	191
United States	446000	9900	10200	8900	8900	9800	11200
Zaire	25600	0	0	0	0	0	0
Total	172100	19880	19773	18472	19080	22705	3860

0 = not available

* Estimated for the Maximum Capacity of the Four NATO Working Party of Common Resources
Sweden total cumulative capacity for 1975 was 200 tonnes t
Source: Uranium Resource, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 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3799, 3800, 3801, 38

Figure S.2

MAJOR FEDERAL ORGANIZATION, 1979 TO 1982

BIBLIOGRAPHY

PUBLIC DOCUMENTS:

- Atomic Energy of Canada Limited. Activities and Achievements.
Mississauga, Ontario: Public Affairs Office, AECL, 1980.
- Atomic Energy of Canada Limited. Annual Report; 1979-80.
Ottawa: Minister of Supply and Services, 1980.
- Atomic Energy of Canada Limited. Annual Report; 1980-81.
Ottawa: Minister of Supply and Services, 1981.
- Atomic Energy of Canada Limited. Guide to the Canadian
Nuclear Fuel Waste Management Program.
Pinawa: Whiteshell Nuclear Research Establishment, 1981.
- Atomic Energy of Canada Limited. Management of Radioactive
Fuel Wastes; The Canadian Disposal Program.
Pinawa: Whiteshell Nuclear Research Establishment.
- Atomic Energy of Canada Limited. Nuclear Energy in Canada:
The CANDU System. Report Prepared by J.A.L. Robertson.
Mississauga, Ontario: Public Affairs Office, AECL, 1981.
- Atomic Energy of Canada Limited. Nuclear Responsibility.
Mississauga: Public Affairs Office, AECL.
- Canada. Atomic Energy Control Board. Annual Report; 1980-81.
Ottawa: Minister of Supply and Services Canada, 1981.
- Canada. Atomic Energy Control Board. A History of the Atomic
Energy Control Board. Prepared by Gordon H.E. Sims.
Ottawa: Minister of Supply and Services Canada, 1981.
- Canada. Atomic Energy Control Board. Licensing and Safety of
Nuclear Power Plants in Canada. INFO-0051, September 1981.
- Canada. Atomic Energy Control Board. The Nature of Reactor
Accidents. INFO-0053, January 1981.
- Canada. Atomic Energy Control Board. Three Mile Island -
A Review of the Accident and Its Implications.
INFO - 0003, March 1980.
- Canada. Atomic Energy Control Board. Safety in the Nuclear
Fuel Cycle. INFO - 0015, August 1980.
- Canada. Department of Energy, Mines and Resources.
An Energy Strategy for Canada.
Ottawa: Minister of Supply and Services, 1976.

Canada. Department of Energy, Mines and Resources.

Answers to Your Energy Questions.

Ottawa: Minister of Supply and Services Canada, 1978.

Canada. Department of Energy, Mines and Resources.

Electric Power in Canada 1981.

Ottawa: Minister of Supply and Services Canada, 1982.

Canada. Department of Energy, Mines and Resources.

Energy Futures for Canadians. Report of a Study
Prepared by J.E. Gander and F.W. Belaire.

Ottawa: Minister of Supply and Services Canada, 1978.

Canada. Department of Energy, Mines and Resources.

Energy Update.

Ottawa: Minister of Supply and Services, 1981.

Canada. Department of Energy, Mines and Resources.

The National Energy Program 1980.

Ottawa: Minister of Supply and Services.

Canada Gazette. Part 11, Vol. 108, No.12. SOR/74-335, 4 June, 1974.

Canada. House of Commons. Bill C-14: 1977.

Proposed Nuclear Control and Administration Act.

Third Session. Thirtieth Parliament.

Canada. House of Commons. Debates 1977-78.

Third Session. Thirtieth Parliament.

Canada. House of Commons Special Committee on Alternate

Energy and Oil Substitution. Report.

Energy Alternatives.

Ottawa: Minister of Supply and Services Canada, 1981.

Canada. National Energy Board. 1980 Annual Report.

Ottawa: Minister of Supply and Services Canada, 1981.

Canada. National Energy Board. Canadian Energy:

Supply and Demand - 1980-2000.

Ottawa: Minister of Supply and Services Canada, 1981.

Canada Year Book: 1980-81.

Ottawa: Minister of Supply and Services Canada.

Letter dated 23 July 1980 from William C. Davis,

Premier of Ontario, to Miss D. Bechelt

(Pollution Probe Office, Ottawa).

Ontario Hydro. The Gifts of Nature.

Ontario Hydro, 1979.

Ontario Royal Commission on Electric Power Planning.

Interim Report.

A Race Against Time.

Toronto: Ontario Queen's Printer, 1978.

Ontario Royal Commission on Electric Power Planning.

Report. Vol. 1.

Toronto: Ontario Queen's Printer, 1980.

Science Council of Canada. A Nuclear Dialogue. ed. by

R.W. Jackson and J.A. Potworoski.

Ottawa: Science Council of Canada, 1976.

Science Council of Canada. Regulatory Processes and
Jurisdictional Issues in the Regulation of
Hazardous Products in Canada.

A Study Prepared by G. Bruce Doern.

Ottawa: Minister of Supply and Services Canada, 1977.

BOOKS:

Ahmed, S. Basheer. Nuclear Fuel and Energy Policy.

Toronto: D.C. Heath and Company, 1979.

Allison, Graham T. Essence of Decision: Explaining the
Cuban Missile Crisis.

Boston: Little, Brown and Company, 1971.

Beale, Barry. Energy and Industry.

Toronto: James Lorimer and Company, 1980.

Berger, John J. Nuclear Power: The Unviable Option.

New York: Dell Publishing Co., Inc., 1977.

Reprint ed. 1979.

Brooks, David B. Zero Energy Growth for Canada.

Toronto: McClelland and Stewart Ltd., 1981.

Doern, G. Bruce. Government Intervention in the
Canadian Nuclear Industry.

Montreal: The Institute for Research on Public Policy, 1980.

Doern, G. Bruce, and Aucoin, Peter, eds.

Public Policy in Canada.

Toronto: The Macmillan Company of Canada Ltd., 1979.

- Doern, G. Bruce, and Morrison, Robert W., eds.
Canadian Nuclear Policies.
Montreal: The Institute for Research on Public Policy, 1980.
- Downs, Anthony. An Economic Theory of Democracy.
New York: Harper and Row Publisher, 1957.
- Dwievedi, O.P., ed. Resources and the Environment Policy:
Perspectives for Canada.
Toronto: McClelland and Stewart Ltd., 1980.
- Dye, Thomas R. Understanding Public Policy.
Englewood Cliffs, N.J.: Prentice Hall, Inc., 1981.
- Eggleston, Wilfrid. Canada's Nuclear Story.
Toronto: Clarke, Irwin and Company Ltd., 1965.
- Fenn, Scott. The Nuclear Power Debate: Issues and Choices.
New York: Praeger Publishers, 1980.
- Freeman, Leslie J. Nuclear Witnesses: Insiders Speak.
New York: W.W. Norton and Co., 1982.
- Garvey, Gerald. Nuclear Power and Social Planning.
Toronto: D.C. Heath and Company, 1977.
- Gwathrop, Louis C. Administrative Politics and Social Change.
New York: St. Martin's Press, 1971.
- Hodgetts, J.E. Administering the Atom for Peace.
Atherton Press, 1964.
- Kuhn, Thomas S. The Structure of Scientific Revolution.
Chicago: University of Chicago Press, 1962.
- Landsberg, Hans H. et al. Energy: The Next Twenty Years.
Report by a Study Group Sponsored by the Ford Foundation.
Cambridge: Bellinger Publishing Company, 1979.
- Loon, Richard J. Van, and Whittington, Michael S.
The Canadian Political System.
Toronto: McGraw-Hill Company of Canada Ltd., 1971.
- Lovins, Amory B. Non-nuclear Futures: The Case
for an Ethical Energy Strategy.
London: Friends of the Earth, 1975.
- Mangone, G.J., ed. Energy Policies of the World. Vols. 1 and 11.
New York: Elsevier, 1976.

- Nemetz, Peter N., ed. Energy Crisis: Policy Response.
Montreal: The Institute for Research on Public Policy, 1981.
- Nemetz, Peter N., ed. Energy Policy: The Global Challenge.
Toronto: Institute for Research on Public Policy, 1979.
- Olson, Mckinley C. Unacceptable Risk: The Nuclear Power Controversy.
New York: Bantam Books, Inc., 1976.
- Organization for Economic Co-operation and Development.
Environmental Policies for the 1980s.
Paris: 1980.
- Peat, D. The Nuclear Book. Ottawa:
Deneau and Greenberg Publishers Ltd., 1979.
- The Research and Policy Committee of the Committee
for Economic Development.
Nuclear Energy and National Security.
New York: The Committee for Economic Development, 1976.
- Rosenbaum, Walter A. Energy, Politics and Public Policy.
Washington, D.C.: Congressional Quarterly Inc., 1981.
- Sherfield, Lord., ed. Economic and Social Consequences
of Nuclear Energy.
London: Oxford University Press, 1972.
- Shrader-Frechette, K.S. Nuclear Power and Public Policy.
Boston: D. Reidel Publishing Company, 1980.
- Skinner, R.F. Beyond Freedom and Dignity.
New York: Vintage Books, 1971.
- Solomon, Kenneth A. Some Implications of the Three Mile
Island Accident for LMFBR Safety and Licensing:
The Design Basis Issue. N-1559-DOE. Prepared for the
U.S. Department of Energy, 1980.
- Thur, Livia M. Energy Policy and Federalism.
Toronto: The Institute of Public Administration
of Canada, 1981.
- Watkins, G.C., and Walker, M.A., Co-eds.
Reaction: The National Energy Program.
The Fraser Institute, Canada, 1981.
- Wyatt, Alan. The Nuclear Challenge: Understanding
the Debate.
Toronto: The Book Press Ltd., 1978.

Willrich, M. Energy World.
New York: The Free Press, 1975.

Ziegler, H. Interest Groups in American Society. Englewood Cliffs,
New Jersey: Prentice-Hall, Inc., 1964.

MISCELLANEOUS PUBLICATIONS;
SURVEY REPORTS and
PROCEEDINGS

Canadian Nuclear Association.
Nuclear Energy: Canada's Resources and Industry.
Toronto: Canadian Nuclear Association, 1974.

Canadian National Energy Forum.
Proceedings of the Conference.
Calgary: November 19 and 20, 1979.

Sivard, Ruth Leger. World Energy Survey. 2nd. ed.
The Rockefeller Foundation, 1981.

THESES and OTHER PAPERS

Cranker, G.A. Nuclear Energy and Environmental
Protection: Canadian Perspectives.
Montreal: McGill University, 1974. (Mimeographed).

Data Resources of Canada. The National Energy Program:
An Appraisal of a New Policy Initiative, 1981.
(Mimeographed).

Schrecker, Ted. "Strategic Planning Versus Clientele
Satisfaction: Nuclear Power in Canadian Energy Policy."
Paper Presented to the 1982 Annual Meeting of the
Canadian Political Science Association, Ottawa.

Sims, Gordon H.E. "The Evolution of AECL."
Unpublished Master's Thesis, Carleton University,
Ottawa, 1979.

PERIODICALS and
NEWSPAPERS

The American Political Science Review.
Vol. 75, No.1, March 1981, pp. 132-140.

The Citizen.
12 March 1982, p. 31.

Engineering Journal.
Vol. 61, No.3, July 1978, p.15.

Environmental Affairs.
Vol. 6 (1977-78), p.46.

Fusion.
Annual Review: February 1980, p.40.

The Globe and Mail.
11 March 1982, p.11.

The New York Times.
October 31 1979, p. A.22.

Public Administration Review.
(Spring 1959), p.86.

Social Science Quarterly.
Vol. 63, No.1, March 1982, pp.3-13.

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