CANADA

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1. GENERAL INFORMATION

1.1. General Overview

Canada, occupying about 10 million km^2 and having a population of over 30 million (Table 1), is one of the least densely populated countries in the world. Canada's birth rate, at present, is 12 per 1,000 whereas death rate is seven per 1,000 with the result that the rate of natural population increase now stands at five per 1,000 persons. Canada has strong seasonal changes and large regional variations in temperature. The rigorous climate, the energy intensive nature of the country's industries, and the large distances between population centres produce a high per capita energy use.

TABLE 1. POPULATION INFORMATION

	1960	1970	1980	1990	2000	2001	Growth rate (%) 1980 To 2001
Population (millions)	17.9	21.7	24.5	27.7	30.8	31.0	1.1
Population density (inhabitants/km²)	1.8	2.2	2.5	2.8	3.1	3.1	

Predicted population growth rate (%) 2001 to 2010	7.2
Area (1000 km²)	9976.1
Urban population in 2001 as percent of total	

Source: IAEA Energy and Economic Database.

1.2. Economic Indicators

Table 2 gives the statistical Gross Domestic Product (GDP) data and the GDP by sector.

TABLE 2. GROSS DOMESTIC PRODUCT (GDP)

	1970	1980	1990	2000	2001	Growth rate (%) 1980 To 2001
GDP (millions of current US$)		266,002	572,676	687,752	711,912	4.8
GDP (millions of constant 1990 US$)	286,186	434,401	572,676	748,108	779,872	3
GDP per capita (current US$/capita)		10,850	20,674	22,361	22,954	3.6

Source: IAEA Energy and Economic Database.

1.3. Energy Situation

The energy sector is an important part of Canada's economy. The energy sector employs more than 280,000 Canadians and accounts for 6.7% of Gross Domestic Product (GDP). However, there are marked regional differences in energy production and consumption. The Canadian energy sector enjoys a strong presence in all primary energy commodities and strong electricity and energy efficiency industries. Canada has more lakes and rivers than any other country in the world. Electricity accounts for about 15 per cent of domestic energy requirements. Canada's total hydropower potential is estimated at approximately 600 TW·h. Canada is also well endowed with oil, natural gas and coal. Canada produces a surplus of crude oil above its domestic needs. At year-end 1997, remaining established reserves amounted to 4.2 billion barrels. Proven reserves of natural gas were 2.7 trillion m^3, about three per cent of global reserves. Canada has extensive coal reserves estimated at 7,298 million metric tonnes. They represent about 90 times the 1998 Canadian production. Alberta, British Columbia and Saskatchewan account for over 90 per cent of total output. Coal production is high due to strong growth in exports, which now account for almost 60 per cent of the industry's output. Canada produces a wide range of metals and minerals and is the world's leading producer of uranium. As of January 1st 1999, its proven uranium deposits amount to 212,000 metric tonnes. Table 3 shows the energy resources in exajoules.

Canada has been a net exporter of most energy forms since 1969. In 1998, Canadian energy exports were valued at $US18.2 billion. The United States is by far Canada's largest customer (91% of Canada's energy exports). Virtually all of Canada's exports of oil, natural gas and electricity and 65% of uranium exports go to the US. The energy statistics are given in Table 4.

TABLE 3. ESTIMATED ENERGY RESERVES

	Estimated energy reserves in 1999 (Exajoule)					
	Solid	Liquid	Gas	Uranium (1)	Hydro (2)	Total
Total amount in place	174.21	33.15	64.29	178.21	124.26	574.12

(1) This total represents essentially recoverable reserves.
(2) For comparison purposes a rough attempt is made to convert hydro capacity to energy by multiplying the gross theoretical annual capability (World Energy Council - 2002) by a factor of 10.

Source: IAEA Energy and Economic Database.

1.4. Energy Policy

Canada's energy policy supports a variety of energy sources, including nuclear energy, in order to ensure a secure and "sustainable" energy future for Canadians. There are three major areas of active federal energy policy development: conventional energy, environment and nuclear energy.

The federal government's approach to energy policy has gradually evolved over the last two decades to a stronger market-driven and less interventionist approach to energy development. In recent years environmental pressures are shaping the energy policy agenda. Environmental protection, energy efficiency and the development of new alternative sources of energy remain high on the list of federal objectives for the energy sector. The focus now is on achieving a balance between economic, environmental and security objectives, i.e., sustainable development. Meeting Kyoto targets is high on the federal government agenda and a domestic consultation process has been established to develop measures to address the challenges of climate change.

With respect to nuclear energy, the federal government is supportive of the nuclear energy option for Canada and views nuclear energy as an important component of a diversified energy mix. The federal government provides funding for Atomic Energy of Canada Limited's (AECL) nuclear R&D programme. The federal government also regulates the development and application of nuclear energy in Canada. Decision-making responsibility for planning, construction and operation of nuclear plants reside with the provinces and provincial electric power utilities. There are currently no firm plans to build additional nuclear plants in Canada although there is growing recognition that nuclear energy will be required to meet future demand and at the same time meet climate change and air quality concerns. Servicing of existing reactors and possible life extension of some of the units is the present focus of the nuclear utilities.

TABLE 4. ENERGY STATISTICS(*)

	1960	1970	1980	1990	2000	2001	Average annual growth rate (%) 1960 To 1980	1980 To 2001
Energy consumption								
- Total (1)	4.00	6.53	9.31	10.79	13.83	13.75	4.31	1.87
- Solids (2)	0.90	0.83	1.15	1.35	3.95	3.91	1.24	6.02
- Liquids	1.69	2.94	3.65	3.29	2.83	2.83	3.91	-1.20
- Gases	0.44	1.27	1.96	2.62	3.34	3.35	7.80	2.58
- Primary electricity (3)	0.97	1.50	2.55	3.52	3.70	3.65	4.94	1.72
Energy production								
- Total	3.25	7.09	10.23	13.44	19.79	19.73	5.91	3.17
- Solids	0.59	0.53	1.19	1.91	4.44	4.39	3.52	6.43
- Liquids	1.09	2.92	3.45	3.81	4.53	4.53	5.91	1.31
- Gases	0.54	2.11	2.79	4.20	6.83	6.86	8.56	4.38
- Primary electricity (3)	1.02	1.52	2.81	3.53	3.99	3.95	5.20	1.63
Net import (Import - Export)								
- Total	0.87	-0.32	-0.52	-2.38	-5.81	-5.86	2.56	12.23
- Solids	0.30	0.32	-0.05	-0.49	-0.38	-0.25	8.44	7.86
- Liquids	0.67	0.17	0.37	-0.38	-1.69	-1.66	-2.90	-7.40
- Gases	-0.09	-0.81	-0.84	-1.51	-3.75	-3.95	11.72	7.65

(1) Energy consumption = Primary energy consumption + Net import (Import - Export) of secondary energy.

(2) Solid fuels include coal, lignite and commercial wood.

(3) Primary electricity = Hydro + Geothermal + Nuclear + Wind.

(*) Energy values are in Exajoule except where indicated.

Source: IAEA Energy and Economic Database.

2. ELECTRICITY SECTOR

2.1. Structure of the Electricity Sector

Canada's electric power industry is made up of provincial Crown corporations, investor-owned utilities, municipal utilities and industrial establishments. The federal role is restricted to nuclear energy, international and inter-provincial trade.

Under the Canadian constitution, electricity is primarily within the jurisdiction of the provinces. The provincial governments own the natural resources and are responsible for most aspects of regulation and energy sector development within their geographical boundaries. The federal government is responsible for harmonizing energy policy at the national level, promoting regional economic development, frontier lands, offshore development, inter-provincial works (i.e. pipelines), international and inter-provincial trade. Both levels of governments are involved with energy research.

As a result of the division of power, Canada's electrical industry is organized along provincial lines. In most provinces the industry is highly integrated, with the bulk of the generation, transmission and distribution provided by a few dominant utilities. Although some of these utilities are privately owned, most are Crown corporations owned by the provinces. Among the major electric utilities, seven are provincially owned, six are investor owned, two are municipally owned, and two are territorial Crown corporations. In 1997, provincial electric utilities owned about 83% of Canada's total installed generating capacity and produced about 78% of total generated electricity.

On 1 April 1999, Ontario Hydro, once North America's largest power company, officially ceased to exist. The provincially owned electricity giant established in 1906, was split up into five separate entities under a provincial restructuring plan. The two largest of the successor companies are Ontario Power Generation Inc. (OPG) the entity that will run the province's 80 generating stations, and

Ontario Hydro Services Co., which will run the province's 29,000 kilometre transmission network and supply electricity to about one million customers, mostly in rural Ontario.

Traditionally, there have been 3 nuclear utilities in Canada (Ontario Hydro- now called OPG-, Hydro Quebec and New Brunswick Power). A fourth, Bruce Power Inc., was added to the list in May, 2001 when it leased the 8 reactors at Bruce from OPG.

To enhance competition, the province has adopted rules that will break the generation company's near monopoly of the power market. Currently, the utility has an 85% market share, but it is being required to reduce this to 35 per cent over the next 10 years. This means that there may be new owners of nuclear generating units in the new competitive electricity market in Ontario. This is implied as nuclear electricity accounts for 44% of OPG's total electricity output and Ontario Power Generation Inc. will not be permitted effective control of generation capacity greater than 35%.

The electric power industry has a significant presence within the Canadian economy. There were more than 80 000 people directly employed by the industry in 1997, (about 0.6% of total Canadian employment, down 3.5% from 1996) reflecting the continuous restructuring of Canada's electric power industry. Total revenue for the largest utilities amounted to about $26.8 billion in 1997. Of this total, approximately $1,378 million or 5.2% came from export earnings. Over the last decades, the electric power industry has steadily increased its contribution to Canada's Gross Domestic Product, from 2.3% in 1960, to 2.5% in 1970, to 3.0% in 1980, to 3.0% in 1990, to 3.6% in 1995. However, this share has dropped to 2.9% in 1997.

	Capacity (MW)	Share (%)
Government Owned:	93,563	83
Investor Owned:	12,291	11
Industrial (not shown):	6,752	6

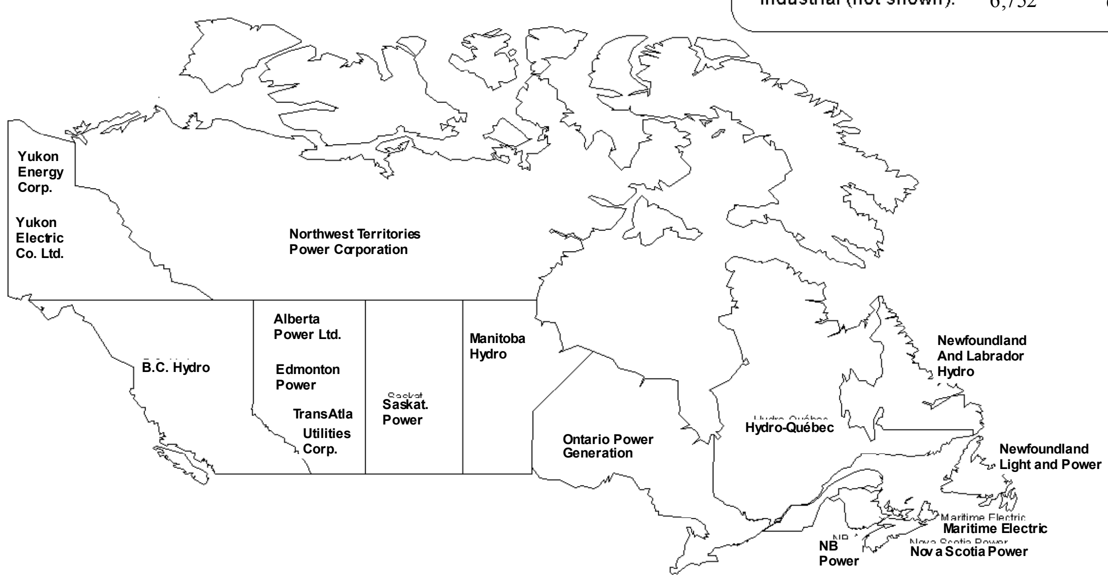


FIG. 1. Major Generating Utilities in Canada -1997

The electric power industry had a large investment share in the energy sector in 1997, with total capital expenditures of $5.2 billion accounting for about 21% of the total investment in the energy sector, and 3% of the total investment in the economy. Total assets of the industry were about $135 billion in 1997. This reflects the capital-intensive nature of the electric power industry. Hydro-Québec, Ontario Power Generation (OPG), formerly Ontario Hydro, and B.C. Hydro were the three largest electric utilities in Canada. Figure 1 shows the major generating utilities in Canada.

2.2. Policy and Decision Making Process

The provincial electric power utilities are responsible for electricity supply and make decisions about the type of technology to be used for electricity generation; they are also responsible for building, operating and maintaining provincial power facilities, including nuclear facilities. Utilities with nuclear plants in operation in Canada are Ontario Power Generation (OPG, formerly Ontario Hydro), Bruce Power Inc. (the principle shareholder is British Energy), New Brunswick Power Corporation and Hydro-Québec. Apart from Bruce Power Inc., which is a newcomer in the electric power scene, the three provincial utilities, particularly OPG, have had critical roles to play in the development of Canada's nuclear programme and worked closely with AECL in the design and construction of the power reactors in their respective provinces.

2.3. Main Indicators

Canada ranks sixth in the world with an installed generating capacity of about 118 GW (behind the United States, Japan, Russia Federation, China and Germany), accounting for about 4% of the world total. Canada also is a world leader in long-distance electric power transmission. Hydroelectric power is the largest domestic source of electric energy representing about 59% of the nation's supply in 2000. Nuclear power represented about 12% of electricity supply in 2000. The electricity production and installed capacities are given in Table 5 and the energy related ratios in Table 6.

Electricity is vital to almost every aspect of the Canadian economy and is projected to continue to expand its role over the next century. From 1980 to the end of 2000 net electricity generation increased at an annual average rate of 2%, compared with real Gross Domestic Product of 2.6%, and total population growth of 1.1%. Canada's total electricity consumption in 2000 was 564 TWh with per capita consumption of 17,117 kWh. In the same year, total electricity produced amounted to 554 TWh.

2.4. Impact of Open Electricity Market in the Nuclear Sector

As a result of the opening of the market in Ontario, OPG has been able to divest its nuclear assets and has leased 8 units a Bruce to Bruce Power Inc. A major player in the Bruce Power consortium is British Energy. British Energy's financial difficulties and impact of these on the structure of the consortium have not impacted on the operations at Bruce. The New Brunswick government and New Brunswick Power are looking at the refurbishment of Point Lepreau. Private equity will be needed for the refurbishment program to proceed.

From a regulatory perspective, the federal government has introduced legislation (Bill C-4) to amend subsection 46-3 of the Nuclear Safety and Control Act which presently discourages private sector lending to the nuclear industry. The subsection has an immediate negative impact on Bruce Power Inc. which requires bank lending to retrofit two reactors at Bruce A.

3. NUCLEAR POWER SITUATION

3.1. Historical Development

Canada has developed a successful nuclear programme based on the unique heavy water natural uranium reactor system (now known as CANDU), which uses pressurized fuel channels instead of a pressure vessel, natural uranium instead of enriched uranium and heavy water as coolant/moderator instead of light water as coolant/moderator found in the pressurized water reactor designs.

TABLE 5. ELECTRICITY PRODUCTION AND INSTALLED CAPACITY

							Average annual growth rate (%)	
	1960	**1970**	**1980**	**1990**	**2000**	**2001**	**1960 To 1980**	**1980 To 2001**
Electricity production (TW.h)								
- Total (1)	114.38	204.72	377.52	482.03	582.27	563.12	6.15	1.92
- Thermal	8.50	47.05	85.95	116.34	168.49	153.84	12.27	2.81
- Hydro	105.88	156.71	253.07	296.85	344.87	336.67	4.45	1.37
- Nuclear		0.97	38.50	68.84	68.68	72.35		3.05
- Geothermal								
Capacity of electrical plants (GWe)								
- Total	23.04	42.83	82.00	104.12	110.04	110.63	6.55	1.44
- Thermal	4.39	14.29	28.36	31.37	32.70	32.94	9.78	0.72
- Hydro	18.64	28.30	47.77	59.38	67.24	67.58	4.82	1.67
- Nuclear		0.24	5.87	13.37	10.02	10.02		2.58
- Geothermal								
- Wind					0.08	0.08		

(1) Electricity losses are not deducted.

Source: IAEA Energy and Economic Database.

TABLE 6. ENERGY RELATED RATIOS

	1960	**1970**	**1980**	**1990**	**2000**	**2001**
Energy consumption per capita (GJ/capita)	223	301	380	389	450	443
Electricity per capita (kW.h/capita)	6,100	9,317	13,853	16,865	17,299	16,982
Electricity production/Energy production (%)	34	28	36	35	28	28
Nuclear/Total electricity (%)			10	14	12	13
Ratio of external dependency (%) (1)	22	-5	-6	-22	-42	-43
Load factor of electricity plants						
- Total (%)	57	55	53	53	60	58
- Thermal	22	38	35	42	59	53
- Hydro	65	63	60	57	59	57
- Nuclear		46	75	59	78	82

(1) Net import / Total energy consumption.

Source: IAEA Energy and Economic Database.

Since the early 1950's, Canada has pursued the nuclear power option through the development of the CANDU system. Canada decided to proceed with the nuclear programme (a) because it had accumulated considerable experience in the heavy water natural uranium reactor system which enabled Canada to make use of Canadian resources and technology; and (b) because in some regions of Canada (particularly Ontario) major hydro resources had been largely developed and fossil fuels would have to be imported; and (c) because it had abundant supplies of uranium.

The main milestones of the Canadian nuclear programme are:

- In 1955, AECL, Ontario Hydro and Canadian General Electric (CGE) made a commitment to build the first small-scale prototype 22 MW CANDU reactor at Rolphton, Ontario;
- A larger prototype was constructed at Douglas Point, Ontario. The 200 MW reactor went into service in 1967; these two reactors established the technological base for the larger commercial units to follow and for Canada's nuclear programme;
- Two 500 MW(e) reactors at Pickering, Ontario were committed under a tri-partite agreement between OPG, AECL and the federal government; Ontario Hydro later committed two more units to make an integrated 4-unit station; the units (Pickering A) came into operation between 1971 and 1973;
- Conceptual design studies on the Bruce A station were initiated in 1968; the 4x800 MW unit Bruce A station came into service from 1977 to 1979;
- AECL developed the CANDU 6 reactor design and was successful in selling four of these in the early to mid-1970's: Gentilly-2 (Hydro-Quebec, 1973), Point Lepreau (New Brunswick, 1974), and two abroad;
- In July 1974, Ontario Hydro decided to add 4 units at the Pickering A station; the 4 units (Pickering B) came into service from 1983 to 1986;
- Four additional units (Bruce B), came into service from 1984 to 1987;
- Four 900 MW(e) units at Darlington were committed in the early 1980's; these went into service in 1989-1994;
- Lay up of 8 units at Bruce A and Pickering A (Bruce unit 2 in 1995 and the remaining 7 in 1998);
- Successful completion of the environmental assessment of the four units laid up at Pickering A and decision to return Pickering A to service in 2000/2001;
- On 16 February 2001, the Canadian Nuclear Safety Commission (CNSC) announced that it had determined that the restart of the Pickering A units would not cause significant adverse environmental effects. The ruling allows the CNSC to proceed to formal consideration of OPG's application to re-start the reactors. The first Pickering A reactor could be brought back on-line by 31 March 2003. OPG announced in October 2002 that while one of the units would be returned to service by March 2003, the return to service of the remaining 3 units would have to be reassessed. The cost overruns associated with the program is the issue at hand. While a delay is anticipated, its is expected that all the units will be brought back in the 2003-04 time-frame.

- In May 2001, OPG announced that a contract had been concluded for the proposed lease of the 8 unit Bruce nuclear station to Bruce Power Inc. The lease covers the period to 2018, with an option to extend for up to another 25 years. Bruce Power is evaluating the possible restart of units 3 and 4 at the Bruce A facility and plans to bring the two units back into operation by the summer of 2003, subject to regulatory approvals. Bruce Power is a joint venture of British Energy plc, Cameco. All indications are that British Energy's financial problems will not impact on the operations at Bruce.

Canada also made entry into the international power reactor supply field while it was building a major nuclear programme at home. Canadian General Electric (CGE) had played a major role in the export market in the 1960's but abandoned this activity in the late 1960's leaving AECL to pick up the leadership drive for CANDU exports (see Chapter 4).

3.2. Status and Trends of Nuclear Power

At the end of 2000, Canada had 22 units installed with a capacity of 15,437 MW(e) accounting for close to 15% of total installed electrical capacity in Canada. Only 14 of these were in full commercial operation. Table 7 gives an overview of the main nuclear power data in Canada and its provinces.

TABLE 7. CANADIAN NUCLEAR POWER DATA

	Canada	Ontario	New Brunswick	Québec
Electricity Demand Growth (% p.a.)	1.24	1.04	1.07	1.03
Nuclear Share (%) of Electric Utility Generation	13.5	42.6	19	2
Capacity/Number of Reactors In Service (Net MW(e)/#)	10 301/14	9 028/12	635/1	638/1
Capacity/Number of Reactors laid up (Net MW(e)/#)	5 136/8	5 136/8		

Source: Country Information.

In 2000, 13.5% of total electricity generation in Canada came from the 22 CANDU reactors in Ontario, Quebec and New Brunswick although when fully operational, these units provide 20% of Canada's electricity supply. Almost 60% of Ontario's electricity comes from nuclear energy. The status of the Canadian nuclear power plants is given in Table 8.

TABLE 8. STATUS OF NUCLEAR POWER PLANTS

Station	Type	Net Capacity	Operator	Status	Reactor Supplier	Construction Date	Criticality Date	Grid Date	Commercial Date	Shutdown Date
BRUCE-5	PHWR	785	OPG	Operational	OH/AECL	01-Jun-78	15-Nov-84	02-Dec-84	01-Mar-85	
BRUCE-6	PHWR	785	OPG	Operational	OH/AECL	01-Jan-78	29-May-84	26-Jun-84	14-Sep-84	
BRUCE-7	PHWR	785	OPG	Operational	OH/AECL	01-May-79	07-Jan-86	22-Feb-86	10-Apr-86	
BRUCE-8	PHWR	785	OPG	Operational	OH/AECL	01-Aug-79	15-Feb-87	09-Mar-87	22-May-87	
DARLINGTON-1	PHWR	881	OPG	Operational	OH/AECL	01-Apr-82	29-Oct-90	19-Dec-90	14-Nov-92	
DARLINGTON-2	PHWR	881	OPG	Operational	OH/AECL	01-Sep-81	05-Nov-89	15-Jan-90	09-Oct-90	
DARLINGTON-3	PHWR	881	OPG	Operational	OH/AECL	01-Sep-84	09-Nov-92	07-Dec-92	14-Feb-93	
DARLINGTON-4	PHWR	881	OPG	Operational	OH/AECL	01-Jul-85	13-Mar-93	17-Apr-93	14-Jun-93	
GENTILLY-2	PHWR	635	HQ	Operational	BBC	01-Apr-74	11-Sep-82	04-Dec-82	01-Oct-83	
PICKERING-5	PHWR	516	OPG	Operational	NEI.P	01-Nov-74	23-Oct-82	19-Dec-82	10-May-83	
PICKERING-6	PHWR	516	OPG	Operational	OH/AECL	01-Oct-75	15-Oct-83	08-Nov-83	01-Feb-84	
PICKERING-7	PHWR	516	OPG	Operational	OH/AECL	01-Mar-76	22-Oct-84	17-Nov-84	01-Jan-85	
PICKERING-8	PHWR	516	OPG	Operational	OH/AECL	01-Sep-76	17-Dec-85	21-Jan-86	28-Feb-86	
POINT LEPREAU	PHWR	635	NBEPC	Operational	AECL	01-May-75	25-Jul-82	11-Sep-82	01-Feb-83	
BRUCE-1	PHWR	769	OPG	Laid up	OH/AECL	01-Jun-71	17-Dec-76	14-Jan-77	01-Sep-77	16-Oct-97
BRUCE-2	PHWR	769	OPG	Laid up	OH/AECL	01-Dec-70	27-Jul-76	04-Sep-76	01-Sep-77	08-Oct-95
BRUCE-3	PHWR	769	OPG	Laid up	NEI.P	01-Jul-72	28-Nov-77	12-Dec-77	01-Feb-78	09-Apr-98
BRUCE-4	PHWR	769	OPG	Laid up	NEI.P	01-Sep-72	10-Dec-78	21-Dec-78	18-Jan-79	16-Mar-98
PICKERING-1	PHWR	515	OPG	Laid up	OH/AECL	01-Jun-66	25-Feb-71	04-Apr-71	29-Jul-71	31-Dec-97
PICKERING-2	PHWR	515	OPG	Laid up	OH/AECL	01-Sep-66	15-Sep-71	06-Oct-71	30-Dec-71	31-Dec-97
PICKERING-3	PHWR	515	OPG	Laid up	OH/AECL	01-Dec-67	24-Apr-72	03-May-72	01-Jun-72	31-Dec-97
PICKERING-4	PHWR	515	OPG	Laid up	OH/AECL	01-May-68	16-May-73	21-May-73	17-Jun-73	31-Dec-97
DOUGLAS POINT	PHWR	206	OPG	Shut Down	AECL	01-Feb-60	15-Nov-66	07-Jan-67	26-Sep-68	04-May-84
GENTILLY-1	HWLWR	250	HQ	Shut Down	AECL	01-Sep-66	12-Nov-70	05-Apr-71	01-May-72	01-Jun-77
NPD	PHWR	22	OH	Shut Down	CGE	01-Jan-58	11-Apr-62	04-Jun-62	01-Oct-62	01-Aug-87

Source: Natural Resources Canada; IAEA Power Reactor Information System as of 31 December 2001.

Since 1990, due to Canadian economic and political situation domestic utilities have postponed indefinitely their expansion plans, and their nuclear plans particularly. There is little prospect for a domestic CANDU sale in Canada during the early part of the next decade although there is still demand for servicing the current fleet of reactors as well as life-extension. Plans and decisions with respect to climate change could kick-start nuclear builds in Canada.

In the latter part of the 1980's, domestic market prospects were much stronger than they are today. OPG's Demand-Supply Plan at this time foresaw the return of a measure of economic growth in the early 1990's and over a 25 year horizon a need for enough new reactor units to establish a solid domestic market base for CANDU. Utilities were also actively considering expanding or establishing their nuclear power capacity. The offshore market was likewise expected to grow but not to be a major market until the turn of the century (The old plan was premised on a forecast of median load growth and a need to install 15,000 MW of additional capacity by 2014 to augment the 1989 capacity of 23,000 MW. Ten CANDU reactors were to provide 8,880 MW of the new capacity).

Ontario's Nuclear Asset Recovery Plan (NAOP) is starting to show positive results as demonstrated by improvements in performance of its units. The capability factor of the 12 operating units in Ontario was over 80% in 2000. The CANDU 6 units in Canada and abroad continue to show good performance with gross lifetime capacity factors of over 80%.

3.3. Current Policy Issues

The federal government's view is that, on balance, Canada is fortunate to have a variety of energy options at its disposal and that it is necessary to continue to develop a mixture of energy sources. Within the supply system there is an important role for nuclear energy as long as it is responsibly managed and strictly regulated.

The provinces have overall responsibility for the development and management of their nuclear supply system, including nuclear power stations. Although the three provinces with nuclear facilities do not have any plans to build additional nuclear plants, they are undertaking or planning to undertake refurbishment programmes to ensure long-term supply from their nuclear assets. The Ontario government recognizes that nuclear energy will remain a very important component of the supply mix and that it represents a major technical achievement.

Ontario

On August 13, 1997, the Ontario Hydro (OH) Board of Directors announced its Nuclear Asset Recovery Plan (NAOP) which entailed the lay-up of seven of its 19 operating CANDU reactors in order to dedicate resources to bringing the other 12 units back to their previous standard of excellence (one unit, Bruce unit 2, was laid up in 1995). The Board decided that once that target is achieved, OH (now OPG) will evaluate the restart of the eight laid-up units by preparing the necessary business cases including a review of other generation options that will be available to the utility at that time.

The NAOP was based on the results of the *Independent, Integrated Performance Assessment (IIPA)* by the Nuclear Performance Advisory Group headed up by Mr. Carl Andognini, former Executive Vice-President and Chief Nuclear Officer of OH. The *IIPA* report indicates that OH had difficulty in making a smooth transition from a large, design and construction organization to an operating-and-maintenance-driven company and that the root cause of OH declining nuclear performance was the manner in which the corporation manages and operates its nuclear facilities. OH's (now OPG's) IIPA is serving as a model for other countries with large nuclear programmes and ageing facilities

In 2000-2001, we have seen the successful completion of the environmental assessment of the four units laid up at Pickering A and a decision by the OPG Board to return the four units at Pickering A to service, starting in March 2002. On 16 February 2001, the CNSC announced that it had determined that the restart of the Pickering A units would not cause significant adverse environmental effects. The ruling allows the CNSC to proceed to formal consideration of OPG's application to re-start the reactors. In May, 2001, OPG announced that a contract had been concluded for the proposed lease of the 8 unit Bruce nuclear station to Bruce Power Inc. The lease covers the period to 2018, with an option to extend for up to another 25 years.

Work is near completion on one unit at Pickering A. However, OPG has indicated that it is assessing the restart of the remaining 3 units at Pickering. While it is anticipated that they will be refurbished, delays are likely.

New Brunswick

The New Brunswick government is also reviewing the future structure of the electricity market and the future role of NB Power. A study on Point Lepreau by Hagler, Bailly, a consulting firm commissioned by NB Power, concluded that the reactor could not be expected to be operated beyond 2008 without substantial new investment. The decision NB Power and the government must make regarding investing to extend the life of Point Lepreau beyond 2008 will entail a comparison between the total costs of electricity production at Point Lepreau and the total cost at an alternative facility.AECL has completed a feasibility study on the refurbishment of Lepreau. Whether or not it actually goes ahead will very likely depend on the ability of New Brunswick Power to attract private investment.

There is also the issue of whether Point Lepreau will be privatized along with NB Power's conventional generation facilities if the decision is made to privatize NB Power. No decision has been made, yet, by the government concerning the future of NB power.

Quebec

Quebec has a single CANDU 6 unit in operation at Gentilly. Hydro Quebec's Board of Directors has agreed to initiate a detailed study aimed at assessing the life extension of Gentilly 2 station after 2008 for an additional 25 years. The study will be conducted by AECL and will include a comprehensive engineering evaluation of the rehabilitation work to be done as well as a detailed cost estimate. Based upon the findings, a proposal will be submitted to the Board of Directors for approval. Preliminary assessments indicate that the refurbishment of Gentilly 2 would be fully competitive when compared to other electricity generating options.

3.3.1 Advanced Reactors

New reactor builds would likely be of the Advanced CANDU design presently being developed by AECL for the domestic and international markets.Whether or not new nuclear units are added to meet climate change objectives is still a big unknown. AECL plans to bring to the market a world-leading "next-generation" power reactor which is 40% less expensive as well as faster to build than existing reactors and has safety enhancements.

AECL is developing a lower-cost CANDU reactor (the Advanced CANDU Reactor or ACR), which will be 40% cheaper to build than existing CANDU technology due to such design evolutions as a smaller core, 75% reduction in quantity of heavy water, and use of slightly enriched uranium fuel. The 700MW ACR aims to be cost-competitive with other methods of power generation, including natural gas, and international experts have ranked the ACR highly for economics in comparison with other advanced reactor concepts. There would be significant emissions avoided by subsequent construction of other ACRs to meet increased domestic demand for electricity, or to replace older CANDUs reaching the end of their lives.

3.3.2 Nuclear Energy - Its Contribution to Climate Change

- Nuclear energy is currently providing 13 per cent of Canada's total electricity requirements (40 per cent in Ontario), a source of electricity which is virtually GHG emissions free.
- Since the first nuclear reactor came on line in 1971, nuclear power has offset the release of over 1,500 Megatonnes (Mt) of CO_2 emissions in the atmosphere, assuming that coal was the most likely alternative to nuclear over that period.
- Last year, nuclear energy precluded the release of CO_2 emissions ranging between 40 to 70 Mt assuming that nuclear energy would have been displaced by natural gas and/or coal, respectively.
- If Canadian electric utilities had not chosen to build nuclear reactors and had built fossil-fueled plants instead, Canada's total GHG emissions gap would be 20 to 35% higher in 2010, than currently forecast.
- A CANDU 6 (similar to the Point Lepreau reactor) avoids annually the release of around 4.5 Mt of CO_2, whereas a CANDU 9 (similar to one of the Darlington reactors) avoids 6.1 Mt compared to an existing coal plant with the same generating capacity (2.5 and 3.5 Mt of CO_2 respectively when compared to a natural gas plant).

Over the next two years, six of the eight laid-up units at Pickering A and Bruce A are expected to return to service. If not, CO_2 emissions in 2010 will exceed the most recent GHG emissions forecast by 15 to 25 Mt (depending upon whether natural gas or coal replaces nuclear).

For most of this decade, we do not foresee any tangible prospects for any new nuclear power plants in Canada, even in Ontario, based on the most recent electricity market outlooks. The return to service of the laid-up nuclear units and the completion of gas-fired units already under construction in Ontario should ensure more than adequate electricity supplies. This is in-line with the 10-year outlook recently published by the Ontario Independent Electricity Market Operator. Moreover, based upon the most recent Levelized Unit Energy Cost[1] (LUEC) published by the Nuclear Energy Agency, the current market conditions and the fact that electricity generated from fossil fuel sources does not internalize all of its costs results in the nuclear option not being the most economical option for new generating capacity.

However, by 2010, we foresee better opportunities for the deployment of new nuclear generating capacity in Canada. AECL is currently working on the development of the Advanced 700 CANDU Reactor (ACR), and it is aiming at reducing the capital cost to build a reactor by up to 40%. AECL foresees the potential for two ACRs in Canada by 2010.

While market prospects for new reactor sales in the near to mid-term are not too promising, the refurbishment of existing units, e.g., Point Lepreau and Gentilly 2 by 2008-09, seems more promising. Hence, the refurbishment of existing reactors would, at least in the mid-term, avoid the replacement of nuclear generating capacity with fossil-fueled plants.

Over the next two decades, nuclear energy will have to face major challenges in order to be able to compete with the other technologies for generating electricity in an open and deregulated market environment. These challenges include:

1- the ability to develop a cost competitive ACR;
2- the ability to mobilize large capital investment for projects in an open market;
3- the siting and licensing requirement for new nuclear plants;
4- the price of fossil fuels; and

[1] The levelized Unit Energy Cost (LUEC) method compares the economics of various generating options taking into account the total discounted cost of producing the energy (capital, operating and maintenance and fuel costs) and the amount of energy produced over the life of the plant, and distributes these costs over the anticipated operating life of the station.

5- continued fiscal which do not internalize the externalities related to the production of electricity from fossil fuels.

The industry is addressing those challenges by investing in the development of an advanced nuclear reactor and developing consortia to finance the refurbishment or the construction of new reactors. From a climate change perspective, the industry has indicated that open markets may not on their own choose nuclear, unless:

1- all fuels are required to internalize their own externalities; and that
2- measures are taken to ease the siting and licensing burden on new plants.

For more than three decades, nuclear energy has contributed significantly to avoid Canada's GHG emissions. Although there are a number of challenges currently facing the nuclear option, it is clear that nuclear is well positioned to help Canada in its effort to address climate change, as it is essentially GHG emissions free.

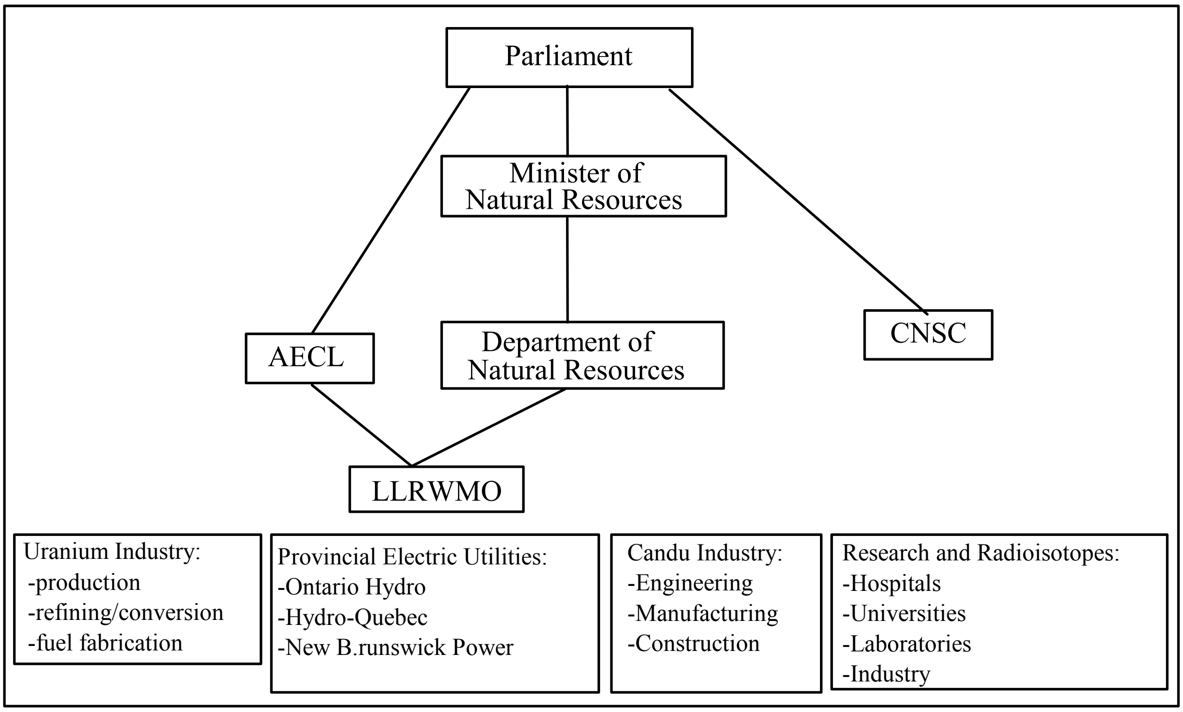
3.4. Organizational Charts

The structure of the Canadian Nuclear Industry is shown in Figure 2.

4. NUCLEAR POWER INDUSTRY

The Canadian nuclear industry consists of a mixture of private sector firms and public sector organizations at both the federal and provincial levels. The federal government provides leadership, support and a regulatory framework for the nuclear industry through AECL and the Canadian Nuclear Safety Commission (CNSC), two federal government agencies (known as "Crown" corporations) which report to the Canadian Parliament through the Minister of Natural Resources. The Minister of Natural Resources relies directly on the Department of Natural Resources for policy advice on nuclear matters including issues pertaining to AECL and the CNSC. The CNSC regulates the safety and security aspects of nuclear materials and facilities in Canada and participates, on behalf of Canada, in international measures of control.

AECL has both a public and commercial mandate. It has overall responsibility for Canada's nuclear research and development (R&D) programme as well as the Canadian reactor design (CANDU), engineering, marketing programme. Canada also has an indigenous nuclear power industry established around the CANDU reactor technology. Private sector firms, which undertake the manufacturing of CANDU components and the engineering and project management work for reactors outside of Canada, act as subcontractors to AECL.



CNSC	Canadian Nuclear Safety Commission
AECL	Atomic Energy of Canada Limited
LLRWMO	Low Level Radioactive Waste Management Office

FIG. 2. Structure of the Canadian Nuclear Industry

Although both the federal and Saskatchewan governments have played a major role in Canada's uranium industry in the past, through Cameco Corporation and its predecessors, their role is diminishing as Cameco moves towards full privatization (as of August, 2001, 91% of Cameco was privately owned and 9% was owned by the Saskatchewan Government). Operation and maintenance of nuclear plants provide the largest single source of jobs in the nuclear industry.

The Canadian nuclear industry covers all phases of the fuel cycle. The industry's activities are focused on the design, engineering, construction and servicing of CANDU reactors in Canada and abroad; on fuel and component manufacturing; and, on the mining, milling, refining and conversion of uranium. The most significant members of the industry are AECL, the CNSC (previously AECB), provincial utilities, and private sector firms involved in equipment manufacturing, engineering and the mix of private and government (both domestic and foreign) firms involved in uranium production. In addition, there are about 125 hospitals and universities across Canada involved in nuclear medicine and radiology.

4.1. Supply of Nuclear Power Plants

AECL is responsible for engineering, nuclear design, business management, and construction of CANDU reactors in Canada and abroad. It leads the marketing and sales initiatives on behalf of the nuclear industry. It also manages contracts for building the reactors and servicing them. AECL's CANDU operations are based in Mississauga, Ontario and Montreal, Quebec. It also has offices around the world.

The industry is not vertically integrated. There are over 150 companies that supply products and/or services to AECL and the utilities. 58% of these firms are located in Ontario, 14% in Alberta and 12% in Quebec. The remaining provinces have 16% of the suppliers to the nuclear industry. 66% of the nuclear industry supplier companies are in the manufacturing sector, 30% are in engineering and design and 16% in R&D.

Manufacturing: Because of the cyclical nature of the nuclear industry, most of the firms are also active suppliers to other industries.

Engineering: A number of Canadian engineering consulting firms, working closely with AECL, assume the conventional design responsibilities as well as project and construction management and other services, which are often required during plant construction.

Operation and Maintenance: A number of private sector suppliers work as sub-contractors for provincial utilities for some of the O&M work.

Construction: This activity is cyclical in nature and the impact on employment can be significant (for example, the construction of a CANDU 6 requires 15,000 person-years over the construction period of 5-6 years). The construction of reactors is undertaken by general construction contractors.

4.1.1. Status of the International Nuclear Programme

Offshore markets have been the major component of the CANDU business during the past decade and indications are that this situation will continue for some time.

AECL assisted India in the construction of two 200 MW Douglas Point-type reactors (RAPP 1 and RAPP 2). An agreement was signed with India in 1963 to build RAPP 1 and RAPP 1 was completed in 1973. Assistance for the construction of RAPP 2 was terminated following India's explosion of a "peaceful nuclear device" in 1974 although India eventually completed RAPP 2 in 1981 without Canadian involvement. Canada does not have a nuclear co-operation agreement with India and therefore cannot conduct nuclear trade with India.

In 1964, CGE entered into an agreement with Pakistan to supply a 120 MW CANDU-type reactor (KANUPP). The plant entered commercial operation in 1972. As Pakistan did not agree to meet the requirements of Canada's 1974 non-proliferation policy, Canada terminated nuclear co-operation with Pakistan. Canada does not have a nuclear co-operation agreement in place with Pakistan although some "limited" safety assistance is currently being provided through the CANDU Owners Group.

AECL developed the CANDU 6 reactor design and was successful in selling four of these in the early to mid-1970's: Gentilly-2 (Hydro-Quebec, 1973), Point Lepreau (New Brunswick, 1974), Cordoba (Argentina, 1973) and Wolsong (South Korea, 1976). All four of these units went into service in the early 1980's. In 1979, an agreement was signed with Romania to build a multi-unit 600 MW CANDU station at Cernavoda. The first reactor, Cernavoda 1, was completed and went into commercial operation in 1996. In 1991, AECL sold an additional CANDU 6 unit to South Korea and a further two units in 1992.

The CANDU 6 unit in Romania is fully operational and is producing about 10% of the country's electricity. AECL and its partner ANSALDO signed a contract in May 2001 with Romania to complete the second unit at the same site. The unit is about 40% complete and is expected to commence operation in 2005. The CANDU 6 units, in South Korea at the Wolsong site, are now in service (Wolsong 2, 3 and 4). Wolsong 4 was completed in July 1999.

Two CANDU 6 reactors are under construction at Qinshan, near Shanghai, China. The $4 billion contract for these units was signed by the federal Crown Corporation, Atomic Energy of Canada Limited, and the China National Nuclear Corporation (CNNC) in November 1996.

4.2. Operation of Nuclear Power Plants

As noted earlier, all Canadian electric utilities are under provincial jurisdiction and are responsible for building, operating and maintaining provincial power facilities, including nuclear facilities. The utilities operating nuclear facilities, are OPG, Bruce Power Inc., Hydro-Québec and New Brunswick Power. The main activity of the utilities is operation and maintenance. This activity provides the largest single source of jobs in the nuclear industry. Private sector suppliers work as sub-contractors for utilities for some of this work.

The utilities are members of the CANDU Owners Group (COG) and share in funding the industry's R&D effort. COG was formed in mid-1984 by the Canadian utilities, which own CANDU plants and AECL. COG was set up to promote closer co-operation among the nuclear utilities in matters relating to plant operations and maintenance and to foster co-operative development programmes leading to improved plant performance.

4.3. Fuel Cycle and Waste Management Service Supply

4.3.1. Uranium

Canada is the world's leading producer and exporter of uranium, with output of some 10 700 tU in 2000 representing about 31% of total world production. In 2000, all uranium produced came from higher-grade, lower-cost production centres at Key Lake, Rabbit Lake, Cluff Lake, McClean Lake and McArthur River in Saskatchewan's Athabasca Basin. Canada's largest uranium producer, Cameco Corporation, also operates Canada's only uranium refining and conversion facilities at Blind River and Port Hope, Ontario respectively. Table 9 contains the uranium data for Canada. Fuel Fabrication in Canada is carried out by two companies, which produce fuel assemblies for the CANDU reactor. There are no uranium enrichment and reprocessing facilities in Canada.

The key companies involved in the nuclear fuel cycle in Canada are Cameco Corporation, COGEMA Resources Inc. (uranium mining and milling); Cameco (refining and conversion); and General Electric Canada Inc. and Zircatec Precision Industries Inc. (fuel fabrication).

TABLE 9. CANADIAN URANIUM DATA.

	2000	1999	1998	1997	1996
Known Uranium Resources Recoverable from Mineable Ore (1,000 tU as of January 1)*	417	433	419	430	490
Total Primary Production (tU)	10 683	8 214	10 922	12 031	11 706
By-product** Production (tU) [not included above]	0	0	0	0	48
Total Producer Shipments (tU)	9 921p	10 157	9 984	11 127	11 396
Value of Shipments ($C millions)	485p	500	500	554	624
Average Price for Deliveries under Export Contracts ($C/kgU) / ($US/lb U_3O_8)	47.70/12.40	49.10/12.70	51.10/13.30	51.30/14.20	53.60/15.10
Exports of Uranium of Canadian Origin (tU)	10 966	7 146	8 274	10 255	11 223
Uranium Exploration Expenditures ($C millions)	48p	49	60	58	39

*Resources at prices of $150/kgU or less.
**Uranium from refinery/conversion facility by-products recovered at Elliot Lake. With the closure of Rio Algom's Stanleigh operation in mid-1996, by-products from Cameco's refinery/conversion facilities in Ontario are no longer processed in Canada.
p provisional

Recent Uranium Developments

Mining began at the McArthur Rive mine, the site of world's largest high-grade uranium deposit discovered to date, in December 1999. During November 2000 commercial production was achieved and Cameco expects to achieve the mine's monthly design capacity of 577 tU consistently throughout 2001. In January 2001, it was announced that McArthur River's total reserves and resources had been increased by more than 50%. The mine now has total reserves and resources amounting to some 150 000 tU, with an average grade of 18% U.

After commissioning in 1999, production at McClean Lake reached licensed capacity (2 308 tU) by the end of October 2000. The mill was fed throughout 2000 by ore from the Sue C open pit and stockpiled ore from the JEB open pit. Ore from the Sue C mine is expected to provide mill feed fro some twelve to eighteen months. In its 2001 licence renewal application to the CNSC, majority owner and operator COGEMA Resources Inc. (CRI), requested that the McClean Lake annual production capacity be increased by an additional 769 tU. A decision on the McClean Lake licence renewal is expected in August 2001. Following two years of preparation, the McClean Lake operation received ISO 14001 certification for its environmental management system, the first uranium mine in North America to do so.

Mining is ongoing at the Dominique-Janine underground mine at Cluff Lake and is expected to continue throughout 2001. With allowable capacity remaining in the tailings management area (TMA), higher ore grades, lower production costs and improved productivity, operations are continuing at Cluff Lake into 2002 until all stockpiled ore is processed. Although higher than expected ore grades have resulted in fewer tailings, production at the site remains limited by the capacity of the TMA.

In 1998, Cameco announced production cutbacks in response to the low price and to ease the transition to the new high-grade mines in northern Saskatchewan. These cutbacks included the suspension of mining operations at the Rabbit Lake Eagle Point underground mine on 31 March 1999. In August 2000, Cameco announced an extension to this temporary suspension of mining activities. As a result, when the existing ore stockpile is depleted (expected in June 2001), the mill will be placed on standby for approximately on year, depending on market conditions. Cameco has re-evaluated the Eagle Point mining plan to achieve further efficiencies and, in 2001, is expected to seek regulatory approval to re-open the facility based on the revised mining plan.

In October 2000, Cameco Corporation announced that it had signed an agreement with British Energy Plc to acquire a 15% interest in the Bruce Power Partnership (Bruce Power). Under the terms of the agreement, Cameco will have the full responsibility to manage all of Bruce Power's fuel procurement needs. The agreement came into effect on 12 May 2001, shortly after the Bruce Power Partnership received an operating licence from the CNSC.

In October 1999, Cameco obtained all the necessary licensing to begin production at the McArthur River mine. The Key Lake mill, closed since 30 June 1999, for a $25 million refurbishment, received the necessary licensing to process McArthur River ore in November 1999. Production from the McArthur River mine commenced late 1999.

4.3.2. Canadian Uranium Industry Highlights

Despite low prices, Canadian uranium production capability continues to expand in the province of Saskatchewan. The McClean Lake mill, which entered into production in June 1999, reached its annual licenced production capacity of 2 300 tU in November 2000. The McArthur River mine, which entered into production in December 1999, continued to ramp up towards its annual licenced production capacity of 6 900 tU, producing about 3 740 tU in 2000. Test mining and development continued at Cigar Lake in 2000, with the mine expected to begin production in 2005.

As of 1 January 2001, Canada's total "known" recoverable uranium resources were 437 000 tU, compared with 417 000 tU as of January 1, 1999. This upward adjustment of some 5 per cent is primarily the result of increased MacArthur resources. Canadian uranium production in 2000 amounted to 10 683 tU, up some 30% from the 1999 total, mainly due to contributions from the new McClean Lake and McArthur River mines (Table 10).

4.3.3. Federal Environmental Assessment Reviews

Most nuclear projects undergo a federal environmental assessment process under the *Canadian Environmental Assessment Act* (CEAA). Recent assessments are reported below:

In 1995 Rio Algom agreed to licence historic mines in Elliot Lake region (Spanish American, Milliken, Lacnor, Nordic, Buckles and Pronto) that are not presently under CNSC licence. In support its licence application, Rio Algom submitted an environmental assessment screening report that is currently under review.

COGEMA Resources Inc. (CRI) is currently preparing a comprehensive study (CS) environmental assessment under the CEAA of its plans to suspend the operations at Cluff Lake. Early in 2001, the CS that outlines, among other issues, the decommissioning plan, options and mitigation measures, was submitted to the CNSC for preliminary review.

In its 2001 operating licence application renewal to the CNSC, CRI has requested that the McClean Lake annual production capacity be increased by some 769 tU (to 3 077 tU). The requested amendment requires a screening report environmental assessment that is expected to be completed before the initial CNSC hearing on the McClean Lake licence scheduled on 28 June 2001.

In late 2000, CRI and the Cigar Lake Mining Corporation submitted a screening report environmental assessment of the preferred of options to dispose of potentially acid generating waste rock from the Cigar Lake mine. The proponents determined that the preferred option is disposal in the mined out Sue C pit at McClean Lake. The report is now under review by regulatory agencies.

A CS environmental assessment of the proposal to mill approximately half of the Cigar Lake ore at the Rabbit Lake mill is expected to be submitted to regulators in 2001. Subject to regulatory approvals and mutually agreeable business arrangements among the joint venture partners, ore from Cigar Lake could feed Rabbit Lake mill for some 10 to 14 years.

4.3.4. Radioactive Waste Management

In July 1996, the Government of Canada announced a Policy Framework for Radioactive Waste. The Framework lays out the ground rules and sets the stage for the further development of institutional and financial arrangements to implement disposal of radioactive waste in a safe, environmentally sound, comprehensive, cost-effective and integrated manner. The Policy Framework specifies that the federal government has the responsibility to develop policy, to regulate, and to oversee radioactive waste producers and owners in order that they meet their operational and funding responsibilities in accordance with approved disposal plans. The Framework recognizes that there will be variations in approach in arrangements for the different waste types in Canada, i.e., nuclear fuel waste, low-level radioactive waste and uranium mine and mill tailings.

4.3.5. Radioactive Waste

In April 2001, consistent with the Policy Framework for Radioactive Waste , the Government of Canada introduced new legislation for the long-term management of nuclear fuel waste. The Nuclear Fuel Waste Bill C-27 is the culmination of many years of federal research, environmental assessments and discussions with stockholders, including the nuclear industry, provinces and the public. The Nuclear Fuel Waste Act has received Royal Assent and entered into force on November 15, 2002.

4.3.5.1. Nuclear Fuel Waste

In 1988, the Minister of Energy, Mines and Resources (now Natural Resources Canada) referred the concept of deep geological disposal of nuclear fuel waste developed by AECL to the Minister of the Environment for a public review by an environmental assessment panel. In 1989, the Minister of the Environment appointed a Panel to undertake the public review. In October 1994, AECL submitted an Environmental Impact Statement to the Panel. Public hearings on the AECL disposal concept took place between March 1996 and March 1997.

On March 13, 1998, the Panel presented its recommendations on the safety and acceptability of the disposal concept and on the next steps for the long-term management of nuclear fuel waste in Canada to the Minister of Natural Resources and the Minister of Environment. The Government of Canada's response to the recommendations was publicly announced on December 3, 1998. In its response, the Government laid out its objectives for federal oversight. This oversight was to be exercised through legislation. On November 15, 2002, the Act respecting the long-term management of nuclear fuel waste went into force.

4.3.5.2. Low-Level Radioactive Waste

OPG produces about 80% of the annual volume of low-level radioactive waste in Canada. To date there has been no pressing need in OPG for early disposal; volumes are small and the waste is being safely stored on an interim basis. However, in its 1992 plan for these wastes the utility fully recognized that, in the longer term, disposal is a necessary step in responsible waste management, so that future generations are not burdened with managing this waste. OPG has completed conceptual engineering studies and costed out options for a low-level radioactive waste disposal facility. The year 2015 is considered an achievable target date for bringing a disposal facility into service.

The other major producer of on-going low-level radioactive waste, AECL, is currently in discussions with the CNSC to license a prototype below-ground concrete vault known as IRUS (Intrusion Resistant Underground Structure) for relatively short lived waste.

4.3.5.3. Port Hope Area Wastes

The bulk of Canada's historic low-level radioactive waste is located in the southern Ontario municipalities of Port Hope and Clarington. These wastes, amounting to roughly one million cubic metres, relate to the historic operations of a radium and uranium refinery in the Town of Port Hope. While these wastes are being safely managed in their current locations, the federal government has been seeking a long-term management approach. In early 2001, the Minister of Natural Resources Canada signed a legal agreement with the communities for the design, construction and maintenance of local engineered facilities to manage these wastes in the long-term.

With the signing of the Agreement for this 10-year $260 million project, the environmental assessment licensing phase was initiated. Expected to last 5 years, this phase will be followed by implementation and operations scheduled to last 3-7 years. The final project phase will be post closure monitoring of the facilities.

4.3.5.4. Radioactive Contamination in Northern Alberta and Northwest Territories

Uranium ore was mined in the 1930s, 1940s and 1950s at Port Radium on Great Bear Lake in the Northwest Territories by the uranium mining company Eldorado. It was transported by barge to Fort McMurray in northern Alberta, where the cargo was put on rail and transported to southern Ontario for processing. Cargo spills occurred at barge transfer points. Although the radiological impact of the contaminated sites discovered in 1991 is minimal, the federal government nevertheless decided to conduct a phased project involving clean-up activities based on sound waste disposal principles. Action has been taken annually since 1991 in the areas of site characterization, clean up, and monitoring activities. This project is on-going.

4.3.5.6. Uranium Mine and Mill Tailings

In Canada, about 200 million tones of uranium mine and mill tailings have been generated since the mid 1950s. These comprise about two percent of all mine and mill tailings in the country. Most of the existing uranium tailings are located in the provinces of Ontario and Saskatchewan. There are a total of twenty-four tailings sites in Canada, twenty of which are no longer receiving waste material. Only the operations in Saskatchewan are now active.

Uranium tailings are decommissioned on-site. Uranium producers in co-operation with provincial and federal governments are involved in on-going research on the decommissioning of uranium tailings, specifically tackling the problem of acid mine drainage and increasing the stability of engineered barriers. Successful decommissioning has been achieved at sites in Saskatchewan and Ontario. Other sites are either decommissioned or are still in operation.

With regard to financial responsibility for decommissioning and long-term maintenance of the tailings, the CNSC requires that present-day operators provide financial assurances that decommissioning of uranium facilities will take place in a responsible and orderly manner in the short- and long-term. Where a producer or owner cannot be identified, cannot be located or is unable to pay, responsibility for decommissioning would rest with the Canadian federal and provincial governments. In January 1996, a Memorandum of Agreement (MOA) on cost-sharing for management of abandoned uranium mine tailings was signed between the federal and Ontario governments. The MOA recognizes that present and past producers of uranium are responsible for all financial aspects of the decommissioning, and long-term maintenance of uranium mine sites, including the tailings. In the case of abandoned sites, the MOA outlines how governments will share the long-term management responsibilities and associated costs. A similar MOA between the federal Saskatchewan governments is currently under consideration.

4.3.5.7. Decommissioning Reactors

CANDU reactors are to be decommissioned in a staged fashion. NPD (a 25 MW(e) reactor), Douglas Point (a 220 MW(e) reactor) and Gentilly-1 (a 266 MW(e) reactor), all owned by AECL, are in a shutdown phase. The nuclear fuel waste has been stored and the containment buildings are intact. After a period of about 30 years, remaining structures will be dismantled, the site restored and the waste disposed of off-site.

4.4. Research and Development Activities

The federal government has funded the research and development programme of Atomic Energy of Canada Limited since AECL was first established in 1952. As part of its overall review of federal programmes in 1995-96, the Department of Natural Resources reviewed the structure and funding of the AECL R&D programme in co-operation with other key departments and AECL. As a result of the review, federal funding was reduced to $100 Million per annum and a strategic decision was taken to focus AECL's R&D efforts on CANDU-related R&D and close the AECL laboratories at Whiteshell. The government's objective was to maintain a viable R&D programme at reduced cost to the federal government. AECL receives commercial revenues from its customers and it also receives government appropriations for its nuclear R&D programme. Reviews are underway help the government determine whether the existing level of appropriations for AECL is appropriate. They do not represent a shift in government policy (The Government of Canada periodically reviews its own services, agencies and programmes to ensure that Canadians receive the most for their tax dollars).

AECL is responsible for Canada's nuclear research and development programme, which includes activities in support of CANDU technology as well as basic science activities to support AECL's applied programmes in the nuclear, biological and material sciences. AECL's internationally acclaimed research centres at Chalk River, Ontario and Whiteshell, Manitoba play a critical role in the development of the CANDU reactor, in safety and environmental protection, in nuclear medicine, in health sciences, in nuclear fuel waste management and in the basic sciences that spawn the technological advances.

Nuclear research and development in Canada began in the 1940's as a responsibility of the federal government. The Chalk River Laboratories (CRL) were originally established as a part of the National Research Council's wartime research effort. Early CRL pursuits were in the "new" sciences at the time - nuclear physics, nuclear chemistry and radiation biology - and the creation of the National Research Experimental Reactor (NRX).

The NRX facility and the National Research Universal (NRU) reactor brought on-stream a decade later were critical to CRL's early programmes of basic science and isotope production and to the development of the CANDU reactor system. CRL supported federal government's initiatives to develop national radiological health and safety regulations and to contribute to international efforts to control the proliferation of nuclear materials.

Nuclear R&D in Canada has always been distinct from that undertaken in other nuclear countries. This is because the Canadian research reactors were designed to use natural (rather than enriched) uranium and heavy (rather than light) water.

Although responsibility for the design, construction and operation of nuclear power plants has generally been shared between AECL, the nuclear power utilities and private companies, most of the related R&D activities have remained in the AECL laboratories. Such activities have included the development of CANDU design methods, experimental verification of CANDU reactor components and design characteristics, as well as detailed safety analyses. On going work has been on improved durability and reliability of CANDU components, and flexibility of fuel cycles. Basic and applied sciences not related to nuclear energy have also been significant research components in these laboratories.

As the CANDU nuclear energy system is unique in concept among nuclear systems in the world, the required R&D support is also unique and cannot be derived from research results in other countries. Therefore, a continuing R&D programme specific to CANDU is necessary to support existing and future plants, either at home or abroad. In terms of the accumulated electricity produced, however, the costs of R&D specific to Canada's nuclear energy programme has been much less than the costs in any other country's civilian nuclear programme.

The continuing design and development programme for HWRs in Canada are primarily aimed at reduction of plant costs through plant optimization and simplification and at an evolutionary enhancement of plant performance and safety. Two new 728 MW(e) CANDU-6 units with improvements over earlier versions of this model are under construction in Qinshan, China. Up-front basic engineering continues on the 935-MWe CANDU-9 reactor, a single unit adaptation of reactor units operating in Darlington, Canada. The two year licensability review by the Canadian Nuclear Safety Commission was completed in January 1997, and found that the CANDU-9 meets the country's licensing requirements. Further studies are being carried out for advanced versions of the next generation CANDU plants (ACR) to incorporate further evolutionary improvements and to increase the output of the larger reactor up to 1300 MW(e). New features include simple, inexpensive fuel-bundle design based on slightly enriched uranium and light water coolant. AECL plans to have the ACR licensed in Canada, the UK and the USA and is planning joint licensing reviews for the technology.

There are also innovative small heavy water reactors under development. AECL has undertaken a design initiative called CANDU X within which the future steps in CANDU technology are investigated. These include consideration of improved thermodynamic efficiency using supercritical coolant.

4.5. International Co-operation in the Field of Nuclear Power Development and Implementation

Private and public organizations in Canada's nuclear programme are active in bilateral co-operative work in many countries often under the umbrella of a Memorandum of Understanding between parties. Co-operative work is carried out with countries with which Canada has established formal nuclear relations under a Nuclear Co-operation Agreement. Canadian public and private sector firms are also active in a variety of multilateral activities carried out in a number of international nuclear fora including the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development (OECD), the G-7 Nuclear Safety Working Group, etc.

5. REGULATORY FRAMEWORK

5.1. Safety Authority and the Licensing Process

The Canadian Nuclear Safety Commission

On 31 May 2000, the Canadian Nuclear Safety Commission (CNSC) replaced the Atomic Energy Control Board (AECB), which had served as the regulator of Canada's nuclear industry for more than 50 years. The Commission's creation followed the coming into force of the *Nuclear Safety and Control Act* and its regulations. The new law represents the first major overhaul of Canada's nuclear regulatory regime since the AECB was established. The new legislation under which the CNSC operates mirrors the latest scientific knowledge in the areas of health, safety, security and environmental protection.

The mission of the Canadian Nuclear Safety Commission (CNSC) is to regulate the use of nuclear energy and materials to protect health, safety, security and the environment and to respect Canada's international commitments on the peaceful use of nuclear energy.

Under the *Nuclear Safety and Control Act*, the CNSC's mandate involves four major areas:

- Regulation of the development, production and use of nuclear energy in Canada;
- Regulation of the production, possession and use of nuclear substances, prescribed equipment and prescribed information;
- Implementation of measures respecting international control of the use of nuclear energy and substances, including measures respecting the non-proliferation of nuclear weapons; and
- Dissemination of scientific, technical and regulatory information concerning the activities of the CNSC.

The Canadian regulatory system is designed to protect people and the environment from licensed sources of man-made radiation resulting from the use of nuclear energy and materials. This is accomplished through a licensing process that requires the licensee to prove that their operations are safe. CNSC staff monitor and inspect licensed activities. At the basis of the regulatory system is the principle that no technology is fail proof, so licences must incorporate multiple layers of protection whenever radioactive materials are used.

The CNSC controls the import, export and transportation of nuclear materials and other prescribed substances, equipment and technology. Staff also plays an important role in international activities aimed at the non-proliferation of nuclear weapons. A number of other agencies, both provincial and federal, are involved in the regulation of some activities in the nuclear fuel cycle, but the CNSC retains the primary regulatory function and is the only agency empowered to license the operation of nuclear facilities. The CNSC reports to Parliament through a designated Minister, currently the Minister of Natural Resources. The CNSC also participates in the IAEA activities and ensures compliance with Canada's non-proliferation policy and the Treaty on the Non-Proliferation of Nuclear Weapons.

The licensing process for all nuclear facilities is the most visible function of the CNSC in the control of safety of the nuclear fuel cycle. CNSC regulations require prior authorization in the form of a license to possess, use, export or import nuclear materials or to operate uranium mines and mills, refineries, fuel fabrication plants, heavy water plants, nuclear reactors and waste management facilities. The CNSC develops safety standards, assesses applications, issues licenses, and inspects facilities. Standards applied for radiological protection have been developed over the years at both national and international levels. The basis for the Canadian regulatory radiation dose limits originates from the recommendations of the International Commission on Radiological Protection (ICRP).

The basic approach in all regulatory matters is that the applicant is primarily responsible for safety. The CNSC's role is to ensure that the applicants live up to their responsibility. The onus is on the applicant or the holder of the license to justify the selection of a site, design, method of construction, and mode of operation of a facility, etc.

5.2. Main National Laws and Regulations

The three main national laws relevant to Canada’s nuclear programme are the *Nuclear Safety Act,* the *Nuclear Liability Act* of 1976, and the *Canadian Environmental Assessment Act*, which came into force in January 1995. The *Atomic Energy Control Act* is the primary piece of legislation.

The new Nuclear Safety and Control Act which was developed to replace the Atomic Energy Control Act was be promulgated in May, 2000 after the regulations under the Act were approved. The new legislation requires that licensees of nuclear facilities, including mine sites and nuclear power plants, provide financial assurances for decommissioning of those facilities.

Under the *Nuclear and Safety and Control Act*, the CNSC requires that operators or proponents of nuclear facilities make adequate provisions for the safe operation and decommissioning of existing or proposed operations. Safe operation and decommissioning include the development of acceptable decommissioning plans, the provision of credible estimates of the costs of implementing such plans, the provision of financial assurances to ensure that the costs for decommissioning will be met and, ultimately, the implementation and completion of accepted decommissioning plans.

5.2.1. National Regulation

In the fall of 1995, the federal government introduced new legislation to replace the 50-year-old Atomic Energy Control Act, which is the basis for regulating the Canadian nuclear industry. The new Act, the *Nuclear Safety and Control Act*, replacing the existing *Atomic Energy Control Act* of 1946, received Royal Assent in March 1997. It came into force on 31May 2000, after new regulations in support of the Act were approved.

The *Nuclear Liability Act* (NLA) establishes the legal regime that would apply in the event of a Canadian nuclear accident affecting third parties. The NLA is modelled closely after the Vienna and Paris conventions. The statute, proclaimed in 1976, governs the liability for third-party injury and damage arising from nuclear accidents. Although the basic principals underlying the NLA remain valid, the Act is twenty-five years old, and needs updating to address issues that have become evident over the years, and to keep pace with international trends. Consequently, the federal government has conducted a comprehensive review of the NLA. It is intended to introduce amendments to the legislation sometime in 2002.

The *Nuclear Liability Act* (NLA) governs the liability for third-party injury and damage arising from nuclear accidents. The Act also provides for a well-defined compensation system for victims. The NLA includes provisions for Canada to enter into agreements of reciprocity with any country that provides satisfactory arrangements for compensation. Currently, the only such reciprocity agreement is the one that exists between Canada and the U.S. It ensures that Canadian victims of a U.S. nuclear accident will be compensated by the U.S. operator, and vice versa. The federal government has conducted a comprehensive review of the NLA.

The *Canadian Environmental Assessment Act* (*CEAA*) establishes in legislation the process and the obligations of federal departments and agencies for the conduct of environmental assessments of public or private projects involving the federal government. In 2000, a five year review of the operation and provisions of the *CEAA* was undertaken by the Minister of Environment. A multi-stakeholder consultation was held on a national scale on how to improve the *Act*. The Minister's report and a bill to amend the *CEAA* were tabled in Parliament in March 2001.

5.3. International, Multilateral and Bilateral Agreements

AGREEMENTS WITH THE AGENCY

• Amendments to articles VI & XIV of the Agency statute	Ratified:	15 September 2000
• Agreement on privileges and immunities	Entry into force:	15 June 1966
• NPT related safeguards agreement INFCIRC/164	Entry into force:	21 February 1972
• IAEA additional protocol	Entry into force:	8 September 2000

OTHER MULTILATERAL SAFEGUARDS AGREEMENTS

• India/Canada INFCIRC/211	Entry into force:	30 September 1971
• Japan/Canada INFCIRC/85	Entry into force:	20 June 1966
• Pakistan/Canada INFCIRC/135	Entry into force:	17 October 1969
• Spain/Canada INFCIRC/247	Entry into force:	10 February 1977

MAIN INTERNATIONAL TREATIES

• NPT	Entry into force:	8 January 1969
• Convention on physical protection of nuclear material	Entry into force:	8 February 1987
• Convention on early notification of a nuclear accident	Entry into force:	18 February 1990

• Convention on assistance in the case of a nuclear accident or radiological emergency	Entry into force:	12 September 2002
• Vienna convention on civil liability for nuclear damage	N/A	
• Paris convention on third party liability in the field of nuclear energy	Not signed	
• Joint protocol relating to the application of Vienna and Paris conventions	Non Party	
• Protocol to amend the Vienna convention on civil liability for nuclear damage	N/A	
• Convention on supplementary compensation for nuclear damage	Not signed	
• Convention on nuclear safety	Entry into force:	24 October 1996
• Joint convention on the safety of spent fuel management and on the safety of radioactive waste management	Entry into force:	18 June 2001

OTHER RELEVANT AGREEMENTS

• Improved procedures for designation of safeguards inspectors	Accepted:	8 June 1989
• ZANGGER Committee	Member	
• Acceptance of NUSS Codes	No reply	
• Nuclear Suppliers Group	Member	
• Nuclear Export Guidelines	Adopted	
• Agenda 21 of the UN Conference on Environment and Development		(1992)
• Comprehensive Test Ban Treaty	Signed:	24 September 1996

BILATERAL AGREEMENTS

Canada has bilateral nuclear co-operation agreements with the following countries:

• Argentina	• Indonesia	• Slovakia
• Australia	• Japan	• Switzerland
• Brazil	• Korea, Republic of	• Taiwan
• China	• Lithuania	• Turkey
• Colombia	• Mexico	• Ukraine
• Czech Republic	• Philippines	• Uruguay
• Egypt	• Romania	• United States
• Euratom	• Russia	•
• Hungary	• Slovenia	•

REFERENCES

[1] Data & Statistics/The World Bank, www.worldbank.org/data.

[2] IAEA Energy and Economic Data Base (EEDB).

[3] IAEA Power Reactor Information System (PRIS).

Appendix

DIRECTORY OF THE MAIN ORGANIZATIONS, INSTITUTIONS AND COMPANIES INVOLVED IN NUCLEAR POWER RELATED ACTIVITIES

FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES

Nuclear Energy Division Department of Natural Resources 580 Booth Street Ottawa, Ontario K1A 0E4	Tel: (+1-613) 996-2598 Fax: (+1-613) 995-0087 http://www.nrcan.gc.ca/
Uranium and Radioactive Waste Division Department of Natural Resources 580 Booth Street Ottawa, Ontario, KIA 0E4	Tel: (+1-613) 996-2395 Fax: (+1-613) 947-4205
Atomic Energy of Canada Limited 344 Slater Street, 18th Floor Ottawa, Ontario K1A 0S4	Tel: (+1-613) 237-3270 Fax: (+1-613) 782-2061 http://www.aecl.ca/
2251 Speakman Drive Mississauga, Ontario L5K 1B2	Tel: (+1-905) 823 9040 Fax: (+1-905) 403 7301
Canadian Nuclear Safety Commission 280 Slater Street, 4th Floor Reception P.O. Box 1046, Station B Ottawa, Ontario K1P 5S9	Tel: (+1-613) 995-5894 or 992 88 28 Fax: (+1-613) 995-5086 http://www.cnsc.gc.ca/

FIRMS INVOLVED IN THE FRONT END OF THE FUEL CYCLE

Cameco Corporation 2121 - 11th Street West Saskatoon, Saskatchewan S7M 1J3	Tel: (+1-306) 956-6200 Fax: (+1-306) 956-6302 http://www.cameco.com/index.html
Uranerz Exploration and Mining Limited 410 - 22nd Street E., Suite 1300 Saskatoon, Saskatchewan S7K 5T6	Tel: (+1-306) 668-1711 Fax: (+1-306) 652-3731
Cogema Resources Inc. 817 - 825, 45th Street West, Box 9204 Saskatoon, Saskatchewan S7K 3X5	Tel: (+1-306) 343-4502 Fax: (+1-306) 653-3883
Rio Algom Limited 120 Adelaide Street West, Suite 2600 Toronto, Ontario M5H 1W5	Tel: (+1-416) 367-4000 Fax: (+1-416) 365-6870
Denison Mines Limited Atrium on Bay - Suite 320 40 Dundas Street West Toronto, Ontario M5G 2C2	Tel: (+1-416) 979-1991 Fax: (+1-416) 979-5893

RELEVANT ASSOCIATIONS

Uranium Saskatchewan Association Inc. 600 Spadina Crescent East Saskatoon, Saskatchewan S7K 3G9	Tel: (+1-306) 242-8222 Fax: (+1-306) 244-4441
Canadian Nuclear Association 130 Albert Street, Suite 1610 Ottawa, Ontario K1P 5G4	Tel: (+1-613) 237-9082 Fax: (+1-613) 237-0989
Canadian Electrical Association 1 Westmount Square, Suite 1600 Montréal, Québec H3Z 2P9	Tel: (+1-514) 937-6181 Fax: (+1-514) 937-6498
Electrical and Electronic Manufacturers Association 10 Carlson Court Suite 210 Rexdale, Ontario M9W 6L2	Tel: (+1-416) 674-7410 Fax: (+1-416) 674-7412

RELEVANT POWER UTILITIES

Ontario Power Generation 700 University Avenue Toronto, OntarioM5G 1X6	Tel: (+1-416) 592-3453 http://www.opg.com/default2.asp
Bruce Power P.O. Box 1540 Tiverton, Ontario, NOG 2T0	Tel. 519-361-3550 Fax: 519-361-3325 http://www.brucepower.com/
Hydro-Québec 75, boul. René Lévesque ouest Montréal, Québec H2Z 1A4	Tel: (+1-514) 289-3811 Fax: (+1-514) 289-3342 http://www.hydro-quebec.com/en/
SaskPower Corporation 2025 Victoria Avenue Regina, Saskatchewan S4P 0S1	Tel: (+1-306) 566-2121 Fax: (+1-306) 566-3523 http://www.saskpower.com/
New Brunswick Power Corporation 515 King Street P.O. Box 2000 Fredericton, New Brunswick E3B 4X1	Tel: (+1-506) 458-4342 Fax: (+1-506) 458-4390 http://www.nbpower.com/en/index.html

CANDU INDUSTRY

Monenco Agra Inc. Monenco Agra Building 2010 Winston Park Drive, Suite 100 Oakville, Ontario L6H 6A3	Tel: (+1-905) 829-5399 Fax: (+1-905) 829-5401
Babcock and Wilcox Canada P.O. Box 310 581 Coronation Boulevard Cambridge, Ontario N1R 5V3	Tel: (+1-519) 621-2130 Fax: (+1-519) 621-5610

Canatom Inc.
2020 University, Suite 2200 — Tel: (+1-514) 288-1990
Montréal, Québec H3A 2A5 — Fax: (+1-514) 289-9813

CAE Electronics Ltd.
C.P. 1800 — Tel: (+1-514) 341-6780
Saint-Laurent, Québec H4L 4X4 — Fax: (+1-514) 341-7699

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C.P. 1800 — Tel: (+1-514) 341-6780
Saint-Laurent, Québec H4L 4X4 — Fax: (+1-514) 341-7699

Dominion Bridge
500 Notre-Dame Street — Tel: (+1-514) 634-3551
Lachine, Québec H8S 2B2 — Fax: (+1-514) 631-2668

GE Canada Inc.
Nuclear Products
107 Park Street North — Tel: (+1-705) 748-7509
Peterborough, Ontario K9J 7B5 — Fax: (+1-705) 748-7338

RADIOISOTOPES

Nordion International Inc.
447 March Road — Tel: (+1-613) 592 2790
Kanata, Ontario K2K 1X8 — Fax: (+1-613) 592 5302

HIGH ENERGY RESEARCH INSTITUTES

Canadian Institute for Synchrotron Radiation (CISR) — http://www.uwo.ca/cisr/index.html

TRIUMF (Canada) — http://www.triumf.ca/

Centre canadien de fusion magnétique (CCFM) — http://www.ccfm.ireq.ca/

INRS - Energie et Matériaux — http://www.inrs-ener.uquebec.ca/

Plasma Physics Laboratory at the University of Saskatchewan — http://physics.usask.ca/research/plasma.htm

UNIVERSITIES

University of Saskatchewan — http://www.usask.ca/

University of Western Ontario — http://www.uwo.ca/

OTHER ORGANIZATIONS

Canadian Centre for Occupational Health and Safety (CCOHS) — http://www.ccohs.ca/

Canadian Coalition for Nuclear Responsibility (CCNR) — http://www.ccnr.org/

Friends of the Earth (Canada)	http://www.foecanada.org/
War, Peace and Security WWW Server (Department of National Defense, Canada)	http://www.cfcsc.dnd.ca/
Energy Council of Canada (ECC)	http://www.energy.ca/
Canadian Nuclear Association	http://www.cna.ca/
Canadian Nuclear Society (CNS)	http://www.cns-snc.ca/
Atlantic Nuclear Services Ltd. (ANSL)	http://www.ansl.ca/
Can Nuke Technologies Ltd	http://www.cannuke.com/
International Energy Foundation (IEF)	http://www.cableregina.com/nonprofits/ief/Index.htm