

**ECONOMIC IMPACT OF THE NUCLEAR INDUSTRY
IN CANADA**

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Highlights

Economic Impact Study on the Nuclear Industry in Canada

- 1) The value of production of the nuclear industry (uranium production, nuclear electricity generation, reactor sales and service, fuel and isotope production, research and development) was about \$5 billion in 2001.
- 2) Canada's nuclear electricity generating capacity provided 13% of total electricity in 2002.
- 3) The impact of nuclear generated electricity on Gross Domestic Product for Canada was some \$2.0 billion in 2001.
- 4) Exports of uranium, nuclear generated electricity, heavy water, reactor fuel and isotopes were some \$1.2 billion in 2001.
- 5) Total employment in the nuclear industry in Canada is over 30,000 with 20,794 direct jobs and 11,771 indirect jobs created in association with the nuclear industry in 2002.
- 6) Direct and indirect annual employment associated with the generation of electricity by nuclear fission in Canada was about 25,000 in 2001.
- 7) Canada ranks first in the world for high-grade uranium deposits with known uranium resources of over 400,000 tonnes and is the world's largest producer of uranium, providing over one third of total world production.
- 8) Canada is the world's leading supplier of medical isotopes used to diagnose, prevent and treat disease in over 80 countries and produces 75% of the world's supply of Cobalt-60 used to sterilize some 40% of the world's disposal medical supplies.
- 9) Sales of two 720 MW CANDUs abroad result in exports from Canada of over \$760 million during the period of their construction and generate some 9,700 person years of employment.
- 10) Atomic Energy of Canada (AECL) estimates that the supply of nuclear and non-nuclear components for reactor projects and services is provided from 1500 direct manufacturers located in Canada for export overseas.
- 11) In Canada if two CANDU reactors, each of 720 MW capacity, were constructed, the economic impact on GDP would be approximately \$2.6 billion over the period of their construction. Total person years of employment associated with two reactor construction projects are about 40,000.
- 12) The Canadian Nuclear Association (CNA) reports that the value of electricity generated from nuclear power reactors in Canada over an assumed life span of forty years is estimated to be in excess of \$177 billion.

Executive Summary

The purpose of this study is to describe the Canadian nuclear industry and assess its overall economic impact.

The existence of Atomic Energy of Canada Limited (AECL), the fact that Canada is rich in uranium resources, and the existence of a substantial nuclear electricity generating capacity and a world scale isotope manufacturing industry makes the Canadian nuclear industry as diverse as any in the world:

- Canada has substantial known uranium resources, over 400,000 tonnes. It ranks third in the world for total uranium deposits and is the world's largest producer of uranium, providing over one third of total world production.
- Processing facilities exist to refine uranium.
- Canadian companies fabricate fuel for CANDU reactors.
- There are 22 nuclear power reactors in Canada. Of the eight that are currently laid up, three are scheduled to return to service in 2003 and another three over the next three years. Nuclear reactors collectively provided about 13 percent of all the electricity produced in Canada in 2001, and over 41 percent in Ontario.
- Canada is the world's leading supplier of medical isotopes. Radiation therapy equipment produced in Canada is used in cancer clinics and hospitals around the world.
- AECL has been Canada's main nuclear research body since the 1950s and the developer of the CANDU reactor.
- There are currently eight "operating" research reactors in Canada: two at AECL's Chalk River Laboratories and six at universities.

With respect to the value of production by the nuclear industry, the generation of electricity by nuclear power plants is by far the largest component.

Substantial shares of Canadian production of uranium, nuclear-generated electricity and reactor fuel, radioisotopes and heavy water are sold abroad. In addition, a number of CANDU reactors have been sold to other countries and these entail the export of goods and services from Canada when the reactors are being built.

Over 80 percent of the uranium produced in Canada is exported. Uranium exports peaked in 1996 in both volume and value terms, and declined in 1998 and 1999. In the past two years exports have recovered in value and volume terms. The value of uranium exports was \$467 million in 2001.

On the assumption that electricity exports are generated from a fuel mix similar to that used for total generation, the amount and value of exports of nuclear-generated electricity are estimated to have been 3.7 million MW.h and \$195.1 million, respectively, in 2000.

In total, the annual export value of nuclear fuel, isotopes and heavy water has averaged between \$300-400 million except for 2001. In that year they were upwards of \$500 million due to large exports of heavy water.

Employment data for the nuclear industry were collected with a view to obtaining information about its quality as well as quantity. To that end, a questionnaire was developed requesting information on numbers of employees by skill level and status – full-time, part-time or on contract:

- Employment in uranium mining and milling has declined substantially from a peak level of 2,772 in 1998 to some 1,632 in 2001. Most of the decline was in contract employees associated with completion of the McArthur project.
- In contrast, employment in uranium processing plants has tended to increase, from 196 full time employees in 1996 to 390 employees in 2001.
- Total employment in Canada's nuclear power reactors was 13,542 in 2002.
- The labour force in reactors is relatively highly skilled; almost 20 percent of employees have university degrees and over 52 percent have more than two years of post-secondary education.
- In 2002, there were approximately 1,370 people employed in the fuel fabrication and isotope production industries in Canada of which seventy-five percent have at least 2 years of post-secondary education.
- Over three thousand employees support AECL's activities. The majority is highly educated having at least two years of post-secondary education.

Total direct employment in the nuclear activities considered in this study was over 20,000 in 2001-02. The additional, indirect, employment associated with the provision of goods and services to nuclear electricity generators is estimated to be 12,000 annually. Thus, the total employment associated with nuclear activities is over 30,000 person years.

Annual incremental employment associated with nuclear electricity generation is estimated to be close to 12,000 nationwide, of which some 9,300 jobs occur in Ontario. Combined with the 13,542 people employed directly by the nuclear generators, the total annual employment, direct and indirect, associated with the generation of nuclear electricity is estimated to have been some 25,000 in 2002.

The employment associated with the export of CANDUs is estimated to total some 9,700 person years.

The employment numbers are not additive across the three cases simulated: the construction and export employment numbers are person year estimates – the employment will be spread over a number of years.

Given the overwhelming importance of nuclear-generated electricity and CANDU construction in the nuclear industry, the assessment of overall economic impact for this study focussed on analysis of these three categories of production.

The value of nuclear-generated electricity used for this analysis is \$2.7 billion, the estimated value of the generation at the busbar. Of this total some \$1.4 billion is estimated

to have been value added by generators and \$1.2 billion of purchased inputs from other industries.

The impact of nuclear-generated electricity on Gross Domestic Product (GDP) for Canada is estimated to have been \$2.0 billion in 2001. The impact is less than the value of nuclear energy produced because part of that value ‘leaks’ abroad when goods and services used in the production process are imported. As would be expected, the bulk of the impact occurs in Ontario followed in order of size by Quebec, the Atlantic region and the Prairies/BC/Territories. In the Atlantic region most of the impact is in New Brunswick where the Point Lepreau reactor is located.

The economic impact of reactor construction in Canada was simulated by assuming that two units, each of 720 MW capacity, were constructed in Ontario. Of the estimated total cost of the reactors of some \$3.4 billion, about \$2.2 billion consists of value added (payments to labour and capital used directly in the reactors’ construction) and \$1.2 billion of purchased inputs from other industries.

Indirect employment, in terms of numbers of person years, spread over the construction period, associated with reactor construction in Ontario is about 6200. This is in addition to the 34,000 person years of employment that, according to AECL, are likely to be associated directly with construction of the reactor itself. Thus total person years of employment associated with the construction of two 720 MW CANDUs in Canada is estimated to be about 42,000.

Regionally, the impacts are concentrated in Ontario. The labour income associated with construction of the reactors would, of course, accrue to residents of that province and impacts associated with purchased inputs are also concentrated there.

It is important to note that the construction of CANDUs would occur over a number of years. Thus, the economic impact would be correspondingly spread out over the time period taken to complete construction.

When CANDU reactors are exported there will be an economic impact on Canada as AECL receives license fees and sells its project management and other consulting services to the importing country. Further, some of the reactor components may be purchased in Canada. The impact of the export of two 720 MW reactors was simulated using data supplied by AECL.

Sales of CANDUs abroad result in substantial exports from Canada, some \$763 million in total of which over \$300 million – 40 percent – consist of ‘architect, engineering and related services’. These largely represent payments to AECL for project management and technical advice. Other exports are widely distributed across a range of goods and services. Because indirect import leakage associated with the direct export of reactor goods and services is relatively small, the impact on GDP – some \$610 million – is large relative to the initial exports of \$763 million. Again the impact is overwhelmingly in Ontario.

The industry snapshot provided by this study will change as the industry develops:

- existing CANDU reactors are scheduled to return to service in Ontario;
- two 'MAPLE' reactors for the production of isotopes are nearing completion; and
- AECL is working on a new reactor design -- the Advanced CANDU Reactor.

An analysis additional to that provided in this study would be needed to assess the overall benefits of the nuclear industry to Canadian society.

1.0 Introduction

The purpose of this study is to describe the Canadian nuclear industry and assess its overall economic impact, specifically to:

- describe the characteristics of the components of the Canadian nuclear industry: uranium mining and processing, electricity generation, fuel fabrication and isotope production, waste management, and research and development;
- outline the economic dimensions of industry components including: value and volume of production, exports, investment and employment; and
- assess the direct and indirect economic impacts of the largest components of the nuclear industry, actual and potential, on the Canadian economy– electricity generation from existing facilities, the construction of a new nuclear generation facility in Canada, and the Canadian content associated with the export of a pair of CANDU nuclear reactors – on the Canadian economy.

The information required to conduct the study was obtained from:

- a literature review of relevant reports and documents;
- companies in the Canadian nuclear industry involved in electricity generation, uranium production and processing, fuel fabrication and isotope production, and research and development; and
- analysis using Statistics Canada’s national and interprovincial Input Output models.

Since its development in the 1940s nuclear energy has been harnessed to produce electricity and to diagnose and treat disease, and it is used in a number of other applications. In Canada development of a nuclear industry was stimulated by the creation of a Crown Corporation – AECL – in 1952.

The existence of AECL, the fact that Canada is rich in uranium resources – the raw material used to generate nuclear energy – and the existence, in 2003, of a substantial nuclear electricity generating capacity and a world scale isotope manufacturing industry means that the Canadian nuclear industry is as diverse as any in the world. It extends from research and development (R&D), fundamental and applied, through the exploration for uranium and the production of nuclear fuel, to the use of nuclear energy in a variety of production processes. Thus, Canada’s nuclear industry contributes to many sectors of the economy: uranium mining, the manufacture of reactor fuel, the generation of electricity and the production of radioactive isotopes for use in medicine, industry and agriculture.

Advances in nuclear technology are moving the industry toward ‘next generation’ mines, mills, reactors and medicines and efforts are underway to further improve upon safety and waste management practices. Accordingly, there is a relatively large R&D component associated with the ‘industry’.

The diffuse nature of nuclear activities makes it difficult to conduct a comprehensive integrated analysis of its economic impact. This is so because there is no ‘nuclear industry’

identified as such in the National Accounting framework used to measure economic activity. The ‘nuclear’ concept refers to the generation of energy by fission, using uranium.

Ongoing economic activities related to the production and uses of nuclear energy are spread over a number of industries:

- uranium mining in the mining industry;
- nuclear fuel fabrication and isotope production in the manufacturing industry;
- electricity generation from nuclear power plants in the electric generation industry; and
- research and development in the service industries.

In addition there is, on a less regular basis, substantial economic activity resulting from the construction of CANDU reactors in Canada and abroad. Such activity affects the Gross Domestic Product (GDP) directly as investment spending in the case of reactor construction in Canada. When CANDU reactors are sold to other countries they lead to exports of goods and services from Canada as reactor components and professional services are purchased in this country.

Further, all spending by components of the nuclear industry has widespread indirect effects as large numbers of firms in a range of Canadian industries supply goods and services to firms engaged in nuclear-related production.

In addition to being diverse in nature, the different nuclear activities are quite different in scale. As will be seen, some are quite small in relative terms. For example, the value of fuel fabrication and isotope production in 2001 is estimated to have been \$308 million. Though of critical importance in other respects – the value of isotopes in the treatment of cancer, for example – in macroeconomic terms it is small.

The components of the nuclear industry in Canada with the largest economic impact are: the generation of electricity, the production and processing of uranium, and the construction of CANDU reactors. With respect to assessing the overall economic impact, direct and indirect, this study concentrates on electricity generation and CANDU construction.

It is important to note that this study does not describe or assess the economic impact of all nuclear-related activities in Canada. For example, there are a number of firms that produce and export components used in reactors other than CANDU's. Such firms are integrally engaged in the manufacture of reactor components and the provision of nuclear engineering services. The economic impact of their activities is captured in this study to the extent their production is sold to builders of CANDU reactors. To the extent their production is sold to builders of other reactor types in other countries this analysis will not capture the impact.

Section 2 outlines the composition and characteristics of the components of the Canadian nuclear industry. The economic dimensions of the industry components are described in section 3.0. Section 4.0 describes the direct and indirect impacts of the largest

components of the industry, electricity production and reactor construction. As noted, these impacts were determined using Statistics Canada's Input/Output models.

2.0 The Canadian Nuclear Industry

Canada is a pioneer in developing nuclear energy for peaceful uses. The industry spans the nuclear fuel cycle, and includes uranium mining and electricity production, nuclear research and development, the application of nuclear technology in the medical field, and the management of nuclear fuel-waste.

The federal government has funded nuclear research and development for several decades. Government support has enabled Canada to develop its own nuclear reactor technology and other related technologies.

2.1 The Role of Atomic Energy of Canada Limited

For many years, AECL, a federal Crown corporation, has served as the national laboratory for nuclear research and development to support and advance CANDU nuclear reactor technology. AECL is the centre for neutron beam and materials research in Canada.

Recently, the National Research Council (NRC) and AECL developed a proposal for a Canadian Neutron Facility to replace the National Universal Research reactor, which is nearing the end of its life. In addition, two isotope production reactors are under construction at Chalk River.

In 1994, the federal government altered AECL's mandate requiring it to concentrate on "its role as a reactor designer and vendor"¹ AECL is still responsible for most nuclear R&D occurring in Canada and it develops, markets and manages the construction of CANDU power reactors (AECL's core business product) and MAPLE research reactors. In addition, AECL provides engineering and consulting services to owners of CANDU reactors at home and abroad, and offers radioactive waste management products and services.

CANDU reactors have been successfully installed and sold in a number of other countries. Eight CANDU reactors are currently in operation outside Canada. They operate in China (two), South Korea (four), Argentina (one) and Romania (one). A second unit is under construction in Romania.

The two 728 MW reactors at Qinshan in Eastern China are the most recent to have been completed. They entered service in 2003.

2.2 Uranium

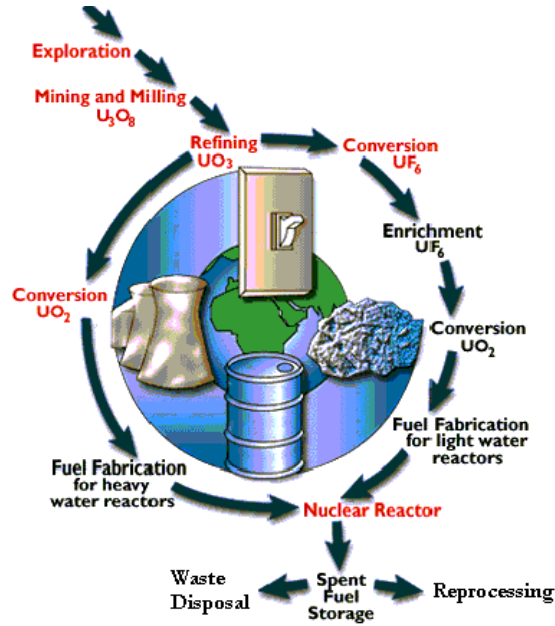
Uranium is one of the most common heavy elements in nature, traces of it occur almost everywhere.

Once a uranium deposit is discovered, the mined uranium undergoes a series of steps (mining, milling, enrichment for non-CANDU reactors, and fuel fabrication) at the 'front end' of the nuclear fuel cycle (Figure 1) to prepare it for use in a nuclear reactor.

¹AECL. "Report of the AECL Research & Development Advisory Panel for 2001". pg. 8.

After being used in a reactor to produce electricity the 'spent fuel' may undergo a further series of steps including temporary storage, reprocessing, and recycling before eventual disposal as waste. Collectively these steps are known as the 'back end' of the fuel cycle.

**Figure 1
Nuclear Fuel Cycle**



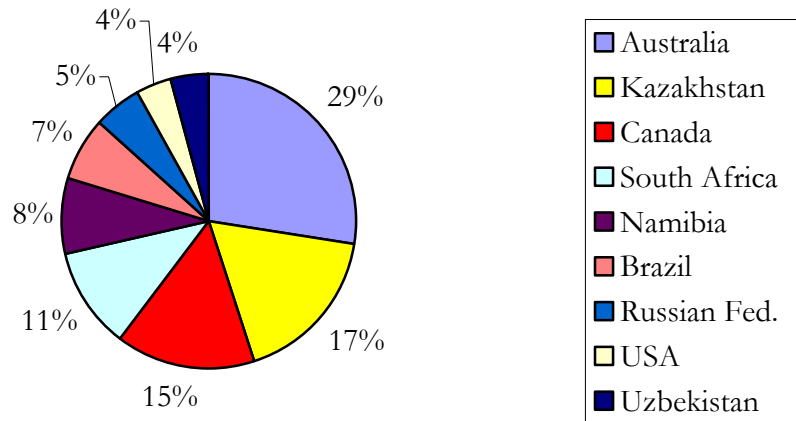
Source: Cameco Corporation.

Canada has substantial “known” uranium resources,² over 400,000 tonnes. It ranks third in the world for total uranium deposits and has the world’s largest known high-grade deposits.

Other countries with more than 10 percent of the world total are Australia, Kazakhstan, and South Africa (Figure 2).

²The estimates of "known" resources [i.e., measured + indicated + inferred] represent tonnages estimated to be recoverable from mineable ore at prices of \$100/kgU or less.

Figure 2
Known Recoverable Resources of Uranium



Source: Uranium: Resources, Production and Demand 1999, OECD NEA & IAEA, July 2000.

In Canada, uranium ores were first produced in the early 1930s when the Eldorado Gold Mining Company began operations at Port Radium, Northwest Territories, to recover radium, a substance found in uranium ore. A refinery to produce radium was built the following year at Port Hope, Ontario.³ Exploration intensified in the early 1940s, in response to a request to supply the USA nuclear weapons program. By the late 1950s, 23 mines with 19 treatment plants were in operation in five districts. The main production centre was around Elliot Lake in Ontario, but northern Saskatchewan hosted some plants. This first phase of Canadian uranium production peaked in 1959 when more than 12,000 tonnes were produced. Uranium yielded more in export revenue than did any other mineral export from Canada in that year.⁴

Exploration waned in the 1960s but was revived during the 1970s, concentrated in northern Saskatchewan's Athabasca Basin. All major uranium discoveries in Canada in the last twenty years have occurred in the Athabasca Basin although there is some activity at the Thelon Basin in Nunavut.

The first uranium discovery in Saskatchewan occurred in 1950 at Beaverlodge.⁵ In 1968 the Rabbit Lake deposit was discovered in northern Saskatchewan, and was brought into production in 1975. Cluff Lake and Key Lake were discovered in the Athabasca Basin in 1972 and 1975 respectively; they started production in 1980 and 1983 respectively. Exploration expenditure in the region peaked at this time, resulting in the discoveries of

³Hans Tammemagi and David Jackson, "Unlocking The Atom", The Canadian Book on Nuclear Technology", McMaster University Press, 2002, pg 182.

⁴Ibid., pg 183.

⁵Ibid., pg 183.

Midwest, McClean Lake and Cigar Lake. Then in 1988 the newly formed Cameco Corporation discovered the massive McArthur River deposit.

The uranium ore deposits discovered in Saskatchewan were a higher grade than the resources in Ontario, making it difficult for Ontario operations to compete. The Ontario mines were shut down in the early 1990s and have now been decommissioned. All of Canada's uranium production is now located in Saskatchewan.

Canada is the world's largest producer of uranium, providing over one third of total world production. The major uranium mining companies in Canada are Cameco Corporation and COGEMA Resources Inc. There are currently three producing mines in Saskatchewan: McClean Lake, Rabbit Lake, and McArthur River. Cameco, in partnership with COGEMA, hopes to bring Cigar Lake on stream by 2005, although regulatory processes have not been completed.

Mined uranium ore is sent to a mill, usually located close to the mine, where the uranium is separated from the waste rock as uranium concentrate. This product is trucked to refining plants in Blind River and Port Hope, Ontario.

At the Blind River facility, the concentrates are first refined to remove impurities. They are then chemically converted to uranium trioxide (UO_3). Uranium trioxide is transported by truck to Port Hope where it is converted to either uranium dioxide (UO_2), or to uranium hexafluoride (UF_6). About 80 percent of the UO_3 from Blind River is converted to UF_6 to be shipped outside of Canada where it is enriched for use in light water reactors. The UO_2 is used to fabricate fuel bundles for CANDU reactors in Canada and abroad.

Two Canadian companies fabricate fuel for CANDU reactors: Zircotec Precision Industries manufactures fuel pellets and fuel bundles and General Electric (GE) Canada assembles fuel bundles.

2.3 Electricity Production

The first prototype nuclear reactor in Canada was the Nuclear Demonstration Plant (NPD) in Rolphton, Ontario that entered service in 1962. Next came Douglas Point, which began operating in late 1966, Pickering A, which went into operation between 1971 and 1973 and Bruce A, a station with four 900 MWe class units, in 1977.

In the 1980s more CANDUs were constructed: a 600 MWe class unit at Point Lepreau, New Brunswick; a similar unit at Gentilly, Quebec; four 600 MWe class units at Pickering B in Ontario; and four 900 MWe class units at Bruce B in Ontario. The four 935 MWe units at Darlington station in Ontario were completed in 1993.

In December 1997, the four reactors at Pickering A were laid up. Bruce A units were laid up in 1995 and 1998. Thus, of the 22 nuclear power reactors in Canada, eight were laid up in January 2003.

Work is underway to return to service six of the eight laid-up units in Ontario (four at the Pickering A station and two at Bruce A station). The refurbishment at Pickering A,

will add 2,160 MWe capacity to the Ontario system and is expected to enable these units to operate until approximately 2015. The two refurbished units at Bruce A are scheduled to be restarted in 2003. New Brunswick Power and Hydro Québec are also considering refurbishment of the Point Lepreau and Gentilly 2 units, respectively.

If all the reactors in Canada were operating after refurbishment and life extension, their combined capacity would represent about 19 percent of Canada's electricity generating capacity. The status of nuclear reactors in Canada in 2002 is listed in Table 1.

Table 1
Status of Canadian Nuclear Reactors 2002
(gross generating capacity)

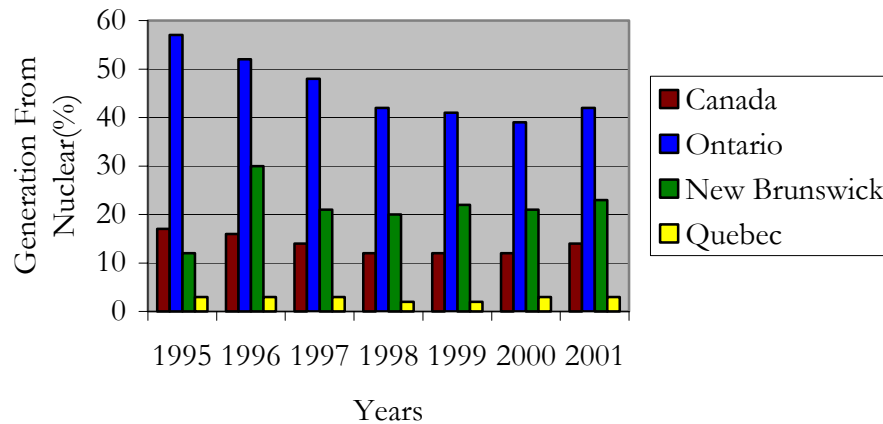
Site	Reactors	Status	Installed Capacity (MW)	
			Gross	Net
Bruce A	4	Laid up	3,300	3,000
Bruce B	4	Operating	3,440	3,140
Pickering A	4	Laid up	2,168	2,060
Pickering B	4	Operating	2,160	2,064
Darlington	4	Operating	3,740	3,524
Gentilly 2	1	Operating	685	635
Point Lepreau	1	Operating	680	635
Total	22		16,077	15,154

SOURCE: CANDU Owners Group website: www.candu.org.

In May 2001, Ontario Power Generation (OPG) leased the two stations at the Bruce site on Lake Huron to a private company, Bruce Power Inc., until 2018 with an option to extend the lease for a further 25 years.

Nuclear reactors collectively provided 13.2 percent of all the electricity produced in Canada in 2001, and over 41 percent of the electricity used in Ontario. In general, the nuclear share of Canada's total electrical generation has declined since the mid 1990s, both because of the reduction in operating capacity at Bruce and Pickering and the continuing growth in total generation. (Figure 3).

Figure 3
Nuclear Percentage of Total Electricity Generation



Source: Statistics Canada (57-202).

2.4 Radioisotopes

Radioisotopes for medical and industrial applications have been produced at the Chalk River research reactors since the 1940s. In 1951 the world's first cobalt radiotherapy units for the treatment of cancer were produced and installed in hospitals in London, Ontario, and in Saskatoon, Saskatchewan.

The main producer of isotopes in Canada is MDS Nordion, a company formed originally in 1946 as the radium sales department of Eldorado Mining and Refining (1944) Ltd. It was soon transferred to AECL and began to market a variety of radioisotopes produced at the NRC's reactor at Chalk River. As a result of research and development conducted at AECL, the division began to produce isotopes for commercial use in 1972. In 1991 the commercial products division of AECL – known as Nordion International Inc. – was sold to MDS Health Group. It is now known as MDS Nordion and is the world's leading supplier of medical isotopes.

MDS Nordion specializes in radioisotopes, radiation and related technologies used to diagnose, prevent and treat disease in over 80 countries. The company's radiation therapy equipment is used in cancer clinics and hospitals around the world and it is used in about 15 million cancer treatments every year. MDS Nordion supplies over two-thirds of the world's medical isotopes. Some 13 million diagnostic imaging procedures are performed globally using medical isotopes from MDS Nordion. The Ottawa-based company is also working with outside partners to develop and manufacture new radiopharmaceuticals to treat cancer, such as non-Hodgkin's lymphoma, and to produce new proprietary treatments, such as for liver cancer.

Canada is the world's largest supplier of cobalt-60, produced in CANDU reactors at (Bruce Power) Pickering (Ontario Power Generation) and Gentilly – 2 (Hydro Québec) and processed by MDS Nordion.

MDS Nordion's cobalt-60 irradiation systems are used by companies to sterilize some forty percent of the world's disposable medical supplies and a vast array of consumer products. Its equipment is also used to make the world's food supply safer by destroying harmful bacteria that cause food-borne disease.

2.5 Waste Management

The Canadian Nuclear Fuel Waste Management Program was established in 1978 to ensure the safe and permanent disposal of nuclear wastes. The primary responsibility for management of radioactive wastes in Canada lies with the producers and owners of the wastes. The Canadian Nuclear Safety Commission (CNSC) licenses sites where nuclear wastes are stored.

On June 13, 2002, the Government of Canada passed legislation dealing with the long-term management of the country's spent reactor fuel. The legislation requires nuclear power generators to establish a waste management organization the Nuclear Waste Management Organization (NWMO) that will recommend, by November 15, 2005, a long-term solution to the disposal of the waste now stored at the nuclear reactors. The project is to be financed from a trust fund set up by OPG, New Brunswick Power and Hydro Québec. The Government of Canada will make a decision on the long-term waste management option to be used. Implementation of the decision is to be the responsibility of NWMO.

2.6 Role of Government

The Nuclear Safety and Control Act, which replaced the Atomic Energy Control Act, came into effect in May 2000. It established CNSC as a successor to the Atomic Energy Control Board. The Act provides the CNSC with the necessary mandate, tools and independence to regulate the nuclear industry. The CNSC is an independent agency of the Government of Canada and reports to parliament through the Minister of Natural Resources.

The CNSC regulates nuclear power plants, nuclear research facilities and numerous other uses of nuclear material including radioisotopes, the operation of uranium mines and refineries, and radioactive devices used in a variety of applications such as oil exploration and precipitation measurement.

In addition, trade in nuclear materials is governed by the CNSC's act and regulations, and in accordance with international and bilateral agreements and Canadian non-proliferation policy.

2.7 Research and Development

Nuclear research in Canada is conducted by a number of bodies including: AECL, the CANDU Operators Group (COG), the NRC, the nuclear power generating companies, MDS Nordion, other private sector companies, universities and other institutions.

Atomic Energy of Canada Limited

As noted, AECL has been Canada's main nuclear research body since the 1950s. Chalk River laboratories serve as the hub for AECL's research and development activities.

The AECL R&D program includes work needed to ensure that CANDU technology has a solid technical base, and applied programs that result in qualification of equipment, processes and systems for power and research reactors.

AECL's research focuses on eight key technologies: safety; fuel and fuel cycles; fuel channels; components and systems; heavy water production and processing; environment, emissions and waste management; control and information; and constructability.

AECL is currently pursuing detailed work on a "next generation" design of the CANDU Reactor – the ACR 700. It is expected to have a 40 percent lower capital cost, shorter construction time, and produces less waste than the current generation of CANDUs. The target is to have this new design come to market in 2005.

CANDU Operators Group

To aid in nuclear research, COG was formed in 1984 by an agreement among the Canadian CANDU-owning utilities Ontario Hydro (now Ontario Power Generation), Hydro-Québec and New Brunswick Power, plus AECL. The purpose of COG is to provide programs for co-operation, mutual assistance and exchange of information for the successful support, development, operation, maintenance and economics of CANDU technology. The foreign organizations that own CANDU units are now also members of COG.

Under the original agreement, the former Ontario Hydro was the administrator of COG, reporting to a Directing Committee comprised of representatives of the four Canadian Members. However, in 1999 COG was registered as a not-for-profit corporation, and a Board of Directors was appointed to replace the previous Directing Committee.

In 2001, Bruce Power joined COG as an independent Canadian member. Currently COG membership includes six Canadian and five offshore members (Argentina, Romania, Pakistan, India⁶ and South Korea).

The COG Research & Development Program addresses current and emerging operating issues to support the safe, reliable and economic operation of CANDU reactors in the areas of safety and licensing, fuel channels, health and environment, and chemistry, materials and components.

The two main sources of funding for COG are annual membership fees and project subscriptions. Members have access to the results of the R&D projects.

⁶ The terms of membership are different for Pakistan and India than for other members.

In addition to R&D, COG facilitates sharing of information with respect to safety, reliability and performance of CANDUs.

National Research Council

NRC operates a neutron beam laboratory at Chalk River, not as a facility for "nuclear R&D" as such, but to use neutrons from the Chalk River nuclear research reactor to probe materials of all kinds to extract information about molecular structures and dynamics. NRC operates a suite of five neutron beam instruments as an international facility to which researchers and students travel to carry out experimental measurements on a wide range of materials in all physical science disciplines.

In addition, this laboratory operates as a centre for the training of highly qualified personnel. It supports graduate student research (about 40 graduate student research visitors each year), and projects by post-doctoral and other young researchers from universities across Canada and abroad.

Research Reactors

There are currently eight "operating" research reactors in Canada: two at AECL's Chalk River Laboratories and six at universities (Table 2).

Research reactors have a wide range of uses, including analysis and testing of materials and production of radioisotopes.

**Table 2
Research Reactors in Canada**

Non-Power Reactors	Total Staff	Annual Operating Cost (\$Cdn Million)	Owner	Status
Chalk River (NRU)	200	20	AECL	Operating
Chalk River (ZED-2)	5	.3	AECL	Operating
McMaster University (MTR-type research reactor)	10	1.1	McMaster University	Operating
Ecole Polytechnique (Slowpoke-2)	4	.22	Univ. of Montreal	Operating
Dalhousie University (Slowpoke-2)	3	.12	Dalhousie Univ.	Operating
Saskatchewan Research Council (Slowpoke-2)	6	.05	SRC	Operating
University of Alberta (Slowpoke-2)	4	.1	U of A	Operating
Royal Military College of Canada (Slowpoke-2)	8	1	Royal Military College	Operating

Source: International Atomic Energy Agency (IAEA).⁷

⁷International Atomic Energy Agency website, <http://www.iaea.org/worldatom/rrdb/>. Accessed September 2002.

3.0 Economic Dimensions of the Nuclear Industry

As noted above, the main activities of the nuclear sector are uranium mining and nuclear reactor fuel production, electricity generation, radioisotope production, the design and construction of CANDU reactors, and research and development. This section brings together available information on a number of economic dimensions of each component: production, exports, investment and employment.

3.1 Production

Uranium/Fuel Fabrication

Canada's uranium production increased from 1995 to 1997 followed by declines in 1998 and 1999. Production rebounded to a record level in 2001, up 17 percent from 2000, following the start of production at the new McArthur River mine in 1999 (Table 3).

Table 3
Uranium Production
[Tonnes of Uranium and Value (Millions of Cdn\$)]

	1995	1996	1997	1998	1999	2000	2001
Cluff Lake	1,214	1,926	1,962	1,039	1,230	1,462	1,269
McClean, Sask	-	-	-	-	-	2,308	2,539
Rabbit Lake	3,148	3,976	4,663	4,500	2,693	2,808	1,755
McArthur River, Sask	-	-	-	-	-	3,739	6,640
Key Lake, Sask	5,464	5,429	5,434	5,385	3,731	415	299
Stanleigh	647	378	Closed	0	0	0	0
Canadian Total	10,473	11,706	12,059	10,924	8,232	10,732	12,502
World	33,300	35,784	35,692	33,728	31,065	34,734	35,500
Value of Canadian Production (Millions \$)	492	627	619	558	404	512	583

Source: Saskatchewan Mining Association and World Nuclear Association.

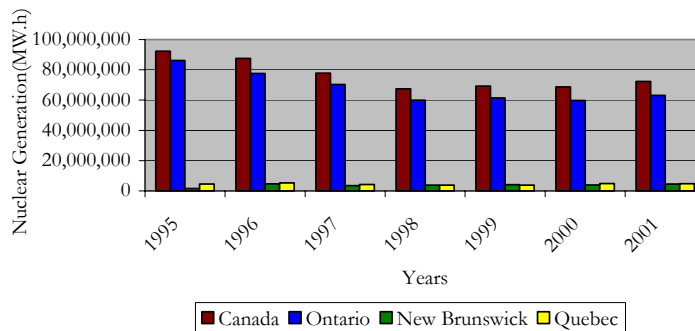
Although uranium production reached a record level in 2001 in volume terms, its average price has declined steadily since 1996 from \$C 53.6/kg to \$C 46.60/kg in 2001. As a consequence, the value of production in 2001 was slightly lower than in 1996. Despite declining export prices, uranium exploration continues in Canada, mainly in the Saskatchewan Athabasca Basin.

Electricity

Nuclear electricity generation declined some 20 percent from 92,305,784 MW.h in 1995 to 72,353,647 MW.h in 2001 due to the reactor lay-ups at Bruce and Pickering (Figure 4).

The value of nuclear-generated electricity is estimated to have been between \$2,700 and \$3,700 million in 2001⁸.

Figure 4
Nuclear Electricity Generation (MW.h)



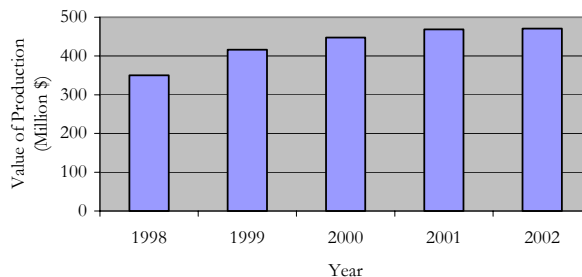
Source: Statistics Canada (57-202).

Reactor Fuel, and Radioisotopes

As noted earlier, there are two companies in Canada that fabricate fuel for CANDU reactors: Zircatec Precision Industries and GE. The main producer of isotopes in Canada is MDS Nordion, the world's leading supplier.

There has been a steady increase in the total value of these products from \$350.1 million in 1998 to \$470.8 million in 2002 (Figure 5).⁹

Figure 5
Value of Production of Reactor Fuel and Isotopes, 1995-2002¹⁰



Source: Zircatec Precision Industries, General Electric (GE) Canada and MDS Nordion.

As noted, the impact of Canada’s isotope production is far greater than these numbers suggest.

⁸ The lower value is at “busbar”, valued at utility transfer prices (between generation and transmission). The higher value is at export prices.

⁹These products are grouped together to protect the anonymity of the data.

¹⁰Data for 2002 are estimates reflecting expenditures to date and predicted expenditures to year-end.

Research and Development

Nuclear R&D is funded by AECL, the COG, the federal government and members of the industry such as manufacturers of fuel and isotopes. The nuclear generators also allocate funds for research that falls outside of the scope of COG.

Table 4
R& D Expenditures (Million \$)^a

	1997	1998	1999	2000	2001	2002
AECL	256.0	232.0	202.0	173.0	171.0	162.0
(Government of Canada Contribution)	(167.4)	(100.0)	(100.0)	(100.0)	(100.0)	(102.8)
COG	92.0	71.0	24.0	23.0	30.0	30.0
Other^b	39.6	66.2	115.4	96.5	61.2	100.2

NOTES: ^aThe columns should not be added; there is a degree of double counting.

^bOther represents R&D spent by generators, fuel fabricators, and manufacturers of isotopes. It does not take into account nuclear R&D in universities and the National Research Council.

SOURCE: CERI survey.

R&D spending declined by some 30 percent between 1997 and 2000. As the industry matured from the design and construction phase in the 1970s and 1980s to operation and maintenance, the federal government reduced funding, and generators concentrated resources on operation and maintenance of their reactors rather than R&D. During the 1990s, expenditure restraint led to a reduction in the federal government's contribution.

AECL Sales and Services

In the fiscal year ending on March 31, 2001, AECL's commercial operations generated about \$500 million of revenue. These "include reactor build projects, engineering and management services, heavy water supply and equipment and technology"¹¹

In Canada, AECL led the construction of two MAPLE reactors and an isotope processing facility for MDS Nordion at Chalk River, and provided technical support to Hydro Québec for condition, safety and reliability assessments, plant life management studies and improvements to Gentilly-2's spent fuel bay. It also led the repair of three cracked feeder pipes at the Point Lepreau power plant in New Brunswick. In Ontario, AECL undertook design and engineering work to refurbish the Pickering 'A' generating units and the associated fuel handling systems. As noted below, a substantial part of this revenue also results from exports of services.

¹¹ AECL Annual Report 2001-2002, p. 44.

Summary

It is evident that, in terms of value of production, the generation of electricity by nuclear power plants is by far the largest component of the ‘nuclear industry’ (Table 5).

Note that the total value of production does not represent the contribution of the nuclear industry to GDP. In fact, as will be noted in Section 4 below, its contribution to GDP will be less than this.

Table 5
Nuclear Industry Value of Production: 2001
(\$Cdn million)

Uranium	583
Nuclear Electricity	2700 – 3700 ^a
Reactor Fuel and Isotopes	469
Research and Development	262 ^b
AECL	500
TOTAL	4514-5514

^aThe lower value is at "busbar", valued at utility transfer prices (between generation and transmission). The higher value is at export prices.

^bThe total of AECL's and ‘other’ R&D expenses

3.2 Exports

Exports indicate the importance of the nuclear industry to Canada’s international trade. It is important to note, however, that the export numbers presented below do not measure the total impact of the nuclear industry on Canada’s balance of payments. This is because the production of the exported goods themselves entails the use of imported goods and services.

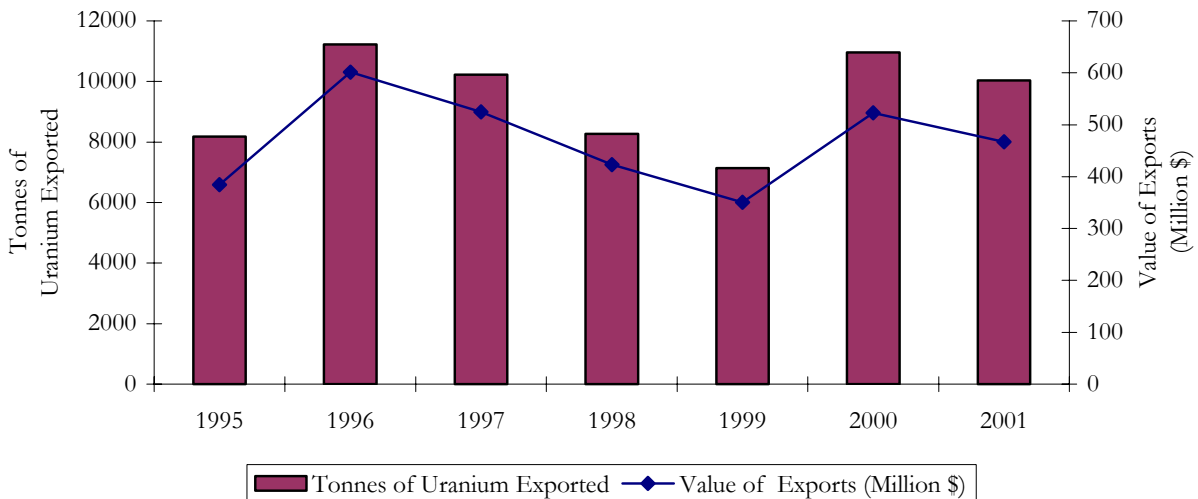
Substantial shares of Canadian production of uranium, nuclear generated electricity and reactor fuel, radioisotopes and heavy water are sold abroad. In addition, AECL sells services abroad related to the management of construction and generation of CANDU reactors sold to other countries. Finally, the CANDU reactors sold to other countries entail the export of a range of goods and services from Canada. Section 4 provides an analysis of the potential impact on the Canadian economy of exports associated with foreign sales of a CANDU reactor.

Uranium

Over 80 percent of the uranium produced in Canada is exported. Most exports go to the USA and France. Smaller amounts are exported to a number of countries. In 2001 these included Japan, South Korea, Taiwan, Spain, Belgium, Mexico and the UK.

As shown below (Figure 6) uranium exports peaked in 1996 in both volume and value terms, and declined in 1998 and 1999. In the past two years exports have recovered in value and volume terms. As noted above, uranium prices have been declining so the increase in value has been more modest than that in volume.

Figure 6
Uranium Exports (tonnes of Uranium) and Value of Exports (Millions \$)
1995-2001



Source: Natural Resources Canada.

Electricity

The only export market for Canada’s electricity is the USA. Since all electrons are the same, whether produced in a nuclear, hydro or fossil-fuel generating station, it is, in principle, impossible to quantify the value of nuclear electricity exports.

However, on the assumption that electricity exports are generated from a fuel mix similar to that used for total generation, the amount and value of exports of nuclear-generated electricity are estimated to have been 3.7 million MW.h and \$195.1 million, respectively, in 2000.¹²

¹²As exports of electricity cannot be tracked by type of fuel used to produce the electricity, these figures were determined by multiplying the total exports of electricity (in NB, QC and ON) by the nuclear share of total electricity production in New Brunswick, Quebec, and Ontario.

Given the assumption used, exports of nuclear electricity mirror the trend in total electricity exports. These declined by one third in volume terms between 1995 and 2000. In value terms, however, there was a dramatic increase in value as prices increased sharply (Table 6).

Table 6
Nuclear Power Exported
(Thousands of \$)

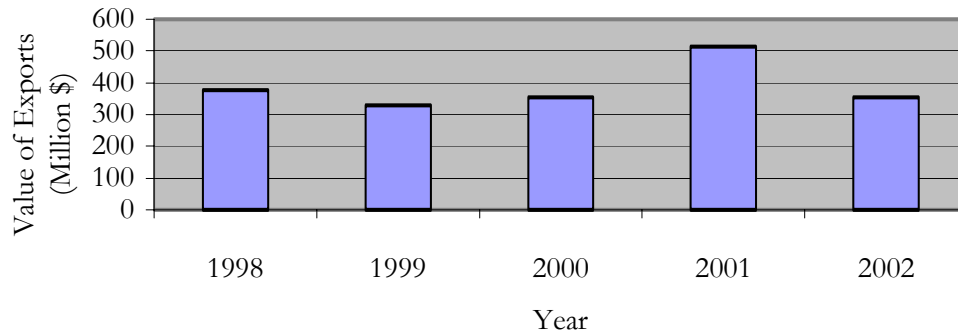
	1995	1996	1997	1998	1999	2000
Quebec	14,597	16,257	15,464	12,164	13,627	29,008
New Brunswick	14,577	34,045	34,672	32,983	49,453	52,816
Ontario	134,861	82,533	77,313	51,154	70,768	113,346
Canada	164,036	132,836	127,449	96,301	133,848	195,173

Source: Statistics Canada (57-202).

Reactor Fuel, Radioisotopes, and Heavy Water

The value of exports of reactor fuel, isotopes and heavy water – used in CANDU reactors as a moderator and heat transfer agent – is shown in Figure 7. Though exports of reactor fuel and isotopes have shown a steady increase in recent years, exports of heavy water are variable, reflecting the variability of market demand. In total, the annual export value of fuel, isotopes and heavy water has averaged between \$300-400 million except for 2001. In that year it was upwards of \$500 million due to large exports of heavy water.

Figure 7
Value of Exports for Reactor Fuel, Isotopes and Heavy Water



Source: Zircotec Precision Industries, General Electric (GE) Canada, NRCAN and MDS Nordion.

AECL

As noted, a substantial part of AECL's revenue from commercial operations flows from sales abroad. Among its foreign commercial activities in 2001-2002 were management of the construction of the nuclear reactors at Qinshan in China and Cernavoda in Romania; and design for a tritium removal facility at Wolsong in Korea. It also supplied a spare fuelling machine to the Wolsong power plant.

In fiscal year 2001-2002, AECL's revenues from exports were \$257 million.

Summary

In summary, exports of uranium, nuclear generated electricity, heavy water, reactor fuel and radioisotopes are estimated to have totaled \$1,212.3 million in 2001.

Table 7
Nuclear Industry Exports

	Millions of \$ Cdn	Year
Uranium	467.4	2001
Electricity	195.2	2000
Reactor Fuel, Isotopes, Heavy Water	349.7	2002
AECL	257.0	2001*
TOTAL	1212.3	

*Fiscal 2001-2002.

3.3 Investment

In addition to its contribution to GDP through the production of goods and services noted above, the nuclear industry contributes through its investment spending. Investment consists of spending in exploration and development by the uranium industry, the construction of new nuclear reactors and of new buildings and equipment for the production of isotopes. Expenditures on the refurbishment of existing reactors are also part of investment spending.

Since the 'nuclear' industry as defined in this report is not identifiable as such in Statistics Canada's National Accounting framework, estimates of total investment spending for the industry are not available.

That said, it is probable that investment spending by components of the nuclear industry has not been large relative to the size of the economy in recent years. There has been no major expansion in any component of the industry although refurbishment of the Pickering and Bruce reactors appears to have entailed substantial expenditures. Information

from various annual reports for 2001 suggests that capital spending was in the neighbourhood of \$400 million in that year (Appendix A).

3.4 Employment

Employment data were collected with a view to obtaining information about its quality as well as quantity. To that end, a questionnaire was developed requesting information on numbers of employees by skill level and as to whether they are full-time, part-time or on contract.

With respect to skill level, the criteria used by Human Resources Development Canada in its National Occupational Classification were adopted (Table 8).

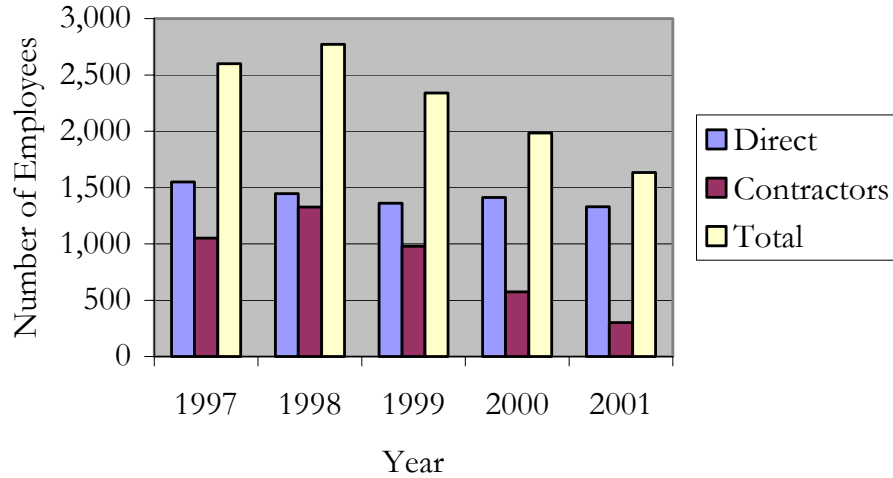
Table 8
Employment Classification

Skill Level	Description
A	University degree, e.g., bachelor's, master's or post-graduate.
B	Two to three years of post-secondary education at community college.
C	One to four years of secondary school education.
D	Up to two years of secondary school and short work and job training.

The survey was sent to companies engaged in the production of nuclear generated electricity, nuclear fuel and radioisotopes. The survey was not used for uranium mining and processing because employment data were available from other sources.

As noted above, all uranium mining activity and corresponding employment occurs in Saskatchewan. Employment in mining and milling has declined substantially from a peak level of 2,772 in 1998 to some 1,632 in 2001. Permanent employment has been relatively stable, but there has been a substantial decline in contractors since 1998. This is a consequence of completion of the McArthur mine project. Cameco has a project at Cigar Lake scheduled to begin construction in 2003-2004 that is likely to result in an increase in contract employment.

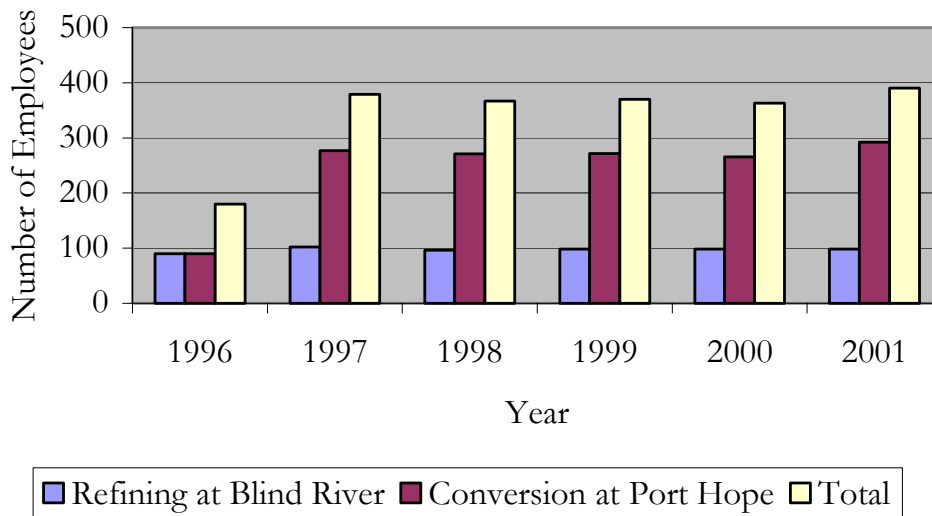
Figure 8
Uranium Mining and Milling Employment



Source: Saskatchewan Mining Association.

In contrast to its decline in mining and milling, employment in uranium processing plants has tended to increase, from 196 full time employees in 1996 to 390 employees in 2001 (Figure 9).

Figure 9
Employment at Uranium Processing Plants



Source: Cameco Corporation.

Total employment in Canada's nuclear power reactors was some 13,542 in 2002 (Table 9).

The labour force in reactors is relatively highly skilled; almost 20 percent have university degrees and over 52 percent have more than two years of post-secondary education (Table 9).

Table 9
Employment in Nuclear Electricity Generators: 2002

Skill Level Description	Bruce Power	NB Power	Hydro Québec	OPG	Total
Full-time					
University degree, e.g., bachelor's, master's or post-graduate	581	215	190	1,588	2,574
Two or three years of post-secondary education at community college	1,674	474	480	1,275	3,903
One to four years of secondary school education	841	0	98	3,753	4,692
Up to two years of secondary school and short work and job training	0	0	0	192	192
Total	3,096	689	768	6,808	11,361
Part-time					
University degree, e.g., bachelor's, master's or post-graduate	7	32	47	6	92
Two or three years of post-secondary education at community college	0	134	30	0	164
One to four years of secondary school education	10	43	0	7	60
Up to two years of secondary school and short work and job training	0	0	0	5	5
Total	17	209	77	18	321
Contract					
University degree, e.g., bachelor's, master's or post-graduate	0	9	20		29
Two or three years of post-secondary education at community college	254	0	75		329
One to four years of secondary school education	549	0	0		549
Up to two years of secondary school and short work and job training	0	0	0		0
Total	803	9	95	953	1,860
Grand Total	3,916	907	940	7,779	13,542

Source: Bruce Power, Hydro Québec, NB Power, OPG.

The majority of the people employed at nuclear generators are full-time (84 percent).

In 2002, there were approximately 1,370 people employed in the fuel fabrication and isotope production industries in Canada of which seventy-five percent have at least 2 years of post-secondary education (Table 10).

Table 10
Employment in Fuel Fabrication and Isotope Production: 2001-2002

Skill Level Description	2001	2002
<u>Full-time</u>		
University degree, e.g., bachelor's, master's or post-graduate	339	296
Two or three years of post-secondary education at community college	685	719
One to four years of secondary school education	179	141
Up to two years of secondary school and short work and job training	183	179
Total	1386	1335
<u>Part-time</u>		
University degree, e.g., bachelor's, master's or post-graduate	5	5
Two or three years of post-secondary education at community college	5	7
One to four years of secondary school education	3	3
Up to two years of secondary school and short work and job training	1	1
Total	14	16
<u>Contract</u>		
University degree, e.g., bachelor's, master's or post-graduate	11	8
Two or three years of post-secondary education at community college	19	9
One to four years of secondary school education	0	0
Up to two years of secondary school and short work and job training	0	0
Total	30	17
Grand Total	1430	1368

SOURCE: Zircotec Precision Industries, GE Canada and MDS Nordion.

As described earlier, AECL is the major player in the nuclear industry, responsible for most nuclear research and development and for development of the CANDU reactor. Over three thousand employees support AECL's activities (Table 11). The majority is highly educated having at least two years of post-secondary education. Ninety-seven percent of AECL employees are full-time.

The 1993 Ernst & Young study reported AECL full-time employment to be 4,500. This compares to 2002 full-time employment of 3,374. The decrease in employment is a result of a decline in demand and a change in operational practices. In comparison to 1992, AECL now uses more contract labour, it has transferred employment to the manufacturing sector and it has automated many work processes, all of which contribute to the decrease in employment.

Table 11
Employment at AECL

Skill Level Description	2000	2001	2002
<u>Full-time</u>			
University degree, e.g., bachelor's, master's or post-graduate.	1464	1399	1536
Two to three years of post-secondary education at community college.	1021	1006	1031
One to four years of secondary school education.	697	660	654
Up to two years of secondary school and short work and job training.	179	166	153
Total	3361	3231	3374
<u>Part-time</u>			
University degree, e.g., bachelor's, master's or post-graduate.	19	17	19
Two to three years of post-secondary education at community college.	21	25	16
One to four years of secondary school education.	10	9	8
Up to two years of secondary school and short work and job training.	2	2	0
Total	52	53	43
Grand Total	3413	3284	3417

Source: AECL.

The CNSC employs some 450 people across Canada to fulfill its regulatory role. There are four main branches of CNSC: operations, corporate services, office of international affairs, and office of regulatory affairs.

Professionals account for 43 percent of all employment at CNSC (Table 12). The majority of employees work in the Ottawa area, but there are additional offices in other regions of Ontario, New Brunswick, Saskatchewan and Alberta.

Table 12
Employment at CNSC: As of March 31, 2001

Occupation Group	Total
Senior Managers	23
Middle Managers	64
Professionals	193
Technicians	56
Clerical/Administrative	109
Total	445

Source: CNSC.

Summary

In summary, total direct employment in the nuclear activities considered in this study was 20,794 in 2001-02 (Table 13). These numbers refer to direct employment only. They underestimate the impact of the nuclear industry on total employment in that they do not take account of the impact of the nuclear industry on industries that supply goods and services to it.

Table 13
Nuclear Industry Total Employment (2001-2002)

Uranium Mining	1,632*
Uranium Processing	390*
Electricity Generation	13,542
Fuel Fabrication and Isotope Production	1,368
AECL	3,417
CNSC	445
Total	20,794

*2001 Statistics

4.0 The Overall Economic Impacts of the Nuclear Industry

Previous sections of this report have described the economic dimensions of various ongoing components of the nuclear industry in Canada. It was noted that, in economic terms, by far the largest component is the generation of electricity. Further, there are components of the industry that, though they are relatively large in economic terms, are of a 'one off' nature. These are the construction of new CANDU reactors in Canada and abroad.

The generation of electricity from existing nuclear power plants requires the use of a number of goods and services; labour and capital, nuclear fuel, heavy water, and data processing services among others. To the extent they are purchased in Canada, economic activity here will be increased.

Similarly, construction of new reactors in Canada impacts the economy through the hiring of construction workers, spending on engineering and project management and other services, and the purchase of reactor components from Canadian companies. Not all spending on new reactors affects the Canadian economy, however; some components and some services are purchased abroad and imported into Canada. The larger these imports, the smaller will be the domestic economic impact.

Sales of CANDU reactors abroad have a positive impact on the Canadian economy to the extent that goods and services used in their construction are imported from Canada. Because CANDU technology was developed in this country it may be expected that such Canadian exports, particularly sales of consulting services, will be substantial.

Given the overwhelming importance of electricity generation and CANDU construction, in Canada and abroad, insofar as the economic impact of nuclear activities is concerned, the assessment of overall economic impact for this study was confined to analysis of these three categories of activity.

To estimate the total economic impact of these activities on the economy, an analytical and accounting framework is required that traces the linkages through all sectors and regions of the economy and estimates their size. Statistics Canada's system of Input/Output tables constitutes such a framework. The economic impacts of the nuclear industry described in this section are derived from a number of customized model runs conducted by Statistics Canada for purposes of this study.¹³

The data required to conduct this analysis were not available from Statistics Canada's Input/Output system. Data are required relating to the nature and values of the purchased inputs needed to produce the goods and services in question classified according to the Statistics Canada system.

Some data were provided by AECL and some estimated by CERI. Thus, in the case of the production of electricity, the data used do not reflect exactly the experience of the

¹³ The analysis was conducted using the 1999 Interprovincial Input/Output Model – the latest version available.

utilities with nuclear generators – OPG, Bruce Power, Hydro Québec and NB Power – rather they are generic data based on AECL’s knowledge of the costs of operating CANDU reactors.

Estimates of input costs by commodity provided by AECL were circulated to all of the relevant utilities for comment. Officials of one utility responded; the AECL data used were judged to be a reasonable approximation to its experience.

A detailed description of data sources and methods is contained in Appendix B.

The economic impact analysis that follows takes account of the "direct effects" and "indirect effects of the expenditure analyzed.

Direct effects are those directly associated with the activities, the impact of which is being estimated. For example, in the case of the construction of nuclear reactors, the direct effects would be measured by the value of the reactor being built. That value is, in turn, equal to the total value of all equipment used in construction, the wages and salaries paid to workers involved in the construction, and profits earned by companies managing the construction process.

But the companies selling equipment used in building the reactor must also purchase goods and services to make that equipment and must pay wages and salaries to workers engaged in producing the equipment. In this way the impact of the reactor construction spreads through the economy. These secondary effects are referred to as indirect effects.

There is a third effect associated with the economic impact. That is the impact on the economy that results when the income generated in the process of producing electricity or of constructing reactors is respent by its recipients on goods and services or on taxes or is saved.

These secondary income effects are called induced and input/output models – referred to as "closed models" – have, in the past, been used to approximate them. The input/output models currently used by Statistics Canada are "open". They do not take account of induced income effects.

Statistics Canada states:

“The use of a Keynesian spending multiplier with the help of an input-output model with partial closure on consumption raises numerous problems. Within the framework of the input-output model, partial closure gives greater importance to a partial category of spin-off effects related to consumer spending by employed individuals, and neglects spin-off spending that may be carried out by firms. The determination of the spin-off effects will also depend upon the nature of the impact, its amplitude, and the phase of the economic cycle at the time the project starts. The input-output model used to calculate the spin-off effects mechanically by partial closure on consumption cannot take all these factors into account. In fact, to take these

various economic circumstances into consideration, the calculation cannot be carried out mechanically, and requires the intervention of the analyst . . .

Finally, in a more general context, where we take into account general equilibrium relationships in the economy, and in particular the interactions that exist between the real relationships and financial sectors, the value of the multiplier obtained by partial closure becomes even more difficult to interpret. The value of such a multiplier may in fact not be very credible when we consider dimensions such as monetary policy, inflation, interest rates and exchange rates.

Under these conditions, it appears preferable, for the benefit of the users of the input-output model of the Canadian economy, that Statistics Canada not offer mechanical impact solutions with partial closure on consumption. Such an analytical tool is too simplistic, and the results may be doubtful or debatable.”¹⁴

A summary of the results of the analysis for each of the three cases examined follows.

4.1 The Economic Impact of Nuclear Electricity Generation

For this study, inputs by commodity in the year 2001 were estimated separately for nuclear generation in New Brunswick, Ontario, and Quebec. The impacts were estimated separately for each of the three provinces and collectively for the national impact of the total of nuclear generation. The national results are reported here; detailed tables for results of individual provinces are contained in Appendix C.

Table 14 shows the estimated distribution and value of commodity inputs used in the generation of nuclear electricity in Canada in 2001. The value of the electricity generated used for this estimate is some \$2.7 billion. This is a CERI estimate of the value of the generation at the busbar.¹⁵ The higher value assigned to nuclear electricity output is some \$3.7 billion, valued at export prices. Of these values some \$1.4 to \$2.4 billion is estimated to have consisted of value added by generation and \$1.2 billion of purchased inputs from other industries in Canada and abroad.

Details of the economy-wide impact of the purchased inputs are contained in Table 15. Almost half of the inputs are estimated to have been sourced abroad, either directly by the generators or indirectly as inputs into the goods and services supplied to the generators by Canadian companies. But Indirect Domestic Demand – the indirect impact on Canadian companies – was also considerable and distributed across a wide range of commodities and industries.

¹⁴ “Statistics Canada’s Input-Output Model: General Description, Critical Analysis of Partially Closed Version and Alternative Solutions,” #52-E. *Statistics Canada National Accounts and Analytical Studies System of National Accounts Input-Output Division*, June 2001.

¹⁵Details are contained in Appendix B.

The impact of nuclear electricity generation on GDP for Canada is estimated to have been \$2.0 billion in 2001 (Table 16). The impact is less than the value of nuclear energy produced because part of that value ‘leaks’ abroad when goods and services are imported.¹⁶ As would be expected, the bulk of the impact occurs in Ontario followed in order of size by Quebec, the Atlantic region and the Prairies/BC/Territories. In the Atlantic region most of the impact is in New Brunswick where the Point Lepreau reactor is located.

Table 14
Distribution Of Annual Inputs
Nuclear Electricity Generation

	Millions of 2001 Canadian Dollars
Radioactive ores & concentrates	159
Advertising flyers, catalogues, directories	11
Electrical generators & motors	197
Deuterium oxide (heavy water)	10
Repair construction	10
Non-life insurance	63
Architect, engineering, & related services	186
Accounting & legal services	53
Data processing services	164
Computer systems design and related services	186
Investigation and security services	88
Other professional, scientific and technical services	22
Other administrative and support services	59
Spare parts & maintenance supplies	8
Sales of other government services	22
Subtotal	1238
Indirect taxes on products	94
Wages and salaries	560
Supplementary labour income	140
Other operating surplus (residually)	646 to 1669
Gross value of nuclear electricity at busbar	2678 to 3701

Note: Total of \$2,678 million is value of nuclear electricity at busbar based on transfer prices; total of \$3,701 million is corresponding value at export prices.

¹⁶Details of the estimated direct and indirect imports are contained in Table 15.

Table 15
Indirect Impacts and Imports By Commodity
Nuclear Electricity Generation

Commodities	Direct Imports	Indirect Imports	Indirect Domestic Demand
	Millions of 2001 Canadian Dollars Per Year		
Agricultural, forestry, fishery, food, beverage		0.7	5.3
Metal ores & concentrates	40.6	11	72.8
Mineral fuels		2.2	4.4
Non-metallic minerals		0.4	0.9
Services incidental to mining			2
Leather, rubber, and plastic products		3.6	2.4
Textile products		0.6	0.4
Hosiery, clothing and accessories		0.2	0.2
Lumber and wood products		0.1	0.9
Wood pulp, paper and paper products		4	5.6
Printing and publishing	2	2.7	11.7
Primary metal products		3	4.3
Other metal products		3.4	4
Machinery and equipment		13	2.6
Motor veh., oth. transport equip. And parts		3.3	1.4
Electrical, electronic and communic. Prod.	187.4	16.9	-0.7
Non-metallic mineral products		1.1	1.3
Petroleum and coal products		0.8	4.8
Chemicals, pharmaceuticals & chemical prod.		7	-5.2
Other manufactured products		3.4	0.9
Repair construction			6.4
Transportation and storage		2.3	20.7
Communications services		1.8	19.6
Other utilities (primarily nuclear generation)		0.1	14.4
Wholesaling and retailing margins		0.2	25.4
Other finance, insurance, and real estate services	10	8.2	69.1
Business and computer services	169.8	17.5	96.2
Private education services		0.1	2.8
Health and social services		0.2	6.5
Accommodation services and meals		2.8	7.2
Other services		1.5	27.3
Transportation margins			4.9
Operating, office, cafeteria and lab. Supplies		0.1	63.9
Travel & entertainment, advertising & promotion		1	37.2
Sales of other government services	0.1		1.8
Total	409.9	113.2	523.4

Table 16
Impact On Annual Gross Domestic Product By Region And Industry - Nuclear Electricity Generation

	ATL	QUE	ONT	PRAIRIE	BC/TERR	CANADA
INDUSTRY	Millions of 2001 Canadian dollars					
Agriculture and Forestry	0.1	0.2	0.4	0.1	0.0	0.8
Mining and Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0	0.1
Utilities (primarily nuclear electricity generation)	62.1	59.4	1,265.0	10.4	0.2	1,397.0
Construction	0.0	1.2	6.9	0.6	0.1	9.0
Manufacturing	0.7	1.1	8.1	0.5	0.1	10.5
Wholesale Trade	1.2	6.0	26.8	1.2	0.4	35.7
Retail Trade	0.8	2.9	17.1	1.1	0.4	22.4
Transportation and Warehousing	0.7	1.1	6.9	0.3	0.1	9.2
Information and Cultural Industries	0.8	2.5	10.6	1.2	0.7	15.8
Finance, Insurance, Real Estate and Renting and Leasing	1.9	7.9	51.1	1.0	0.9	62.7
Professional, Scientific and Technical Services	3.6	7.4	59.7	1.9	1.0	73.5
Administrative and Support, Waste Management and Remediation Services	12.6	25.2	205.4	1.5	1.5	246.2
Education, Health Care, Arts	3.3	11.8	77.8	1.2	0.2	94.4
Accommodation and Food Services	0.0	0.1	1.2	0.0	0.0	1.4
Other Services (Except Public Administration)	0.1	0.3	4.1	0.0	0.0	4.5
Operating, Office, Cafeteria and Laboratory Supplies	0.0	0.2	0.4	0.0	0.0	0.6
Travel, Entertainment, Advertising and Promotion	0.3	0.6	3.1	0.3	0.2	4.5
Transportation Margins	0.1	0.7	4.0	0.2	0.1	5.2
Non-Profit Institutions Serving Households	0.0	0.0	0.2	0.0	0.0	0.2
Government Sector	1.2	1.9	14.7	0.3	0.1	18.1
Total	90.2	130.5	1,763.3	21.6	6.2	2,011.7

4.2 The Economic Impact of CANDU Reactor Construction in Canada

The economic impact of reactor construction in Canada was simulated by assuming that two units, each of 720 MW capacity, were constructed. In principle, construction could take place in any province, this analysis assumes it occurs in Ontario.

As noted, information on costs and on their distribution across commodities (Table 17) was obtained from AECL. Of the estimated total cost of some \$3.4 billion, about \$2.2 billion consists of value added (payments to labour and capital used directly in the reactors' construction) and \$1.2 billion of purchased inputs from other industries.

The analysis suggests (Table 18) that a large proportion of the direct and indirect purchased inputs for reactor construction would consist of imports of goods and services from abroad.

The estimated impact of reactor construction on Canada's GDP is about \$2.5 billion (Table 19).

Regionally, the impacts are concentrated in Ontario. The labour income associated with construction of the reactors would, of course, accrue to residents of that province. Further, the impacts associated with purchased inputs are also concentrated in Ontario and, to a much lesser extent, in Quebec.

It is important to note that the costs of construction of CANDUs would be disbursed over a number of years. Thus, the economic impact would be correspondingly spread out over the time period taken to complete construction. In contrast, the impact of the electricity generation discussed above would occur in a single year and recur on an annual basis. The two numbers are, therefore, not additive.

4.3 The Economic Impact of Exports of CANDU Reactors

When CANDU reactors are exported there will be an economic impact on Canada as AECL receives license fees and sells its project management and other consulting services to the importing country. Further, some of the reactor components may be purchased in this country. The impact of the export of two 720 MW reactors was simulated using data supplied by AECL.

In fact, sales of CANDUs abroad result in substantial exports from Canada, some \$763 million in total of which over \$300 million – 40 percent – consist of 'Architects, engineering and related services' (Table 20). These largely represent payments to AECL for project management and technical advice. Other exports are widely distributed across a range of goods and services.

Taking indirect impacts into account (Table 21), reactor exports generate production over a range of commodities.

Table 17
Distribution of Inputs - Construction Of CANDU Reactors In Canada

	Millions of 2001 Canadian Dollars
Other iron & steel pipes & tubes	11
Other iron & steel pipe fittings	95
Metal tanks	46
Power boilers	100
Iron & steel structural materials	42
Prefabricated metal structures	162
Metal doors and windows	13
Other hardware	34
Valves	48
Pumps, compressors, fans & blowers	59
Industrial trucks & material handling equipment	5
Other industry specific machinery	12
Air conditioning equipment, wall & window	8
Power generation & marine prop., non-electric	194
Electrical generators & motors	130
Transformers & converters	18
Industrial electric equipment, incl. safety	10
Wire & cable, insulated, excl. aluminum	9
Measuring & controlling instruments	30
Truck transportation	61
Telephone & other telecommunications	4
Non-life insurance	15
Accounting & legal services	2
Data processing services	6
Computer systems design and related services	40
Other professional, scientific and technical services	18
Other administrative and support services	28
Other goods & services	21
Subtotal	1221
Indirect taxes on products	27
Indirect taxes on production	28
Wages and salaries	1277
Supplementary labour income	403
Other operating surplus	448
Total	3404

Note: These inputs relate to multi-year periods for constructing a pair of 720 MW generating units. They are not annual. Included are both imports and inputs from domestic suppliers.

Table 18
Indirect Impacts And Imports By Commodity
Construction Of Two 720 Mw CANDU Reactors In Canada

Commodities	Direct Imports	Indirect Imports	Indirect Domestic Demand-
Millions of 2001 Canadian dollars			
Agricultural, forestry, fishery, food, beverage		0.5	3.2
Metal ores & concentrates		2.6	3
Mineral fuels		5.5	6.1
Non-metallic minerals		0.2	0.3
Services incidental to mining			0.4
Leather, rubber, and plastic products	1.3	3.3	-0.9
Textile products		0.6	0.3
Hosiery, clothing and accessories		0.1	0.1
Lumber and wood products		0.2	1.6
Furniture and fixtures		0.2	0.1
Wood pulp, paper and paper products		2.9	3.9
Printing and publishing		1.3	6
Primary metal products	72.4	27.4	48
Other metal products	102.7	12.4	-2.7
Machinery and equipment	71.5	10	-31.9
Motor veh., oth. Transport equip. and parts		4.1	-3.3
Electrical, electronic and communic. prod.	318.1	10.2	-47
Non-metallic mineral products		1.9	1.5
Petroleum and coal products		1.7	9.4
Chemicals, pharmaceuticals & chemical prod.		6.2	4.1
Other manufactured products	28.5	4.1	0.3
Repair construction			3
Transportation and storage	8.7	4.2	35.3
Communications services	0.2	0.8	7.4
Other utilities			9.8
Wholesaling and retailing margins		0.2	71
Other finance, insurance, and real estate services	2.4	3.1	32.2
Business and computer services	11.4	5.1	29.1
Private education services			0.6
Health and social services			0.4
Accommodation services and meals		1.2	3.1
Other services		0.7	13.9
Transportation margins		-0.1	14.3
Operating, office, cafeteria and lab. Supplies		0.1	29.1
Travel & entertainment, advertising & promotion		0.4	15.5
Sales of other government services			0.7
Total	617.2	111.1	267.9

Note: These are impacts over a multi-year construction period. They are not annual.

Table 19
Impact on Gross Domestic Product by Region and Industry
CANDU Reactor Construction in Canada

	ATL	QUE	ONT	PRAIRIE	BC/TERR	CANADA
INDUSTRY						
Agriculture and Forestry	0	0.2	0.4	0	0	0.7
Mining and Oil and Gas Extraction	0.4	0.6	0.4	3.9	0.2	5.6
Utilities	0.1	1.3	4.2	0.4	0.1	6
Construction	0	0.3	2,129.9	0.2	0.1	2,130.6
Manufacturing	3.2	26.8	140.3	6.6	1.3	178.1
Wholesale Trade	0.3	3.3	30.4	1.6	0.5	36.2
Retail Trade	0	0.3	7.3	0.1	0.1	7.8
Transportation and Warehousing	0.6	3.1	38.9	2.3	1	46
Information and Cultural Industries	0.2	1.4	12.2	0.5	0.4	14.8
Finance, Insurance, Real Estate and Renting and Leasing	0.4	2.3	23.9	1.1	0.5	28.2
Professional, Scientific and Technical Services	0.1	2.9	35.3	0.5	0.4	39.2
Administrative and Support, Waste Management and Remediation Services	0	1.1	14.3	0.2	0.1	15.9
Education, Health Care, Arts	0	0	0.7	0	0	0.9
Accommodation and Food Services	0	0.3	1.4	0.1	0.1	1.9
Other Services (Except Public Administration)	0	0.3	1.8	0.1	0.1	2.3
Government Sector	0	0.4	2.5	0.1	0.1	3.1
Total	5.5	44.7	2,443.9	18	5.1	2,517.4

Note: These impacts relate to a multi-year construction period for a pair of 720 MW generating units. They are not annual numbers. The generating units are assumed to be located in Ontario, therefore the direct construction activity all takes place there.

Table 20
Distribution of Inputs - Export of CANDU Reactors

	Millions of Canadian Dollars
Other iron & steel pipes & tubes	5
Other iron & steel pipe fittings	59
Metal tanks	24
Iron & steel structural materials	39
Metal doors and windows	4
Other hardware	7
Valves	36
Pumps, compressors, fans & blowers	9
Industrial trucks & material handling equipment	5
Other industry specific machinery	68
Air conditioning equipment, wall & window	1
Electrical generators & motors	2
Transformers & converters	10
Industrial electric equipment, incl. safety	5
Wire & cable, insulated, excl. aluminum	2
Measuring & controlling instruments	24
Industrial safety equipment	13
Truck transportation	6
Telephone & other telecommunications	4
Paid charges, banks & oth. dep. acc. Intermed.	25
Management fees of companies and enterprises	19
Non-life insurance	17
Architect, engineering, & related services	303
Accounting & legal services	2
Data processing services	6
Computer systems design and related services	34
Other administrative and support services	15
Other goods and services	19
Total	763

Note: These inputs relate to Canadian exports over a multi-year period in the construction of a pair of 720 MW CANDU generating units. They are not annual.

Table 21
Indirect Impacts and Imports by Commodity
Export of CANDU Reactors

Commodities	Imports (All Indirect)	Indirect Domestic Demand
Agricultural, forestry, fishery, food, beverage	0.8	8.5
Metal ores & concentrates	2.7	3.3
Mineral fuels	4.4	4.9
Non-metallic minerals	0.2	0.3
Services incidental to mining		0.3
Leather, rubber, and plastic products	4	-1.2
Textile products	2	0.8
Hosiery, clothing and accessories	0.2	0.2
Lumber and wood products	0.1	1.2
Wood pulp, paper and paper products		4.6
Printing and publishing	3.4	9.1
Primary metal products	2	29.2
Other metal products	20.2	42.7
Machinery and equipment	6.1	-32.8
Motor veh., oth. transport equip. and parts	14.5	-2.8
Electrical, electronic and communic. prod.	4.4	2.8
Non-metallic mineral products	17.8	1.3
Petroleum and coal products	1.4	5.8
Chemicals, pharmaceuticals & chemical prod.	1.9	4.6
Other manufactured products	7.6	0.4
Repair construction	6.2	3.9
Transportation and storage	3.3	28.9
Communications services	1.1	11.6
Other utilities	0.1	10.6
Wholesaling margins	0.2	34.1
Retailing margins		3.1
Other finance, insurance, and real estate services	4.5	46.7
Business and computer services	22.3	64.6
Private education services	0	0.8
Health and social services	0	0.5
Accommodation services and meals	2.8	6.7
Other services	1.4	21.9
Transportation margins	-0.1	12.8
Operating, office, cafeteria and lab. Supplies		36.5
Travel & entertainment, advertising & promotion		27.3
Non-competing imports	0.1	
Unallocated imports and exports	0.4	
Sales of other government services		0.9
Total	136	394.1

Note: These are Canadian outputs over a multi-year construction period. They are not annual.

Because indirect import leakage associated with the direct export of reactor goods and services is relatively small, the impact on GDP is large relative to the initial exports, some \$610 million compared to \$763 million (Table 22). Again the impact is overwhelmingly in Ontario.

As is the case with the impact of reactor construction in Canada, the impact of exports of reactor component goods and services will be spread over a period of years broadly similar to the construction period for the reactor.

4.4 Summary of Employment Impacts

Total employment in the components of the nuclear industry discussed earlier in this report is estimated to have been 20,794 in 2002 (Table 13). Of this total, some 13,542 people were employed in nuclear power generation in OPG, Bruce Power, Hydro Québec and NB Power. A further 3,417 were employed in AECL.

In addition to this, incremental indirect employment will be generated as a result of the impacts associated with the generation of electricity. And employment would result were new reactors to be constructed in Canada or CANDUs exported abroad. These estimated incremental employment impacts are summarized in Table 23.

Annual incremental employment associated with nuclear electricity generation is estimated to be close to 12,000 nationwide, of which some 9,300 are in Ontario. Combined with the 13,542 people employed directly by the nuclear generators the total annual employment, direct and indirect, associated with the generation of nuclear electricity is estimated to have been over 25,000 in 2001-02.

Indirect employment, in terms of numbers of person years, spread over the construction period, associated with reactor construction in Canada – assumed to be in Ontario – is about 6,200. These jobs are associated with the manufacture of goods and services used in the construction process. This is in addition to the 34,000 person years of employment that, according to AECL, are likely to be associated directly with construction of the reactor itself. Thus total person years of employment associated with the construction of two 720 MW CANDUs in Canada is estimated to be 40,200.

As noted, *exports* from Canada associated with sale of CANDUs abroad are estimated to be \$763 million. The employment associated with these exports is estimated to be over 9,700.

Table 22
Impact on Gross Domestic Product by Region and Industry - Export of CANDU Reactors

	ATL	QUE	ONT	PRAIRIE	BC/TERR	CANADA
INDUSTRY	Millions of 2001 Canadian dollars					
Crop and Animal Production	0.0	0.2	0.4	0.1	0.0	0.7
Mining and Oil and Gas Extraction	0.4	0.7	0.6	3.2	0.2	5.0
Utilities	0.0	0.8	5.3	0.2	0.0	6.5
Construction	0.0	0.2	2.8	0.1	0.1	3.2
Manufacturing	0.4	7.5	158.4	1.3	0.5	168.3
Wholesale Trade	0.2	1.7	20.8	0.9	0.4	24.0
Retail Trade	0.0	0.2	3.4	0.1	0.1	3.8
Transportation and Warehousing	0.4	1.6	14.6	1.3	0.7	18.6
Information and Cultural Industries	0.2	1.0	17.2	0.5	0.4	19.3
Finance, Insurance, Real Estate and Renting and Leasing	0.2	1.2	66.0	0.9	0.5	68.9
Professional, Scientific and Technical Services	0.0	1.4	258.0	0.3	0.3	260.1
Administrative and Support, Waste Management and Remediation Services	0.0	0.6	16.0	0.1	0.1	17.0
Education, Health Care, Arts	0.0	0.0	0.9	0.0	0.0	0.9
Other Services (Except Public Administration)	0.1	0.5	6.8	0.2	0.3	8.0
Non-Profit Institutions Serving Households	0.0	0.0	0.0	0.0	0.0	0.0
Government Sector	0.0	0.2	5.1	0.0	0.0	5.5
Total	2.2	17.9	576.4	9.6	3.7	609.9

Note: These Canadian outputs relate to a multi-year construction period. They are not annual numbers. By assumption, the export industries are located in Ontario, although their direct and indirect suppliers are located across the nation and beyond.

Table 23
Incremental Employment Impacts of Nuclear Generation and Construction

	ATL	QUE	ONT	PRAIRIE	BC /TERR	Total
Nuclear electricity generation (person years per year)						
- at nuclear power plants	907	940	11695	0	0	13542
- elsewhere	650	1474	9278	257	112	11771
- total	1557	2414	20973	257	112	25313
CANDU construction in Canada (total person years)						
- direct labour force	0	0	34000	0	0	34000
- other employment	139	685	5076	224	84	6208
- total	139	685	40076	224	84	41208
Export of CANDU reactors (total person years)	39	254	9293	109	59	9754

Note: "Nuclear electricity generation" consists of generation at all 14 existing nuclear units in Canada; CANDU construction in Canada and "export of CANDU reactors" each contemplate two 720-MW generating units. The employment figures for nuclear electricity generation are annual, whereas the employment figures for construction in Canada and for export relate to multi-year construction periods.

As was noted in the discussion of the GDP impacts above, most occurs in Ontario. It follows that the employment impact will also be in that province.

Finally it is important to reiterate that the employment numbers are not additive across the three cases simulated: the construction employment numbers are person year estimates; the employment will be spread over a number of years.

5.0 Concluding Comments

The goal of this study has been to describe the characteristics and key economic dimensions of the nuclear industry, as it exists today.

This was accomplished by outlining the production, exports and employment of its major components: uranium production and processing, fuel and isotope production, nuclear electricity generation, the development and sale of CANDU reactors by AECL, and research and development.

The impact of the industry is, however, broader than is indicated by the production and employment associated directly with its components. The purchase of goods and services required as inputs into the production of the nuclear industry's output affects a wide range of other industries. Moreover such impacts are associated not only with such ongoing activities as nuclear-generated electricity but with less regular, 'one off', production associated with the construction of CANDU reactors in Canada and abroad. This study provides illustrative assessments of the impacts of both ongoing and periodic activities.

Principal findings with respect to the economic impact of the nuclear industry in Canada are:

- 1) The value of production of the nuclear industry (uranium production, nuclear electricity generation, reactor sales and service, fuel and isotope production, research and development) was about \$5 billion in 2001.
- 2) Exports of uranium, nuclear generated electricity, heavy water, reactor fuel and isotopes were some \$1.2 billion in 2001.
- 3) Total employment in the nuclear industry was over 20,000 in 2002.
- 4) Sixty three percent of the people employed full time in the nuclear electricity generation, fuel and isotope production, and AECL have more than two years of post secondary education.
- 5) The annual employment, direct and indirect, associated with the nuclear industry in Canada was over 30,000 in 2002.
- 6) AECL estimates that "the supply of nuclear and non-nuclear components for reactor projects and services is provided from 1500 direct manufacturers located in Canada for export overseas".
- 7) The impact of nuclear generated electricity on Gross Domestic Product for Canada was some \$2.0 billion in 2001.
- 8) If two CANDU reactors, each of 720 MW capacity, were constructed in Canada, the impact on GDP would be approximately \$2.6 billion over the period of their

construction. Total person years of employment associated with the new reactor construction would be about 40,000.

- 9) Sales of two 720 MW CANDUs abroad would result in exports from Canada of over \$760 million during the period of their construction and generate some 9,700 person years of employment.

This study provides a snapshot of the nuclear industry as it exists today and illustrates the potential economic impact were further CANDU construction to occur in Canada or abroad.

Clearly the picture will change as the industry develops and changes:

- existing CANDU reactors are scheduled to return to service in Ontario;
- two 'MAPLE' reactors for the production of isotopes are nearing completion; and
- AECL is working on a new reactor design -- the Advanced CANDU Reactor.

An analysis additional to that provided in this study would be needed to assess the overall benefits of the nuclear industry to Canadian society.

Appendix A: Capital Spending in the Nuclear Industry

AECL had capital spending of \$22 million during the fiscal year ending March 31, 2002, mostly on upgrading at Chalk River.

MDS Nordion reported capital spending of \$15 million (consisting of \$4 million of construction plus \$11 million of capitalized interest) on its two MAPLE reactors at Chalk River. In addition, MDS Nordion announced in mid-2001 that it would be spending \$20 million to build an isotope-producing cyclotron in Vancouver, with commissioning scheduled for January 2003. MDS' Health Sciences Division (which includes MDS Nordion plus non-nuclear capital outlays for developing drugs and other medicine-related items) reported \$65 million of capital outlays.

Cameco reported exploration outlays of \$10 million in Canada and Australia. It also reported outlays on property, plant and equipment of \$58 million, of which \$55.9 million was nuclear. Some of the latter may relate to testing of a uranium deposit in Kazakhstan. The Cluff Lake uranium mine is slated for decommissioning in 2003. A new mine at Cigar Lake is provisionally slated to begin production in 2005, subject to various approvals.

COGEMA is a French organization, which does not put financial statements of its Canadian subsidiary on the Web. No information was found for Zircotec or GE Canada.

Bruce Power reported \$8 million of capital expenditures in 2001, presumably all nuclear-related. NB Power reported capital outlays of \$140 million in fiscal 2001/02, including pre-engineering work on refurbishment of the Point Lepreau nuclear power plant. OPG reported \$130 million of spending on its "nuclear recovery program" in 2001. Hydro Québec did not provide a figure for its nuclear-related capital spending in 2001, but it did state that there was \$19 million of construction work in progress at year-end.

Appendix B: Data Sources and Methods for Economic Impact Analysis

B.1 The Economic Impact of Nuclear Electricity Generation (refer to Section 4.1)

Annual operating and maintenance costs were first estimated for a single CANDU 6 generating unit, as exists in New Brunswick and Quebec. They were then scaled up to an Ontario total that consists of a mix of sizes of generating units.

The basis for scale-up, suggested by AECL, was that the payroll and repair maintenance costs of a unit are independent of unit size, whereas other costs are proportional to a unit's capacity.

The estimation of annual operating and maintenance costs relied heavily on AECL's experience, but also drew on Statistics Canada's aggregate information for purchased inputs in Canada's 'Electricity Generation, Transmission and Distribution' industry.

Special treatment was given to the following categories:

- 1) Statistics Canada reported that in 1998 Canada's 'Electricity Generation, Transmission and Distribution' industry spent \$159 million on Radioactive Ores & Concentrates, and advised that all of this was nuclear fuel. This amount was divided among the three provinces according to scale of operations, with \$10 million apiece ascribed to New Brunswick and Quebec.
- 2) AECL identified \$35 million as the annual outlay for 'Purchased Services/Contractors' by a single CANDU 6 generating unit. This was distributed among a number of categories: 'Architect, Engineering & Related Services'; 'Data Processing Services'; 'Computer Systems Design and Related Services'; 'Other Professional, Scientific and Technical Services'; and 'Other Administrative and Support Services'. The distribution was in proportion to the amounts assigned to those categories by Statistics Canada for the national 'Electricity Generation, Transmission and Distribution' industry in 1998. Regulatory Cost of \$5 million as estimated by AECL was assigned to the category 'Accounting & Legal Services' and 'Other Miscellaneous' costs of \$2.5 million as estimated by AECL was split evenly between 'Electrical Generators & Motors' and 'Other Government Services'.
- 3) Gross Value of Output was separately calculated by multiplying output in MW.h by a transfer price obtained (or inferred) from published sources:
 - Bruce Power received 3.8 c/kW.h for its output as it entered the transmission system, and this was used for the entire Ontario nuclear generation industry.
 - Hydro-Québec Production received 2.79 c/kW.h for electricity generated by its Heritage Pool.

- For New Brunswick, an assumption was made that unit transmission and distribution costs are the same as in Ontario. Thus, the difference in average final selling price of electricity between the two provinces was assumed to reflect the difference in busbar values, producing a deemed busbar value of 3.13 c/kW.h.

An alternative valuation of nuclear electricity output was obtained by adjusting export prices, reported by the NEB, for transmission losses. No data were available for associated transmission costs.

- 4) Other Operating Surplus was calculated residually, and may be interpreted as earnings before interest, income taxes, depreciation and amortization.
- 5) Indirect Taxes were taken as 7 percent of 'Other Operating Surplus', based on the corresponding calculation performed on Statistics Canada's 1998 data for the 'Electricity Generation, Transmission and Distribution' industry.

B.2 The Economic Impact of CANDU Reactor Construction In Canada (refer to Section 4.2)

Officials at AECL estimated the construction cost of building a pair of 720 MW CANDU units based largely on their recent experience with the Qinshan Project in China. The estimated total value/cost of construction is \$3,349 million. To this CERI added \$55 million to incorporate two categories of indirect taxes, arriving at a total figure of \$3,404 million. Within this total several adjustments were made:

- 1) AECL valued materials on a delivered basis, whereas Statistics Canada estimates transportation costs separately. To adjust AECL's materials costs to a factory-gate basis, the estimate of transportation costs in Statistics Canada's industrial category 'Electric Power Engineering Construction' was used. This amounted to 5.2 percent of the corresponding value of materials. Thus, each of AECL's delivered cost figures for materials were reduced by 5.2 percent and an offsetting adjustment made to 'Truck Transportation'.
- 2) AECL's total cost estimate of \$3,349 million included a 10 percent provision for contingency that, according to AECL, relates essentially to costs other than materials. Since Statistics Canada's input-output tables are not designed to handle such a category, the contingency was allocated among all non-material cost categories by adding 14.5 percent to each.
- 3) AECL's category 'Other Equipment and Materials Not Classified Above' was split evenly between 'Truck Transportation' and 'Prefabricated Metal Structures' based on a discussion with AECL.
- 4) The sum of AECL's estimated costs for 'Power Generation & Marine Propellers, Non-Electric' and 'Electric Generators & Motors' was split 60 percent to the former and 40 percent to the latter, based on the split between these two

categories in Statistics Canada's estimates for purchased inputs in 'Electric Power Engineering Construction'¹⁷.

- 5) Based on discussions with AECL, estimates originally provided for 'Other General Purpose Machinery and Industrial Safety Equipment' were moved to 'Industrial Electric Equipment including Safety'. Similarly, AECL estimates provided for 'Fans & Air Circulation Units, Not Industrial' were moved to 'Air Conditioning Equipment, Wall & Window'.
- 6) AECL used Statistics Canada's categories 'Wages & Salaries', 'Supplementary Labour Income' and 'Mixed Income' to identify payroll costs associated with different classes of employee. These costs were combined and distinguished between 'Wages & Salaries' and 'Supplementary Labour Income' by moving such benefits categories as vacation and sick pay into 'Wages & Salaries' in accordance with Statistics Canada's classifications.
- 7) Although AECL provided estimates to the nearest \$100 thousand, these were rounded to the nearest million dollars.

B.3 The Economic Impact of Exports to CANDU Reactors (refer to Section 4.3)

- 1) The menu of cost categories of purchased inputs was the same as for domestic construction. AECL was asked to value only the Canadian content associated with building a two-unit CANDU generating station overseas; inputs supplied locally or by a third country will have little or no impact on the Canadian economy. This is in contrast to CANDU construction in Canada (and to the operation of existing Canadian nuclear generating capacity), where data were requested irrespective of sourcing.
- 2) As with domestic CANDU construction, delivered prices of materials had to be split into factory gate value and value of onward transportation. In order to convert from a delivered basis to a factory-gate basis, all material costs were divided by 1.042, the estimated ratio of delivered to factory-gate costs, with an offsetting adjustment to 'Truck Transportation'.
- 3) Unlike the case of domestic construction, the value of AECL's inputs, including those related to payroll, was allocated to "Architect, Engineering & Related Services".

¹⁷Statistics Canada, Input/Output Division, 1998 Input Matrix, Aggregation Level W.

Appendix C: The Economic Impact of Nuclear-Generated Electricity in New Brunswick, Québec and Ontario.

Table 12 NB
Distribution of Annual Inputs
Nuclear Electricity Generation in New Brunswick
(2001 Millions of \$Cdn)

Radioactive ores & concentrates	10
Advertising flyers, catalogues, directories	1
Electrical generators & motors	12
Deuterium oxide (heavy water)	1
Repair construction	1
Non-life insurance	4
Architect, engineering, & related services	11
Accounting & legal services	3
Data processing services	10
Computer systems design and related services	11
Investigation and security services	5
Other professional, scientific and technical services	1
Other administrative and support services	4
Spare parts & maintenance supplies	1
Sales of other government services	<u>1</u>
Subtotal	76
Indirect taxes on products	4
Wages and salaries	40
Supplementary labour income	10
Other operating surplus (residually)	<u>12 to 151</u>
Gross value of nuclear electricity at busbar	142 to 281

Note: Total of \$142 million is value of nuclear electricity at busbar based on transfer prices; total of \$281 million is corresponding value at export prices.

Table 13 NB
Indirect National Impacts and Imports by Commodity
Nuclear Electricity Generation in New Brunswick
(2001 Millions of \$ Cdn per year)

COMMODITIES	Direct Imports	Indirect Imports	Indirect Domestic Demand
Agricultural, forestry, fishery, food, beverage		0	0.6
Metal ores & concentrates		1	7.3
Mineral fuels		0.3	0.3
Non-metallic minerals		0	0.1
Services incidental to mining		0	0.1
Leather, rubber, and plastic products		0.3	0.3
Textile products		0	0
Hosiery, clothing and accessories		0	0
Lumber and wood products		0	0.1
Wood pulp, paper and paper products		0.2	0.5
Printing and publishing	0.3	0.2	0.7
Primary metal products		0.2	0.4
Other metal products		0.3	0.3
Machinery and equipment		1.2	0.3
Motor veh., oth. transport equip. and parts		0.3	0.1
Electrical, electronic and communic. Prod.	9.7	1.7	-0.5
Non-metallic mineral products		0.1	0.1
Petroleum and coal products		0	0.4
Chemicals, pharmaceuticals & chemical prod.		0.5	-0.6
Other manufactured products		0.2	0.1
Repair construction		0	0.5
Transportation and storage		0.1	1.5
Communications services		0	1.4
Other utilities (primarily nuclear generation)		0	1.3
Wholesaling and retailing margins		0	2.6
Other finance, insurance, and real estate services	0.7	0.5	5.6
Business and computer services	2.4	0.9	5.4
Private education services		0	0.2
Health and social services		0	0.2
Accommodation services and meals		0.2	0.6
Other services		0	2
Transportation margins		0	0.5
Operating, office, cafeteria and lab. Supplies		0.1	5.8
Travel & entertainment, advertising & promotion		0	2.5
Sales of other government services	0	0	0.1
Total	13.1	8.3	41

Table 14 NB
Impact on Annual Gross Domestic Product by Region and Industry
Nuclear Electricity Generation in New Brunswick
(2001 Millions of \$ Cdn)

Industry	ATL	QUE	ONT	PRAIRIE	BC/TERR	CANADA
Agriculture and Forestry	0.0	0.0	0.0	0.0	0.0	0.1
Mining and Oil and Gas Extraction	0.0	0.6	3.2	0.2	0.0	4.1
Utilities (primarily nuclear electricity generation)	62.1	0.1	0.5	0.0	0.0	62.8
Construction	0.7	0.0	0.2	0.0	0.0	1.0
Manufacturing	0.8	0.8	1.8	0.1	0.0	3.5
Wholesale & Retail Trade	1.5	0.4	1.0	0.0	0.0	3.1
Transportation and Warehousing	0.4	0.2	0.4	0.0	0.0	1.2
Information and Cultural Industries	1.5	0.6	1.6	0.0	0.1	3.8
Finance, Insurance, Real Estate and Renting and Leasing	3.0	0.4	1.7	0.0	0.0	5.2
Professional, Scientific and Technical Services	12.1	1.7	5.1	0.2	0.2	19.4
Administrative and Support, Waste Management and Remediation Services	3.3	0.8	1.4	0.0	0.0	5.5
Education, Health Care, Arts	0.1	0.0	0.0	0.0	0.0	0.3
Accommodation and Food Services	0.1	0.1	0.1	0.0	0.0	0.4
Other Services (Except Public Administration)	0.1	0.1	0.1	0.0	0.0	0.3
Non-Profit Institutions Serving Households	0.0	0.0	0.0	0.0	0.0	0.0
Government Sector	1.2	0.1	0.2	0.0	0.0	1.6
Total	87.4	5.9	17.5	1.0	0.5	112.2

Table 21 NB
Incremental Employment Impacts of Nuclear Generation in New Brunswick

	ATL	QUE	ONT	PRAIRIE	BC/TERR	Total
Nuclear electricity generation (person years per year)						
- at nuclear power plant	907	0	0	0	0	907
- elsewhere	596	108	266	14	9	992
- total	1,503	108	266	14	9	1,899

Table 12 QC
Distribution of Annual Inputs
Nuclear Electricity Generation in Québec
(2001 Millions of \$Cdn)

Radioactive ores & concentrates	10
Advertising flyers, catalogues, directories	1
Electrical generators & motors	12
Deuterium oxide (heavy water)	1
Repair construction	1
Non-life insurance	4
Architect, engineering, & related services	11
Accounting & legal services	3
Data processing services	10
Computer systems design and related services	11
Investigation and security services	5
Other professional, scientific and technical services	1
Other administrative and support services	4
Spare parts & maintenance supplies	1
Sales of other government services	<u>1</u>
Subtotal	76
Indirect taxes on products	4
Wages and salaries	40
Supplementary labour income	10
Other operating surplus (residually)	3 to 89
Gross value of nuclear electricity at busbar	133 to 219

Note: Total of \$133 million is value of nuclear electricity at busbar based on transfer prices; total of \$219 million is corresponding value at export prices.

Table 13 QC
Indirect National Impacts and Imports by Commodity
Nuclear Electricity Generation in Québec
(2001 Millions of \$ Cdn per year)

COMMODITIES	Direct Imports	Indirect Imports	Indirect Domestic Demand
Agricultural, forestry, fishery, food, beverage			0.5
Metal ores & concentrates	4.7	0.6	3.8
Mineral fuels		0.1	0.2
Non-metallic minerals			0.1
Services incidental to mining			0.1
Leather, rubber, and plastic products		0.3	0.2
Textile products			0
Hosiery, clothing and accessories			0
Lumber and wood products			0.1
Wood pulp, paper and paper products		0.3	0.6
Printing and publishing	0.2		1.1
Primary metal products		0.2	0.3
Other metal products		0.2	0.3
Machinery and equipment		0.9	0.2
Motor veh., oth. transport equip. and parts		0.3	0.1
Electrical, electronic and communic. prod.	11.1	1.1	0
Non-metallic mineral products			0.1
Petroleum and coal products			0.3
Chemicals, pharmaceuticals & chemical prod.		0.4	-0.6
Other manufactured products		0.3	0.1
Repair construction			0.4
Transportation and storage		0.1	1.2
Communications services		0.1	1.4
Other utilities (primarily nuclear generation)			0.9
Wholesaling and retailing margins			1.8
Other finance, insurance, and real estate services	0.6	0.4	4.1
Business and computer services	5.2	0.9	6.1
Private education services			0.2
Health and social services			0.3
Accommodation services and meals		0.1	0.5
Other services			1.9
Transportation margins			0.3
Operating, office, cafeteria and lab. supplies		0.1	4.4
Travel & entertainment, advertising & promotion			2.5
Sales of other government services			0.1
Total	21.8	6.4	33.3

Table 14 QC
Impact on Annual Gross Domestic Product by Region and Industry
Nuclear Electricity Generation in Québec
(2001 Millions of \$ Cdn)

Industry	ATL	QUE	ONT	PRAIRIE	BC/TERR	CANADA
Mining and Oil and Gas Extraction	0.0	0.4	1.7	0.2	0.0	2.3
Utilities (primarily nuclear electricity generation)	0.0	53.3	0.3	0.0	0.0	53.6
Construction	0.0	0.8	0.1	0.0	0.0	0.9
Manufacturing	0.0	1.6	1.2	0.1	0.0	2.9
Wholesale & Retail Trade	0.0	1.5	0.5	0.0	0.0	2.1
Transportation and Warehousing	0.0	0.6	0.3	0.0	0.0	1
Information and Cultural Industries	0.0	3.6	0.6	0.0	0.0	4.3
Finance, Insurance, Real Estate and Renting and Leasing	0.0	3.3	1.1	0.0	0.1	4.5
Professional, Scientific and Technical Services	0.0	14.6	2.3	0.1	0.1	17.1
Administrative and Support, Waste Management and Remediation Services	0.0	5.1	0.5	0.0	0.0	5.6
Education, Health Care, Arts	0.0	0.3	0.0	0.0	0.0	0.4
Accommodation and Food Services	0.0	0.2	0.1	0.0	0.0	0.3
Other Services (Except Public Administration)	0.0	0.2	0.1	0.0	0.0	0.3
Government Sector	0.0	1.2	0.1	0.0	0.0	1.3
Total	0.2	86.7	8.8	0.6	0.3	96.7

Table 21 QC
Incremental Employment Impacts of Nuclear Generation in Québec

	ATL	QUE	ONT	PRAIRIE	BC/TERR	Total
Nuclear electricity generation (person years per year)						
- at nuclear power plant	0	940	0	0	0	940
- elsewhere	4	670	127	9	5	815
- total	4	1,610	127	9	5	1,755

Table 12 ON
Distribution of Annual Inputs
Nuclear Electricity Generation in Ontario
(2001 Millions of \$Cdn)

Radioactive ores & concentrates	139
Advertising flyers, catalogues, directories	9
Electrical generators & motors	173
Deuterium oxide (heavy water)	8
Repair construction	8
Non-life insurance	55
Architect, engineering, & related services	164
Accounting & legal services	47
Data processing services	144
Computer systems design and related services	164
Investigation and security services	78
Other professional, scientific and technical services	20
Other administrative and support services	51
Spare parts & maintenance supplies	6
Sales of other government services	20
Subtotal	1086
Indirect taxes on products	86
Wages and salaries	480
Supplementary labour income	120
Other operating surplus (residually)	631 to 1,429
Gross value of nuclear electricity at busbar	2,403 to 3,201

Note: Total of \$2,403 million is value of nuclear electricity at busbar based on transfer prices; total of \$3,201 million is corresponding value at export prices.

Table 13 ON
Indirect National Impacts and Imports by Commodity
Nuclear Electricity Generation in Ontario
(2001 Millions of \$ Cdn per year)

COMMODITIES	Direct Imports	Indirect Imports	Indirect Domestic Demand
Agricultural, forestry, fishery, food, beverage		0.6	4.2
Metal ores & concentrates	35.8	9.4	61.6
Mineral fuels		1.7	3.9
Non-metallic minerals		0.3	0.8
Services incidental to mining		0	1.8
Leather, rubber, and plastic products		3	1.9
Textile products		0.5	0.3
Hosiery, clothing and accessories		0.2	0.1
Lumber and wood products		0.1	0.7
Wood pulp, paper and paper products		3.5	4.6
Printing and publishing	1.6	2.4	10
Primary metal products		2.5	3.6
Other metal products		2.9	3.3
Machinery and equipment		10.6	2.2
Motor veh., oth. transport equip. and parts		2.5	1.2
Electrical, electronic and communic. prod.	166.6	14.1	-0.3
Non-metallic mineral products		0.9	1.1
Petroleum and coal products		0.5	4.1
Chemicals, pharmaceuticals & chemical prod.		6	-4
Other manufactured products		3	0.7
Repair construction		2	5.5
Transportation and storage		1.6	18
Communications services		0.1	16.7
Other utilities (primarily nuclear generation)		0.1	12.2
Wholesaling and retailing margins		16	20.9
Other finance, insurance, and real estate services	8.6	169.3	59.3
Business and computer services	162.1	-162	84.5
Private education services		0.2	2.5
Health and social services		2.5	6
Accommodation services and meals		1.3	6.1
Other services		0	23.5
Transportation margins		0	4.1
Operating, office, cafeteria and lab. Supplies		0.9	53.7
Travel & entertainment, advertising & promotion		0	32.2
Sales of other government services	0.1	0	1.6
Total	374.9	96.6	448.9

Table 14 ON
Impacts on Annual Gross Domestic Product by Region and Industry
Nuclear Generation in Ontario
(2001 Millions of \$ Cdn)

Industry	ATL	QUE	ONT	PRAIRIE	BC/TERR	CANADA
Agriculture and Forestry	0	0.1	0.3	0.1	0.0	0.6
Mining and Oil and Gas Extraction	0	5.5	29.0	9.9	0.1	44.6
Utilities (primarily nuclear electricity generation)	0	0.8	1,237.1	0.6	0.0	1,238.6
Construction	0	0.3	7.8	0.3	0.1	8.6
Manufacturing	0.3	3.7	23.9	0.9	0.4	29.2
Wholesale & Retail Trade	0.1	2.2	22.5	1.3	0.5	26.5
Transportation and Warehousing	0.4	1.7	9.9	1.1	0.6	13.7
Information and Cultural Industries	0.3	3.7	48.8	1.0	0.8	54.5
Finance, Insurance, Real Estate and Renting and Leasing	0.5	3.7	56.9	1.7	0.9	63.8
Professional, Scientific and Technical Services	0.3	8.9	198.0	1.2	1.2	209.7
Administrative and Support, Waste Management and Remediation Services	0	5.8	75.9	1.2	0.2	83.2
Education, Health Care, Arts	0	0.3	5.5	0.0	0.0	5.8
Accommodation and Food Services	0	0.4	2.9	0.2	0.2	3.8
Other Services (Except Public Administration)	0	0.4	3.8	0.2	0.1	4.6
Non-Profit Institutions Serving Households	0	0.0	0.2	0.0	0.0	0.2
Government Sector	0	0.6	14.4	0.2	0.1	15.3
Total	2.5	37.9	1,737.0	19.9	5.4	1,802.8

Table 21 ON
Incremental Employment Impacts of Nuclear Generation in Ontario

	ATL	QUE	ONT	PRAIRIE	BC/TERR	Total
Nuclear electricity generation (person years per year)						
- at nuclear power plants	0	0	11,695	0	0	11,695
- elsewhere	49	696	8,885	235	98	9,964
- total	49	696	20,580	235	98	21,659