

Uranium

Robert T. Whillans¹

The author was with the Energy Sector, Natural Resources Canada. Enquiries should be directed to Robert Vance at tel. (613) 996-2599. E-mail: rvance@nrcan.gc.ca

OVERVIEW

In August 1997, the outlook for Canada's uranium industry improved when an agreement in principle was signed by Cameco Corporation, COGEMA of France, and Nukem Inc. of the United States to purchase uranium derived from dismantled Russian nuclear weapons. However, the agreement fell through when discussions were terminated in December, renewing uncertainty in the global uranium market. A successful agreement could have eased concerns about the uncontrolled release of surplus Russian uranium into world markets.

Despite further drawdowns of Western uranium inventories, world uranium spot prices declined until September, but increased in the fourth quarter. In some countries, low prices have deferred decisions to bring new mines on stream, even though primary global uranium output remains well below world requirements. Nonetheless, development work on important new production centres advanced during the year.

In Canada, uranium production capability continues to expand. In May 1997, the McArthur River project cleared the environmental review process when government approvals to proceed were received and a construction licence was granted in August. Ore from McArthur River will greatly extend the useful life of the Key Lake mill and allow an annual increase in output to 6900 tU.

Public hearings were concluded in August for the Cigar Lake and Midwest projects, and the Joint Panel on Uranium Mining Developments in Northern Saskatchewan reported its recommendations to governments in mid-November. Ore from these projects will be milled at McClean Lake, where combined annual production could exceed 9000 tU. At

McClean Lake, site construction was essentially completed in 1997 in anticipation of production during 1998.

In 1997, primary production in Canada surpassed the 11 706 tU produced in 1996. As Figure 1 shows, three of the world's top ten uranium-producing companies have operations in Canada. As of January 1, 1997, Canada's total "known" recoverable uranium resources were 430 000 tU, compared with 490 000 tU as of January 1, 1996. The downward adjustment of some 14% relates mainly to the closure of Rio Algom Limited's Stanleigh operation at Elliot Lake, Ontario, in mid-1996, and to the increase in overall Canadian uranium production during 1996.

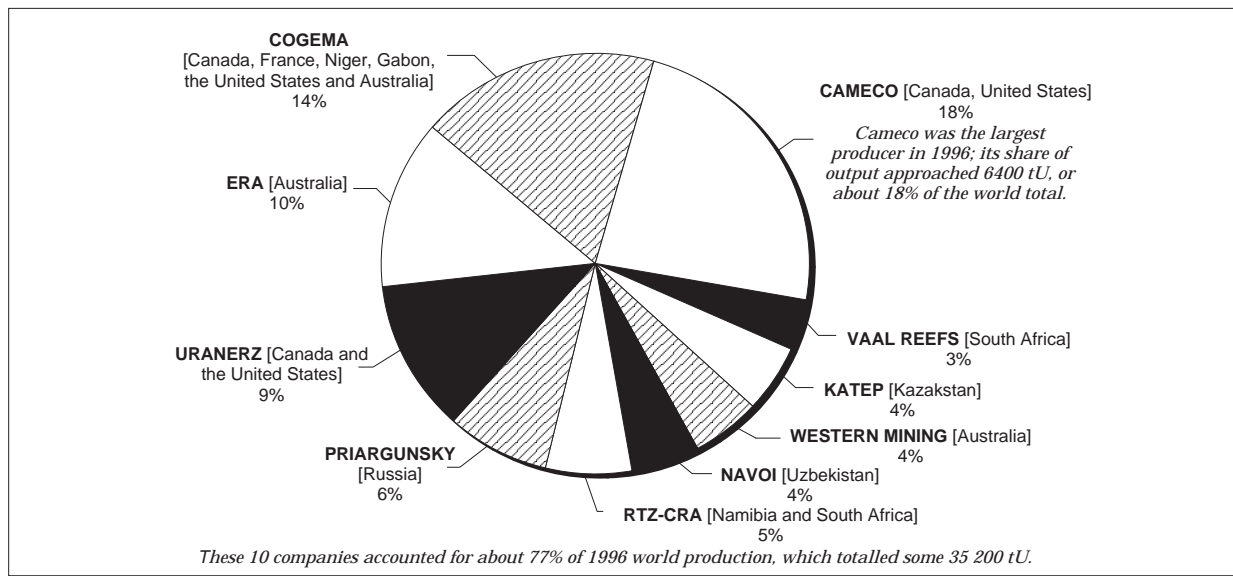
DOMESTIC PRODUCTION AND DEVELOPMENTS

Primary output from Canada's three uranium-producing operations in 1997 reached some 12 030 tU, up by almost 3% from 1996 production (see Table 1). Overall employment at Canada's producing operations approached 1000 in mid-1996 due to the Stanleigh mine closure, but has increased due to pre-production activities at the McClean Lake and McArthur River projects in Saskatchewan. As indicated in Table 2, preliminary estimates of 1997 mine shipments, under all domestic and export contracts, increased in tonnage and decreased in value compared with the revised 1996 estimates. Uranium continues to rank among Canada's top ten metal commodities in terms of output value. Table 3 highlights the main operational characteristics of the existing uranium production centres in 1996, the most recent year for which complete data are available. Table 4 updates the status of new projects that represent Canada's future production capability, while Figure 2 locates Canada's producing uranium mines and major deposits and Figure 3 shows domestic production by project and owner for 1996.

Elliot Lake, Ontario

In June 1996, the Elliot Lake Environmental Assessment Panel submitted recommendations to the federal government concerning plans by Rio Algom and Denison Mines Limited to decommission mill tailings sites in the Elliot Lake area. The Panel

Figure 1
World's Top Ten Uranium Mining Companies in 1996



Source: Uranium Institute Pocket Guide, July 1997.

Note: Ranking reflects equity interest in production facilities, not market share.

agreed with the decommissioning proposals set out by Rio Algom and Denison, and recommended certain conditions for closing and reclaiming the Quirke, Panel, Denison and Stanrock tailings facilities.

On April 2, 1997, the federal government responded to the Panel, agreeing with its recommendations that proposals submitted by Denison and Rio Algom should form the basis of the decommissioning licences for the uranium tailings waste management areas, and that the licensing process may proceed. Decommissioning is now proceeding at the specific sites in compliance with regulatory guidelines.

Athabasca Basin, Saskatchewan

The Rabbit Lake uranium production facility is operated by Cameco Corporation in a joint venture with Uranerz Exploration and Mining Limited. The Rabbit Lake mill increased its annual output again in 1997 to produce 4633 tU, up sharply from 1996. While the Eagle Point underground mine was the major ore source, mining at the Collins Bay "C" Zone, which began in January and was completed in March, produced ore containing more than 6500 tU. Stockpiled Collins Bay "D" Zone ore was milled during the first half of 1997, but the mill switched to a mixture of Collins Bay "A" and "B" Zone ores for the remaining six months. Decommissioning of the three Collins Bay mine sites is proceeding. The "B" Zone pit, mined out in 1991, was flooded after special mineralized waste rock was put in place and covered with till; the "B" Zone waste rock stockpile remains to be contoured and revegetated. Filling of the "D" Zone pit was completed in 1996, while the "A" Zone

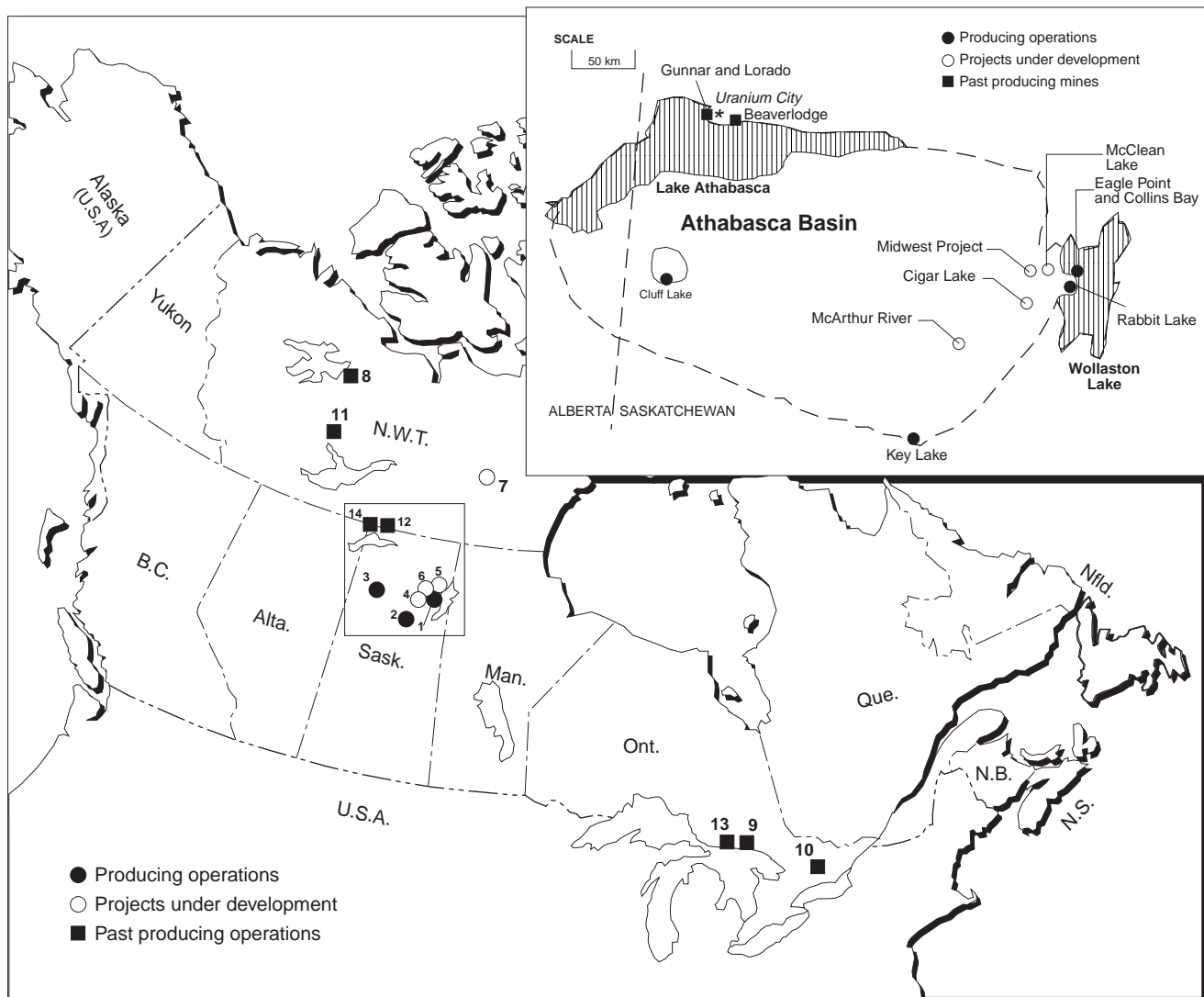
pit was filled by the end of 1997. Final decommissioning will follow.

The Key Lake uranium production facility is also operated by Cameco in a joint venture with Uranerz. The last ore mined at Key Lake came from the Deilmann pit in April 1997. During the year, production from stockpiled Deilmann ore reached 5434 tU, up slightly from 1996. On August 22, 1997, the Atomic Energy Control Board (AECB) renewed the operating licence for the Key Lake mine to September 30, 1999. It also licensed the construction of surface and underground facilities, as well as service infrastructure, at the McArthur River mining project, which received federal and provincial approvals to proceed in May. If the regulators grant the final approvals to proceed to production, the McArthur River project will begin feeding the Key Lake mill in late 1999.

The Cluff Lake uranium production facility, owned by COGEMA Resources Inc. (CRI), is located in the western Athabasca Basin. In 1997, its overall production reached 1964 tU, up almost 2% from 1996. Open-pit mining, which began in 1979 and continued except in the early 1990s, was completed in July 1997 when the south extension of the Dominique-Janine orebody was mined out. The remaining resources at Cluff Lake are all underground at the Dominique-Peter and Dominique-Janine West orebodies.

The McClean Lake uranium production facility being developed on the eastern edge of Saskatchewan's Athabasca Basin is majority-owned and operated by CRI. On February 21, 1997, the AECB approved

Figure 2
Uranium Mining in Canada, 1997



Numbers refer to locations on map above.

PRODUCING OPERATIONS

- 1. Rabbit Lake (incl. Eagle Point and Collins Bay)
- 2. Key Lake
- 3. Cluff Lake

PROJECTS UNDER DEVELOPMENT

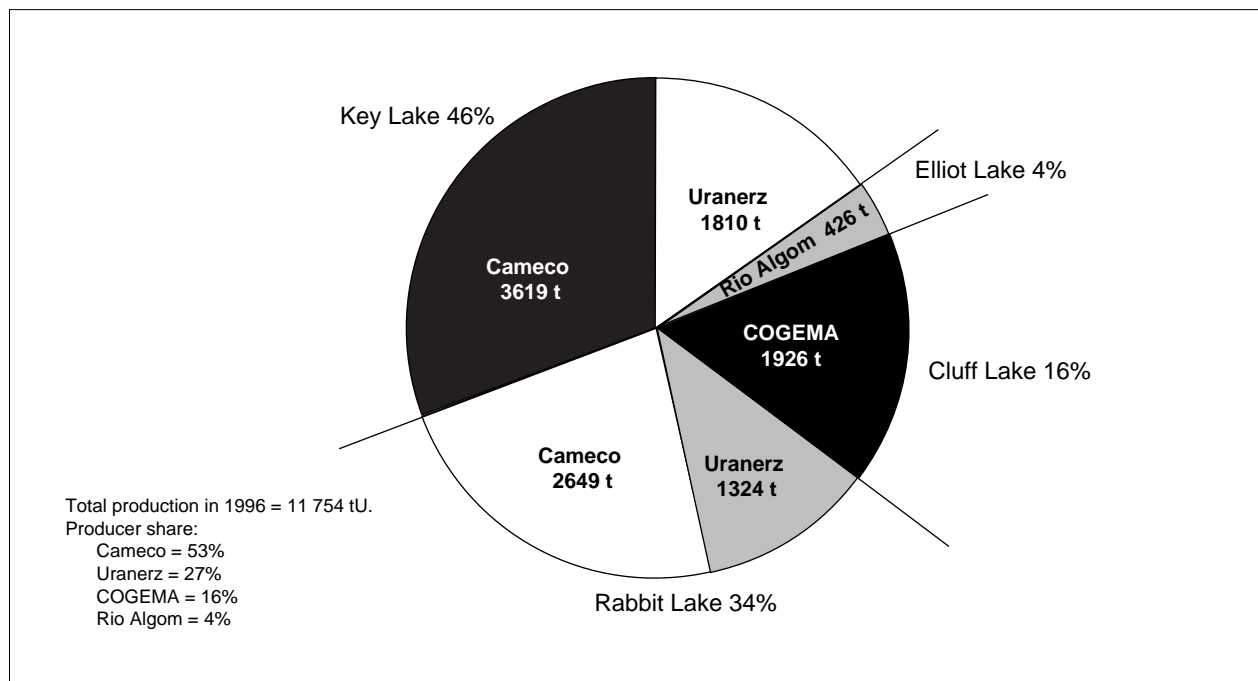
- 4. McArthur River
- 5. Midwest/McClean
- 6. Cigar Lake
- 7. Kiggavik

PAST PRODUCING DEVELOPMENT

- 8. Port Radium
- 9. Agnew Lake
- 10. Madawaska et al (Bancroft)
- 11. Rayrock (Marian River)
- 12. Beaverlodge et al
- 13. Quirke/Panel/Denison and Stanleigh et al (Elliot Lake)
- 14. Gunnar and Lorado et al

Source: Uranium and Radioactive Waste Division, Natural Resources Canada.

Figure 3
Canadian Uranium Production and Ownership, 1996



Source: Uranium and Radioactive Waste Division, Natural Resources Canada.

an amendment to the McClean operating licence, authorizing CRI to prepare the Sue C1 open pit for mining and to operate the associated water treatment facilities. By year-end 1997, site construction at McClean was complete, with all buildings covered and all major equipment received and in place; the JEB open pit was mined out, the ore stockpiled, and the pit prepared for use as a tailings management facility (TMF). At the Sue C1 site, mining was on target, averaging 12 000 m³/d.

Good progress had been made toward an anticipated July 1, 1997, production start-up of the McClean mill. However, compliance delays pushed this date into the fall, and the AECB decided not to give initial consideration to CRI's application to construct the TMF. The Joint Panel had requested supplementary information on the TMF, which was presented at final public hearings held from August 26 to 28, 1997, to complete the reviews of the Cigar Lake and Midwest projects (see below). In November 1997, Denison reported that the start-up of the McClean mill was not expected until mid-1998, with full production by the fourth quarter.

Conditional upon the necessary approvals being granted by the regulators, throughput capacity at the McClean mill may be expanded fourfold from 2300 to 9200 tU in order to handle ore from the Cigar Lake project beginning around 2001. After the last McClean Lake ore from the JEB and Sue deposits is

processed through the mill around 2003, ore from the Midwest project will be milled, followed by ore from the McClean underground mine around 2009.

Early in 1998, the McClean Lake project remained in standby mode awaiting approval of a construction licence for the JEB TMF. Staff at the mill are maintaining the JEB water treatment plant and dewatering wells, and completing commissioning modifications and training sessions.

Additional Production Possibilities

Beyond these existing and committed centres of uranium production, there are a number of new projects that could be brought on stream in the next few years if environmental and regulatory approvals are received. Table 4 updates, as of December 1997, recent developments at the mining projects that will form the basis of Canada's uranium production capability well into the future, and indicates the current status of the environmental review process for each of them.

Saskatchewan Environmental Assessment and Review Panels

Background

In 1991, six uranium mining projects in Saskatchewan were referred pursuant to the federal

Environmental Assessment and Review Process (EARP) Guidelines Order. In October 1993, a Joint Federal-Provincial Environmental Assessment Panel on Uranium Mining Developments in Northern Saskatchewan (the Joint Panel) reported on three projects, namely the Dominique-Janine Extension at Cluff Lake, the McClean Lake project, and the Midwest Joint Venture project. Federal and provincial governments responded to the recommendations of this panel in December 1993. Essentially, both governments stated that the Cluff Lake and McClean Lake projects should proceed, subject to the phased AECB licensing process, but that the Midwest project should not be approved as then designed. A second panel, representing only the federal government, reported on the Eagle Point/Collins Bay expansion at Rabbit Lake in December 1993. The federal government responded to the recommendations of this panel in March 1994, stating that the Rabbit Lake expansion should also proceed subject to AECB licensing.

McArthur River Project

In late February 1997, the Joint Panel submitted its report on the McArthur River uranium project, recommending that approval be granted for mining, for mill tailings disposal, and for building a road from McArthur River to the Key Lake mill, each with certain conditions. The provincial and federal governments released their reports on May 5 and 8, respectively, agreeing that the McArthur River project should be allowed to proceed, subject to the normal phased licensing process of the federal and provincial regulators.

As this project involves mining high-grade ore, the proponent is required to provide solutions for two primary technical problems: how to safely mine the ore, and how to securely dispose of the tailings. Given the possible impacts on Northern people and the environment, the Joint Panel also emphasized two ongoing requirements: the monitoring of environmental impacts over the very long term, and the need to ensure participation by Northerners in major decisions as the development proceeds. The key issues addressed by the Joint Panel include: rigorous enforcement of appropriate procedures to protect workers from unnecessary radiation exposure; the development of plans for perpetual monitoring of the tailings management facility before tailings deposition begins; long-term monitoring of environmental impacts downstream from release sites to protect Northern people and the environment; a gradual increase in employment for Northerners from the present 50% level to 67%; and an objective of obtaining 35% of the goods and services for the project from Northern suppliers.

On August 22, 1997, the AECB licensed the construction of surface and underground facilities and service infrastructure at the McArthur River uranium mining project. Cameco reported that construction crews began work immediately so that production could start in late 1999. Total employment at both sites is

expected to peak at 600 during the two-year construction period, and then level off to about 530 workers during production. The granting of the AECB construction licence marks an end to the multi-phase, six-year environmental review process.

Cigar Lake and Midwest Projects

Supplementary information requested by the Joint Panel in late 1996 on the disposal of tailings into the JEB pit at McClean Lake was submitted by the proponents on May 2, 1997. After a 30-day public review, the Panel decided that sufficient data had been provided to warrant holding public hearings. Final hearings were held in late August to complete the environmental review of the Cigar Lake and Midwest projects. Prior to these hearings, the AECB had decided not to give initial consideration to CRI's application to construct the JEB TMF where the Cigar Lake and Midwest tailings will be deposited. This decision delayed the start-up of the McClean Lake mill until 1998, affecting a work force of 250 persons.

On November 12, 1997, the Joint Panel released to governments its reports on the Cigar Lake and Midwest uranium mining projects, as well as a third report that summarizes the Joint Panel's "cumulative observations" on the five uranium mining developments that it had reviewed in Saskatchewan since 1991. The main recommendations in the Joint Panel's latest report are generally similar to those noted above relating to the McArthur River project. However, the Panel had very specific reservations about use of the JEB TMF, making a number of recommendations that it felt were necessary before tailings deposition should be permitted, including certain experiments. Overall, the Panel recommended that these projects should be allowed to proceed to the regulatory licensing approval phase, subject to certain conditions. The federal and provincial governments carefully reviewed all of the Panel's recommendations, and were expected to respond early in 1998.

Other Developments Affecting Canada's Uranium Industry

In June 1997, Cameco acquired from CRI the remaining 25% interest in the Highland *in-situ*² leach (ISL) uranium project in Wyoming that was not previously owned through Power Resources Inc. (PRI), which Cameco acquired in January 1997. In return, Cameco transferred to CRI its participating 20% interest in the Kiggavik uranium property located in the Northwest Territories, and entered into a contract to supply CRI with some 300 tU over the 1997 and 1998 period.

Also in mid-1997, Tokyo Electric Power Co., Inc. (TEPCO), Japan's largest nuclear power utility, acquired a 5% interest in the Cigar Lake project from Idemitsu Kosan. The transaction reduced Idemitsu's holding in Cigar Lake to 7.875% (see Table 4).

On August 20, 1997, Cameco announced that it had agreed to sell four million common shares for \$51 per share to a group of underwriters on a bought-deal basis for sale in Canada, the United States and internationally. Cameco expects to use the proceeds from this sale for expenditures related to the company's uranium business, which may include development and exploration activities, product purchases, or the acquisition of further property interests. On September 4, Cameco announced that this sale had been successfully completed.

On August 25, 1997, it was reported that CRI had signed a 10-year contract with TEPCO to supply some 5400 tU beginning in 1999. The uranium, to come from the McClean Lake and Midwest projects in northern Saskatchewan, will be supplied by McClean Uranium Limited, which is owned by CRI (70%) and Denison Mines Limited (30%).

EXPLORATION

Natural Resources Canada (NRCan) completed its twenty-third annual assessment of Canada's uranium supply capabilities and an associated survey of uranium exploration activity, and reported³ the results in July 1997. Uranium exploration activity remains concentrated in areas favourable for the occurrence of deposits associated with Proterozoic unconformities, notably in the Athabasca Basin of Saskatchewan and the Thelon Basin in the Northwest Territories. In 1996, overall uranium exploration expenditures reached \$39 million, while uranium exploration and surface development drilling approached 79 000 m, up from about 75 000 m reported for 1995.

In recent years, most of the increase in the overall expenditures noted above can be attributed to advanced underground exploration, deposit-appraisal activities, and care-and-maintenance expenditures associated with those Saskatchewan projects awaiting production approvals. In comparison, the Saskatchewan government estimates that "grass-roots" uranium exploration in the province reached \$17 million in 1996, up from some \$12.5 million in 1995, and could exceed \$20 million in 1997. A summary of uranium exploration activity in Canada from 1980 to 1996 is provided in Table 5.

In recent years, the number of companies with major exploration programs in Canada has declined. However, more than half of the 70 uranium projects maintained in good standing in 1996 were actively explored. The top five operators,⁴ accounting for nearly all of the \$39 million expended in 1996 are: Cameco Corporation, Cigar Lake Mining Corporation, CRI, PNC Exploration (Canada) Co. Ltd., and Uranerz Exploration and Mining Limited. Expenditures by CRI include those of Urangesellschaft Canada Limited.

RESOURCES

NRCan's annual assessment of domestic uranium supply capability provides a compilation of Canada's "known" uranium resources, based on the results of an evaluation of company data. Uranium supply from Canada in the next decade will come from known resources, estimates of which are divided into three major categories, *measured*, *indicated* and *inferred*, that reflect different levels of confidence in the reported quantities. Most of these resources are associated with deposits identified in Figure 2.

Recent NRCan assessments of Canada's uranium resources have been restricted to those recoverable from mineable ore at prices of \$150/kgU or less. Table 6 shows the breakdown of the latest resource estimates, compared with those of the previous year. It indicates that with the closure of the last mine at Elliot Lake, Ontario, there are now no known mineable resources estimated within the \$100-\$150/kgU price range. As of January 1, 1997, total recoverable known uranium resources were estimated at 430 000 tU, compared with 490 000 tU as of January 1, 1996. The downward adjustment of some 14% relates mainly to the closure of Rio Algom Limited's Stanleigh mine at Elliot Lake, Ontario, in mid-1996, and to increased overall Canadian uranium production during the same year.

SUPPLY CAPABILITY

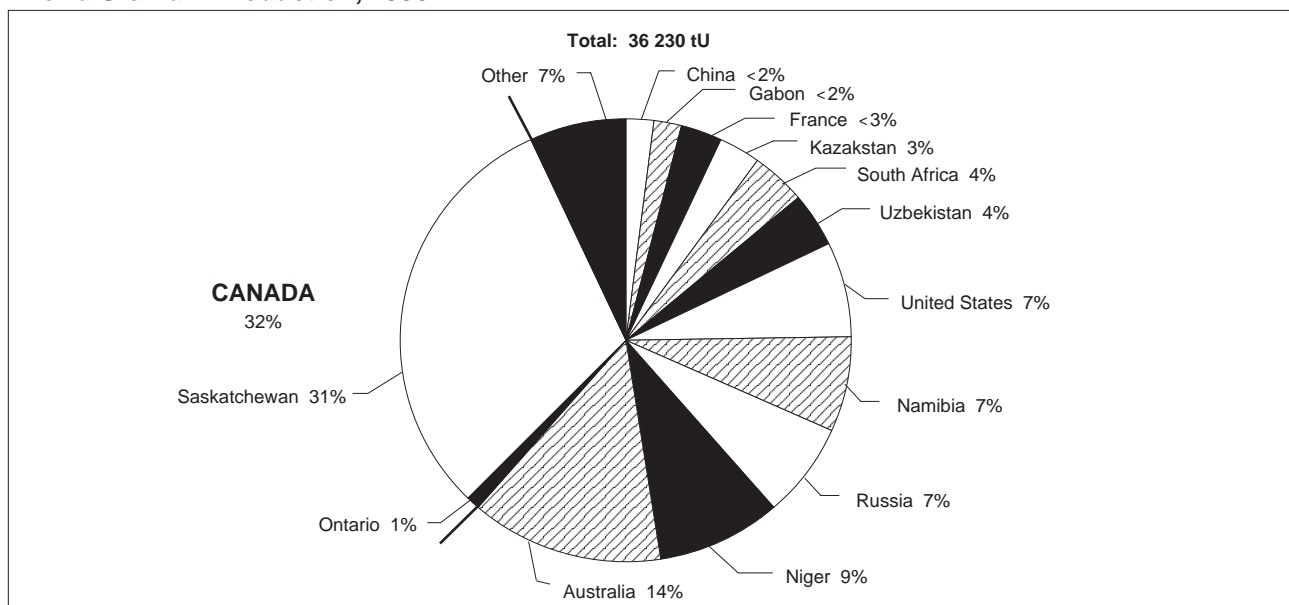
In 1997, Canada's uranium supply capability was maintained as producers were able to adjust output levels to compensate for the mine closure in Ontario. Timely environmental approvals and higher uranium prices will be required to allow Canada's production capability to expand to its full potential of 20 000 tU or more annually early in the next century.

Developments in the international uranium market, the rate at which projects clear environmental reviews, and uncertainty regarding the costs associated with certain of the planned new projects preclude projecting future production capability levels with much certainty. Table 7 ranks Canada among the world's major producers, showing actual uranium production from 1992 through 1996. Figure 4 illustrates Canada's share of world output in 1996 compared with other major producers.

GOVERNMENT INITIATIVES

On March 20, 1997, Bill C-23, the *Nuclear Safety and Control Act* (NSCA), received Royal Assent. One goal of the new Act was to meet the need for clear, strong, up-to-date legislation governing uranium mining and milling. Regulations under the NSCA are now being prepared, and it is anticipated that the Act and related regulations will come into force late in 1998.

Figure 4
World Uranium Production, 1996



Source: Uranium and Radioactive Waste Division, Natural Resources Canada.

THE URANIUM MARKET

Overview

World uranium production continues to provide just over half of the world's uranium requirements, with the balance coming largely from inventory. During 1997, the United States Department of Energy (USDOE) announced that the sale of up to 1230 tU of its excess inventory would not have an adverse impact on the global uranium market. As well, various agreements now in place will limit the rate at which surplus military uranium from the Former Soviet Union (FSU) and the United States enters the key U.S. market. These developments bode well for the Canadian uranium industry.

Developments Involving Surplus Uranium from the Former Soviet Union and the United States

On May 8, 1997, Cameco responded to international media coverage of ongoing negotiations involving Cameco, COGEMA of France, and the Russian Federation Ministry of Atomic Energy (Minatom) concerning natural uranium derived from the dismantling of Russian nuclear weapons. Cameco confirmed that discussions with Minatom on alternative proposals for the disposition of this uranium had been under way since 1993, but that no agreement had yet been concluded. The uranium involves the equivalent of some 154 000 tU, representing less than three years of Western World uranium con-

sumption. The sale of this material is governed by previously announced U.S. legislation that limits the annual volumes entering the U.S. market to a maximum of 770 tU beginning in 1998 and rising gradually to 7770 tU by 2009.

On August 18, 1997, Cameco reported that it had signed an agreement in principle to purchase uranium from dismantled Russian nuclear weapons. The agreement was to cover the purchase by Cameco, COGEMA of France, and Nukem Inc. of a majority of the natural uranium hexafluoride that becomes available through 2006 as a result of the dilution in Russia of weapons-grade "highly enriched uranium" (HEU) to commercial-grade, low-enriched uranium for delivery to the United States Enrichment Corporation (USEC). Cameco and the other purchasing companies were to pay discounted market prices for the uranium and guarantee minimum prices subject to certain conditions being met. Each company was to market its share independently in compliance with the *USEC Privatization Act* and other applicable laws.

However, on December 11, 1997, Cameco confirmed that discussions with Minatom had been suspended. The parties were unable to agree upon a structure that would provide the Western companies with the assurance contemplated in the agreement in principle signed in August that the final agreement would be carried out in accordance with the principles established in the 1993 United States/Russia government-to-government HEU agreement. The Western companies consistently refused to expose themselves

financially or otherwise to the risks inherent in the alternative structures that had been advanced by the Russian representatives of Minatom's affiliates Global Nuclear Services and Supply (GNSS) and Technabexport (TENEX).

Cameco noted Minatom's intention to market the uranium on its own through GNSS and TENEX, selling the material at floor prices above the average of world market prices. This uranium would still be subject to trade restrictions and policies limiting the volumes that can be sold in the United States and Europe. Cameco noted that the Western companies remain willing to resume serious negotiations with representatives of Minatom as soon as their concerns are satisfactorily addressed.

It is still hoped that this surplus uranium will be directed into long-term contracts with utility customers in a manner that would minimize market disruption. This would remove some uncertainty in the international uranium market, and help provide an environment that would allow the development of new high-grade mines in Saskatchewan to proceed.

It is unlikely that any significant new quantities of government-source uranium originating from disarmament initiatives will become available to the market over the next 10 years. A legislated schedule applies to the release in the U.S. market of those quantities that will become available during the next decade. Given the restrictions that apply in other important markets, and the certainty brought about by the required disclosure of quantities and scheduling, those companies considering investment in new

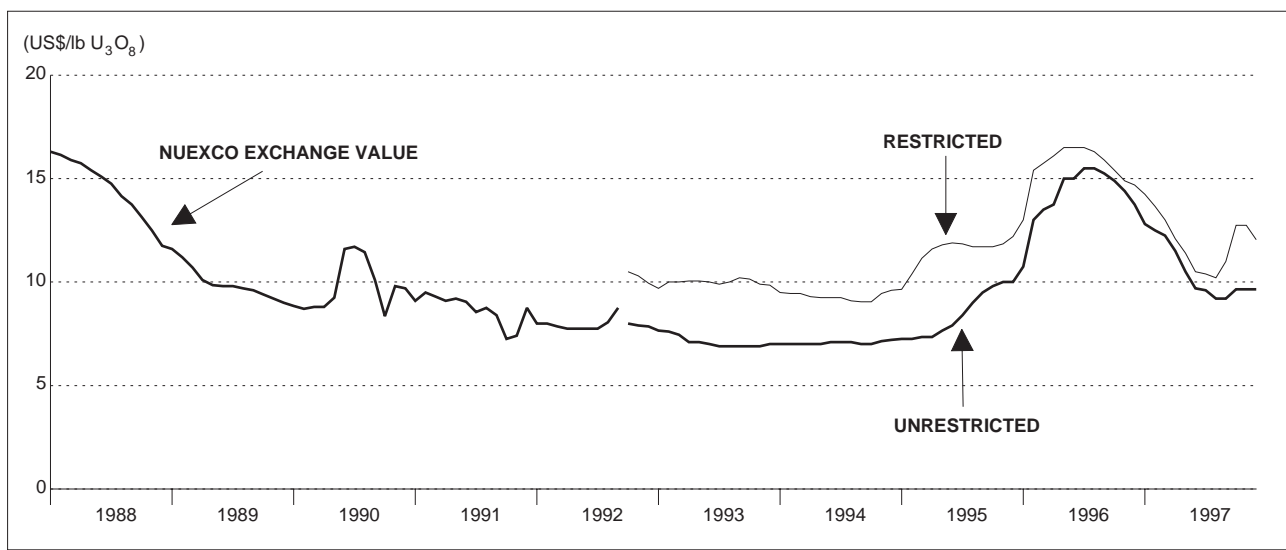
uranium production facilities should be able to make decisions in a much more stable environment.

Uranium Prices

In 1992, a two-tiered spot market price developed when import restrictions were placed on FSU uranium in the United States and the European Union. The "restricted" market price peaked at US\$16.60/lb in mid-June 1996, but ended the year at US\$14.70/lb U_3O_8 . The "unrestricted" price also rose rapidly into 1996, but slipped to US\$13.75/lb U_3O_8 at year-end, as reported by TradeTech, a successor of NUEXCO.⁵ The "restricted" and "unrestricted" spot prices continued their decline through August of 1997, but reversed directions and, by year-end, reached US\$12.05/lb U_3O_8 and US\$9.65/lb U_3O_8 , respectively, with few expecting that prices would decline again to mid-1990 levels. Figure 5 shows the development of uranium spot prices from 1988, the last time prices were above US\$15.00/lb U_3O_8 .

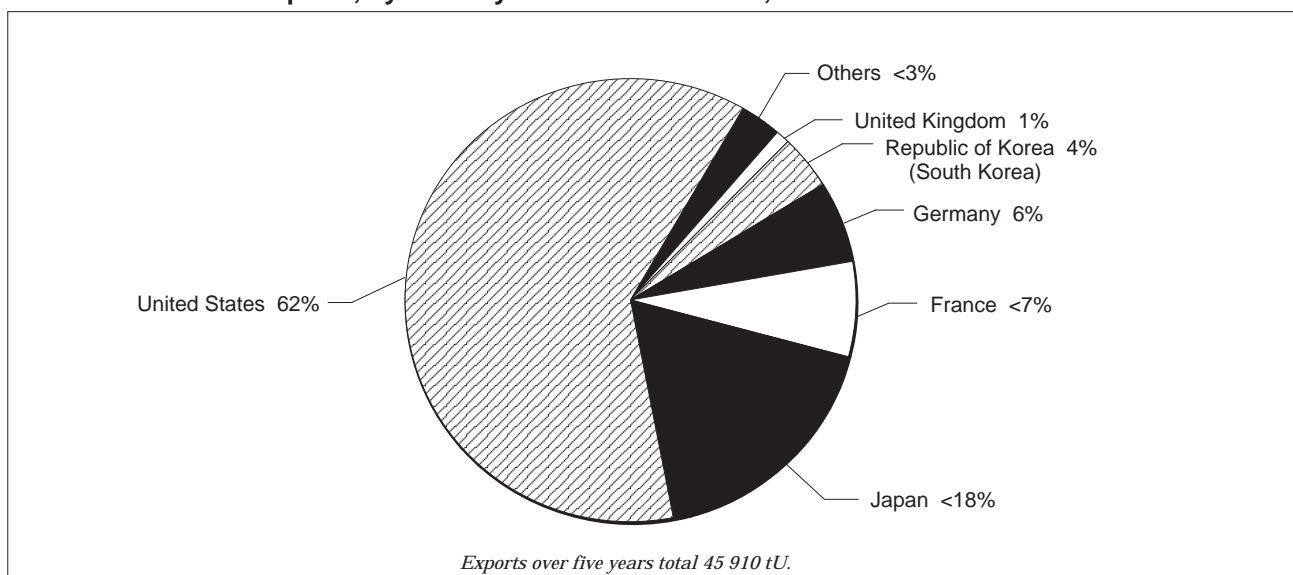
In comparison with spot market prices, the average price of Canadian export deliveries decreased from \$53.60/kgU (US\$15.10/lb U_3O_8) in 1996 to \$51.30/kgU (US\$14.20/lb U_3O_8) in 1997, reflecting mainly the decline in spot prices. Table 8 shows the export price trend from 1974 to 1997, while Table 9 indicates actual exports of Canadian-origin uranium to principal customers from 1991 to 1996. The destination of Canada's exports of uranium in concentrates on a cumulative basis (1992-96 inclusive) is illustrated in Figure 6, which highlights the importance of the United States as a major customer.

Figure 5
Trend in Uranium Spot Prices, 1988-97



Source: TradeTech.

Figure 6
Canadian Uranium Exports, by Country of Final Destination, 1992-96



Source: Atomic Energy Control Board (AECB), Canada.

REFINING AND CONVERSION

Cameco operates Canada's only uranium refining and conversion facilities, located at Blind River and Port Hope, Ontario, respectively. At the Blind River refinery – the world's largest – uranium mine concentrates from Canada and abroad are refined to uranium trioxide (UO_3), an intermediate product. The UO_3 is then trucked to the Port Hope facilities, which have about one quarter of the Western World's annual uranium hexafluoride (UF_6) conversion capacity and currently provide the only commercial supply of fuel-grade natural uranium dioxide (UO_2). UF_6 is enriched outside Canada for use in foreign light-water reactors, while natural UO_2 is used to fabricate fuel bundles for CANDU reactors in Canada and abroad. About 80% of the UO_3 from Blind River is converted to UF_6 , while the remaining 20% is converted to UO_2 . Table 10 tabulates Canada's production of refined and converted uranium, and notes the associated work force, from 1993 to 1996, inclusive.

NUCLEAR POWER DEVELOPMENTS

On August 13, 1997, Ontario Hydro's Board of Directors announced the lay-up of 7 of its 19 operating CANDU reactors in order to dedicate resources to bringing the other 12 units back to their previous standard of excellence through a major overhaul. Once that target is achieved, Ontario Hydro will evaluate restarting the 7 laid-up units by preparing the necessary business cases, including a review of other generation options that will be available to the utility at that time.

The decision was based on the results of the *Independent, Integrated Performance Assessment (IIPA)* of Ontario Hydro's 20 reactors, including one unit at Bruce A that was mothballed in 1995. The IIPA report, by the Nuclear Performance Advisory Group, indicated that Ontario Hydro had difficulty in its transition from a large, design-and-construction organization to an operating-and-maintenance-driven company. The report emphasized that CANDU technology is not the problem, for it is fundamentally sound and "robust," and that nuclear plants are being operated safely under licences approved by the AECB within its established standards. The reactor lay-up is not because of safety problems. At the root of Ontario Hydro's declining nuclear performance over the past few years is the manner in which the corporation was managing and operating its nuclear facilities. The prevalent view on how the utility had arrived at this critical juncture is that organizational changes and downsizing in recent years led to insufficient resources (financial and human) being made available to properly manage the nuclear operations.

The relevant statistics for Canada's nuclear energy program are provided in Tables 11 and 12.

Internationally, bids were requested by Turkey for the first nuclear power station at the Akkuyu site. Atomic Energy of Canada Limited (AECL) expressed an interest and submitted its bid during 1997. Construction is proceeding on schedule for the three CANDU reactors at Wolsong in the Republic of Korea (South Korea). Wolsong 2 was declared in-service in July 1997, while Units 3 and 4 are scheduled for 1998 and 1999, respectively. CANDUs for Bongil 1 and 2 may also be purchased as AECL develops a larger

950-MWe capacity reactor for the Korean market. In China, the contract between AECL and the China National Nuclear Corporation for the sale of two CANDUs took effect in January 1997; the in-service dates for two 700-MWe reactors at Qinshan are January and October 2003.

OUTLOOK

Declining uranium spot market prices in 1997 did little to reassure Canada's uranium producers, which have successfully guided several new mining proposals through the public environmental review process. Subject to licensing approvals, the start-up over the next few years of the McClean Lake, McArthur River and Cigar Lake world-class projects in Saskatchewan will form the basis of enhanced Canadian production capability well into the next century.

With these world-class projects and the significant potential for discovering additional uranium resources, Canada will be able to maintain its role as a reliable and competitive supplier to its trading partners. Having established a sizeable baseload of long-term supply contracts with customers in the United States, Western Europe and the Far East, Canada's uranium producers are well positioned to remain competitive with the world's other major uranium suppliers. As a result, Canada's uranium industry can maintain its place as the world's leading supplier of uranium for many years to come.

ENDNOTES

¹ John French, an advisor on uranium markets (tel.: 613-995-7474), has contributed to the text in those sections dealing with international uranium market developments and uranium prices.

² *In-situ* leaching involves extracting uranium from ore in place in the deposit; acidic or basic solutions dissolve uranium as they are circulated through holes drilled into the orebody from surface.

³ *Canada's Uranium Industry - World's Largest High-Grade Uranium Mine Proceeding*, NRCan Mailing, July 25, 1997.

⁴ In certain cases, the identified operator has reported the total expenditures of a joint-venture effort. Therefore, contributions by other parties not responding to the NRCan survey are accounted for in the \$39 million total expenditure for 1996.

⁵ NUEXCO, an international uranium brokerage firm, was originally called the Nuclear Exchange Corporation. Several companies in the NUEXCO organization, which were associated with uranium trading, declared bankruptcy in early 1995. Certain of these have been reorganized and continue to provide brokerage services. NUEXCO's publication activities are carried on by TradeTech.

Notes: (1) For definitions and valuation of mineral production, shipments and trade, please refer to Chapter 65. (2) Information in this review was current as of March 1, 1998.

TABLE 1. URANIUM PRODUCTION AND ASSOCIATED WORK FORCE IN CANADA, 1994-96

Province and Producer	Company Work Force ¹ (Dec. 31)			Annual Output ² (tU)		
	1994	1995	1996	1994	1995	1996
ATHABASCA BASIN, SASKATCHEWAN						
Cluff Mining (COGEMA Resources Inc., 100%)	188	208	234	1 065	1 214	1 926
Key Lake JV (Cameco, 66 2/3%; Uranerz, 33 1/3%)	399	397	395	5 074	5 464	5 429
Rabbit Lake JV (Cameco, 66 2/3%; Uranerz, 33 1/3%)	234	249	281	2 868	3 148	3 973
McClean Lake (pre-production)	214	-	-	-
Subtotal	821	854	1 124	9 007	9 826	11 328
ELLIOT LAKE, ONTARIO						
Rio Algom Limited Stanleigh	550	488	31	640	647	378
Total	1 371	1 342	1 155	9 647	10 473	11 706

Sources: Company annual reports; Atomic Energy Control Board open files.

- Nil; .. Not available.

¹ Figures (rounded) are for company-payroll employees only; on-site contractors (mining, construction, services, etc.) are not included. ² Primary output only. In 1996, an additional 48 tU was recovered by the remaining Elliot Lake producer from Cameco's refinery/conversion facility by-products, compared with about 55 tU in 1995 and 53 tU in 1994. While these amounts are NOT included in the Canadian totals of primary uranium production noted above, they are included in the shipments and value of shipments figures provided in Table 2.

TABLE 2. VALUE¹ OF URANIUM SHIPMENTS² BY PRODUCERS IN CANADA, 1993-97

	Unit	1993	1994	1995	1996	1997 ^p
Total producer shipments	tU	8 727	11 253	10 293	11 396	11 416
Total value of shipments	C\$ millions	497	625	534	624	560

Source: Natural Resources Canada.

^p Preliminary.

¹ Value of shipments includes the value of uranium recovered from the refinery/conversion facility by-products noted in Table 1, which are not included in primary production. ² Shipments in tonnes of uranium (tU), contained in concentrate, from ore-processing plants.

TABLE 3. OPERATIONAL CHARACTERISTICS OF EXISTING CANADIAN URANIUM PRODUCTION CENTRES, 1996

Operating Entity (Operator)/Location	Ore-Processing Plant ¹			
	Capacity Nameplate	Recovery Overall	Annual Throughput	
	(t/d)	(%)	Total Ore (t)	Ore Grade (%)
Cluff Mining (COGEMA Resources Inc.)/ Cluff Lake, Saskatchewan	>950	98	312 500	0.63
Rabbit Lake JV (Cameco Corporation)/ Rabbit Lake, Saskatchewan	>2 500	97	260 700	1.58
Key Lake JV (Cameco Corporation)/ Key Lake, Saskatchewan	>800	98	321 100	1.72
Stanleigh Mine (Rio Algom Limited)/ Elliot Lake, Ontario	>4 500	93	437 300	0.081

Sources: Corporate annual reports; Atomic Energy Control Board open files.

¹ Figures are rounded.

TABLE 4. SUMMARY, CANADIAN URANIUM MINING PROJECTS, AS OF DECEMBER 31, 1997

Project, Province/Operator	Owners Percentage Share	Deposit Type/ Discoverer and Discovery Date	Resources (Company Estimates)	Ore Grade and Notes on Deposits	Mining Method, Milling Rate and Capacity	Project Particulars and Status	Location of Project/ Notes of Interest
(%)							
NEW PROJECTS PLANNED FOR PRODUCTION							
Cigar Lake, Sask./ Cigar Lake Mining Corporation	Cameco (48.75), COGEMA (36.375), Idemitsu (7.875), TEPCO (5), KEPCO (2 non-voting)	Unconformity-related/ COGEMA 1981	Overall property 136 000 tU, <i>mineable</i>	Overall property grade of 12% U; grades vary from 5% to 70% U; orebody at depth of 450 m	"Non-entry" underground; "jet-boring" mining method; milling at McClean Lake contributing from 2300 to 6900 tU/y	C\$555 million project; test mining completed in 1992; EIS submitted in October 1995; hearings concluded August 1997 and Panel reports November 1997	670 km N of Saskatoon; 500-m-deep shaft sunk; brine freezing of ground is required to mine the ore; project to produce in 2001
McClean Lake, Sask./COGEMA Resources Inc.	COGEMA (70), Denison (22.5), OURD (7.5)	Unconformity-related/ original McClean by CanOxy/Inco 1979-80; JEB & Sue <i>et al</i> - 1982 to 1990 by Minatco	Overall property 17 300 tU, <i>mineable</i>	2.7% U average overall; open-pit depths from 20 to 145 m; McClean under- ground ore to 4% U at depth of 170 m	75% by open pit at JEB, Sue A, B & C; under- ground at McClean; mill capacity may be expanded to 9200 tU/y (see Cigar Lake)	C\$200 million project (alone); public hearings in 1993; approved subject to AECB licensing process; construc- tion completed during 1997	350 km N of La Ronge; JEB open-pit mining started in 1996; milling delayed until 1998; mine life of the co- enterprise >2010
Midwest Project, Sask./COGEMA Resources Inc.	COGEMA (56), Denison (19.5), Uranerz (20), OURD (4.5)	Unconformity-related/ Esso Minerals 1977 (interests of Bow Valley, Numac Oil & Gas, <i>et al</i> bought by partners)	Overall property 13 000 tU, <i>mineable</i>	Overall property grade of 4% U; grades vary from 2% to 30% U; orebody at depth of 200 m	"Non-entry" underground; "jet-boring" mining method; milling at McClean Lake; contribut- ing 2300 tU/y	\$80 million co-venture with McClean; in 1993, Panel rejects proposal; new EIS in 1995; final hearings August 1997; Panel report November 1997	710 km N of Saskatoon; 185-m-deep test-mine shaft; new operator, COGEMA, revised EIS; start-up in 2003 (?)
McArthur River, Sask./Cameco Corporation	Cameco (55.844), Uranerz (27.922), COGEMA (16.234)	Unconformity-related/ Cameco 1988	Overall property 160 000 tU; but 73 000 tU <i>mineable</i>	Overall property grade varies from 2% to 70% U, but averages 13% U; <i>mineable</i> grade 16% U; orebody at depth of 550 m	"Non-entry" underground mining method with milling at Key Lake; licensed mill capacity 6150 tU/y but expandable to 6900 tU/y	C\$400 million project; 1993 underground exploration; EIS December 1995; public hearings 1996; Panel report February 1997; government approval May 1997	80 km NE of Key Lake; construction licence August 1997; start-up expected late 1999; will extend operations at Key Lake mill beyond 2015
Kiggavik, N.W.T./ Uranengesellschaft Canada Limited	Uranengesellschaft (79), COGEMA (20), Daewoo Corp. (1)	Unconformity-related/ Uranengesellschaft 1977	Overall property 15 000 tU, <i>mineable</i> ; (more incl. Andrew Lake <i>et al</i>)	0.41% U average overall; depth Centre pit 100 m, Main pit 200 m	Open-pit mining methods; 1200 t/d mill feed; output rate of 1200 tU/y originally expected	EIS submitted but project deemed deficient by Panel; COGEMA expected to review project and submit new EIS	75 km W of Baker Lake; start- up not likely before 2000; >11-year mine life with tributary ore included
RECENTLY APPROVED EXTENSIONS OR EXPANSIONS TO EXISTING OPERATIONS							
Dominique-Janine Extension (DJX) at Cluff Lake, Sask./ COGEMA Resources Inc.	COGEMA Resources Inc. (100)	Unconformity-related/ "D" pit by Mokta 1969 (depleted 1981); Claude <i>et al</i> /Amok 1970-76 (Claude depleted 1989); D-J & Dominique-Peter 1980-86	Overall property 13 000 tU <i>mineable</i> , D-J Extension 5000 tU, <i>mineable</i>	Mill-feed grade for 1996 was 0.63% U; DJX to mine >680 000 t of ore grading 0.73% U to yield in excess of 5000 tU	Open pit at DJX before underground; re-licensed mill capacity to 2020 tU/y; milling rate being increased from half- capacity operation	C\$10 million Cluff Lake extension; hearings in 1993; approval to proceed subject to AECB licensing; mining well under way in 1995	720 km N of Saskatoon; revised three-phase mine plan offers mining flexibility; mine life beyond 2000 with DJX
Eagle Point & Collins Bay at Rabbit Lake, Sask./Cameco Corporation	Cameco (66.67), Uranerz (33.33)	Unconformity-related/Gulf Minerals 1968; Rabbit Lake (depleted 1984); 1971-79 for Collins Bay ("B" pit depleted 1991); 1980 for Eagle Point	Eagle Point <i>et al</i> , 18 000 tU <i>mineable</i> , overall property 27 000 tU (incl. stockpiles)	Mill-feed grade for 1996 was 1.58% U; mineable grade 1.2% U for Eagle Point and 3.45% U for Collins "A&D"; Eagle Pit depth 120-335 m	"Non-entry" underground methods at Eagle Point, open pit for others; milling rate below 5400 tU/y licensed capacity, but increased in 1995	Eagle Point test mining 1992; Panel reviewed and federal government approved in 1993; Eagle Point in produc- tion, Collins A&D being mined	805 km N of Saskatoon; mining Eagle Point ore since late June 1994; expansion will extend mine life beyond 2000

Notes: OURD (Canada) Co., Ltd. is a subsidiary of the Overseas Uranium Resources Development Corporation (OURD) of Japan. Uranengesellschaft Canada Limited, operated by COGEMA Resources Inc., is a subsidiary of COGEMA of France. Idemitsu Uranium Exploration Canada Ltd. is a wholly owned subsidiary of Idemitsu Kosan Co., Ltd. of Japan. Korea Electric Power Corporation (KEPCO) is the Republic of Korea's only nuclear-electric utility. In June 1997, COGEMA acquired the 20% interest in the Kiggavik (Northwest Territories) project that Cameco had purchased earlier in the year when it acquired Power Resources Inc. The Tokyo Electric Power Co., Inc. (TEPCO), Japan's largest nuclear power utility, acquired a 5% interest in Cigar Lake from Idemitsu Kosan in mid-1997.

TABLE 5. URANIUM EXPLORATION ACTIVITY IN CANADA, 1980-96

Year	Expenditures ¹	Drilling ²	Million-Dollar Projects ³
	(C\$ millions)	(km)	(number)
1980	128	503	24
1982	71	247	13
1984	35	197	12
1986	33	162	11
1987	37	164	12
1988	59	201	11
1989	58	158	11
1990	45	66	6
1991	44	67	4
1992	46	79	4
1993	40	62	5
1994	36	67	8
1995	44	75	10
1996	39	79	8

Source: Natural Resources Canada.

¹ Direct exploration and drilling expenditures in current dollars; from the late 1980s, includes advanced underground exploration and deposit appraisal expenditures; from the mid-1990s, may also include care-and-maintenance costs associated with deposits awaiting production approvals.

² Exploration and surface development drilling; excludes development drilling on producing properties. ³ Number of projects where direct exploration and drilling expenditures exceeded C\$1 million in current dollars.

TABLE 6. ESTIMATES OF CANADA'S URANIUM RESOURCES RECOVERABLE FROM MINEABLE ORE,¹ JANUARY 1, 1997, AND JANUARY 1, 1996

Price Ranges Within Which Mineable Ore is Assessed ²	Measured		Indicated		Inferred	
	1/1/97	1/1/96	1/1/97	1/1/96	1/1/97	1/1/96
	(000 tU)					
Up to C\$100/kgU	151	165	180	201	99	118
C\$100 to \$150/kgU	–	<1	–	3	–	3
Total	151	165	180	204	99	121

Source: Natural Resources Canada.

¹ Actual or expected losses in mining recovery and ore processing have been accounted for; these factors were individually applied to resources tributary to existing or prospective production centres. In underground operations, mineable ore is generally 75% to 85% of the ore-in-place; higher mining recoveries are achievable in open-pit operations. Canada's weighted average ore processing recovery for existing conventional operations exceeded 97% over the 1995/96 period.

² The Canadian dollar figures reflect the price of a quantity of uranium concentrate containing 1 kg of elemental uranium. The prices were used in determining the cut-off grade at each deposit assessed, taking into account the mining method used and the processing losses expected. The price of C\$100/kgU was used by Natural Resources Canada to illustrate those resources that were of economic interest to Canada during the survey period.

Note: \$1/lb U₃O₈ = \$2.6/kgU.

TABLE 7. PRODUCTION OF URANIUM IN CONCENTRATES BY SELECTED MAJOR PRODUCING COUNTRIES, 1992-96

	1992	1993	1994	1995	1996
	(tonnes U)				
Canada ¹	9 340	9 190	9 700	10 530	11 750
Russia	(in Other)	2 700	2 350	2 200	2 600
Kazakstan	(in Other)	2 700	2 240	1 580	1 210
Uzbekistan	(in Other)	2 700	2 120	1 700	1 460
China	(in Other)	950	480	780	560
United States	1 860	1 290	1 290	2 324	2 430
South Africa	1 670	1 710	1 670	1 420	1 440
Namibia	1 680	1 670	1 900	2 010	2 450
Australia	2 330	2 270	2 210	3 710	4 970
Niger	2 970	2 910	2 980	2 980	3 320
France	2 150	1 710	1 050	1 020	930
Gabon	540	550	650	630	570
Other ²	12 600	2 770	2 370	2 730	2 540
Total ³	35 140	33 120	31 010	33 610	36 230

Sources: *Uranium: Resources, Production and Demand*, a biennial report published jointly by the Nuclear Energy Agency of the OECD and the International Atomic Energy Agency; miscellaneous corporate, national and international reports.

¹ Figures include refinery/conversion facility by-product uranium, and differ from primary production figures shown elsewhere. ² Includes Argentina, Belgium, Brazil, Bulgaria, China, the Czech Republic, Germany, Hungary, India, Israel, Japan, Kazakstan, Mongolia, Pakistan, Portugal, Romania, Russia, Spain, Ukraine, Uzbekistan and Yugoslavia; from 1993, *Other* excludes China, Kazakstan, Russia and Uzbekistan, which are listed separately. ³ Totals are of the listed figures only and represent global production.

Note: Country figures are rounded to the nearest 10 tU.

TABLE 8. CANADIAN URANIUM EXPORT PRICE,¹ 1974-97

Year	Average Export Prices		Spot Sale Portion of Deliveries
	Current Dollars	Constant 1997 Dollars	
	(C\$/kgU) ²		(%)
1974	39	118	n.r.
1975	52	143	n.r.
1976	104	263	n.r.
1977	110	259	n.r.
1978	125	276	n.r.
1979	130	262	n.r.
1980	135	246	n.r.
1981	110	180	1
1982	113	171	1.5
1983	98	140	10
1984	90	125	26
1985	91	123	20
1986	89	117	21
1987	79	99	35
1988	79	95	13
1989	74	85	<1
1990	71	79	<1
1991	61	66	<2
1992	59	63	<1
1993	50	53	<1
1994	51	53	<1
1995	47	48	2
1996	53.60	53.90	1
1997	51.30	51.30	<1

Source: Natural Resources Canada.

n.r. Not reported.

¹ NRCan derives the Export Price figure annually based on the average price under all export contracts made by Canadian producers for deliveries in the given year. ² \$/kgU x 0.38465 = \$/lb U₃O₈.

Notes: Prices are rounded. Constant dollar values are derived using the Implicit Price Index for Gross Domestic Product.

TABLE 9. EXPORTS OF URANIUM OF CANADIAN ORIGIN, 1991-96

Country of Final Destination	1991	1992	1993	1994	1995	1996
(tonnes of contained uranium ¹)						
Argentina	19	20	29	–	–	–
Belgium	–	–	–	115	3	115
France	822	111	461	766	1 016	679
Germany	459	534	665	465	348	776
Japan	399	2 328	523	3 443	363	1 490
Korea, Republic of	215	104	715	455	290	261
Spain	–	–	–	274	186	103
Sweden	91	170	–	–	84	142
United Kingdom	498	19	–	50	188	250
United States	5 307	4 032	6 291	4 938	5 702	7 407
Total	7 810	7 318	8 684	10 506	8 180	11 223

Source: Atomic Energy Control Board.

– Nil.

¹ Some of this uranium was first exported to an intermediate country for conversion and/or enrichment prior to transfer to the country of final destination.

TABLE 10. URANIUM PROCESSING PRODUCTION AND ASSOCIATED WORK FORCE IN CANADA, 1993-96

Process and Location (Nameplate Capacity)	Production				Site Work Force			
	1993	1994	1995	1996	1993	1994	1995	1996
	(tU)				(number)			
Refining at Blind River (18 000 tU as UO ₃)	6 833	9 445	10 729	10 190	81	81	86	90
Conversion at Port Hope (10 500 tU as UF ₆ and 2500 tU as UO ₂)	7 853	9 490	10 552	10 127	198	198	231	257

Source: Cameco Corporation.

TABLE 11. NUCLEAR POWER PLANTS IN CANADA AS OF DECEMBER 31, 1997

Reactors	Owner	Net Capacity (MWe)	In-Service Dates
Pickering 1 to 4	Ontario Hydro	2 060	1971-73
Bruce 1 to 4 ^a	Ontario Hydro	2 307	1977-79
Point Lepreau	NB Power ¹	635	1983
Gentilly 2	Hydro-Québec	638	1983
Pickering 5 to 8	Ontario Hydro	2 064	1983-86
Bruce 5 to 8	Ontario Hydro	3 440	1984-87
Darlington 1 to 4	Ontario Hydro	3 524	1990-93
Total net capacity		14 668	

Source: Natural Resources Canada.

^a Bruce Unit 2 out of service on October 8, 1995, and being mothballed.

¹ New Brunswick Power Corporation.

TABLE 12. NUCLEAR POWER DATA IN CANADA AS OF DECEMBER 31, 1997

	Unit	Canada	Ontario	New Brunswick	Quebec
Electricity demand growth	%	0.1	-0.6	2.6	2.1
Nuclear share of electric utility generation	%	14.2	49.0	20.9	2.5
Reactors in service	no.	21	19	1	1
Capacity in service	Net MWe	14 668	13 395	635	638

Source: Natural Resources Canada.

Note: Unit 2 of the Bruce Nuclear Generating Station was taken out of service on October 8, 1995.