T HARRR.

KPMG Peat Marwick Stevenson & Kellogg
Management Consultants

Project Report

PROSPECTS FOR SASKATCHEWAN'S NUCLEAR INDUSTRY AND ITS POTENTIAL IMPACT ON THE PROVINCIAL ECONOMY 1991-2020

Prepared for

Atomic Energy Canada Ltd.
Saskatoon, Saskatchewan

Submitted by

Roy Lloyd
Jim Bonny
Jim Macdonald

Saskatoon
October 21, 1991
3049/RL/89/tm

Contents

Executive Summary 1

I Current Impact Of The Nuclear Industry On The Saskatchewan Economy 3

A. Uranium mining 3

II Potential For Future Saskatchewan Participation In The Nuclear Fuel Cycle 11

A. Conversion 11

B. Enrichment 14

C. Fuel fabrication 17

D. Electrical generation 18

E. Reprocessing 31

F. Waste disposal 32

III Impact Of Incremental Participation In The Nuclear Fuel Cycle On The Saskatchewan Economy 41

A. Synergy amongst fuel cycle opportunities 41

B. Strategy to achieve public acceptance 42

C. Economic impact 43

Executive Summary

Uranium mining is an important industry in Saskatchewan. In 1990 it provided 2,125 person years of employment producing 16 million pounds U_3O_8. A combination of excessive inventories and new supply from the USSR is reflected in the very low spot price for uranium, currently less than US $10 per pound. However, as inventories are reduced to normal levels, prices are generally expected to strengthen to the US $20 range by the mid 1990's, a level required to bring forth sufficient mine production to meet demand. With large high grade reserves in place, Saskatchewan producers should be able to attain a 30% world market share and sustain this level at least through the year 2020. With the depletion of the Key Lake mine, about 20 million pounds of new mining capacity will have to be developed by the year 2000 to support 33 million pounds of annual sales. This will generate annual employment estimated at 3,365 person years.

Over the period 1991-2020 the uranium mining industry has the potential of contributing over $10 billion to Gross Saskatchewan Expenditures, over $7 billion to the provincial GDP, gross employment of over 100,000 person years, and Labour Income approaching $4 billion. Based on the 1989 Saskatchewan Economic Indictors, the average annualized uranium industry activity represents 1.3% of GDP and 1.4% of Labour Income.

From a strong uranium mining base, there is excellent potential for developing other areas of the nuclear fuel cycle in Saskatchewan, particularly enrichment, electrical generation, and used fuel disposal.

If the current R & D efforts by Cameco and Isotope Technologies are successful in developing the Crisla enrichment process, a small commercial plant of 250,000 SWU could be constructed by 1997 and then expanded progressively as markets are developed. If Crisla is not proven economic then a facility based on conventional centrifuge technology would be another possibility.

By the year 2000, including operation of the new Shand coal-fired station and the implementation of certain demand management measures, a shortfall of at least 400 MW of electrical generating capacity is projected. By 2005 normal demand growth and the planned retirement of the Queen Elizabeth coal-fired station in Saskatoon would increase this shortfall to at least 850 MW. Of the five potential sources for additional electricity supply in Saskatchewan (hydro, coal, natural gas, other technologies, and nuclear), nuclear power offers a number of advantages. A Candu-3 prototype would receive substantial financial support from the Federal Government. A successful Candu-3 project could result in a new Saskatchewan based export-oriented industry. The high initial capital cost of nuclear power is mitigated by the lower operating cost compared to coal-fired plants. Nuclear plants have no atmospheric emissions to contribute to the greenhouse effect or acid rain. Negative factors to be overcome include the perceived safety issue, the high initial cost and the uncertain costs of used fuel disposal and plant decommissioning. Nevertheless, there is good potential for constructing up to three 450 MW Candu-3 reactors prior to 2020.

With the world's largest uranium industry and a nuclear power program, Saskatchewan would be well positioned to develop a used fuel repository for disposal of used Canadian nuclear fuel. AECL estimates total direct costs of such a facility, excluding financing costs, at $9 to $14.5 billion, direct employment of 1,100 during construction and 600 during operation. Public hearings on AECL's proposal will likely occur in late 1992 or 1993 by which time Saskatchewan would have to declare its candidacy. A successful domestic used fuel disposal operation would generate some very profitable opportunities to lease uranium fuel, taking back the used fuel for disposal, which in turn would enhance the market for Saskatchewan uranium.

An expanded nuclear industry in Saskatchewan would provide a number of synergies. Uranium mining has put Saskatchewan in the nuclear industry and has established a basis of public acceptance to expand into enrichment and nuclear power generation. A commitment to nuclear power would in turn enhance the global markets perception of Saskatchewan as a secure source of uranium supply. A further commitment to waste disposal would permit the development of fuel leasing concepts which could increase Saskatchewan uranium sales by up to 10%.

The economic impact of an expanded nuclear industry in Saskatchewan was estimated with the aid of an input-output model of the Saskatchewan economy. The results for the thirty year period 1991-2020 are very significant. Gross Saskatchewan Expenditures in 1991 dollars would be $20 billion, or over $650 million annually. The industry would contribute over $12.5 billion to the provincial GDP, or $420 million annually. This represents 2.2% of the 1989 provincial GDP. Gross employment from an expanded nuclear industry would average 6,650 person years annually, or 1.49% of the current provincial labour force. Because of the nature of the employment, Labour Income would average more than $220 million annually, or 2.47% of the province's Labour Income in 1989.

To build on Saskatchewan's uranium industry and benefit from the other opportunities in the nuclear fuel cycle, a sufficient level of public acceptance must be developed and maintained. The world class uranium mining base, the need for electrical power generation capacity, and the comparative advantages of the Candu-3 form the basis for achieving public acceptance.

I

Current Impact Of The Nuclear Industry On The Saskatchewan Economy

A. Uranium mining

1. Supply-demand outlook

The demand for western world mine production can be estimated from nuclear generating capacity forecasts, deducting other sources of supply.

The requirements for uranium fuel are derived from forecast nuclear generating capacity (usually expressed in gigawatts electric, GWe), making reasonable assumptions for operating and fuel management parameters. Other sources of supply which must be deducted include recycled uranium and plutonium from reprocessed used fuel, direct and indirect supply from U.S.S.R. and China and drawdown of the large surplus inventories which accumulated during the 1970's and the first half of the 1980's.

The primary sources for Exhibit I-1 below are the forecasts prepared by the Uranium Institute in September, 1990.

Exhibit I-1
Western world demand for mine production (millions of lbs U_3O_8)

	1990	1995	2000	2005
Nuclear generating capacity (GWe net)	277	304	323	335
Reactor requirements	119	123	135	137
Supply from:				
USSR & China	10	10	10	10
Recycle	5	12	16	16
Inventory	29	11	0	0
Uranium mine production	75	90	109	111

At 75 million pounds western world mine production in 1990 was at its lowest level since 1978. Excess inventory held primarily by utilities, but also by producers and governments, is the primary depressant. Approximately 30 million pounds, or 25% of reactor requirements, was supplied from inventory in 1990. The inventory excess will continue into the mid-1990's although levels of drawdown are expected to fall to about 10 million pounds by 1995. Before the year 2000 the inventory bubble should have been eliminated. Consequently uranium mine production is expected to increase from 75 million pounds in 1990 to about 110 million pounds by the turn of the century.

This forecast assumes that direct and indirect supply in all forms from Russia and China will continue at a level equivalent to 10 million pounds U_3O_8 per year for at least the next 15 years. There is a great deal of uncertainty about the size of inventory which is available for export, the impact of production costs vis-a-vis the need for hard currency export earnings and the effect of the rapidly changing political and economic developments in the USSR.

The current supply demand imbalance is reflected in the very low spot price for uranium, less than US $10 per pound U_3O_8. Prices are generally expected to strengthen by the mid-1990's to the US $20 range which will be required to bring forth sufficient mine production to meet demand.

2. Saskatchewan's competitive position

Saskatchewan uranium producers have extensive high grade reserves and large efficient mining and milling operations. As a consequence the industry is highly competitive with cash costs amongst the lowest in the world. The producers rely primarily on long-term sales contracts. Recently with the low spot price, Saskatchewan producers have refrained from making spot sales. Consequently production in 1990 at 15 million pounds was only 50% of full capacity and below 1989 and 1988 production levels of 19 and 21 million pounds respectively.

In 1990 Saskatchewan production represented only 20% of western world production. Utility customers are very conscious of security of supply and consequently diversify their supply sources. In addition there are a number of tied-supply arrangements which further limit Saskatchewan's market penetration. On the positive side the rapid reduction of Elliot Lake production should result in a larger Saskatchewan market share than might otherwise be the case. With effective marketing, and continued reliable operations, Saskatchewan producers have the potential to reach about 30% of western world production.

Developments in Australia (1990 production 9.2 million pounds U_3O_8) which currently restricts uranium production to two mines and in South Africa (6.6 million pounds) and Namibia (8.3 million pounds) will affect Canada's and Saskatchewan's market potential.

Exhibit I-2
Saskatchewan production potential (millions of lbs U_3O_8)

1990	1995	2000	2005
15*	27	33	33

*Actual

It should be noted that Canadian production has ranged from 30% to 33% of western world production over the last five years. Thus a 30% level for Saskatchewan producers and 1.5% to 2% for an Ontario producer supplying 40% of Ontario Hydro requirements seems realistic. If Elliot Lake were to be shut down completely in 1996 as now appears likely, Saskatchewan producers might do slightly better than 30%. However, most major utilities would be reluctant to see "too many eggs in one basket". Overall the 30% market share projection is a conservative one which assumes that Saskatchewan producers will not over produce to the point that profits as well as prices would decline.

3. Saskatchewan's current production sources

There are three mines in Northern Saskatchewan, two of which are currently operating, Key Lake and Cluff Lake. The third mine Rabbit Lake is shut down because of the weak uranium market. It is expected to restart in August this year.

Exhibit I-3
Existing Saskatchewan uranium mines

	Key Lake	Rabbit Lake	Cluff Lake
Capacity (million lbs U_3O_8/yr)	14	12	4
1990 Production (million lbs U_3O_8/yr)	12.9	0	2.0
Reserves (million lbs U_3O_8)	110	163	43
Average Grade (% U_3O_8)	1.75%	1.05%	0.77%
Mining Method	O/P	O/P & U/G	O/P & U/G

Key Lake reserves will be depleted in the late 1990's. However, the mill will likely continue to operate with feed from new mines, namely Cigar Lake and/or McArthur River. At Rabbit Lake a new underground mine at Eagle Point will provide mill feed from 1994 and ultimately the Collins Bay A and D deposits may also be developed.

4. New Saskatchewan production sources

There are four deposits, all in northern Saskatchewan, which may reach the production stage in the decade ahead.

Exhibit I-4
Potential new Saskatchewan uranium mines

	Cigar Lake	McArthur	Midwest	McClean
Current Status	Test mining	Pre-feasibility	Test mine complete EIS submitted Final feasibility.	EIS submitted, Final feasibility.
Reserves (million lbs U_3O_8)	385	200	36	39
Average Grade (U_3O_8)	9.04%	4%	4.5%	3%
Mining method	U/G	U/G	U/G	O/P and U/G
Capacity (million lbs U_3O_8/yr)	12	12	3.6	4
Earliest production	1995	1996	1994	1995
Capital cost ($million)	n/a	n/a	$200	$250

The pace at which these potential new mines develop will depend on a number of factors including uranium market conditions, technical aspects of underground mining, environmental approvals, ownership, financing etc. Clearly there is insufficient market demand for all projects to proceed.

In April, 1991, a joint federal/provincial environmental assessment panel was announced to review uranium mine development proposals. Over the next 18 months the panel will review the Midwest and McClean Lake proposals as well as the Dominique-Janine Extension at Cluff Lake. The same panel will also review Cigar Lake and McArthur River project proposals when these are submitted.

5. Development required to maintain market share

By comparing existing capacity with production potential, the pace of required new mine development can be estimated. It should be noted that Eagle Point has been considered a continuing part of the Rabbit Lake operation even though, for regulatory purposes, it may well be considered as a new development.

Exhibit I-5
Saskatchewan uranium mine capacity forecast (million lbs U_3O_8/yr)

	1990	1995	2000	2005
Production Potential	15	27	33	33
Existing Capacity	30	30	16	0
Required New Capacity	0	0	17	33

The analysis in Exhibit I-5 shows that existing capacity will not be fully utilized until about 1995. However, two or three new mines will have to be brought into production shortly thereafter if Saskatchewan is to maintain a 30% market share.

6. Impact on the Saskatchewan economy

The impact of the uranium industry on the Saskatchewan economy results from employment, expenditures on goods and services, capital investment, taxes and royalties. There are two studies currently in progress to update these statistics. Uranium Saskatchewan is surveying the industry to provide basic data which will be published in the form of factsheets. In addition Cameco has engaged Dr. Larry St. Louis of the University of Saskatchewan Economics Department to model the full economic impact of the industry. This study which is not yet completed formed part of a Cameco brief to the Energy Options hearings. Although these studies will refine the available information, the industry's impact can be estimated in broad terms from available general data. Unless otherwise indicated costs and prices are expressed in 1990 Canadian dollars.

i) Sales revenue

The value of Saskatchewan uranium shipments in 1989 was reported by Statistics Canada as $412 million for 17.9 million pounds, an average price of $23 per pound U_3O_8. For 1990 the preliminary shipment statistics are $233 million for 11.9 million pounds an average price of $19.65 per pound. The low volume in 1990 resulted from Cameco purchasing uranium on the spot market to fill certain delivery commitments.

Using an average real price of $25 per pound U_3O_8 ($20 US at a .80 exchange rate), uranium sales revenue will climb to approximately $675 million in 1995 and $825 million by the year 2000.

ii) Employment

The current level of employment in the Saskatchewan uranium industry including contract miners, exploration staff and head office employees is about 1100. Direct employee income and benefits approximate $65 million. Although production may more than double to 33 million pounds by the year 2000, employment is unlikely to exceed 1400, resulting in employee income and benefits of about $85 million. This does not include construction employment related to new mine development.

iii) Capital investment

By the year 2000, with the depletion of the Key Lake mine only 16 million pounds of current capacity will be operational. An additional 20 million pounds of annual capacity must be developed and operated at 92% of capacity to meet Saskatchewan sales potential of 33 million pounds. Each million pounds of annual capacity is estimated to cost an average of $40 million for a total capital investment of $800 million. In addition another $200 million will be required for capital additions at existing operations such as developing the Eagle Point mine at Rabbit Lake and expanding the tailings system at Key Lake. This brings the total capital spending estimate for the 1990's to $1 billion. On average this would result in about 700 construction jobs per year. Capital spending in 1990 was about $44 million.

iv) Goods and services

Current spending on operating goods and services in the uranium industry is in the order of $60 million. Expanded production will add about $4 million per million pounds of annual production. Using this rule of thumb the annual level of goods and services purchased by the industry will rise to about $108 million in 1995 and $132 million by the year 2000.

v) Royalties and taxes

Based on the previous sales and price forecasts, basic royalties will rise from $12 million in 1990 to $34 million in 1995 and $41 million in the year 2000.

Graduated royalties are somewhat more difficult to evaluate because they depend on the specific profitability and recovery banks for each mine. It is likely that graduated royalties will be quite modest in the early 1990's and grow to as much as $100 million per year in the late 1990's after capital costs and basic royalties have been recovered.

Federal and provincial income tax payments will follow a similar profile. Most of the industry will utilize large tax banks in the early 1990's. By the late 1990's income taxes paid could reach as much as $150 million per year.

In 1990 the industry estimated taxes, royalties and other fees at $40 million.

vi) Summary 1990 versus 2000

Exhibit I-6 summarizes the broad direct economic impact of the Saskatchewan uranium industry in 1990 and forecasts its impact for the year 2000.

Exhibit I-6
Economic impact of the Saskatchewan uranium mining industry

	1990	2000
Production (millions lbs U_3O_8)	15.9	33
Sales (millions lbs U_3O_8)	11.9	33
Sales Revenue ($millions)	$233	$825
Goods & Services purchased ($millions)	$64	$132
Basic Royalties ($millions)	$12	$41
Graduated Royalties ($millions)	n/a	$100
~~Income Taxes ($millions)~~	~~n/a~~	~~$150~~
Capital Spending ($millions)	$44	$100
Operating Employment	1,100	1,400
Construction Employment	200	700
Total Direct Employment	1,300	2,100
Indirect Employment	825	1,265
Total Employment	2,125	3,365
Percentage of Saskatchewan Workforce	0.44%	0.7%

II

Potential For Future Saskatchewan Participation In The Nuclear Fuel Cycle

A. Conversion

1. UF_6 supply-demand outlook

Currently western world converters are operating at only 65% of their capacity of 52,000 tonnes U as UF_6. Demand is forecast to grow to about 42,000 tonnes U by the year 2000 and could be met by existing facilities operating at 81% of capacity. Incremental expansion at existing facilities, if needed, would be much cheaper than new greenfield facilities.

The conversion market is very weak. Prices for new long-term contracts have fallen from US $6 to $7 per KgU in UF_6 in the mid 1980's to US $4.50 or lower today. Spot prices are in the US $2—$3.50 per KgU range as a result of excess inventories of UF_6 which can be "deconverted" by swapping for concentrates. Full costs for converters are in the range of $5 per KgU.

Exhibit II-1
Nuclear fuel cycle

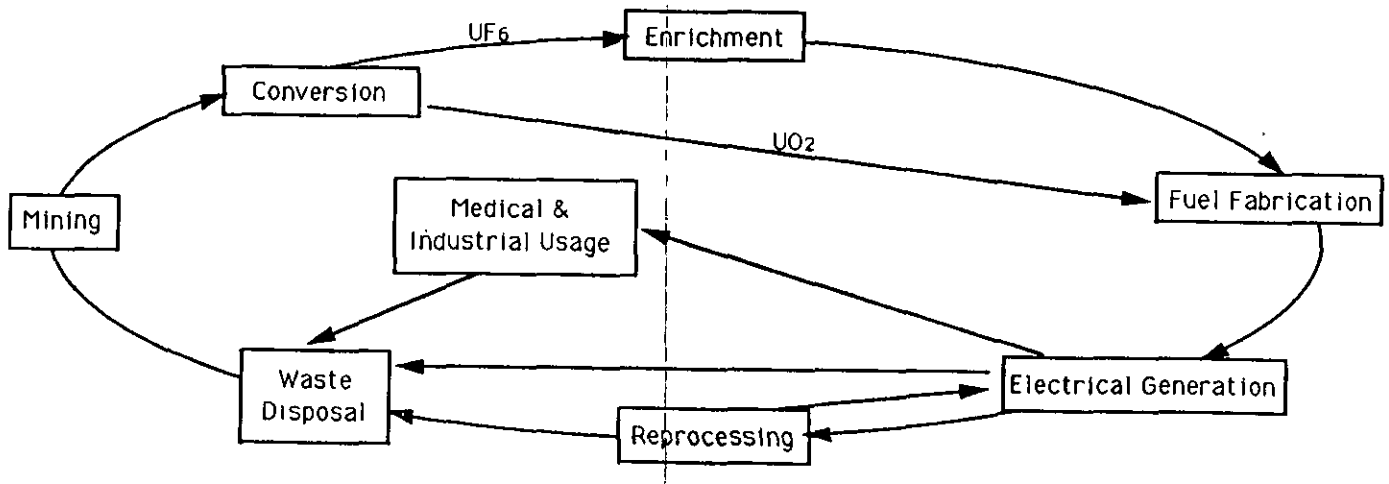

Exhibit II-2
Existing UF_6 conversion plant capacity

Converter	Country	Process	Capacity (KgU as UF_6/yr)
Cameco	Canada (Ontario)	Wet	10,500
Allied Signal	USA	Dry	12,700
Sequoyah Fuels	USA	Wet	9,000
Comurhex	France	Wet	14,000
British Nuclear Fuels Ltd.	U.K.	Wet	5,800
TENEX/CNEC	Export as enriched uranium from USSR and China	N/A	4,000
			56,000

All western converters except for Allied Signal use the wet process wherein concentrates are leached in nitric acid, purified by solvent extraction and denitrated to UO_3. The UO_3 is reduced to UO_2 and then fluorinated in two steps to UF_6. In the dry process the concentrates are not purified prior to fluorination and final purification is achieved by distillation of UF_6.

It appears unlikely that there will be major technological breakthroughs in the conversion process although Cameco continues to carry out R & D activities in this area.

2. UO_2 supply-demand outlook

Cameco is the sole supplier of ceramic grade UO_2 for Candu fuel in Canada. The Port Hope, Ontario UO_2 plant uses UO_3 feedstock from Cameco's Blind River Ontario refinery and has a capacity of 2,500 tonnes U per year. By using parts of the north UO_2 plant, at Port Hope which is maintained on standby, Cameco could increase its annual capacity to over 3000 tonnes U.

Canadian UO_2 demand is currently 1,500 tonnes U and will not exceed 1,800 tonnes U throughout the 1990's. Ontario Hydro represents 85-90% of this demand.

There is a small export market in the order of 100 tonnes U per year for use as blanket fuel in light water reactors.

More than enough UO_2 conversion capacity is in place at Port Hope to meet Canadian requirements over the next 15 years.

3. Saskatchewan's competitive potential

There is also ample capacity in place in the western world to meet UF_6 conversion demand over the next 15 years. Further, there is little likelihood of a technological breakthrough which would be significantly lower cost than existing processes. A new greenfield conversion facility would have to have a minimum capacity of a least 8,000 tonnes (19% of western world demand in the year 2000) and would have a capital cost in excess of $250 million.

There is little potential for a greenfield conversion facility in Saskatchewan, or for that matter, anywhere in the world in the next 10 or 15 years.

B. Enrichment

1. Supply-demand outlook

Current enrichment capacity at 39 million separative work units (SWU) is considerably in excess of today's reactor requirements of 23.5 million SWU. Reactor requirements are expected to grow to about 29 million SWU by the year 2000 and 31 million SWU by 2005.

Thus, on the surface, there would seem to be little reason to consider new facilities which would add further capacity. However, this is not the case. The U.S. Department of Energy gaseous diffusion plants with 19 million SWU capacity and built in the 1950's are rapidly becoming technologically obsolete. The diffusion process is tremendously energy intensive using 2,500 kwh for each SWU. By comparison, newer technologies such as ultracentrifuges and laser processes use only 20-50 kwh per SWU. Therefore, there is significant potential for new technology and new facilities to displace DOE enrichment facilities. The French Eurodif plant, built in 1979 with a capacity of 10.8 million SWU also uses the diffusion process and may ultimately be replaced with new technology.

Both the US DOE and the French are developing an atomic vapor laser isotope separation process, "Avlis" in the US and "Silva" in France. The US DOE has invested about $1.5 billion to date in Avlis development A commercial scale demonstration module is expected to be completed in 1992, although the program is reported to be encountering significant difficulties which may erode the potential cost advantage of this new proprietary process. Congress has approved $160 million in 1991 and $215 million in 1992 to complete the demonstration. No funding has been authorized for further siting and deployment activities. Although no Industrial Access program is yet in place Congress favors deployment being carried out by the private sector. The Smith Barney review of the Avlis program suggested that Avlis deployment would cost twice as much and take five years longer than DOE estimates. It is likely that commercial deployment will not be achieved until the year 2000, if at all.

With the capacity oversupply and inventories of enriched uranium overhanging the market, spot SWU prices have dropped to about $50 per SWU compared to the DOE contract price of $118 per SWU. To effectively displace diffusion a new technology should be profitable at US $80-$90 per SWU.

2. Current producers

Exhibit II-3
Existing uranium enrichment plants

Producer	Country	Enrichment Process	Millions SWU/yr Capacity
DOE	USA	Diffusion	19.2
Eurodif	France	Diffusion	10.8
Urenco	UK/Holland/Germany	Centrifuge	3.1
TENEX	Export from USSR	Centrifuge	3.5
PRC	Export from China	Diffusion	2.5
			39.1

The diffusion process pumps UF6 gas through hundreds of thousands of porous barriers to achieve enrichment. The pumping requires a huge amount of electrical energy costing more than US $50 per SWU at current US industrial power rates. High speed centrifuge plants require only about 2% of the electrical power of a diffusion plant. This low operating cost, however, is offset by the high capital cost to manufacture tens of thousands of ultra high speed centrifuges. This capital cost is about US $500 per SWU of capacity.

3. Saskatchewan's competitive potential

Most utilities are committed to long-term contracts for the bulk of their requirements through 1995. After 1995, however, long-term contractual volumes fall off creating opportunity for new suppliers who can be competitive because of low cost technology.

From a practical point of view the two technologies with the greatest potential for Saskatchewan are Crisla, still unproven, and centrifuge. Urenco and its partners in Louisiana Energy Services have proposed to build a 1.5 million SWU centrifuge plant in Louisiana at a cost of US $800 million. Production in the first module would start in late 1995 with full production expected in late 1997. Under recently passed legislation, the plant would be licensed by the Nuclear Regulatory Commission under 10 CFR 40 and 70 similar to a fuel fabrication facility. The licence application was filed on schedule with the NRC on January 31, 1991 and LES anticipates that a combined construction and operating license will be issued in early 1993. There is well organized opposition by environmental groups who have filed for intervener status. If the licensing process in Louisiana is ultimately not successful then Saskatchewan might be considered as an alternate site. Alternately, in the longer-term Saskatchewan could become the site of a second North American centrifuge plant.

Cameco and Isotope Technologies have formed a new venture named Crisla Technologies which is continuing the development of the Crisla process in Saskatoon. "Crisla" is an acronym for chemical reaction by isotope selective laser activation. The Crisla process uses a carbon monoxide laser to activate an isotope selective chemical reaction. It potentially could have quite low capital and operating costs. It can also be built in small modules and added to. To date, however, only milligrams of enriched uranium have been produced in the laboratories, so Crisla is not a proven process. However, if the development program over the next two years is successful in demonstrating commercial viability, commercial deployment as early as 1996 may be achievable.

There are two more remote possibilities which cannot be dismissed. The first would be to use Russian centrifuge technology. The Russians reportedly have a reasonably large number of centrifuges in storage and would certainly be in a position to manufacture more. These centrifuges are not as efficient as Urenco's latest models but are adequate. During 1990, General Atomic tried to do a deal with the Russians to build a centrifuge plant at the Sequoyah Fuels UF_6 conversion plant site in Oklahoma. This initiative was unsuccessful because the Russians refused to export technology or equipment.

The second remote possibility is the chemical exchange process, using resin beds, which the Japanese have been researching for some ten years. For its commercial plants, however, the Japanese have selected centrifuge technology.

4. Impact on the Saskatchewan economy

The current development work on Crisla employs six scientists with a budget of about $2.5 million per year. A 250,000 SWU Crisla plant would have a capital cost of $50—$80 million and generate revenues of about $25 million. Operations which could start as early as 1996 would employ approximately 80 people with expenditures for goods and services of about $6 million annually. Subsequent plant expansion to 500,000 or 1 million SWU would require less unit capital than the first greenfield phase and yield significant economies of scale.

If the Crisla development project is not successful in demonstrating commercial viability over the next 2-3 years then a centrifuge plant is the only other option presently worthy of consideration. Such a venture would likely require the technology and active participation of Urenco. A more remote possibility would be to use Russian technology if it can be made available.

C. Fuel fabrication

1. Nature of the market

Globally there is significant overcapacity for fuel fabrication. Each country with a significant nuclear generating program has its own facilities and the industry is dominated by the major reactor manufacturers.

Fuel fabrication involves the production of UO_2 pellets, zirconium tubing, end plates and other parts, and assembly into fuel elements. There is continued development in fuel design to achieve higher burnups, improved fuel management, and high reliability. Manufacturing processes are becoming increasingly automated with the result that the economic plant size is becoming larger—at least 500 tonnes U per year. There is also a lengthy period required for new manufacturers to become qualified including QA audits and one or two years in-core testing.

2. Canadian supply-demand

Canadian fabrication demand is currently about 1,500 tonnes U and will not exceed 1,800 tonnes U through the 1990's. Ontario Hydro is the dominant user representing 85-90% of this demand. The two Canadian fuel fabricators are both located in Ontario: General Electric and Zircatec Precision Industries (previously Westinghouse) with capacities of 1,200 tonnes and 800 tonnes respectively. If required, a 20% increase in capacity could be achieved by both fabricators through debottlenecking with very little capital expenditure.

A third plant was operated by Combustion Engineering in New Brunswick. This plant was too small a scale to be competitive and shut down several years ago.

3. Saskatchewan potential

With the Ontario demand well served by two long-term Ontario suppliers and no export markets there is little potential for fuel fabrication in Saskatchewan.

If a Candu-3 was constructed in Saskatchewan it would be possible to encourage a small dedicated facility to fabricate the fuel in Saskatchewan. However, such a facility would not be economically competitive with either of the two Ontario suppliers.

D. Electrical generation

1. Saskatchewan's future electrical needs

Currently, essentially all of Saskatchewan's electrical power is provided by Saskatchewan Power Corporation, a provincial Crown corporation. SaskPower provides electrical power from the following sources of supply:

Source	Gross Capacity (MW)	% of Gross Capacity	% of Supply
Coal-fired stations (3)	1,500	50%	70%
Hydro stations (7)	840	28%	25%
Natural gas stations (4)	360	12%	3%
Imported power[1]	300	10%	2%

The differences above between "% of Capacity" and "% of Supply" reflect the mix of power sources that SaskPower uses to meet the province's power demands. Coal-fired stations provide the majority of "base-load" power at a more-or-less constant level of generation (after adjustment for seasonal differences). The amount of hydro generation is a function of water availability and is used mainly to displace higher-cost generation such as natural gas or imported power. Natural gas stations and imported power provide additional supply to meet "peak demand", such as occurs on especially cold winter days.

Maintaining a reasonable surplus of electrical supply over peak demand is essential. This "generation reserve capacity" enables a utility to meet customer requirements in spite of scheduled or unscheduled shortfalls in supply due to equipment maintenance or failures. SaskPower attempts to maintain a reserve capacity of 15 to 20%.

---

[1] *SaskPower has contracts with Basin Electric (North Dakota) for 50MW of purchased power and for 100MW under a seasonal "swap" arrangement, and with Alberta Integrated System for 150MW under a reserve-sharing arrangement.*

Currently, SaskPower's total system capacity (including imported power) is about 3000 MW (at gross or "nameplate" capacity; actual net capacity is about 2900 MW). A further 300 MW gross (280 MW net) will be available from the new Shand station in 1992 (at which time the existing Estevan station will be closed, and one of the contracts for imported power will terminate, reducing capacity by 115 MW net). Total capacity availability will be about 3050 MW net from all of the above sources at the end of 1992.

Because of the long lead-time in designing, approving and constructing generating stations, utilities must undertake detailed and comprehensive forecasts of future electrical energy demand. It typically takes ten years from project conception to power generation, and the evolving nature of environmental assessment requirements might lengthen this period to twelve to fifteen years. Therefore, the demand forecasts prepared by utilities must project electrical energy to be supplied up to twenty years ahead. Factors to consider in forecasting future electrical energy demand include the rate of economic growth, demographic projections, economic development plans, and other national and international macro economic trends.

In its publication "Our Future Generation", SaskPower has shown graphically its projections of future energy demand and supply. These projections are based on very sophisticated forecasting models, which are updated on a continuous basis. To assess the reasonableness of these projections, we have compared them to the results from a simple forecasting model developed by Peat Marwick Stevenson & Kellogg. Our model is based solely on the relationship between Provincial Gross Domestic Product and electricity demand; this relationship has historically been one of the best predictors of electricity consumption. Exhibit II-4 below shows this comparison:

Exhibit II-4
Electrical capacity requirement forecasts for Saskatchewan[1]

	SaskPower Forecast	PMS&K Forecast
1995	3150	3100
2000	3450	3400
2005	-----	3800

The data in Exhibit II-4 shows that SaskPower's generation reserve capacity ratio will fall below 15% by 1995. The shortfall in supply by 2000 (which is approximately the earliest date that a station now in the planning phase could

[1] *These forecasts include a "generation reserve capacity" of approximately 15%.*

deliver power) is projected to be at least 400 MW. This shortfall does not include any plant retirements other than that planned for the Estevan Generating Station in 1992.

By the year 2000 the coal-fired Queen Elizabeth Generating Station in Saskatoon, built in the late 1950's, will be due for retirement. This retirement, together with normal demand growth over the following five years, will mean a shortfall of at least 850 MW by 2005.

It should be noted that all of the above demand forecasts represent a projection based on the best information available at the time the forecast was done. Any good forecasting model must therefore be "dynamic" in nature rather than "static", that is, it must be capable of being updated and changed as actual events occur. For instance, if a major new industry were to be developed in Saskatchewan, or an existing industry were to expand significantly, this would likely mean a significant revision to these electrical demand forecasts (not only to accommodate the direct industrial development component but also to reflect the increased economic activity thereby engendered).

2. Options available to meet increased demand for power

To meet the future electrical requirements of Saskatchewan residents and industries, there are three options:

- Demand management.
- Import power.
- New generating capacity.

In this section, we will discuss each of these options with emphasis on the amount of power that each could supply and the factors clearly favoring or disfavoring each option as an alternative to meet the projected shortfalls identified previously.

a) Demand management

As defined in SaskPower's "Our Future Generation", demand side management "is an option in which the utility promotes changes in the way consumers use electricity". In practice, this means that the utility implements policies and practices which have the effect of reducing (or even eliminating) the rate of growth in electrical demand. SaskPower has introduced a number of programs over the years to promote and support industry and individuals in their efforts to reduce energy consumption—these include programs such as Warm-up Saskatchewan, Enerwise, Energy Audits and the promotion of energy efficient devises. In addition, programs such as street and farm light conversion are beginning to have an impact as should the introduction of interruptible rates for industrial users. SaskPower estimates that these and other new initiatives could mean reductions of from 150 to 200 MW from the growth that would have occurred without demand side management through 2005. These reductions are already reflected in the demand forecasts described earlier. This effect is seen in the rates of demand growth underlying these forecasts; for instance, the ten-year forecast included in "Our Future Generation" is based on growth rates of between 2.4 and 3.1 percent per year, compared to the 3.8 percent annual growth in the preceding ten-year period. This decline in electrical demand growth rates is seen below in Exhibit II-5.

Exhibit II-5
Electrical demand growth rates (actual and projected)

	Annual Growth Rate of Previous 5 year period		
	Low Estimate	Most Likely	High Estimate
Actual			
1982	-----	3.4%	-----
1987	-----	4.1%	-----
Projected			
1993	2.6%	3.3%	3.7%
1998	1.9%	2.5%	3.1%
2003	1.0%	1.5%	2.0%
2008	0.9%	1.3%	1.7%

The types of demand side management programs which SaskPower envisions include information campaigns to promote efficient equipment, customer rebates, and rate structures which provide financial incentives to consumers to conserve electricity.

Demand side management by utilities is only one means of improving electricity end-use efficiency. Two other means are technological improvements in electricity end use, and government policies and programs. In a recent paper titled "Electricity End-Use Efficiency: International Prospects" (London, The Uranium Institute, 1990), E. Unterwurzacher notes that:

> As a result of increases in electricity prices in the 1970's and early 1980's, improved technology, and existing government programmes, there were significant efficiency gains in all of the six end-use categories. . . . The trend towards improving efficiency in new equipment and buildings is likely to continue, although the rate of change appears to be slowing. Beside price developments, one of the factors causing this slackening is that the easier efficiency-increasing measures have already been taken.

Unterwurzacher also points out that to maintain the historical level of efficiency increases that have occurred over the last fifteen years will require both enormous capital investment in new technologies as well as significant changes in consumer lifestyles. SaskPower's "Our Future Generation" draws the same conclusion in noting that a further reduction of up to 200 MW in Saskatchewan's demand growth might be feasible but "would require either substantial investment by consumers or significant changes in lifestyle."

Government policies and programs can be used to bridge the gap between the efficiency improvements which are technologically possible and those which consumers are willing to pay for. For instance, government information programs can help to educate consumers as to the long-term cost savings from purchasing energy-efficient equipment. Government can also influence demand through regulatory mechanisms, which Saskatchewan currently does not have. Finally, government can affect demand through economic instruments, as Unterwurzacher states:

> One of the first steps that governments can take to remove market distortions which work against the rational use of electricity is to allow prices to reflect long-term costs of supply, including distribution and external costs [such as debt]. Prices are the single most important instrument for influencing supply and demand.

Other government policy instruments in this area include taxation and environmental protection legislation.

As an option for meeting the growth in demand for electricity in Saskatchewan, demand management is likely the least-cost and most "environmentally-friendly" alternative. However, while such measures can have a significant initial impact their cost effectiveness and public acceptance will tend to diminish particularly when significant changes to lifestyle are required. Consequently, it does not appear that the reduction in demand growth can be sufficient to eliminate the need for increasing supply in the future. Even if growth could be held to zero, new sources of power would still be required as existing plants reached the end of their economically useful lives.

b) Import power

As noted earlier, SaskPower currently buys from and sells power to utilities in Manitoba, Alberta and North Dakota. Historically, each province in Canada has striven to achieve self-sufficiency in electrical supply, with "interties" to neighboring provinces only to ensure adequacy of supply on an as-needed basis. Currently, no province except Prince Edward Island relies on another for any significant proportion of its electrical energy. Several provinces—particularly Quebec—export considerable amounts of power to the United States.

Three issues to consider in determining whether to meet Saskatchewan's future power needs from extra-provincial sources are:

i) Cost

If the cost of purchasing power from other provinces is less than the cost of building new generating facilities, then it might make economic sense to buy power. However, this cost equation should also consider the spin-off economic benefits from constructing and operating generating facilities in Saskatchewan. Electrical utilities, whether Crown-owned or private, have historically been seen as "engines" of economic growth in each province. SaskPower, for instance, through its "Buy Saskatchewan Program" sources nearly 90% of its goods and services from Saskatchewan firms, thus contributing over $350 million annually to the provincial economy.

ii) Security of supply

Each province will naturally seek to ensure that its residents' energy needs are met before determining if there is surplus power for export.

iii) Availability of supply

A recent confidential report prepared by Peat Marwick Stevenson & Kellogg analyzed the supply and demand situations and forecasts of all of the Canadian utilities. That report concluded that virtually all of these utilities must undertake large capital expenditure programs to meet intra-provincial demand growth and to realize on opportunities in the U.S. market. There may be greater cooperation between Canadian utilities in inter-connecting systems, and some firm contracts between utilities for longer-term supply of power (such as between Manitoba and Ontario, and potentially between Quebec and Ontario).

It does not appear that either Manitoba or Alberta currently has the excess capacity to meet Saskatchewan's forecast demand growth. Both provinces have untapped sources of additional power—Manitoba from hydro and Alberta from coal. However, because of the long lead-times involved in designing and building new plants, it is unlikely that either province would take the risk of "over-building" to meet forecast demand in Saskatchewan. Utilities avoid over-building because the surplus power that is generated can usually only be sold at a price lower than the cost to the purchasing utility of generating the power itself.

Given a sufficiently attractive pricing formula, utilities in other provinces might undertake projects to build new plants to meet demand in Saskatchewan. However, because of the cost of transmission lines and system interconnections, it is likely that this purchased power would be more costly than if SaskPower built its own new plants.

c) New generating capacity

Given the inability of demand management to meet all of Saskatchewan's future needs, and the uncertainty and cost factors associated with purchasing power from other utilities, the only remaining alternative is for new generating capacity within Saskatchewan. There are five potential sources for additional electricity supply in Saskatchewan: hydro, coal, natural gas, other technologies, and nuclear.

i) Hydro

In "Our Future Generation" SaskPower states that developable hydro potential in Saskatchewan totals about 1500 MW from major water sources, and a further 600 MW from small (50 MW or less) plants in northern Saskatchewan. Factors militating against use of this potential include:

- High initial capital cost of hydro stations (although life-cycle operating costs tend to be lower with hydro than with other plants).

- Water flows on the North and South Saskatchewan Rivers, with up to 1000 MW of potential power, have tended to fluctuate in recent years, and long-term climatic change might tend to increase this fluctuation, which could affect the reliability of power generation.

- Hydro plants may have significant impacts on the local and down-stream eco-systems of the water sources on which they are located.

ii) Coal

Coal-fired plants currently provide over two-thirds of Saskatchewan's power. All of these stations are located in the extreme southern portion of the province, where there are abundant supplies of low-sulphur lignite coal lying close to the surface. SaskPower has stated that Saskatchewan has enough coal to generate electricity for at least two hundred years at current consumption levels.

The major factor militating against additional coal-fired generation is the nature and extent of atmospheric emissions from these plants. Coal-fired power stations are major contributors both to the "greenhouse effect " (by emission of carbon dioxide) and to "acid rain" (by emission of sulphur dioxide). "Scrubbing" technologies already exist, and are under further development, to partially counter these effects. They do however add to the cost of the power generated. In addition, a new way of burning coal (integrated coal gasification combined cycle technology, or "clean-coal") is being tested, and SaskPower is in the bidding to construct the first demonstration plant in Canada. However, even this type of plant would still release significant amounts of carbon dioxide.

The Federal Government's "Green Plan" may limit the extent to which provinces with coal reserves are able to further exploit that resource to generate electricity, particularly if the plan has the effect of limiting total emissions in the province to 1990 levels.

Another consideration for expansion of coal-fired generation in Saskatchewan is plant location. To be economical, such plants must be close to the source of coal, which in Saskatchewan means in the southern part of the province. However, these plants also require water for cooling. Even with the Rafferty-Alameda water control project in that area, water is not abundant. Air-cooling of coal-fired plants is more expensive than water-cooling.

iii) Natural Gas

SaskPower has four natural gas-fired stations, which are normally used only to meet peak demand. Because of the cost of the fuel supply, these stations are relatively more expensive to operate than other types. Because of the importance of natural gas to the Saskatchewan economy, using it to produce electricity might not constitute the best use of this non-renewable resource. This is due to several factors:

- The majority of homes and buildings in Saskatchewan are heated by natural gas.

- The province can realize substantial export earnings by selling the gas to eastern Canada and the U.S.

- The gas is essential for the development of higher value-added industries such as petrochemicals and fertilizers.

iv) Other Technologies

A variety of other technologies exist which can produce limited amounts of electrical power. Solar, wind, geothermal and biomass technologies are used in many countries, including the United States, typically to produce power for a limited geographic area (that is, the unreliability or limited capacity of these sources makes them unsuitable for providing "base-load" power within an interconnected grid system). It is unlikely that these sources could provide sufficient power to meet Saskatchewan's long-term growth needs, but they might provide local solutions in some instances.

v) Nuclear

Three provinces in Canada use uranium to generate electricity: Quebec and New Brunswick each have one operating reactor, while Ontario generates over 50% of its total power from nuclear plants. Ontario Hydro's recently published 25-year plan, "Providing the Balance of Power" describes how the utility plans to meet Ontario's forecast demand growth over the period. Central to the plan is the construction of three new "base-load" nuclear power stations, each containing four 881 MW Candu reactors. Each station, when completed, would therefore supply over 3500 MW of power, about equal to Saskatchewan's total electrical requirements. Clearly, stations of that size are beyond Saskatchewan's needs. AECL's Candu-3 reactor system, designed to produce 450 MW of power, would be more appropriate here.

Factors militating against the nuclear option for Saskatchewan include:

- The perceived safety issue: despite the impeccable safety record of the Candu reactor design, well-publicized accidents with other types of nuclear power plants in the U.S. (Three Mile Island) and the Soviet Union (Chernobyl) have significantly reduced public acceptance of the nuclear industry.

- The high initial capital cost of a nuclear plant, plus the uncertain costs of used fuel disposal and plant decommissioning.

- The reliance on a commercially unproven source of power for base-load requirements (the Candu-3 is a new design not installed elsewhere in Canada, although it is essentially similar in design to Ontario Hydro's reactors, which have among the highest capacity utilization rates in the nuclear industry).

Factors favoring the nuclear option for Saskatchewan include:

- A Candu-3 to be installed in Saskatchewan would be a prototype project. To ensure its success, and protect its substantial investment in the technology, the Federal Government can be expected to provide significant financial support to the project. This could allow SaskPower to meet the province's electrical demand growth without adding huge amounts of new debt to its balance sheet. In addition to direct financial support for construction, the Federal Government might also be expected to fund, in whole or in part, new spending in research and development, supplier development programs, skilled jobs training, and opportunities for aboriginal people.

- As a prototype project, the Saskatchewan Candu-3 reactor could demonstrate the benefits and advantages of its technology as the basis for a new, Saskatchewan-based export-oriented industry. For instance, the demonstrated success of the project in Saskatchewan would help to sell the technology in other areas of the world with similar electrical energy needs, such as:

  1. Developing countries with high electrical demand growth but no indigenous nuclear energy program, such as Indonesia, Turkey, Thailand or Egypt.

  2. Developing countries with small existing nuclear energy programs and strong demand growth, such as Mexico, Argentina or Chile which do not have established LWR infrastructures.

- Construction and operation of the first commercial Candu-3 in Saskatchewan would present major economic development opportunities for the province. Some of these opportunities would include:

  1. By its commitment to a Supplier Development Program, AECL would ensure that Saskatchewan firms would receive a major share of the work in designing and building the plant. Development of this expertise in Saskatchewan could make suppliers in this province the preferred contractors for installations of Candu-3 reactors throughout the world.

  2. Saskatchewan would be favored as the site of the training and simulation centre for Candu-3 reactors.

  3. Saskatchewan suppliers would also be able to bid as contractors to the three nuclear power stations proposed for Ontario. The track record of Saskatchewan suppliers, and their attainment of the highest Quality Assurance standards, would give them a competitive position in bidding.

4. The establishment by the Government of Canada and Saskatchewan of a major nuclear research and technology program covering such areas as:

   - Applications for Slowpoke Energy Systems.
   - Long-term management of nuclear fuel and fuel waste.
   - Nuclear applications in medicine, agriculture and food processing.
   - University research programs and the enhancement of university programs in nuclear physics, medicine and agriculture.

- The high initial capital cost of nuclear power is mitigated by the lower operating cost for the electricity that is generated, compared to coal-fired plants.

- Nuclear plants are more "environmentally-friendly" than coal-fired plants, because atmospheric emissions are virtually nil. Water used for steam-plant cooling is non-radioactive, and closed-loop designs may be feasible. The "heavy water" used for reactor core cooling is not released to the environment. The multiple levels of redundant safety systems in the Candu design make the possibility of harm to the public very remote.

- The tie-in, or synergies, with the Saskatchewan uranium industry could make this province a world-leader in nuclear technology. Some of these synergies are discussed later in this report.

3. Qualitative advantages of nuclear power over other options

The previous section discussed the five options available to Saskatchewan for future power generation. Certain "qualitative" advantages for the nuclear option are readily apparent:

a) Environmental

Next to demand management, nuclear power is the most environmentally-friendly option to supply Saskatchewan's base-load future power requirements:

- Atmospheric emissions from nuclear plants are minimal, while coal-fired electrical generating plants are one of the major contributors to the greenhouse effect and to acid rain.

- Hydro plants require the flooding of large areas of land to create reservoirs, possibly eliminating arable land and destroying wildlife habitats. Downstream water supply and quality may also be affected.

- Expansion of Saskatchewan's uranium mines would not be necessary to meet the fuel requirements of a Saskatchewan reactor (or even many such reactors). For instance, it would take less than fifteen days for the Saskatchewan uranium industry, operating at full capacity, to supply enough fuel for SaskPower to meet the province's electrical needs if it was all supplied by nuclear power.

- Construction of further coal-fired plants would likely require the expansion of coal-mining in the south-east corner of the province. Saskatchewan's coal reserves are close to the surface, but require "stripping" of the over-burden of soil to reach the coal.

b) Industrial development

The design, installation and operation of a Candu-3 in Saskatchewan would have the effect of creating an entirely new, export-oriented industry for the province. As suppliers to the project, Saskatchewan firms would develop the expertise that could be applied to future Candu sales throughout the world. This type of expertise (particularly in terms of the stringent Quality Assurance standards that would be attained) could also be applied by Saskatchewan suppliers to other industrial opportunities. The province could be recognized as a "Centre of Excellence" in the engineering disciplines, in machine tool design and operation, in modularized construction techniques, and in many other areas. The new jobs that would be created would be high-paying, high-quality jobs requiring skilled, highly-trained people.

Successful implementation of the first Candu-3 prototype in Saskatchewan would make the province a recognized leader in industrial innovation.

c) Training and education

The establishment of a Candu-3 training and simulation facility in Saskatchewan would be a major economic development initiative in itself. It would also provide impetus to further development of the province's capabilities in computer science and systems engineering. There would be more opportunities for highly-trained Saskatchewan graduates in these and other disciplines to stay in the province. Development of the nuclear industry would also provide for industry/university linkages in the pure and applied sciences, and provide a further boost to the province's research and development capabilities.

4. Economic impact of the nuclear power option for Saskatchewan

To the best of our knowledge, no detailed economic impact assessment of the nuclear power generation option for Saskatchewan has been undertaken or published. Such an assessment would be a major interdisciplinary project, and is far beyond the scope of this study. However, in this section of the report we will attempt to give a preliminary indication of the magnitude of the direct economic impact of constructing and installing a Candu-3 reactor in Saskatchewan.

In any economic impact assessment, it is essential to clearly define the "project" that is being analyzed. For these purposes, the "project" is the construction and operation of a single Candu-3 reactor and electrical generating station. The "project" does not include the additional electrical transmission facilities that would be required, because these are site-dependent and there is no firm indication as to where the plant would be located.

The "project" is assumed to generate direct economic impacts in two ways:

- From the construction of the plant: this is a "one-time" impact (although it would be felt over a period of years, it arises from a single set of expenditures over a relatively short period of time).
- From the operation of the plant over its economically useful life, assumed to be 30 years (this is an "annual" impact because it recurs over the period).

a) **Construction impacts (1991 dollars)**

► Direct impact: purchases of commodities	$800 million
► Value of goods produced by Saskatchewan industries included in the above	$371 million
► Direct impact on provincial employment	4,000 person years

b) **Annual operations impacts (1991 dollars)**

► Direct impact: purchases of commodities	$37 million
► Value of goods produced by Saskatchewan industries included in the above	$26 million
► Direct impact on provincial employment	300 person years

5. Benefits of a nuclear reactor for Saskatchewan

As a strategic option to meet Saskatchewan's future electrical energy requirements, a nuclear powered generating station has several clear benefits for the province:

- The nuclear option is a more environmentally-friendly source of power than other sources.
- The direct and indirect economic impacts of the construction and operation of a nuclear plant in Saskatchewan would be enormous.
- Construction of the nuclear generating plant would be a major industrial development and diversification project for Saskatchewan.
- Expansion of the Saskatchewan nuclear industry beyond uranium mining into power generation would afford the opportunity to expand further into other elements of the nuclear fuel cycle.

E. Reprocessing

1. Nature of the marketplace

Initially the prime motivation for large scale reprocessing was a concern in Europe and Japan over the long-term availability of reasonable cost uranium resources. Reprocessed uranium and plutonium is viewed as a domestic energy resource. More recently the prime motivation has shifted and reprocessing has become viewed as a means to minimize the volume of high level waste for disposal. In Germany, for example, reactors cannot be licensed without contracts in place to reprocess used fuel.

With waste management the driving force, the plutonium and uranium recovered are considered "free issue" in determining the economics of recycling.

Commercial reprocessing plants are located in France, Great Britain and Japan. The recycled uranium and plutonium displaced about 5 million pounds U_3O_8 demand in 1990; this will grow to 15 million pounds by the year 2000. Countries which currently plan to reprocess used fuel include France, Great Britain, Germany, Belgium, Switzerland, and Japan.

Reprocessing is not practical or planned in either the United States or Canada where development and demonstration projects are focussed on used fuel storage and disposal—the so called "once-through cycle." Other countries which currently plan the once-through cycle include Sweden, Finland, Spain, Korea, and Taiwan.

2. Cost of participation

The reprocessing facilities are enormously expensive. The La Hague complex in France and the Sellafield facility under construction in the UK each have capital costs well in excess of $10 billion.

It should be pointed out that reprocessing of Candu used fuel would be much more costly than reprocessing LWR used fuel. This is because five times as much Candu used fuel would have to be reprocessed to obtain the same amount of fissile U_{235} and plutonium.

With a used fuel disposal centre costing less than $100 per kg and abundant natural uranium resources it seem highly unlikely that reprocessing can become a viable option in Canada for at least the next 30 or 40 years.

3. Potential for Saskatchewan

Given the prohibitive capital costs, the lack of any North American market, and the fact that European and Asian needs are now satisfied, there is no potential, at least for the next 30 years, for a viable facility in Saskatchewan.

F. Waste disposal

1. Nature of the industry

All nuclear programs require high level waste storage and ultimately disposal. In the USA, Canada and other countries adopting the once-through cycle, used fuel is the high level waste. In countries using reprocessing there will still be high level waste to manage, only a lesser volume.

Fuel generally remains in a reactor from one to three years. When removed, the used fuel is still mostly uranium (96-99%). The balance (1-4%) consists of fission products (3/4's) and transuranic elements (1/4, principally plutonium). The fission products are initially highly radioactive but decay rapidly. The transuranic elements are of lower-level, but longer-lived radioactively.

When removed from the reactor, used fuel is placed in storage pools at the reactor site. The initial high level of radioactivity reduces by 90% in the first 12 months as the fission products decay. After 100 years the radioactivity remaining in used fuel is only 1% of its level one year after discharge from the reactor. Generally used fuel will be kept at the reactor site in storage pools for 5 to 40 or more years.

When there is no longer sufficient storage capacity at the reactor site the used fuel can be transported in specially designed shielded casks to separate "away from reactor" (AFR) or "monitored retrievable storage" (MRS) facilities or to a final disposal repository. One example of an AFR is the underground CLAB facility in Sweden.

For final disposal specially packaged used fuel would be placed several hundred meters below the earth's surface in stable geological formations. For Canada the research and development of a final repository has focussed on stable granite rock in the Canadian Shield. After an initial period of monitoring the repository would be sealed off to isolate it from the environment so that active management of the waste would no longer be necessary.

Most countries, whether opting for reprocessing or the once-though cycle, are in various stages of planning and siting MRS's and/or final repositories. Generally the option of shipping used fuel to another country for disposal has not been available because no country has offered such a service. There are two small exceptions. Russia has supplied fabricated fuel to Russian designed reactors in Finland and eastern Europe and taken back the used fuel after five years of storage at the reactor site. China has offered to take used fuel for ultimate disposal in the Gobi Desert on a commercial basis. Although some countries such as Switzerland have explored this latter this option, no firm arrangements have been put in place.

Most countries have established a fund to finance future waste disposal facilities and their operation. The fund is generally financed by a charge against nuclear electricity generation which is included in establishing electricity rates to consumers. In the United States, for example, the government collects 1 mil per kilowatt hour from the utilities.

2. Canada's used fuel disposal program

In 1978 the Governments of Canada and Ontario agreed to cooperate on a joint program to assess and develop the technology for the safe management and permanent disposal of nuclear fuel waste in the granite rock of the Canadian Shield. AECL was given responsibility for underground disposal of used fuel and Ontario Hydro was given responsibility for interim storage and transportation of used fuel.

AECL has established an Underground Research Laboratory (URL) at 420 meters depth in the Lac due Bonnet batholith. This outcropping granitic pluton is located about 100 km NE of Winnipeg in the Canadian Shield. The URL was completed in 1986 and technology development and demonstration is continuing. The URL will not handle actual used fuel. Instead electric heat sources will be used to simulate the characteristics of used fuel.

AECL has developed a conceptual approach to dispose of used fuel in vaults 500 to 1000 meters deep in a granitic pluton. Used Candu Fuel bundles would be sealed in copper or titanium corrosion resistant containers and emplaced in the floor of rooms in the vault. The containers would be surrounded by a compacted mixture of silica sand and bentonite clay. When the rooms are filled the rooms, access tunnels, and shafts would be backfilled and sealed.

AECL has estimated that a single level repository two kilometers square would handle 190,000 tonnes of used fuel (10 million bundles). This would cover all used fuel produced in Canada until at least the year 2035. To the end of 1989 Canadian reactors were storing 14,000 tonnes of used fuel. AECL estimates the total cost of siting, constructing, operating, and decommissioning the used fuel disposal center over a 70 year period to be $9-$15 billion (1989$). This estimate does not include financing costs or any costs related to interim storage and transportation of used fuel.

Exhibit II-4
AECL's conceptual used fuel disposal centre schedule

Project Schedule	Duration (Years)	Estimated Cost ($1989 millions)	Annual Direct Employment
URL Activities Environmental Assessment Site Screening	5	N/A	N/A
Site Evaluation	10	700-1,170	340
Construction	10	2,300-3,700	1,100
Operation	40	5,420-8,940	600
Decommissioning	16	470-750	N/A
Closure	2	15-25	N/A
Total	83	8,905-14,585	

The schedule developed by AECL does not provide for extended delays in environmental hearings, approvals, and site selection. Under this schedule a site would be selected in 1995, construction would begin in 2005, leading to a commencement of operations in the year 2015.

Used fuel would be transported to the site by rail or road in special casks designed to withstand severe accidents and provide for radiation shielding. Ontario Hydro has engineering a 35 tonne cask which would contain 192 used fuel bundles (3.6 tonnes). Based on the repository capacity, shipments of used fuel would average 1320 per year (about 5 per day). In 1990 the Canadian nuclear program will generate about 1,800 tonnes of used fuel per year which is equivalent to 500 shipments per year (or about 2 per day).

In 1988, a Federal Environmental Assessment Panel was established under the Environmental Assessment and Review Process (EARP). Initial public hearings have been held and the panel will be issuing guidelines shortly. Based on these guidelines, AECL will be submitting an Environment Impact Statement to the EARP Panel in late 1991 or early 1992.

Canada's disposal program is directed solely at used fuel from reactors operated in Canada. Current siting strategy is focussed on Ontario which has over 90% of Canada's nuclear generating capacity. The EARP hearings are planned for Ontario, New Brunswick, and Quebec, Manitoba and Saskatchewan.

The used fuel disposal method could be adapted for used fuel from light water reactors (LWR's). However, this fuel is different in shape and more radioactive than Candu fuel, and hence generates more heat. Although the costs of disposing of LWR fuel may be three or four times higher per tonne than for Candu fuel, it should be recognized that an LWR only generates one-fifth as much used fuel as Candu for the same level of electrical generation.

3. Saskatchewan's potential for a waste repository

There are a number of factors which favor Saskatchewan as the site of a high level repository for used fuel:

- The northern third of the province is covered by Precambrian shield, which hosts geologically stable granitic rock formations which will likely meet the technical criteria established by AECL in cooperation with the regulatory authorities.
- The northern part of Saskatchewan is sparsely populated and that population is already familiar with the nuclear industry because of uranium mining.
- Because of uranium mining, the north is serviced by all weather roads and by a well organized fly-in/fly-out commuter system for employees.

The case for a waste disposal repository in Saskatchewan would become much stronger if nuclear power was included in Saskatchewan's electrical generation plans. This aspect is discussed in greater depth in the final section of this report.

4. Technical feasibility—public acceptance question

The siting of a high level waste disposal facility in Saskatchewan must meet two prime criteria from the outset—technical feasibility and public acceptance. The public, both northerners and the urban and rural population of southern and central Saskatchewan, must be convinced that a waste repository would provide substantial net benefits to the Province. They must agree to accept an identified site provided it can be demonstrated to meet all technical criteria and the facility can operate safely and without adverse environmental impact.

If the Saskatchewan public is prepared to accept a Candu-3 in the Province's electrical generation mix, this means, at a minimum, that used fuel would be stored at the reactor site. It could then be argued that developing a waste repository to ultimately dispose of used fuel generated in Saskatchewan is the responsible course of action.

However, a used fuel disposal centre dedicated to two Candu-3 reactors would be prohibitively expensive in comparison to a national repository. Even if total spending could be restricted to one-third of that of a 190,000 tonne national repository, a small 4,000 tonne repository would increase unit costs from under $100 per kg to $1,000 per kg or more.

For Saskatchewan to become a national high level waste repository the public must be willing to accept used fuel from Candu reactors in Ontario, Quebec, and New Brunswick being shipped to northern Saskatchewan for disposal. This could initially be tied to used fuel derived from Saskatchewan uranium.

During its 40 year operation period AECL estimates that the used fuel disposal centre would use 2.36 million tonnes of bentonite clay, a product which is mined in Saskatchewan and currently sells for $300 per tonne in 25 kg bags. This would provide a $15 million dollar annual market to Saskatchewan bentonite producers.

Once a waste disposal program is firmly in place it could draw from a broader market including Candu-3's exported to third countries, customers of Saskatchewan uranium, and light water reactors generally. Fuel leasing arrangements could be considered where uranium would be provided and the used fuel taken back for ultimate disposal.

The following list outlines the sources for expanding used fuel disposal opportunities available to Saskatchewan.

- Saskatchewan Candu-3.
- Candu in Ontario, Quebec, New Brunswick with Saskatchewan supplied uranium.
- Candu in Ontario, Quebec, New Brunswick without Saskatchewan supplied uranium.
- Candu-3 export to third country with Saskatchewan supplied uranium.
- Candu-3 export to third country without Saskatchewan supplied uranium.
- LWR in third country with Saskatchewan supplied uranium.
- LWR in third country without Saskatchewan supplied uranium.

Taking back used fuel from Saskatchewan uranium customers and/or Candu-3 export customers would reduce the risk of nuclear proliferation. This could be particularly important in developing third world markets for the Candu-3.

Once a high level waste repository is established it may also be practical and commercially lucrative to use the repository for disposal of other highly toxic wastes which cannot be destroyed with conventional waste management practices. At the present time this option is not being considered.

5. Potential market—pricing policy

If Saskatchewan were to become the site for a national used fuel disposal centre, the costs would likely be financed by utilities paying a fee as they generate electricity from nuclear power stations. The fee would be 1 mil per kwh or less and would accumulate in a fund sufficient to meet all costs plus contingencies through final closure. Ownership of the used fuel disposal centre could include the federal government, provincial governments, utilities, and the private sector and any combination thereof.

To further evaluate the technical and economic ramifications of disposing of used LWR fuel, it is recommended that AECL should consider joint venturing such an evaluation with a company which is already active in the US or European fuel disposal.

Using the direct costs estimates provided by AECL in Exhibit II-4 a full cost can be calculated making the following assumptions:

- The real interest rate for financing evaluation and construction capital is 4%.
- The real investment rate for funds set aside for decommissioning and closure and any other prepaid amounts is 2%.
- The capital, capitalized interest and ongoing financing cost is recovered over the 40 year operating life of the repository in equal annual amounts (ie an annuity calculation at 4% to arrive at our annual cost).
- Costs do not include interim storage at reactor sites or transportation of used fuel to the repository.
- The repository operates at 100% capacity, 190,000 tonnes over 40 years or 4,750,000 kg/yr.
- One kg used fuel generated 90,000 kwh.

Exhibit II-5
Full cost of spent fuel repository

	Timeframe	Period Cost	Annual Cost
		Millions of 1989 Dollars	
Capital	1995 - 2015	3,000 - 4,870	
Capitalized Interest	1995 - 2015	1,005 - 1,650	
Total Capital		4,005 - 6,250	200 - 330
Operating Cost	2015 - 2055	5,420 - 8,940	135 - 190
Decommissioning & closure	2056 - 2074	485 - 775	
Investment Income	2056 - 2074	75 - 115	
Net Decommission & closure cost		410 - 660	5 - 10
Total Cost			340 - 530
		1989 Dollars	
Total Cost per kg			72 - 112
Total Cost per kwh			.0008 - .00125
Total cost per kwh if payment made 10 years earlier			.00066 - .0010

If the used fuel disposal fee is collected as the fuel generates electrical power, on average 10 years prior to delivery to the repository then total disposal cost per kwh would range from 0.66 mils to 1 mil. However, this assumes that the used fuel repository would operate at its full capacity of 190,000 tonnes over its 40 year operating life. To the year 2045 the present Canadian nuclear power program (reactors in operation and under construction) will have produced about 115,000 tonnes assuming that existing reactors will be replaced at the end of their normal 40 year lives.

If the repository is not fully utilized unit costs per kwh could rise by as much as 50%. One means of avoiding this problem would be to increase volume by taking used LWR fuel for disposal.

If the operation of the centre was broadened to take used Candu fuel from other countries, substantial cash flow could be generated. Pricing would be based on competitive factors related to the cost/price of other alternatives available to the foreign utility. The price would likely be much higher than the marginal cost to the used fuel disposal centre. If the centre was modified to accommodate used LWR fuel substantial development work and capital would be required. These would have to be prepaid in some fashion by customer utilities. The level of prepayments and prices will again be based on competitive factors and the options available to those utilities. One problem for US utilities, for example, is that they are already paying one mil per kwh to the US government to finance the DOE's development of a waste repository. However, in general, if utilities have no other disposal options and the cost of reprocessing remains high, (currently in excess of $500/kg) disposal of used LWR fuel could be a very lucrative business.

Although no country can be ruled out as a potential customer for a Saskatchewan repository the greatest potential would be countries which are not committed to reprocessing and do not have active programs to develop waste repositories. High on the list would be Switzerland and Holland and countries which are planning new nuclear power programs such as Turkey, Egypt, and Indonesia. However, the major utilities in Japan, Korea, USA, Germany, Belgium, and Sweden would be very supportive of Canada's initiative. That support could well translate into business.

To further evaluate the technical and economic ramifications of disposing of used LWR fuel, it is recommended that AECL should consider joint venturing such an evaluation with a company which is already active in the US or European used fuel disposal programs.

III

Impact Of Incremental Participation In The Nuclear Fuel Cycle On The Saskatchewan Economy

A. Synergy amongst fuel cycle opportunities

The fuel cycle activities which present the greatest opportunities for Saskatchewan are mining, enrichment, electrical generation, and waste disposal. Conversion, fuel fabrication, and reprocessing (particularly in the near term) have little potential.

Exhibit III-1 qualitatively indicates the impact of each fuel cycle activity on the other from a combined economic and public acceptance perspective.

Exhibit III-1
Interactive impact of fuel cycle opportunities

	IMPACT BY			
IMPACT ON	Mining	Enrichment	Electrical Generation	Waste Disposal
Mining	X	Neutral	Positive	Very Positive
Enrichment	Positive	X	Positive	Neutral
Electrical Generation	Positive	Neutral	X	Positive
Waste Disposal	Positive	Neutral	Very Positive	X

Uranium mining has put Saskatchewan into the nuclear industry. Its growing contribution to the Saskatchewan economy is establishing a base of public acceptance on which to expand and diversify into other fuel cycle businesses. This gives Saskatchewan a huge advantage over provinces like British Columbia, Alberta, or Manitoba.

Enrichment is essentially a stand alone opportunity with a neutral impact on the other fuel cycle areas.

Electrical generation with a Candu-3 would be viewed as confirming Saskatchewan's commitment to the nuclear industry. This would reflect positively on mining and enrichment by enhancing the perceived security of supply. In addition, the Candu-3 would provide the need and rationale to develop facilities for used fuel storage and disposal.

Waste disposal facilities could then lead to the implementation of fuel leasing concepts which would enhance the marketing of the Candu-3 to third countries. Fuel leasing in turn could increase Saskatchewan's market share from uranium mining and make a positive contribution towards non-proliferation.

Conversion and fuel fabrication in Saskatchewan do not appear to have great potential to be economically viable. However, it should be pointed out that with the leverage which could be gained from fuel leasing and used fuel disposal, Saskatchewan, for public policy purposes could develop, or directly or indirectly subsidize, the development of conversion and fuel fabrication facilities in the Province. There is, however, no obvious synergy with the other nuclear fuel cycle activities. In fact, enforced used of such facilities could detract from uranium and enrichment sales.

B. Strategy to achieve public acceptance

To develop the full potential of the nuclear fuel cycle in Saskatchewan it will be necessary to nurture public acceptance through its logical stages and take advantage of the mutual synergies amongst uranium mining, electrical generation, and waste disposal. One such strategy could be summarized as follows:

- The uranium mining base, the need for electrical power generation capacity and the comparative advantages of the Candu-3 reactor lead to the construction of a Candu-3 in Saskatchewan.
- The infrastructure developed for the Candu-3 provides stimulus to the research community and other spin-off benefits.
- The Candu-3 creates a need to address used fuel storage and disposal.
- The Candu-3 also creates an export opportunity to third countries. The export potential is enhanced by the ability to lease uranium fuel and take back the used fuel for ultimate disposal.
- Fuel leasing for the Candu-3 would develop the infrastructure in Saskatchewan for returning, storage, and disposal of used fuel.

- This infrastructure would permit leasing fuel and taking back used LWR fuel. This would result in a larger market share for Saskatchewan uranium production.

C. Economic impact

An input-output model of the Saskatchewan economy was used to estimate the economic impacts which the province could anticipate over the next 30 years from uranium mining, enrichment, nuclear power generation, and a used fuel repository.

Gross investment and operating expenditures were estimated in 1991 dollars together with equivalent direct employment figures. In the case of nuclear power generation and a used fuel repository the estimates were provided by AECL. Peat Marwick Stevenson & Kellogg developed the estimates for uranium mining and enrichment.

The model generated estimates of the total economic impact (the sum of direct and indirect economic impacts) of each stage of the nuclear fuel cycle looking at four key economic variables.

1. Gross Spending and Income - includes direct and indirect expenditures made on local goods and services and payments to labour but excludes imports.

2. Provincial Gross Domestic Product - measures the value-added and includes the total direct and indirect impact on payments to labour, net income to unincorporated businesses and other operating surplus. This measure is consistent with the provincial government's methodology of determining gross domestic product at factor cost.

3. Personal Income - is the sum of all direct and indirect payments to labour in the form of wages and salaries and supplementary labour income.

4. Employment - is the total direct and indirect impact on person-years of employment.

It should be noted that this input-output analysis provides only a preliminary valuation of the economic impact of the nuclear industry for Saskatchewan. Detailed breakouts on the specific nature of direct expenditures and labour sourcing were not done. In addition, the analysis assumed no structural change in the Saskatchewan economy where, in fact, given the magnitude of potential nuclear industry investment, some structural change would likely result. As a consequence of these simplifications, interpretation of economic impact should be limited to gross magnitudes only.

1. Uranium mining

The economic and employment impact of the development scenario for uranium mining set out in Section 1-5 and 1-6 of this report is summarized in Exhibits III-2 and III-3. Production is projected to increase to 33 million pounds U_3O_8 per year by the year 2000 and then sustain that level through 2020. This is a very conservative estimate in that it projects no growth in demand in the first two decades of the next century. To achieve and maintain this level of production requires an average level of capital spending of about $100 million per year in 1991 dollars.

Exhibit III-2
Economic impact of uranium mining on the Saskatchewan economy 1991-2020

Millions of 1991 Dollars

	Capital	Operating	Total
Gross Expenditures	3,000	5,825	8,825
Direct Expenditures included in the above	1,640	5,380	7,020
x Impact Multiplier	1.63	1.50	
= Gross Saskatchewan Expenditures	2,670	8,070	10,740
Impact Provincial GDP	1,610	5,730	7,340
Sales Revenue			23,250

Exhibit III-3
Employment impact of uranium mining 1991-2020

	Person-Years		
	Construction Employment	Operating Employment	Total Employment
Direct Employment	20,000	41,500	61,500
x Impact Multiplier	1.88	1.59	
= Gross Employment	37,625	66,180	103,805
Labour Income ($1991 millions)	$1,135	$2,640	$3,775

A detailed assessment of uranium royalties and taxes was not undertaken, however, a rough approximation of their magnitude over the 1991-2020 period is:

	Millions of 1991 Dollars
Basic Uranium Royalties	$1,000 - 1,500
Graduated Uranium Royalties	$1,500 - 2,500
Federal and Provincial Corporate Income Tax	$2,000 - 3,500
Total Taxes and Royalties	$4,500 - 7,500

2. Enrichment

In developing the economic and employment impact of uranium enrichment in Saskatchewan the following scenario was assumed:

- Crisla is successfully demonstrated by 1994.
- A 250,000 SWU facility is constructed by 1997.
- The facility is expanded to 1,000,000 SWU by 2001 and 2,000,000 SWU by 2010.

Exhibit III-4
Economic Impact of uranium enrichment on the Saskatchewan economy 1991-2020

Million of 1991 dollars

	Capital	Operating	Total
Gross Expenditures	440	660	1,100
Direct Expenditures included in the above	175	590	765
x Multiplier	1.66	1.42	
= Gross Saskatchewan Expenditures	290	840	1,130
Impact on Provincial GDP	155	630	785
Sales Revenue			3,000

Exhibit III-5
Employment impact of uranium enrichment 1991-2020

Person-years

	Construction Employment	Operating Employment	Total Employment
Direct Employment	1,100	3,960	5,060
x Multiplier	3.10	1.59	
= Gross employment	3,410	6,300	9,710
Labour Income ($1991 millions)	$85	$240	$325

3. Nuclear power generation

The economic and employment impact of Candu-3 nuclear power generation in Saskatchewan assumes that a first station starts commercial operation in 2000, a second station in 2008 and a third in 2016. This results in 36 reactor years of power generation over the 1991-2020 period. In the following 10 year period, with three reactors operating, the aggregate operating expenditures and employment would nearly double.

Exhibit III-6
Economic impact of nuclear power generation on the Saskatchewan economy 1991-2020

	Millions of 1991 dollars		
	Capital	Operating	Total
Gross Expenditures	2,400	1,315	3,715
Direct Expenditures included in the above	1,110	925	2,035
x Impact Multiplier	1.88	1.94	
= Gross Saskatchewan Expenditures	2,090	1,800	3,890
Impact Provincial GDP	880	1,010	1,890

Exhibit III-7
Employment impact of nuclear power generation 1991-2020

	Person-Years		
	Construction Employment	Operating Employment	Total Employment
Direct Employment	12,000	10,800	22,800
x Impact Multiplier	1.67	1.71	
= Gross Employment	20,010	18,470	38,480
Labour Income ($1991 millions)	$665	$685	$1,350

4. Used fuel repository

The economic and employment impact of a used fuel repository designed to accommodate all used nuclear fuel generated in Canada until the year 2035 has been modeled. The assumptions are consistent with Section II-F-2 of this report. The facility would become operational in the year 2015. No disposal of leased or imported used fuel from light water reactors is included in this economic scenario, other then the projection of increased uranium sales discussed in Section III-C-5.

In the aggregate tables which follow the operating expenditures and employment related to the repository include only six years of operation, and consequently seem low relative to uranium mining. In fact, the economic and employment impact of an operating used fuel repository is about half that of the total uranium mining industry.

Exhibit III-8
Economic impact of a used fuel repository on the Saskatchewan Economy 1991-2020

Millions of 1991 Dollars

	Capital	Operating	Total
Gross Expenditures	4,000	855	4,855
Direct Expenditure included in the above	1,720	775	2,495
x Impact Multiplier	1.67	1.40	
= Gross Saskatchewan Expenditures	2,865	1,080	3,945
Impact on Provincial GDP	1,610	7,80	2,390

Exhibit III-9
Employment impact of a used fuel repository 1991-2020

Person-Years

	Construction Employment	Operating Employment	Total Employment
Direct Employment	14,000	3,600	17,600
x Impact Multiplier	2.54	1.78	
= Gross Employment	35,675	6,390	42,065
Labour Income ($1991 millions)	$950	$180	$1,130

5. Incremental uranium mining

As pointed out in Section III-A of this report the development of a used fuel waste repository could lead to fuel leasing concepts which would increase Saskatchewan uranium sales. In the following economic and employment impact analysis a subjective judgement has been made that Saskatchewan sales would be increased by one million lbs U_3O_8 by 2005 (3%), two million lbs by 2010 (6%) and three million lbs by 2015 (9%). Thus in 2015 Saskatchewan's world market share could increase from 30% to 32.5%. This judgement could prove to be conservative in the longer term.

Exhibit III-10
Economic impact of incremental uranium production on the Saskatchewan economy 1991-2020

Millions of 1991 Dollars

	Capital	Operating	Total
Gross Expenditures	160	120	280
Direct Expenditures included in the above	75	110	185
x Impact Multiplier	1.63	1.50	
= Gross Saskatchewan Expenditures	120	1654	285
Impact on Provincial GDP	70	125	195
Sales Revenue			750

Exhibit III-11
Employment impact of incremental uranium mining 1991-2020

Person Years

	Construction Employment	Operating Employment	Total Employment
Direct Employment	1,065	1050	2,115
x Impact Multiplier	1.88	1.59	
= Gross Employment	2,005	1,670	3,725
Labour Income ($1991 millions)	$60	$60	$121

6. Total economic impact

The total potential impact of the nuclear industry to Saskatchewan is the sum of the individually determined impacts for uranium mining, enrichment, nuclear power generation, used fuel disposal and incremental uranium mining.

Exhibit III-12
Total potential economic impact of the nuclear industry on the Saskatchewan economy 1991-2020.

Millions of 1991 Dollars

	Capital	Operating	Total	Avg. Annual
Gross Expenditures	10,000	8,775	18,775	626
Direct Expenditures included in the above	4,720	7,780	12,500	417
x Impact Average Multiplier	1.70	1.54		
= Gross Saskatchewan Expenditures	8,035	11,945	19,980	666
Impact on Provincial GDP	4,325	8,275	12,600	420

In 1989 the provincial GDP stood at $19,176 million. With an average impact of $420 million per year, the nuclear industry has the potential to represent about 2.2% of the province's GDP for the next thirty years.

Exhibit III-13
Total potential employment impact of the nuclear industry in Saskatchewan 1991-2020

	Person-Years			
	Construction Employment	Operating Employment	Total Employment	Avg. Annual Employment
Direct Employment	48,965	60,910	109,875	3,662
x Impact Average Multiplier	2.06	1.63		
= Gross Employment	100,725	99,010	199,735	6,658
Labour Income ($1991 millions)	$2,895	$3,805	$6,700	$223

Based on 1989 Labour Income ($9,043 million) and Employment (446,000) data the nuclear industry has the potential to contribute 1.49% of provincial Employment and 2.47% of the province's Labour Income.