

Practical Solutions for North American Energy Supply



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1 Abstract

Production of synthetic crude oil from oilsands is a rapidly growing and critical industry in Alberta, Canada. With completed capital projects valued in excess of US\$40 billion, and planned projects worth US\$60 billion, it is clear that investors are committed to expanding the production capacity from these sources to meet the fast-growing demand. The reservoir of oil in this region, estimated at between 200 and 300 billion barrels of presently recoverable oil, will supply millions of barrels per day for hundreds of years to come. By 2010, synthetic oil production in Alberta will be 3 million barrels per day.

The reservoir of uranium in northern Saskatchewan is the world largest high grade deposit, comprising 55% of world supply. Canada has a well-developed nuclear power generation industry in the east, which relies upon fuel from Saskatchewan. Canadians are world leaders in the nuclear power industry through the Crown Corporation Atomic Energy of Canada Ltd. (AECL). The CANDU reactor is among Canada's greatest engineering achievements, with an impeccable safety record and decades of proven reliability around the world.

Production of synthetic crude oil from oil sands bitumen recovery is more energy intensive than conventional oil production. Steam assisted recovery techniques presently consume massive quantities of natural gas (CH_4) in the production of process energy. Accordingly the production of synthetic crude oil produces large carbon dioxide (CO_2) emissions. Canada is a signatory to the Kyoto Protocol, which mandates reductions in the quantity of CO_2 produced. This is a significant threat to future oil sands capital projects. The most productive and effective way to achieve our commitments under the Kyoto Protocol would be to utilize an energy source that does not produce CO_2 , and is capable of producing the massive quantities of power needed to fuel the present and future demand. Nuclear power is the answer.

What is proposed would be the largest and most expensive capital project in the history of Saskatchewan. On a phase determinant and incremental basis, the project would stimulate the Alberta and Saskatchewan economies for many decades to come. The nuclear energy option is the most environmentally responsible means of dealing with burgeoning continental demand. It is a safe, achievable, economically viable and highly secure option for providing stable, multi-dimensional energy supply to Canada and the continental United States. This is a reliable and abundant energy source for the long term.

2 The Proposed Project

The proposed project is the construction of a multi-gigawatt CANDU nuclear generating station near Cree Lake, Saskatchewan, west of Key Lake, Saskatchewan and 275 km east of Ft. McMurray, Alberta (see Figure 2). This remote location is 550 km north of Saskatoon, Saskatchewan and 900 km north of the Montana border. The project should be scaleable, commencing with the Phase 1 construction of two 1-GW ACR-CANDU reactors, and 700kV – DC transmission lines to Fort McMurray, Alberta. Scaleable, in

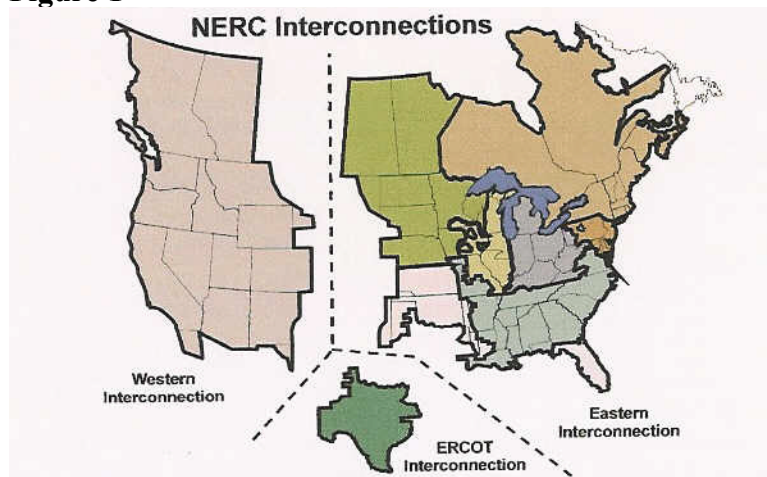
this context implies that further reactors should be added over time as revenues will accommodate, the demand will justify, and transmission infrastructure will allow.

The Phase 1 transmission objective is to supply power to facilitate additional oilsands development and bitumen production. Nuclear generated electrical power would be used to produce process steam instead of CH₄. The steam produced is used for the in-situ process of extracting bitumen from oilsands. Royal Dutch (SHELL) estimates 15% production is lost to process energy. Existing commercial SAGD (Steam Assisted Gravity Drainage) developments near Ft. McMurray predominantly use natural gas (CH₄) fired generators to produce steam for subsurface injection. Recovered bitumen is processed in Edmonton into synthetic crude oil, much of which is exported to the US. An additional 2-GW of electrical power capacity will provide enough extraction steam to produce more than one million barrels of synthetic crude oil daily, while sharply reducing CH₄ consumption and eliminating CO₂ emissions. Though capital intensive, this would be a cost-effective, long-term and secure energy solution for North Americans. It would be the first step in the development of Saskatchewan into the largest producer and exporter of electricity in Canada.

Phase 1 development would take 5-years in the construction phase. Reviews and environmental impact assessments would take years prior to commencement of construction. A transmission right-of-way must be acquired and developed.

In Phase 2 of the Cree Lake project, which could begin 5-years after the initial phase, two more 1-GW ACR-CANDU reactors would be built. Transmission lines would be added to Calgary, and eventually to a supply node at the junction of the US Western and Eastern Interconnects. *(at the Alberta/Saskatchewan border with Montana, north of Havre)*. This timeline would allow American operators to build-up their own infrastructure to the supply node (see Figure 1). Early interest in this supply source would likely come from wholesalers in the Western Interconnect. With 160 GW of peak load expected to rise by 35% over the next two decades.

Figure 1



US Dept. of Energy NERC 2001

3 A Geologically Unique Opportunity

The Cree Lake nuclear development would be the most effective way to take advantage of the unique geological phenomenon that exists in this region. It is the only known place on earth where the natural resource deposits of oil and uranium exist in such close proximity and great abundance. The Athabaska Basin region of northwestern Saskatchewan and northeastern Alberta, and the Key lake region of north central Saskatchewan comprise an area of 80 thousand km², about the size of Lake Superior. Located in this area are more than 50% of the world's known uranium reserves and the world's largest uranium mining operations. The locally available uranium supply could generate multi-GW power for hundreds of years. Add to these valuable mineral resources the proximity of the Athabaska tar sands; a vast reserve containing 15 % of the world's known supply of presently recoverable oil (*with an additional 1.5 to 2 trillion barrels which are thought to be unrecoverable with current technology*). The simultaneous exploitation of the uranium and oilsands resources, with nuclear process power producing millions of barrels per day of synthetic crude oil, is an economic roadmap to sustained growth in both industries.

The extraction of bitumen from oilsands, and subsequent refining into synthetic crude oil is an energy intensive process. The cost and availability of process energy are major parameters in the consideration of extended oilsands development. Of great concern also is Canada's commitment to the Kyoto Protocol which calls for a reduction in CO₂ emissions. Like the developments in and around Ft. McMurray, nuclear power production would be most economical on a colossal scale.

Figure 2 -Proposed Plant Site



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4 Complimentary Industries

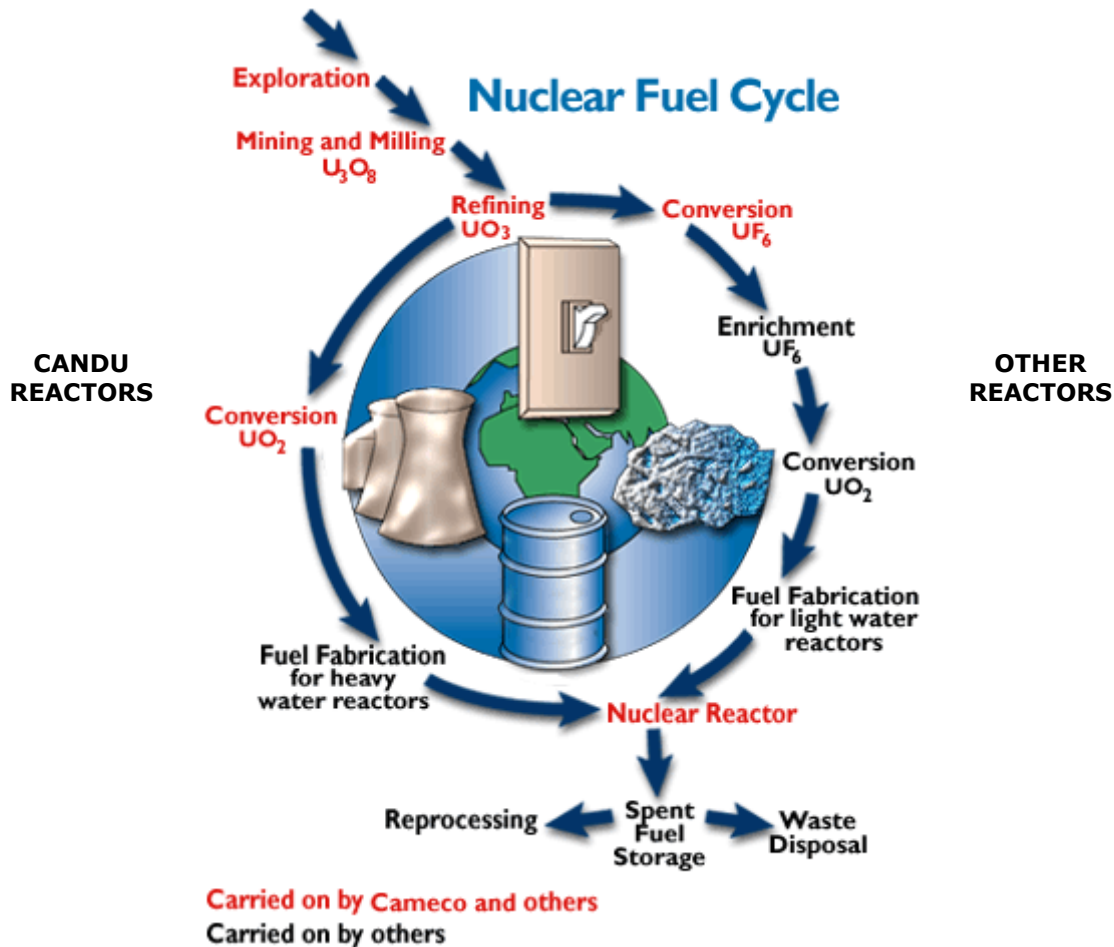
The idea of using nuclear power for oilsands process energy is not a new one. In June of 2003 a paper on the subject was presented at the Canadian International Petroleum Conference. This paper, by R.B. Dunbar and T.W. Sloan of the Canadian Energy Research Institute (CERI), compared the economics of conventional CH_4 fired SAGD methods with a modified ACR-700 (731 MW) CANDU reactor. The study concluded that nuclear steam generation was economically competitive with CH_4 . They modeled a central steam generation site to be located within the oilsands, where in-situ process steam was to be created directly by the heat of nuclear fission, as opposed to producing electric power through generation and transmission. Though direct nuclear steam generation is more efficient and involves significantly less capital cost than power

generation and transmission, the thermodynamic limitations of transporting steam over long distances were thought to be a major constraint.

The heart of oilsands development is Ft. McMurray, Alberta. Estimated synthetic crude output from area operations should reach 550 thousand bpd in 2004. This represents approximately 20% of Canada's total oil output. This proportion is inclined to grow, as many of the corporations have undertaken huge capital projects in oilsands development. Multi-billion dollar projects undertaken by Suncor, Shell Canada, Chevron, Western Oil Sands, Encana and Petrocanada should triple synthetic crude production from oilsands sources over the next decade. The Athabaska tar sands region is interprovincial located over the Alberta-Saskatchewan border. All of the oilsands development presently is in Alberta, centered just north of Ft. McMurray. Total project capital costs to date surpass US\$40 billion, with planned projects of US\$60 billion. Higher CH_4 costs in the last two years have raised production costs, and now Kyoto jitters ripple through the industry. By the year 2025, US oil consumption is predicted to be 30 million bpd, most of which will be imported. The Athabaska tar sands could satisfy the growth in the US demand over the next century.

There is presently no nuclear power generation in Saskatchewan, though there is a nuclear industry. At present, this industry is comprised of the uranium mining operations of *AREVA-Cogema* and *Cameco Corp*, with other minority interests. The Canadian nuclear industry, through the 52-year old Crown Corporation *Atomic Energy of Canada Ltd. (AECL)* is a world leader in the design and construction of nuclear reactors to power generating plants. The newest reactor designed by AECL (ACR series) is light water cooled, and heavy water moderated. Presently, the uranium produced in Saskatchewan is sold around the world, as well as being used to fuel CANDU plants operating in Ontario, Quebec, and New Brunswick. The Provincial utilities are Crown Corporations, and all three of the Provinces that operate CANDU reactors are/have been net exporters of electrical energy to the US. CANDU reactors have the advantage of using simpler conversion to process uranium fuel which reduces fuel reprocessing required by other light-water cooled reactors (see Figure 3). The development of the CANDU technology by Atomic Energy of Canada Ltd. (AECL) ranks as one of the top Canadian engineering achievements of all time. CANDU's and Canadian technology have been exported to Pakistan, Argentina, Romania, South Korea, India and China. All of the CANDU's built this decade have been built in India and China. The 438 nuclear reactors in operation around the world include 32 CANDU's.

Figure3



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5 The Kyoto Protocol

The Kyoto protocol was ratified by the government of Canada on December 17, 2003. The existing text of the agreement calls for a reduction in CO_2 emissions to 6% below 1990 levels by 2012. The US, though not a signatory to the agreement, has developed its own stringent guidelines on emissions, relative to what these standards were in the past. There appears to be little progress in Canada on industry compliance at this point, though the Alberta government has invested more than \$400 million toward greenhouse gas emission reduction. The province of Alberta produces 30% of the CO_2 in the nation, much of it from oilsands extraction operations and synthetic crude production. Alberta environment Minister Lorne Taylor said in April 2004 that it would likely take Alberta until 2050 to achieve the reductions called for under the auspices of the accord. The issue and the timetable have been the subject of considerable federal/provincial discontent between Alberta and Ottawa. Alberta is steadfastly opposed to the accord in the first instance. The major point of contention at present is that Ottawa would like to see Alberta implement a cap on CO_2 emissions, something the province is reluctant to do given the level of oilsands investment and expansion. Ottawa has a long history of

counterproductive meddling Alberta's resource sector, and there is considerable distrust that Ottawa might legislate Kyoto compliance while disregarding Alberta's concerns.

There are at present few alternatives in CO₂ emission reduction other than reducing consumption of power and energy. Though CO₂ can be collected from emissions, the practice is not widespread, and there is a shortage of markets for the CO₂ collected. Transporting collected CO₂ is also a problem. It is being used in the carbon -flood method of enhanced oil recovery, a method proven to extend exploitation of some depleted oil wells in Texas and Saskatchewan. Collection and transport of CO₂ is prohibitively expensive, and the absence of markets for large quantities of CO₂ makes any grand scale efforts at collection improbable. The more likely case scenario is that the growing North American energy supply requirements will continue to result in the production of millions of tons of CO₂ for decades to come. The proposed Cree Lake development would represent the most significant reduction in CO₂ emissions in the history of North American power generation.

The desired impact of industry compliance to the Kyoto Protocol will be to reduce global warming, theoretically resultant of CO₂ emissions. Any measure of CO₂ emission reduction will curtail development in oilsands production, with enormous cost involved, unless energy alternatives can be found. The nuclear alternative is the only large scale power production possibility that can expand current capacity without CO₂ emissions. At the same time, exploitation of regional gas fields would decline. This is preferred because of the geophysical impact of depleting CH₄ reservoirs where exploitation reduces reservoir pressures and makes bitumen extraction more difficult. Many gas wells are shut-in for this reason. The long term impact of the Cree Lake nuclear project would facilitate Canadian compliance to the Kyoto protocol, while preserving CH₄ supplies and expanding both oil and electrical power production to meet growing continental demand.

6 Revitalization of the Canadian Nuclear Industry

On March 15, 2004 a report was released by an Ontario panel chaired by former Deputy Prime Minister John Manley which recommended that Ontario should expand upon their current nuclear generation capacity in an effort to thwart looming power shortages in that Province. Ontario's role as an electricity exporter to the US is jeopardized by their inability to maintain production due to increased domestic demand, and the antiquation of existing nuclear reactors at Pickering. The three Pickering reactors are at or near the end of their design lives, and multibillion dollar upgrades are required as an option to permanent shutdown. When Phase 3 of the Pickering project began operating in 1973, it was the largest nuclear power plant in the world.

The key points made in the 2004 Manley paper as they relate to the proposed Cree Lake project are summarized:

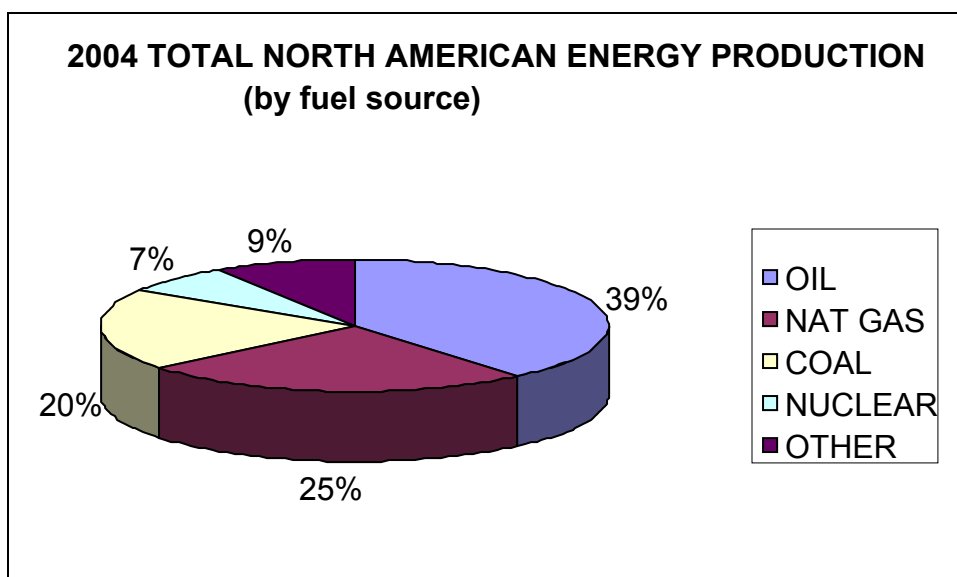
- 1) That Ontario should expand its nuclear power generation capacity;
- 2) The Province should consider private sector financing for nuclear power stations;

The release of the Manley report has provoked some discussion in the private sector, which in turn will generate more public discussion. For potential investors the major risks are regulatory in nature. Consistent government policy is required before the capital markets will commit to nuclear mega projects. Political decision making needs to be consistent over time. Nuclear power should not polarize the political culture, resulting in untenable financial risk.

As Mr. Manley had recommended with regard to Ontario, it would be the private sector that will finance the Cree Lake development. It is certainly the author's opinion that the mark of viability of this project is whether it can raise its own capital, extraneous to government involvement. The private sector role in the development would be to capitalize the project and operate the facility. The government's role would be to regulate. Investors would expect a reasonable return, and the government should expect a royalty and the payroll taxes resultant of tens of thousands of jobs created. The capital costs of this project represent the kind of money that governments don't have and should not even borrow on behalf of taxpayers who could invest in the project individually, if they chose to. This would be a project financed by the public markets and private partnerships.

This would be the second time that Canada laid claim to the world's largest nuclear power plant. Pickering was the world's largest in 1973. In addition to billions of dollars in productivity, Pickering also demonstrated the safety and reliability of the CANDU, Pickering was a resounding success, and it helped establish AECL as the world leader. Given the increase in US oil demands and rising prices, now is the time to build on this valuable Canadian expertise after years of simply exporting it.

Though nuclear reactors supply less than 8% of the North American energy market, their share of the electrical power market has risen from 11% to 20% over the last 25-years. This is important considering that no new nuclear plants have been licensed or built in Canada or the US since the Three Mile Island fiasco 25 years ago. The added production is the result of plant efficiencies, and operation near capacity of existing plants.



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7 Oil is here to Stay

There have been a myriad of studies dedicated to researching energy alternatives to reduce our dependency upon oil. Indeed, alternative energy strategies such as biomass energy, wind-power and solar now comprise 8% of the American energy supply. Technology has played a key role in the development of alternative energy production, as has taxation subsidy. These alternatives are noble pursuits and should continue; however, they have shown little effect on America's ever increasing oil demand. The American economy is oil driven, and there are no initiatives at present that will reduce the growing dependency upon it in the foreseeable future.

Table 1: A Growing Market

US OIL CONSUMPTION (million barrels per day)

	<u>1965</u>	<u>1975</u>	<u>1985</u>	<u>1995</u>	Projected <u>2005</u>	Projected <u>2015</u>	Projected <u>2025</u>
US OIL PRODUCTION	7.8	8.4	9	6.5	5.3	2.8*	2*
US OIL IMPORTS	2.5	6	5	8.8	14.1	22	28
TOTAL	10.3	14.4	14	15.3	19.4	24.8	30
% IMPORTED	24	42	36	58	73	89	93

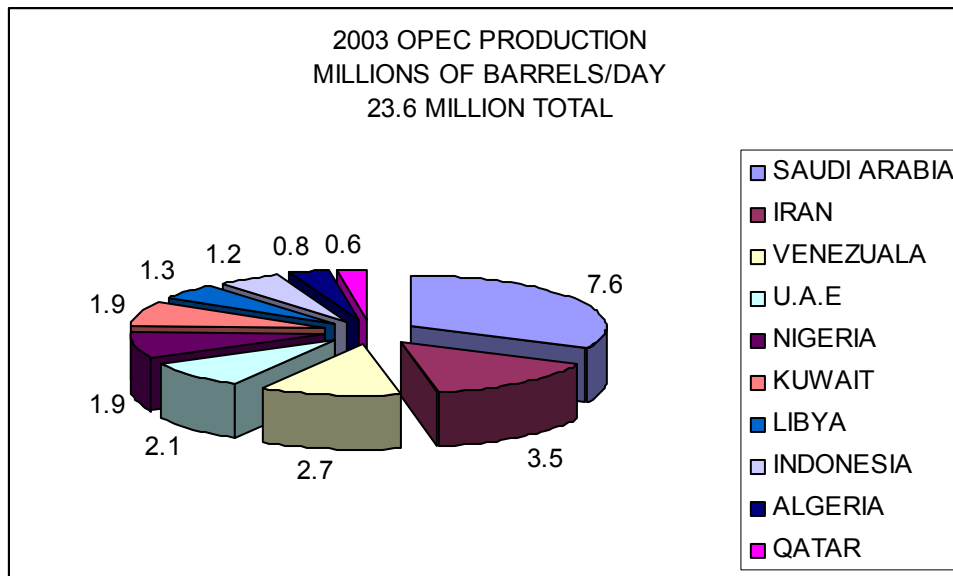
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- *Assuming no development of Alaskan (ANWAR) or new off-shore reserves*

Table 1 indicates the probable growth pattern in US oil consumption, which comprises most of the North American demand. Total North American energy demands are predicted to escalate 40% over the next two decades, from a current level of 131 billion gigajoules (GJ) (125 quadrillion Btu) to 180 billion GJ. (170 quadrillion Btu). Putting

these large numbers in perspective, each CANDU –ACR 1000 at Cree Lake would generate 86,400 GJ / Day, or about 31 million GJ annually.

Figure 5



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Present US oil imports of 14 million bpd are valued at \$448 million per day using a market price of \$32 pb. 2003 imports were valued at US\$163 billion. At the time of this writing, the Iraq situation has not stabilized to the degree that the US can extract troops, and oil prices look to remain high, at least through 2004. The Iraq situation continues to exert upward pressure on prices. It is certainly plausible that there will continue to be security issues in the oil export regions of the Middle East/North Africa/South America, with significant costs to the American taxpayer. In March of 2004, OPEC went ahead with plans to cut production by 1 million bpd. Whether these production cuts will occur or not, it is factual that no supply source in this region is secure. High oil prices reflect this insecurity and this will probably be the case long into the future. Additionally, there is rising demand for oil in the developing world, particularly China. This market is also fast-growing and represents a threat to future supplies, as well as price pressures.

The public overview of energy issues seems almost ambivalent given the scale of the increasing demand, and the potential impact of energy shortages. High oil prices, as we have seen over 2003 and 2004 may change this. With a significant American military operation ongoing in Iraq coupled with high prices, energy issues will eventually find their way to the top of the public agenda. At this time there is very little support in the US for further exploration or development within ANWAR, and even an attitude of preference towards exploitation of all non-American reserves first. America still leads the world in per-capita oil consumption, and the changes in culture necessary to reduce this demand have not taken hold.

Environmental sensitivities related to oil consumption also do not seem to be concerning Americans much, at least as far as public policy is concerned. (*excepting ANWAR*). The US did not sign the Kyoto Protocol, and the size of the movement within America that would support such legislation is probably not a majority. There is a misguidedly candid expectation that technology will solve energy supply problems on a timely basis. There is a belief that H₂ or electric powered vehicles will somehow reduce the dependency on oil. The question of where the H₂ is going to come from, or where the power is going to come from in the case of electric vehicles, doesn't receive as much attention. California has legislated zero emission vehicles onto the road, and expects technology to deliver. In the event that H₂ powered vehicles become widely used, the only way that net CO₂ emissions would be reduced is if the H₂ were liberated from water as opposed to CH₄ or any other hydrocarbon source. Electrolytic H₂ production (from water) requires electrical energy, and given the number of vehicles on the road the demand would be staggering.

The auto industry has delivered combustion systems which are incredibly efficient, given what they were a decade ago, or two decades ago. This has had an extremely beneficial impact on air quality, given the greater numbers of automobiles on the road. Biomass ethanol is a relatively clean burning but very expensive fuel, and when the energy inputs into agricultural commodity costs of the supply grain (normally corn) are considered, there is no collective reduction in CO₂ emissions. Irrespective of the technology, whether biomass ethanol, electric, or H₂ powered, there will be no collective reduction in the dependency on fossil fuels given the existing number of vehicles on the road. Alternative technologies will have beneficial impact on local air quality, but their overall impact on the environment could in some cases be more negative than that of oil. The fact remains that electric vehicles do not reduce emissions overall when the power to charge them is generated using coal, gas, oil or even biomass energy. Though H₂ can be produced from water, it costs much more than producing it from natural gas (CH₄) and/or other fossil fuels. The North American energy demand requires practical solutions to meet the forecast demand.

8 A Depleted Natural Gas Supply

In the absence of energy alternatives such as that proposed in this paper, future development of the Athabaska tar-sands is threatened by dwindling supplies of CH₄. A shortage in gas supply would have a double impact on oilsands development; because it is a primary energy source in the extraction process, and is widely used in the refining process. Depletion of regional gas fields lowers reservoir pressures and makes bitumen within the tar sand and CH₄ more difficult to extract.

The oil industry has been unable to develop gas capacity fast enough to satisfy the growth in demand. Proposed developments in Alaska, the Mackenzie Delta of the Canadian arctic, and in the depths of the Gulf of Mexico could offset declining supply, but these projects are years from production. This has been a major factor in the spike in CH₄ prices for three years continuing on into 2004. CH₄ prices averaged US\$5.49 per million

Btu (MMBtu) throughout 2003 and continued high-prices are a threat to American jobs. This recent upsurge in gas prices is reminiscent of the energy crisis in the late 1970's, though the demand then was much lower. Natural gas is now widely used in the generation of power because it is much cleaner burning than coal. Its utilization as an industrial feedstock is also widespread, most notably in the production of NH_3 as an agricultural fertilizer. Use of ammoniated fertilizers has strongly contributed to a doubling of world food production over the last 30-years, and in the event that gas supplies are not available for this purpose, other more expensive hydrogen sources must be utilized. Production of electrolytic hydrogen requires electrical power, and large quantities of CO_2 are produced to the extent that the power is fossil fuel generated. Whether CH_4 is used as the energy source for oilsands exploitation, as an industrial feedstock, or in fertilizer production, and although it is the cleanest burning of all fossil fuels, the fact remains that greenhouse gas (CO_2) is produced.

9 Why Cree Lake?

The 40-year old Pickering development was a lot closer to a very large electricity market than Cree Lake, Saskatchewan. This all changed in the last decade when oilsands mega projects in northern Alberta established a process energy market. The Phase 1 Cree Lake development could supply that market, safely and economically. 275 km of high voltage transmission is a practical expense to pay in order to locate high-capacity nuclear facilities in such a remote place, buffered by a huge geographic area.

As a remote and isolated location, Cree Lake would be a preferred place to develop the world's largest nuclear power plant. With a regional population of less than 400 persons within a 200km radius, many of them employees of the various uranium mining operations, this regional population density is among the lowest found anywhere in the world. No other nuclear plant would have such an extensive natural buffer, and accordingly no other nuclear reactor anywhere would be as safe.

The political culture of the Province of Saskatchewan gives pause to outside investors, including the capital markets which are critical to the prospects of a project of this magnitude. The history of business relations between the Saskatchewan NDP government and private corporations was scarred by the nationalization of most of the potash industry in the 1970's. Though the potash industry was later re-privatized, the damage was done for the long term. This is the major reason why the province's mineral and oil wealth is virtually undeveloped, with capital spending in neighboring Alberta outpacing Saskatchewan's by a factor of 50 to 1. The reluctance of the capital markets to engage in Saskatchewan is omnipresent, but not insurmountable. The people of Saskatchewan are ready to share in the resource bonanza that has long affected their Alberta neighbor. Political support for the project is soon likely to be at an all time high.

It is true that the geographic isolation of Cree Lake will add significantly to the cost of an industrial development of this scale. This was also a concern 265km west at Ft. McMurray prior to the mega project developments that occurred there in the last 15 years. After the many billions that have already been spent, there are more projects now

proposed and under development. As was the case at Ft. McMurray, there are economies to be realized in plant site development at the point of resource origin. Saskatchewan enjoys a flourishing uranium industry, where milled uranium oxide is either shipped to eastern Canada or exported, and all of this without secondary or tertiary processing benefit to the Provincial economy. What is proposed here is that the Saskatchewan economy will continue to derive the benefits of uranium production, with the additional secondary benefits of uranium processing, and the tertiary benefit of nuclear power production. This development stands to create many thousands of jobs long into the future.

Geologically speaking, Cree Lake is incredibly stable. Located on the Athabaskan Group of Precambrian rock, the sub-Athabaska basement comprises Achaean gneissic granitoid rock, which is incredibly stable. This would be the least likely nuclear reactor anywhere to be damaged by an earthquake, or affected by volcanism, or any natural weather phenomena. Additionally, the plant site would be surrounded by the world's largest reserves of uranium oxide. 70-km to the southeast is the Key Lake Mine, site of the largest high-grade uranium milling facility in the world, operated by Cameco. 80-km east is the Macarthur River mine, the world's largest, high-grade uranium deposit. 95-km to the North West is the Cigar Lake deposit, the world's largest undeveloped high-grade uranium deposit. There are other mines in the area as well, operating as well as depleted.

The extremely stable Precambrian rock, coupled with low elevation and basin-like drainage provides an excellent prospect for the permanent deep geologic disposal of spent fissile fuel, as well as low-level waste and raw uranium tailings. Storage and disposal of spent fuel rods is a great area of concern for nuclear power producers, and citizens everywhere. AECL has long studied the deep geological disposal of spent fuel, and established its effectiveness at their Waste Technology Business Unit (WTBU) research facility located near Pinawa, Manitoba. The geologic conditions near the proposed plant site are known to be among the safest anywhere for deep and permanent disposal. Given the environmental concerns, spatial concerns, and security concerns related to spent nuclear fuel storage and disposal, there is great economy in a safe and permanent solution. High and low grade nuclear waste could be permanently disposed of at or near the same place it was originally mined as uranium ore, and this could be accomplished using existing research and design. With the technical expertise of AECL, the world's safest disposal repository could be developed. The environmental risks related to the transport of high-level nuclear waste would also be minimized. The Cree Lake development would not only be the world's largest and safest nuclear facility, but it would be the most environmentally efficient power plant anywhere.

The new millennium has brought with it a new realm of security concerns. This is especially true with regard to the nuclear power industry, for it has become a serious concern that a reactor site would become a terrorist target. The events of September 11, 2001 introduced the plausibility that nuclear facilities could be attacked in a similar way. The public safety risks associated with nuclear reactors are the major reason that more reactors are not presently being developed to meet our escalating power demands. It is

also the reason why no nuclear generating stations have been built anywhere in North America since the Three Mile Island accident in 1979.

Security initiatives surrounding existing North American reactor sites have made them less vulnerable, but no amount of vigilance can guarantee that terrorists won't attempt to attack a reactor site. It is extremely improbable that the most remote reactor site in the world would be considered a practical terrorist target, given the logistical challenges to access and the absence of a target population. In addition to the fact that the CANDU is the world's safest nuclear reactor, the Cree Lake project would be the world's most secure reactor site.

10 Transmission Limitations

It is the proximity of the Athabaska tar sands and their available bitumen that makes the project feasible in the short-term, but it is the availability of high-grade uranium that will sustain the power industry at the Cree Lake Project long into the future. The project would be feasible even if there were no oilsands, and the ability to input nuclear generated electrical power into oil output didn't exist. It is the proximity of the present industrial complex at Ft. McMurray that makes the project feasible in the short term. It is transmission capacity that will sustain the project over this century.

Simply put, you cannot sell power if no-one can deliver it. Electrical transmission grids in North America are antiquated, and the cost of expanding their capacity and improving reliability are potentially the most expensive consideration in a continental energy strategy. Indeed, merely purchasing the land to establish a 9 metre right-of-way for transmission lines can cost hundreds of millions of dollars and take years to accomplish. This is not the case respecting the proposed transmission from the Cree Lake plant site to Ft. McMurray, since this is largely Crown Land and is presently in its native state. Transmission, however, is what will enable or constrain the sale of electrical power into Alberta and the continental US. Phase 2 of the Cree Lake development is to produce additional electrical power to be delivered in massive quantities to service the growing Alberta load as well as the supply node at the North Dakota/Montana border with Saskatchewan. This will require upgraded capacity on both sides of the border.

In March of 2004 Alberta Energy Minister Murray Smith announced that the Province was appropriating as much as CAN\$45 million to purchase ranch land in eastern Alberta to facilitate construction of transmission lines from Ft. McMurray to Calgary to distribute electrical power generated at the oilsands to Canada's fastest growing city. Though this power could be better used to expand synthetic crude production, the Calgary demand is one that must be dealt with quickly in order to sustain its rapid growth. The Cree Lake proposal could satisfy the Calgary demand requirements long into the future and enhance the feasibility of the project sooner rather than later. Over the longer term, the sale of electrical power to Calgary could pay for the whole Cree Lake development. There is a strong argument to be made that the planned 500kV – DC line between Ft. McMurray

and Calgary isn't large enough, given the simultaneous potential of oilsands cogenerators and the proposed Cree Lake plant.

At the same time the increased availability of multi-gigawatt power at the US border would encourage the development of better grid capacity in the US, and given the growth in demand such development would be arbitrary. A supply node near the Saskatchewan border with North Dakota/Montana could eventually supply Saskatchewan generated electrical power as far to the south as Los Angeles, California and Miami, Florida. Line-losses ($P=I^2R$) in long distance, 700kV transmission would account for only 10% of the load between Cree Lake, Saskatchewan and Los Angeles, California. Transmission capacity is the limiting factor, not production capacity, line losses or the availability of fuel.

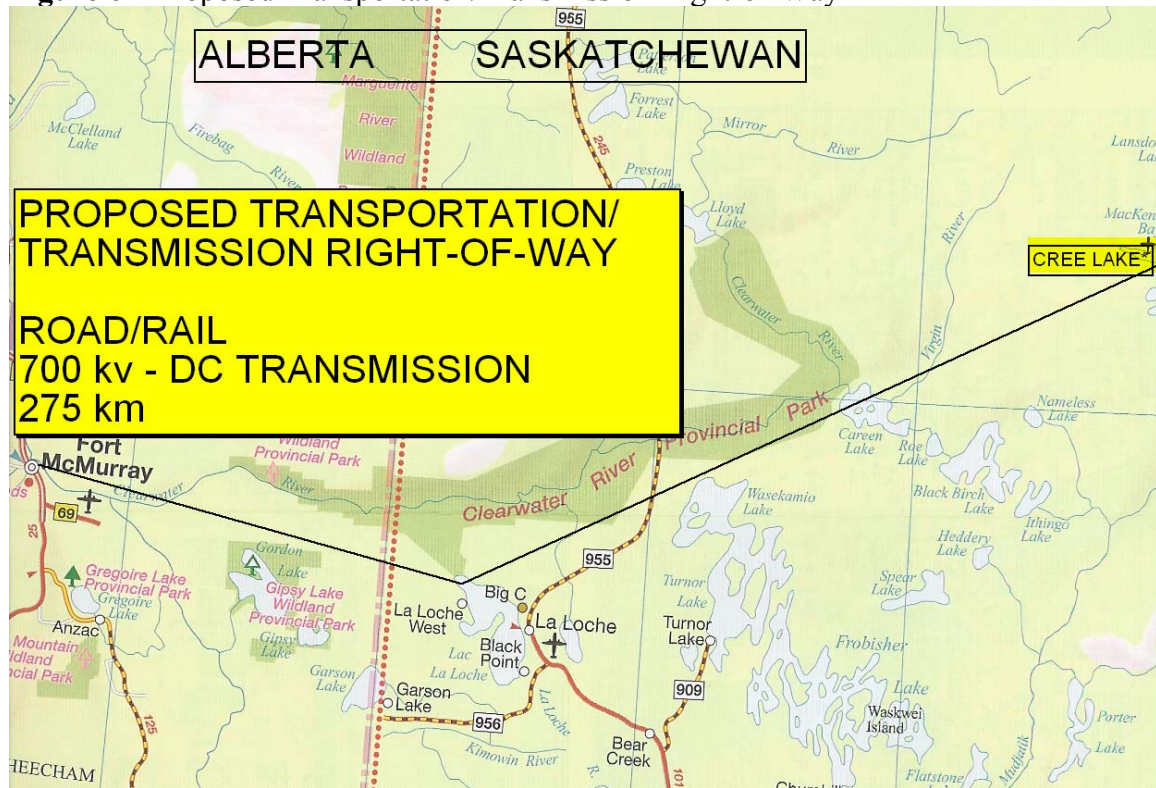
11 Infrastructure: Facilitating the Development

There are at present no roads leading to the proposed plant site. Obviously this will need to change, but the practical route to this site is through Ft. McMurray, as opposed to an extension of the road to Key Lake. The advantage of the Ft. McMurray supply line is manifold. Most notably, the Alberta government announced in March of 2004 that it intends to allow partners to proceed with a huge railway upgrade to link the proposed tar-sands developments around Ft. McMurray to the Edmonton mainline. The proposed \$1.8 billion upgrade will significantly reduce the transportation costs related to moving millions of tons equipment and supplies to proposed oilsands developments. Proposed mega projects in the area are valued at US\$60 billion, excluding any development at Cree Lake.

The proposed \$1.8 billion project would also upgrade Highways 881 and 63, with proposed off-shoot light rail lines into northern work camps. Rail service to Ft. McMurray would better allow for the economical shipment of tar-sands byproducts such as sulfur and coke. The existing rail line (Athabaska Northern) stops short of Ft. McMurray, but is already used to move oilsands freight.

Transportation infrastructure on the Saskatchewan side is much less developed. The existing highway nearest to the site of the proposed development is Highway 914, running to Key Lake, 95km east-south-east. Though this is one of the better highways in Saskatchewan, it could not sustain the development without a major upgrade. Given the need for the simultaneous development of transmission infrastructure, as well as the prospect of a rail link, it is more practical to develop the route directly to Ft. McMurray along the southern boundary of the Clearwater River Provincial Park (see Figure 6).

Figure 6 – Proposed Transportation/Transmission Right-of-Way



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The viability of phase 2 of this project depends to a large degree on the competitiveness of the wholesale price of electricity to the US point of entry at the junction of the Eastern and Western Interconnects. To the extent that the cost component of this level of competitiveness must be analyzed in great detail, this will include the costs of production as well as transmission. The transmission costs include line-losses ($P=I^2R$) which are minimized by stepping up the line voltage to 700kV – DC, however, these losses over the 900 km distance from Cree Lake to the US border will still account for 7% of the feed power.

It is the availability of uranium fuel, and the economy of spent fuel disposal that will minimize the production costs of the power produced at Cree Lake. It is the growth in the market that will insure the demand for added capacity, and it is the price and availability of competing energy sources that will determine the rate of return on power production. In the broader sense, the wholesale power prices will depend on oil prices, and oil prices will depend upon political stability in the oil producing regions, including the Arab Peninsula, Persia, Central Asia, North Africa, and South America.

12 Protecting the Environment

The world's largest nuclear complex at Cree Lake would be the most environmentally efficient large power plant ever built. Not only would it eliminate millions of tons of CO₂ production, but permanent deep geologic disposal of spent fuel within the area's stable granite eliminates the only inefficiency of nuclear power generation. Low level wastes would be returned underground into existing mines for permanent disposal. This would be a closed loop, zero effluent, zero emission operation.

It is clear that we must judge the environmental impact of a project in the macroscopic sense. The Kyoto Accord mandates reductions in CO₂ at a time when global population grows exponentially. Given extensive CO₂ emissions from fertilizer production, in addition to the half-tonne or so spewed by billions of people annually, this does not leave much room for expansion of conventional fossil fuel fired power generation. There is no master plan to deal with an energy demand that will increase 40% in the next twenty years. The probability that the Kyoto Accord will ever achieve its desired impact (*6% below 1990 levels*) is negligible in any time frame, let alone by 2012.

The environmental audit of the power generation industry reveals the trade-off between very small and concentrated amounts of spent fissile material, in the case of nuclear power, and very large and widely dispersed amounts of greenhouse gas. One has a local or regional impact, and one theoretically has a global impact. In the Cree Lake proposal, these spent fissile materials will be encapsulated in a granite sarcophagus, undisturbed for tens of thousands of years. It will not be necessary to store or transport these radioactive materials excepting their permanent placement nearby.

13 The Economic Rebirth of Saskatchewan

Saskatchewan has historically been the least business friendly Province as far as the capital markets are concerned. Some of this relates to the Blakeney Government's decision to nationalize the potash mining industry in the 1970's, prior to its re-privatization in the 1980's. Saskatchewan is the proclaimed birthplace of Canadian socialism, where the late T.C. Douglas of the CCF (NDP) was elected in 1947, after promising to chase the corporations out of the Province. To this day the Provincial utilities, telephone, insurance, liquor and gambling industries are all Crown owned monopolies. Provincial GDP has declined in the last three years of a national growth period, population is declining. The Province is running consecutive deficit budgets and has all but emptied its fiscal stabilization fund. Saskatchewanians arguably have the highest total tax burden in North America. The agricultural industry has been squeezed by a decade's long subsidy battle between the EU and the US, as well as the BSE crisis currently affecting beef exports. Prospects for economic growth through 2010 are negligible.

It is not the destiny of Saskatchewan to be relegated to permanent economic dysfunction. The proposed Cree Lake development is a mega project, and there are tens of thousands of high-paying jobs involved. There are billions of dollars in government royalties involved. It is an industry which will utilize Saskatchewan's own natural resources to produce value-added exports, on a large scale.

The proposal is subject to many years of studies and reviews, based on public safety, environmental impact and economic considerations. The first priority is to gain government approval to move forward with intention to develop nuclear power and transmission infrastructure at/from the proposed location. This will be preceded by much public discussion. The land required is largely provincial Crown land, excepting those areas in the Phase 2 transmission right-of-way to the south. There will be broad public support, or the project would not likely proceed.

14 Facilitating the Alberta Growth Phenomenon

Though the energy pressures of sustaining tar-sands development have been discussed, there is also the issue of Alberta growth in power consumption. As the fastest growing energy market on the continent, the Province had an 8.57 GW peak load in 2003, with a 10.5 GW capacity. These figures exclude cogenerated electricity used in the oilsands industry. The power was produced by the 130 power stations in the province. Many of these plants are antiquated, and small.

In March of 2004, Alberta Energy Minister Smith outlined a \$45 million program to purchase land for a 500 kV transmission right of way from Ft. McMurray to Calgary. The ambition is to tie in Ft. McMurray cogenerators with the fast-growing Calgary load. A line of this size could transmit up to 2GW of power. Cogenerators at Ft. McMurray use CH₄ (predominantly) to produce electrical power, and therefore increased cogeneration will also increase CO₂ emissions, and CH₄ consumption. Cogenerators believe that they too could supply power to the US Western Interconnect competitively, which may be the case. This would depend upon the budget for CO₂, and the penalties for over-production. It may be that the Kyoto Protocol, though ratified by the Canadian Government, will not achieve Provincial or industry compliance, and the cogenerators can competitively supply power to Calgary and the Western Interconnect.

There is also the plausible scenario that CH₄ prices will remain high, and that supply sources will continue to be exhausted at a greater rate than they are replaced. If CH₄ prices are to remain high, then the gas would possibly be more profitable to sell, depending on the wholesale price for power. Also plausible would be the event that the Kyoto Protocol does force industry compliance, and the required reductions in CO₂ emitted. This is obviously inconsistent with the continuation of oilsands development, given that the CO₂ output of the industry is rising sharply, proportionate to the amount of synthetic crude produced from these sources. This does not seem to bode well with the prospect of cogeneration to the Calgary market or the Western Interconnect either.

The Cree Lake proposal would enhance the utility of the proposed transmission line from Ft. McMurray to Calgary, and the Western Interconnect. In addition, the project would insure that the growth in Alberta demand would be addressed for the long term, and that oilsands production and growth could continue uninhibited.

15 Comparative Economics

The wholesale price to be paid for electrical power generated at Cree Lake would have to be competitive with other energy sources. This “other source” would be natural gas as far as oilsands developments go. There is no question that the capital cost of a nuclear development of this nature is significantly higher than a plant with similar capacity that is fueled by hydrocarbons, the savings are in the operating and fuel costs. The longer the term of operation, the greater the savings are to be realized. This was the lesson learned about the competitiveness of nuclear power since the 1973 Pickering mega project.

Phase 1 costs are summarized as follows:

Capital Cost

Reactor Costs	US \$3.3 Billion
Generator Costs	US \$1.4 Billion
<u>Transmission Cost</u>	<u>US \$350 Million</u>
Total Phase 1 Cost	US \$5.05 Billion

Operating Cost

Phase 1 annual operating costs US \$250 Million*
 (* including feed fuel and permanent spent fuel disposal costs, as well as line-losses)

Phase 1 annual debt service costs US \$200 Million*
 (*at 4% compounded annually)

Total Annual Operating Cost US \$400 Million

Total Annual Capital Cost US \$125 Million*
 (* Amortized over the design life of 40-years)

Total Annual Cost US \$575 Million

Annual production cost per gigawatt.hour GWh at capacity

$$\frac{\text{US \$575 Million}}{2\text{GW} * 8760 \text{ hours}} = \text{US \$32,819 /GWh}$$

If oilsands producers could afford to pay US\$33 thousand per gigawatt hour, the project would break even at 4% interest/dividend. More practically, if the price were US\$50

thousand per GWh, the plant would make an annual profit of US \$301 million on sales of US\$876 Million.

Is this production cost competitive? Can oilsands producers compete while paying US\$50 thousand per GWh for electrical energy? Deferring to the analysis of Dunbar & Sloan (CERI 2003) calculated in Canadian dollars, “the cost of steam supply from gas fired facility is very sensitive to the price of CH₄, and any Kyoto compliance costs.” Analyzing conventional steam production costs at a CH₄ cost of \$6.72 GJ, and accounting for Kyoto compliance:

CH ₄ Steam Supply Cost	Kyoto Cost*	Total Cost
\$14.14/t	\$1.58/t	\$15.72

*assuming a Kyoto compliance cost of \$15/t of CO₂ emitted.

In accordance with the CERI analysis, nuclear steam generation was calculated to be \$8.61/t, based upon the capital cost of a \$1.4 billion reactor and operating costs of \$91 million annually. Extrapolation of these figures to accommodate 25% higher capital¹, generation and transmission costs, the cost of nuclear-electric steam would be \$10.29/t.

Even if no Kyoto costs are considered, the cost of nuclear-electric steam generation would be 37% cheaper with CH₄ prices at \$6.72/GJ. In March 2004, CH₄ prices averaged US\$5.53 MMBtu (NYMEX) or CAN\$6.72/GJ, moving higher in April. Indeed it is difficult to make money in oilsands exploitation being CH₄ dependent at current prices. It is likely that all of the feasibility analysis relating to current and proposed oilsands projects use a sharply lower CH₄ price estimate.

Using a CH₄ market price of US\$2.50/MMBtu, for instance, would lower the steam supply cost to CAN\$6.40/t, excluding Kyoto costs.

¹The CERI analysis contemplated a 730 MW reactor, capital cost was adjusted on a per GW basis.

16 **Conclusion**

Construction of a multi-gigawatt nuclear generating station at Cree Lake, Saskatchewan would be an extremely beneficial development. With a Phase 1 objective to supply oilsands process energy, and a Phase 2 objective to charge the international grid with additional power, the economics of investment are sound. The Cree Lake development would be the largest nuclear project in the world, on a phase determinant basis. The world's largest nuclear power plant would be the world's safest and most secure facility. By eliminating millions of tons of CO₂ production and utilizing permanent deep geologic disposal of spent fissile material, it would be the most environmentally efficient large power complex in the world. It would be a practical way of addressing the growth in North American energy demand.

The Cree Lake project would revitalize the Saskatchewan economy. With thousands of jobs created and billions of dollars in royalties and payroll taxes, the Province's out migration, deficit spending and declining GDP would be reversed. At the same time, the growth in the Alberta economy will have found a stable and long-term energy source that accommodates rapid growth and reduces the potential impact of federal government regulation of CO₂ emissions. In short, there is no down side to the proposal.

17 **References:**

- Alberta Energy and Utilities Board-Supply/Demand Outlook 2002-2011**
Atomic Energy of Canada Ltd (AECL) - www.aecl.ca
Atomic Energy of Canada Ltd (AECL) - www.candu.org
Bancroft, A.R. – *Nuclear Energy for Oil Sands (1982)*
Bock, D. and Donnelly, JK - *Fuel Alternatives for Oil Sands Development – The Nuclear Option(1995)*
Neil Brausen P.Eng. Alberta Electric System Operator(AESO) 3/17/2004
Electric Transmission System Development in Alberta
Calgary Herald - Grant Robertson 3/16/2004-*Power Grid Officials Looking East*
Calgary Herald - Paul Haavardsrud 3/4/2004 – *Oilsands Prosperity Depends on \$25 Oil*
Calgary Herald - Scott Haggett 3/5/2004 – *Costs Rise another \$2B for Syncrude*
Calgary Herald - 3/22/2004 - *Nuclear Industry Waits to See What Ontario Does*
Cameco Corporation – www.cameco.com
Canadian Institute of Mining, Metallurgy & Petroleum - Petroleum Society
R.B. Dunbar and T.W. Sloan – Canadian Energy Research Institute
Does Nuclear Energy have a Role in the Development of Canada's Oil Sands?
Paper 2003-096
www.freerepublic.com – *Oil Sands Put Canada on Track for Big '03 Output gain*
Hon Eldon Lautermilch – World Nuclear Association – 2002 Annual Symposium
Sustaining Public Support for Uranium Mining in Saskatchewan
Melis Engineering Ltd. – www.meliseng.com – *Typical Uranium Experience*
OPEC
Pacific Amber – www.pacificamber.com - *Saskatchewan Uranium Properties*
Peopleandplanet.net – www.peopleandplanet.net
Gallon Environmental Letter, 10/8/2002 - *Tar Sands Will Increase Canada's Pollution*
Gerald Leach - *People and Climate Change*
www.planetark.com – US Energy demand to rise by one-third by 2020 (Reuters)
Reuters – *Nuclear Power, 25 years After Three Mile Island – March 26, 2004*
Shawn E. Harvey and Kathryn M. Bethune – U of R Dept. of Geology
Geology of the Key Lake Unconformity – type Uranium Deposit
US Dept. of Energy – *Underground Mining and Deep Geologic Disposal*
N.T. Rempe – Westinghouse DOE/WIPP-95-2129
US Dept. of Energy 2000 *National Transportation Grid Study DOE/PO-0060*
US Dept. of Energy – www.eia-doe.gov – *Canada – Energy Overview*
US Dept. of Energy- www.eia.doe.gov – *International Energy Outlook 2003*