Nuclear Energy in the Oilsands:
Part of the Solution, or the Problem?

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TABLE OF CONTENTS

1. Introduction

Although nuclear power plays a significant role in Canada's energy strategy and overall economy today, it is poised to become even more important source of energy in the future. The lure of "clean, reliable, and affordable" nuclear energy has led the push to develop more nuclear plants in order to enable Canada to meet its significant energy demand while addressing environmental concerns.

2. Nuclear Industry in Canada

Canada's nuclear energy industry began in 1945 when it became the first country outside of the United States to achieve a controlled nuclear chain reaction using the ZEEP research reactor[1]. From those humble beginnings Canada's nuclear industry has developed into a $5 billion-a-year industry responsible for 31,000 jobs in over 150 firms and accounting for $1.2 billion in exports[2].

Nuclear power is obtained when a controlled nuclear reaction heats water to produce steam that drives a turbine to generate electricity. The fuel source for nuclear energy is uranium. Canada, specifically the province of Saskatchewan, is home to some of the richest uranium ores ever discovered[3]. In 2004 Canada produced 13,676 tonnes of uranium oxide concentrate – about 30% of total world production – valued at over $800 million[4].

Today, Canada's nuclear industry is involved in power generation, medicine, agriculture, research and manufacturing. All atomic energy research and development is managed by Atomic Energy Canada Ltd. ("AECL"), a federal

Canadian Crown Corporation. AECL is also responsible for advance and support of the CANDU (CANada Deuterium Uranium) reactor technology, originally developed in the 1950s. In 2006, there were 22 CANDU reactors in Canada with 18 in active service generating roughly 15% of Canada's electricity (over 12,500 MW of power)5. AECL has exported the CANDU reactor technology to Argentina, Romania and several Asian countries.

3. Alberta Oil Sands Development

3.1. Fuelling the Growth

At present, Alberta's oil sands developments generate 1.2 million barrels of oil equivalent per day. That figure is expected to increase to over 3.8 million a day by 2020[6]. Fuelling this production is natural gas, the primary fuel source used in oil sands operations[7]. Natural gas generates the heat required for extraction and is also used as a source of hydrogen to upgrade bitumen into synthetic crude oil. Surface mining and in-situ operations consume 250 and 1000 cubic feet of gas, respectively, per barrel of oil produced. A further 500 cubic feet is then required to upgrade the bitumen into synthetic crude oil[8]. Each day, "the oil sands industry consumes enough natural gas to heat 3.2 million Canadian homes for a day"[9]. The massive amounts of natural gas being consumed have prompted some industry observers to question the logic of using up our cleanest-burning, most environmentally-friendly fossil fuel in order to recover the more valuable but also more harmful bitumen[10].

3.2. Energy Costs

The use of such enormous amounts of natural gas has consequences. As gas supplies in Western Canada become increasingly scarce, producers will likely experience price increases. In fact, it is predicted that Canada will become a net importer of natural gas by 2015[11] and could use up to 2.1 billion cubic feet per day (approximately 12% of total gas output in Western Canada) in oil sands production[12]. With profit margins from the oil sands already low compared to other resource plays around the world, a significant increase in natural gas prices could make the resource less profitable and possibly uneconomical.

If oil sands producers aren't concerned with the amount of natural gas they are consuming, they are certainly concerned with its costs. Natural gas accounts for approximately 15% of the operating cost for mining operations and 60% of the cost of in-situ production plants[13].

3.3. GHG Footprint of the Oil Sands

As one would expect from the large amounts of fossil fuels being consumed by oil sands development, greenhouse gas ("GHC") emissions are just as significant. In fact, oil sands operations are the largest contributor to GHG emissions in Canada. Although improved conservation technology has reduced the intensity of emissions on a per-plant basis, added production from new developments has more than eliminated those gains[14]. Between 2003 and 2010, oil sands production is expected to contribute 41-47% of the growth in Canada's total GHG emissions[15]. With ever-increasing public concern over the environmental impacts of the oil sands and the possibility of emissions regulations related to the Kyoto Accord or other agreements, oil sands companies need to find a more appropriate and efficient way of generating power.

4. Nuclear Power as a Solution in Alberta's Oil Sands

The need to reduce reliance on natural gas and reign in GHG emissions has prompted larger oil companies and government officials in Alberta to examine the potential for using nuclear power to generate electricity and produce steam for in-situ recovery. Non-carbon energy options such as nuclear need be considered because their long-term economic costs could be relatively low and stable, while conversion to nuclear could reduce carbon dioxide emissions as well as pollutants and toxic substances associated with burning fossil fuels.

4.1. Benefits of Nuclear Generation

4.1.1. Access to Uranium

Alberta is uniquely positioned to take advantage of increased use of nuclear energy to supply its future energy needs because of its proximity to Saskatchewan, the world's largest producer of natural uranium. Since most of the uranium is exported, an opportunity exists to utilize more for domestic consumption should domestic demand increase beyond today's levels.

The potential energy stored in Canada's uranium deposits is equivalent to that supplied from 20 billion barrels of oil[16]. Canada also has 40 years of experience building and servicing our own CANDU nuclear reactors which are used around the world, and thus we have the expertise and facilities to support increased production.

4.1.2. Costs per MegaWatt

Nuclear power is also very cost-competitive. For electricity generation it ranks just behind hydroelectric plants in terms of cost per unit supplied. In a 2002 report by the Ontario Power Generation Inc., it stated that it could supply electricity at $0.03/kWh with a nuclear power plant vs. $0.045 for a gas-fired plant[17]. In order for nuclear-supplied electricity to be economical, it is best utilized for base load requirements (e.g., regular consistent daily demand) so that the average capacity factor is high. Such an application, currently gaining attention in Alberta, is the opportunity to use CANDU reactors in the northern oil sands.

4.1.3. GHG Reduction

As a signatory to the international Kyoto Protocol, Canada has committed to reduce GHG emissions 6% below 1990 levels between 2008 and 2012, which would require annual emissions reductions of approximately 45 megatonnes. Although those targets have been criticized as unattainable, Canada will still need to implement clean sources of energy to make progress towards the Kyoto goal.

Nuclear-powered generation could be a major step in the right direction. Nuclear plants do not emit the harmful pollutants and GHG that a similar gas-fired plant would. To date, the use of nuclear generation in Canada has avoided releasing approximately 1.8 billion tonnes of CO_2, 33 million tonnes of acid gas, and more than

80 million tonnes of ash into the atmosphere[18]. Given that our existing nuclear plants save approximately 90 million tonnes of GHGs per year there certainly is a case for increasing our utilization of nuclear energy to help us meet our environmental goals. According to research by Donnelly & Pendergast[19], a CANDU reactor could avoid the release of 1 to 2 million tonnes of CO_2 annually at an in-situ oil sands site that produces 30,000 to 60,000 barrels/day. Similar studies have shown that a nuclear plant can supply the site electricity requirements at equivalent units costs to that of a gas-fired plant.

Such claims are, however, hotly contested by environmental groups such as the Pembina Institute. Although seemingly purposefully overlooked by pro-nuclear agencies, the process of actually mining the uranium produces over 15 tonnes of CO_2 for every tonne of uranium recovered[20]. While power generation from nuclear plants may result in no GHG emissions, it is clear that GHG are in fact emitted at various points in the nuclear cycle.

4.1.4. Reduced Reliance on Natural Gas

Another proposal from Energy Alberta Corp. and consistent with the Donnelly and Pendergast research suggested that a single CANDU 6 reactor configured to produce 75% steam and 25% electricity would replace 6 million cubic metres per day of natural gas and support production of 175-200,000 barrels per day of oil. It would also save the emission of 3.3 million tonnes of CO_2 per year.

4.2. Barriers to Nuclear

The challenges facing the implementation of nuclear energy in Alberta's oil sands are myriad. Experience with nuclear energy has raised public concern over issues such as potential accidents, radiation poisoning and, most significantly, waste management. Water conservation and protection is also an important concern because of the already heavy use of water supplies by the oil sands. In a study commissioned by the Energy Alberta Corporation in Alberta in 2005, only 40% of respondents were in favour of increasing development in nuclear energy and 36% were neutral.

4.2.1. Risk of Accident

In the short history of nuclear power there have only been two serious accidents at nuclear plants. The first occurred at Chernobyl in 1986 where a steam explosion and fire released 5% of the plants radioactive core into the air. The Chernobyl disaster has subsequently been determined to have resulted from a combination of a flawed design and inadequate personnel training that led to simple human error. The Chernobyl plant lacked safety features that are now mandatory in all nuclear plants[21].

The second nuclear accident occurred at the U.S. nuclear plant on Three Mile Island. In that instance, a cooling malfunction causes a meltdown in one reactor. The meltdown was contained by the safety features incorporated in the plant and only a very small amount of radioactive gas was released with no reported injuries[22].

Today, the risk of a similar accident leading to core meltdown is considered extremely remote. Modern plants incorporate multiple safety features to ensure that any accidents are contained with the plant itself and do not pose a danger to surrounding residents[23]. Plant design emphasizes three primary characteristics: the redundancy of backup systems, a diversity of operating pathways and the physical separation of safety systems[24]. Numerous backup safety systems are designed to override human error and do not require operator intervention in the case of an emergency[25].

Safety is also an issue during the transportation of nuclear materials to and from power plants. Such materials are presently transported in sophisticated containers capable of withstanding enormous impacts[26]. Although there have been transportation accidents, the primary containment unit of the radioactive material has never been breached[27].

Terrorism is also a paramount concern in the eyes of the public in today's society. Extensive testing has been done on nuclear plants as well as storage and transportation containers. The results have shown the physical structures implemented to protect the public from radioactive material can withstand enormous impacts, including a high-speed accident with a vehicle or train or even a commercial jetliner used as a weapon[28].

What if an accident should still occur? Although it would be little comfort to the public, most jurisdictions operating nuclear power maintain a strict liability model that places the blame for any accident on the shoulders of the nuclear operator, regardless of whether it is their fault or not. Private insurance systems are also funded by the nuclear industry to bear the costs of any accident.

4.2.2. Risk of Radioactivity

Although radiation exposure is common concern raised as a public fear related to nuclear power generation, it is overstated and misunderstood. Human beings receive radiation from a number of sources, both natural and man-made. Most of that radiation is generated from natural terrestrial sources including radioactive materials present in the Earth's soil and the radon gas that escapes into the atmosphere as they decay[29]. The sun's cosmic rays are another source of natural radiation.

Man-made sources of radiation are dominated by medical technologies including x-rays and CT and PET scans. Nuclear weapons testing and use has released some radioactive material into the atmosphere[30]. Nuclear energy generation, however, is responsible for only a tiny portion of the radiation that we are exposed to on a daily basis.

Finally, it is believed that radiation poses a cancer risk only where exposure has been significant. Because of the amount of naturally-occurring radiation in our environment, human bodies are able to withstand small radiation exposures[31]. Given the safety features incorporated into modern nuclear plants, a significant release of radiation sufficient to cause public harm seems highly unlikely.

4.2.3. Water Conservation and Protection

Oil sands developments are already having a significantly adverse effect on water resources in northern Alberta. Existing technologies for both mining and SAGD bitumen recovery and processing use large massive of water, with mining requiring 2-5 barrels of water for each barrel of oil produced. Although SAGD processes reuse 90-95% of the water they use during production, incremental production continually increases the amount of water needed. Used water is currently being pumped into "tailings ponds" which contain a mixture of bitumen, silt, sand, clay and water slurry and now cover an area exceeding 50 square kilometres. It is currently unclear how these tailings ponds will be dealt with and when the water they contain can be returned to the natural environment. Adding to these concerns is that freshwater use is preferred by companies because it is cheaper to obtain than drilling into saltwater aquifers and then purifying the saline water for us in steam generators.

The implementation of nuclear power in the oil sands would exacerbate these water concerns and generate new ones. Nuclear power has both indirect and direct effects on water resources. Indirectly, mining uranium for use in nuclear plants releases both radioactive and conventionally-dangerous pollutants into freshwater and groundwater. These discharges have been identified as meeting the definition of "toxic" under the Canadian Environmental Protection Act, 1999 by Environment Canada[32]. Mining can also disrupt flow directions of natural bodies of water[33].

Direct impacts result from both fuel processing and power generation. Contrary to industry-favourable literature indicating that the only waste from nuclear power plants is a small amount of radioactive material, uranium processing releases a liquid effluent that contains ammonia, nitrate ion and uranium. This effluent is either released into surface water bodies after being diffused or directed to municipal sanitation systems for processing[34], an option not likely available in Alberta's north. Power generation routinely releases radioactive contaminants such as tritium, which is believed to affect reproduction and increase the risk of cancer, into surface water. Further, the impact of releases of substances like tritium is increased by accidental discharges that have occurred at numerous plants[35].

Finally, it is unclear whether nuclear plants would increase the actual amount of water used for power generation in the oil sands. The answer depends on the relative consumption of water by nuclear and natural-gas powered generation facilities. It is clear, however, that the overall amount of water needed for power generation will increase as oil sands facilities expand and new projects are developed.

4.2.4. Waste Management

By far the most significant concern related to the use of nuclear power is the storage and disposal of radioactive nuclear waste. It has been called the "Achilles heel" of nuclear energy[36]. Nuclear waste is classified as low, intermediate and high-level waste, according to its level of radioactivity and the length of time it remains dangerous[37].

Low-level waste is material that has come into brief contact with small levels of radioactivity. It includes most waste generated during the decommissioning of a nuclear power plant. Very little shielding is required for low-level waste because it does not pose a serious danger. In contrast, medium-level waste is more radioactive and requires shielding to prevent radiation concerns. Medium-level waste generally consists of equipment used in the management and handling of nuclear materials. Because they are less dangerous, low- and medium-level nuclear waste can be disposed of without the need for intermediate storage before they are transported to their final disposal site[38]. High-level waste remains highly radioactive for a long time. It arises from the nuclear fission process and must be heavily shielded during storage and transportation[39]. Unlike other nuclear waste, high-level waste requires intermediate storage to "permit decay of radiation and heat generation"[40].

Fortunately, compared to conventional energy sources, nuclear energy produces an extremely small amount of waste matter per unit of energy generated. These low volumes make nuclear waste more manageable than chemical and other wastes[41]. Used nuclear fuel is primarily stored in steel-lined concrete vaults filled with water, while unused fuel is stored in steel or steel/concrete containers placed over a thick concrete pad[42]. However, despite the comparatively small amount of nuclear waste generated, the need for centralized storage and disposal facilities is increasing as nuclear energy becomes more widely used.

Of the alternatives proposed for permanent disposal of nuclear waste, deep geological storage has received the most attention. It is believed that nuclear waste could be safely buried in stable geological formations deep within the earth's crust and well below any usable water sources. In Canada, the preferred site appears to be the rocky Canadian Shield[43]. Site selection is obviously a paramount concern with geological storage. Any storage site chosen must be free from seismic activity and groundwater sources, which have been identified as the most likely contributors to a release of stored nuclear waste[44]. Waste would ideally be surrounded by clay and any natural barriers to escape would be supplemented with engineered solutions[45].

Despite the apparent confidence of scientists researching geological storage, public opposition is strong and stems from the uncertainties inherent in our ability to store dangerous materials underground for thousands of years[46].

4.2.5. Regulation

In Canada the regulatory and construction time frame to bring a new nuclear power plant into service is quite lengthy. The Canadian Nuclear Association suggests that a new CANDU 6 unit can take as long as 36 months to obtain pre-project regulatory approval and roughly 69 months to construct for a total of approximately 105 months from start to finish[47]. It would be reasonable to assume that the regulatory and construction period may be lengthier in Alberta than the above estimates for a number of reasons. Nuclear power plants have never been constructed in this province, so the public and provincial regulatory scrutiny for the initial projects could be more intense than a typical project in eastern Canada. Also, the lack of local specialized workers versed in the construction of nuclear power projects could increase construction timelines.

This time lag presents a challenge for oil sands producers. Producers must anticipate the amount of energy required to fulfill their production needs for a point that is well into the future. These production needs will be driven by the demand for oil sands oil which could be risky over the long term due to its higher cost structure and potential market substitutes (such as ethanol) over the long run. If demand for the oil happens to be less than projected, these expensive new plants could be redundant and thus increase the costs of the already costly oil sands. Conversely, if demand for synthetic crude oil is greater than anticipated, there will be a lack of power to fulfill production requirements leading to opportunity costs from unearned revenues.

5. Recommendations and Conclusions

The prospect of using nuclear energy in the oil sands has certainty generated significant support and stirred debate. It is clearly competitive as a fuel source with other methods of generating power and has the potential to reduce aggregate GHG emissions and reliance of oil sands operators on natural gas. Significant hurdles remain to be addressed however, in particular issues of water safety and waste management. A lengthy regulatory process makes the decision to encourage the use of nuclear power in Alberta even more difficult.

Although nuclear is no panacea, it appears that switching from natural gas-fired generation to nuclear power would result in material and significant GHG emissions reductions, even if overall reductions are not as large as claimed by some advocates. We therefore believe that the best approach to be taken by the Alberta government is to address water and waste management concerns before proceeding with serious planning for nuclear energy in the oil sands. Once those issues have been resolved, the regulatory process should be streamlined where possible to facilitate the timely implementation of nuclear energy.

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