The use of Small Modular Nuclear Reactors for Canadian Oil Sands Applications: A proposal and way forward

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1. ABSTRACT

It has been estimated that Canada's Oil Sands contain between 160 and 200 billion barrels of oil reserves – the second largest accumulation of oil in the world after Saudi Arabia. It is also estimated that by 2015, output from the oil sands should increase from about 1 million barrels per day (mbbl/day) to approximately 4 mbbl/day.

However, Canada and the world have to pay a price for oil extraction from the sands.It is estimated that about 40 cubic metres of natural gas as fuel must be burned for each barrel of synthetic crude produced. Therefore, if oil sands production did reach 4 mbbl/day, natural gas use for oil production could seriously limit exports of natural gas to the US. It has also been estimated that every barrel of synthetic oil pollutes about 950 liters of fresh water and emits about 100 Kg of Carbon Dioxide (CO_2) along with other pollutants.

Clearly an alternate source of energy is required for oil sands production that will allow our natural gas to be put to better use while simultaneously sustaining our environment. The energy must be continuously obtainable and not be subject to the intermittentavailability of wind or sunlight. Nuclear energy is the obvious choice. Nuclear energy for power generation has been prevalently used around the world since the 1950's. Today, there are more than 440 Nuclear Power Plants(NPPs) operating safely worldwide. Each has different characteristics that would make them comparativelyacceptable for operation in Northern Canada.

This paper will briefly review the various types of nuclear plants that are currently in operation or are being licensed worldwide,as well asthose that are proposed for operation in the near future including small nuclear power reactors (< 300 me). Moreover, it will propose a list of the NPP characteristics that are best suited to oil sands operation. This will lead to a proposal to encourage the development of small modular reactors (SMRs) for installation in oil sands operations.

The paper will further underscore the necessity for government and industry to take prompt action. It has been suggested that due to licensing delays, the implementation of nuclear power in the oil sands region may not be possible until 2020. Given the environmental and hydrocarbon costs associated with the four-fold increase in anticipated production, we may not have until 2020 to find a solution to oil sand production.

2. BACKGROUND

Galena, Alaska is a community of 800 people located on the banks of the Yukon River about 270 miles east of Fairbanks (18). Galena has no road links to any other major cities. When it is ice-free, the Yukon River is the major link between Galena and other cities, but in the winter, only air transportation is available. Moreover, Galena has no connection to an outside power grid. It depends on diesel generation of electricity for all of its power. And, this electricity is prohibitively expensive owing to the need to transport, store and finance large amounts of diesel fuel.

In 2004, the people of Galena received a presentation (18) from Toshiba on its 4S (Super-Safe, Small, and Simple), small modular nuclear reactor (SMR). Toshiba offered to install a 10 megawatt-electric (MWe) unit for electrical generation (me) as a demonstration of the capability of what has been dubbed a ‘nuclear battery’ to provide power and steam for remote locations. On December 14, 2004, the Galena City Council passes a resolution calling for the installation of the Toshiba 4S in the community. In the same year, the US, Department of Energy published a report that concluded the 4S nuclear reactor based power generation facility (NPF) is the “best economic and environmental choice for Galena” (18).

The Toshiba 4S (Super-Safe, Small, and Simple) is just one of a number of small nuclear reactors that have emerged for public use in the last decade. The 4S design consists of a small, liquid metal nuclear reactor (LMR). The cost of producing electricity from the Toshiba 4S SMR is expected to be about 20% of the cost that Galena paid for diesel generation in 2004 (more on this in the following paragraphs). In Canada’s north, similar costs for electricity have been experienced. The Qulliq Energy Corporation in Nunavut, Canada, reports that energy costs in 2011 have risen to about $1.00 /kWh in remote communities like Kimmirut and close to 50 cents/kWh in the capital of Nunavut (25).

3. THE OIL SANDS

While the issue driving the use of nuclear power in the North is the high cost of fossil fuels required to make electricity, the issues in the oil sands are the wasteful use of fossil fuels to make steam for the recovery of bitumen and to make electricity to run the plants and the egregious production of Greenhouse Gas (GHG) emissions that the burning of fossil fuels creates. It has been estimated that Canada's Oil Sands contain between 160 and 200 billion barrels of oil reserves – the second largest accumulation of oil in the world after Saudi Arabia (33). It is also estimated that by 2015, output from the oil sands should increase from about 1 mbbl/day to approximately 4 mbbl/day.

Bitumen is extracted from the oil sands in one of two main ways -- open-pit mining and in-situ extraction. Open-pit mining starts with mining the oil sand mixture from the ground (the mixture is about 6% oil and 94% sand) then extracting the oil from the sand using heat, steam and water. In-situ extraction requires producing steam and pumping it into the ground to heat the bitumen allowing it to flow into collector lines for pumping to the surface. The most common in-situ extraction method is known as Steam Assisted Gravity Drainage (SAGD).

Each extraction process is natural gas intensive (34). In open-pit mining, the natural gas is used to create steam to extract the bitumen from the sand and to produce hydrogen, using steam methane reforming (10), which is used to upgrade the bitumen. In the SAGD process, natural gas is burned in large boilers to produce steam. Table 1 provides estimates of the amount of natural gas required to produce bitumen using the open-pit or SAG-D process.

Table 1: Natural GAS use assumptions (M^3/bbl.)

	LO Case	HI case
Thermal, in-situ	25.5	34
Mining	5.7	8.5
Upgrading	8.5	19.8

(Reference 21)

Much of the oil sands discussion has revolved around the 'misuse' of natural gas to create steam for oil sands extraction and upgrading rather than using it more productively to operate clean vehicles or to heat houses. In a 2007 report of the Parliamentary Standing Committee on Natural Resources, Mr. Michael Raymont of EnergyInet commented that "using natural gas as a fuel in oil sands development is "like turning gold back into lead." (34)

In addition, much of the electricity used in bitumen production is produced with natural gas. As a rule of thumb, for example, an in-situ extraction plant requires 1megawatt of electricity for each 1000 bbl. of bitumen produced (14,12).

It is estimated that open pit mining produces about 0.083 Tons of carbon dioxide (CO_2) for every barrel of upgraded bitumen produced – 0.03 Tons for mining and extraction and 0.053 Ton for upgrading (10).The same report estimates that in-situ production of bitumen using the SAGD process produces about 0.06 Tons of CO_2 for every barrel produced – 0.05 Tons for extraction and 0.01 Tons for upgrading.

Both open-pit mining and in-situ processes used to extract the bitumen from the sand are also major users of water. It is estimated that each barrel of bitumen produced by the SAGD process requires about 3 barrels (bbl.) of water, but only about 0.1 to 0.5 bbl. of fresh water (19). Mining uses about 2-4 bbl. water for each bbl. bitumen produced. However, water use is being reduced as technology improves. Suncor, for example, in 2009 withdrew 33% less water in its mining process than in 2002 even though its production has doubled. Suncor now operates at 1998 levels of water consumption.

4. CAN NUCLEAR POWER REPLACE FOSSIL FUELS IN THE OIL SANDS?

Several studies (2, 10, and 13) have examined the use of large, conventional nuclear reactors to provide power for oil sands operations. It is generally agreed that providing power from conventional nuclear plants can eliminate most of the greenhouse gas emissions that are currently produced in the industry. Moreover, the cost of the power would be competitive with the current costs using non-nuclear generation. But, the disadvantages for using large, commercial nuclear power plants could outweigh the advantages. For one thing, they require large, permanent installations with large support staffs (13). Second, the time currently required forapproving, designing, constructing and commissioning a conventional nuclear plant can be 10-12 years. In addition, large conventional reactors typically have relatively short maintenance and/or refueling cycles (8). And, large reactors are hard to shut off. It’s not easy to reduce the supply of power below certain levels in response to reduced demand (41). Moreover, the CANDU system, which is the standard in Canada for large nuclear plants, would not be effective at meeting the oil sands needs without provision of steam compressors (11). Only the large, High Temperature Gas Reactors could do so. But, the Canadian regulators, the Canadian Nuclear Safety Commission (CNSC),have little or no experience with this technology. So, the time required to build such a plant would likely increase beyond the 12 years required for CANDU. Then there is the need for water cooling which would add an additional burden to the water supply for oil sands operations.

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The alternative to large conventional reactors for oil sands use is the small nuclear 'batteries' like the 4S that was mentioned above in reference to Galena Alaska. Small nuclear reactors, which are defined here as having outputs of less than 300 megawatts of electricity (mWe), have been in use for over 50 years. The original small reactors were used mainly to power naval vessels in the US and Russia during the 1950's. Since 1976, however, four small 62 mWt (thermal) graphite-modulated, boiling water reactors have been operating safely in Siberia much more cheaply that fossil fuel alternatives in that region (8).

The World Nuclear Association (8) has recently reviewed the design and capabilities of SMRs worldwide. It is instructive to examine several of these designs with respect to their application to oil sands use. SMRs can be categorized into four basic technologies (8):

1. Light Water Reactors (LWR) which are moderated and cooled by ordinary water. These reactors are the most common form of large power reactors used today and they have the lowest technological risk. In January, 2012, the US, DOE announced that it would provide financial support for the development of two light water SMRs. Applications were made by four companies and the DOE decision is expected in September, 2012. LWRs may not be the best choice for the oil sands because of their need for water for moderation and cooling.

2. High Temperature, Gas-cooled reactors (HTGR) use graphite to moderate the reaction and either helium, CO_2or nitrogen as the primary coolant. They typically run at very high temperatures and are capable of generating high pressure steam that is useful for oil sands applications, and electricity through a steam turbine.

   The US Energy Policy Act of 2005 established the "Next Generation Nuclear Plant" (NGNP) project to develop, construct and operate a prototype high-temperature, gas-cooled reactor (HTR) and associated electricity and hydrogen production facilities by 2021 (32). In February 2012, the NGNP alliance chose the Areva, steam cycle modular high temperature gas-cooled reactor(SC-HTGR) as the preferred reactor concept. This design builds on the General Atomics' Gas Turbine Modular Helium Reactor (GT-MHR) design (32).

   A Modular Helium Reactor (MHR) is being promoted by General Atomics for the oil sands (31). Its characteristics, which are reported as "well suited for oil extraction" include:

   - Passive safety
   - No CO_2 emission
   - Competitive economics (supposedly with natural gas)
   - High Thermal efficiency
   - Siting flexibility

- High temperature capability with flexible energy outputs (electricity, hydrogen for upgrading, steam)

The reactor that is being designed for oil sands use would have a 30 year plant life, deliver steam at 585^{o}F and 1400 psia, and would produce 25 MWe electricity for site needs. Currently, the design project is being led by the Idaho National Laboratory.

3. Fast Neutron Reactors (FNR) are smaller and simpler than light water types. They have better fuel performance and can have longer refueling intervals. Hence they are good candidate for the oil sands. However, since they are designed to use the full potential of uranium, safety is of concern.

   They have no moderator, high neutron flux and are normally cooled by liquid metal such as sodium, lead, or lead-bismuth with high conductivity and boiling point (8). They operate at or near atmospheric pressure and have passive safety features. Two designs have received recent attention – the Gen4 Module and the Toshiba 4S.

   The G4M was designed by Gen4 Energy to produce 25 mWe to remote mining or oil and gas operations (1), large government complexes and isolated island communities. It was designed to operate 24/7 for 10 years without refueling. It has a lead-bismuth reactor using 20% enriched uranium nitride fuel. In March 2010, Gen4 Energy advised the USNRC that it planned to submit a design certification application in 2012 under the DOE, NGNP Funding Opportunity Announcement. On April 24, 2012, Gen4 energy decided not to pursue the opportunity concluding that “the use of well-known light water reactor (LWR) technology of 45 to 300 MWe had a much higher probability of success given the FOA’s stated maximum of two awards”. However, Gen4 Energy intends to pursue a Memorandum of Agreement with the DOE to deploy an advanced design nuclear reactor (G4M) at the Savannah River research lab.

   The Toshiba 4S is classed as a liquid metal reactor (LMR). It uses sodium as its coolant. It has been designed with a passive safety system. It has a ‘negative temperature coefficient of reactivity’; as the temperature of the reactor increases, the reaction shuts down. Moreover, if there is a power loss, a reflector which allows the reaction to continue, falls to the bottom of the reactor effectively shutting down the system. In addition, the reactor is small, only (7 m) 20 feet by (1.8 m) 6 feet and has been designed to be embedded below grade, resulting in safety and security benefits. It is suggested that the staff required for monitoring the reactor is minimally one or two security guards per shift. The whole installation, including the reactor, turbine generator and control room could be contained in a structure that is 190 feet (61 m) long and 90 feet (29 m) wide (18). The reactor vessel is air-cooled, so no coolant water or intake structures are required. The whole reaction process is self-sustaining and can last for up to 30 years (7) without refueling.

Table 2 provides estimates comparing the costs of generating electricity using the Toshiba 4S, currently available natural gas plants and diesel. Based on a 4S, 2-plant installation, capable of sustaining a 40,000 bbl./day, SAG-D operation the total estimated cost is about $60. /mW-h (e).over the 30-year life of the plants (5).

Table 2: Costs of electrical generation* (capital, operating and maintenance and fuel) – Toshiba 4S, natural gas and diesel ($/Megawatt-hour)

	4S	Nat Gas	Diesel
Capital	38	4	4
O&M	18	16	16
Fuel	4	64	116
Total	60	84	136

*Approximate figures based on a 50 MWth installation (5)

Total costs of the Toshiba 4S are very competitive with those of both natural gas and diesel generation. Finally, the 4S system can produce high pressure steam that can be distributed out to 10 – 15 km (5) as well as electricity which is ideal for oil sands production.

4. Molten Salt Reactors

A **molten salt reactor** (MSR) is a class of nuclear fission reactors in which the primarycoolant or even the fuel itself is a molten salt mixture (40). MSRs run at higher temperatures than water-cooled reactors for higher thermodynamic efficiency, while staying at low vapour pressure. These reactors operate at near atmospheric pressures. So, the mechanical stress to which the system is exposed is reduced thus simplifying aspects of reactor design and improving safety.

An MSR operated at the Oak Ridge National Laboratory for four years in the 1970's at which time interest in MSRs waned and the program was shut down. It is reported that there is now renewed interest in the technology and the MSR is one of the six Generation IV designs selected for further development (8)

The advantage of each of the advanced SMR units is that they are small designs that lend themselves to factory fabrication using modular design techniques. Most modules would be easily transportable from factory to site. In addition, they are typically designed to be installed below ground level enhancing both safety and security. But, there are other advantages of SMRs. Carpenter (4) in her remarks to the Oil Sands Infrastructure summit in 2011, concluded that the benefits of SMRs in the context of the oil sands are:

1. Minimal on-site infrastructure
2. Ability to operate in remote locations
3. Independence from fuel supply chains, i.e. security, availability and price
4. Minimal emissions
5. Transportability
6. High energy density
7. Proven reliable operation
8. Outstanding safety record.

5. What has to be done to make SMRs a reality in the Oil Sands?

Nuclear power is an emotional issue with many people; some welcome it, others rail against it. So, in order to go forward with the concept of using SMRs in the oil sands, its first necessary to identify the stakeholder groups and determine what has to be done to get them on board. For the introduction of SMRs into the oil sands, the following stakeholder groups can be identified:

1. Alberta General Public

   Clearly, the province of Alberta has been vilified world-wide on the production of “dirty oil” from the Oil sands. Environmental Groups have campaigned around the world to halt production of bitumen. Moreover, ‘dirty oil’ is, in part, the reason why the northern U.S. section of TransCanada’s Keystone pipeline was halted in 2012.

   In addition, the recent campaign of people like T.Boone Pickens to reduce the use of natural gas to power electrical turbines and use it instead to power road vehicles has heightened the sensitivity to the wise use of fossil fuels. Moreover, the amount of gas in Alberta is finite. It has been estimated that by 2020, 20% of the gas produced in the province will be used to fire boilers to create steam to lift bitumen from the ground (22).

   The question is whether the people of Alberta care enough about the environment and the misuse of natural gas to support the use of SMRs. It will be necessary to poll the population of Alberta to see where they stand on the issue of the environment and gas use, since governments typically set policy in response to the loudest voice.

2. Alberta Government:

   The Alberta Government is very pro-oil sands. So, whatever is good for the oil sands will influence policy setting (in addition to the above). Sankey (24) suggests that “power decisions are the sole purview of the provinces”. Clearly, the Alberta Government has the power to approve or reject any large industrial construction project (36). So, their stand on nuclear power will affect expansion in the province. While they cannot unilaterally approve or reject nuclear power, they can approve or reject its use. To date, several reports have been written for or addressed to the Alberta Government on the use of nuclear energy for the oil sands.

3. Canadian Government

   The Canadian Government has been criticized worldwide for pulling out of the Kyoto accords and for their lukewarm support of the environment. Their recent announcement to reduce funding to the Ministry of the Environment has raised more questions about their professed support of environmental programs. Research suggests CO_2 emissions that would be avoided by deployment of nuclear energy powered oil sands would be a substantial fraction of Canada’s emission reduction goals for Kyoto (10). So, the approval of nuclear power for the oil sands and the subsequent reduction of GHG emissions would help to repair the Federal Government’s stained reputation.

   The Canadian Government has sole jurisdiction over the approval and use of nuclear energy in Canada. So, all aspects of SMRs will be regulated and any use approved by the Canadian Nuclear Safety Commission (CNSC). Clearly, the CNSC is the big player in any approvals and must be included in all discussions.

4. Environmental Groups

   As noted above, the environmental interests have been very vocal about Canada’s inability to meet any of the international targets for GHG emissions since the Kyoto Agreements were signed. Recently, the same groups have railed against both the Northern Gateway pipeline that is planned to be constructed in northern British Columbia and the northern section of the TransCanada Pipelines Keystone XL pipeline that is planned for construction between Canada and Oklahoma (30). Both will carry bitumen from the oil sands. The Canadian Government now has an opportunity to increase its popularity with environmental groups by endorsing the use of nuclear power for oil sands use to substantially reduced GHG emissions. At the same time, they should develop a fast track approval process for SMRs.These steps will help Canada catch up to the environmental progress of most other developed nations.

The question is whether the environmentalists will like the potential reduction in GHG emissions more than they dislike the use of nuclear power. It has been suggested (5) that nuclear power is associated with severe environmental impacts such as hazardous wastes produced by uranium mining and pollution of surface and ground waters during uranium production.

5. Oil Industry

The oil industry is in business to improve shareholder value while conforming to the safety, security and business regulations of the jurisdiction in which they do business. If nuclear power can be approved and installed in time to positively affect oil sands profits and if the economics of using nuclear for power, steam and hydrogen production outweigh those of using gas, then they will likely be on board. We need to keep in mind that current technologies allow recovery of only about 40 - 60% of the bitumen using current in-situ processes (personal communication). Future technologies will likely allow recovery of more of the oil from current sites. So, when nuclear power is finally approved for oil sands use, secondary recovery may well be cost effective.

6. Regulatory agencies

Application to the US NRC was made by the City of Galena Alaska in 2004, soon after Toshiba offered to provide the city with the 4S reactor without charge (18). Moreover, in a 2004 report, the US, Department of Energy (to whom the NRC reports) suggested that the 4S reactor would provide the best solution to the Galena situation (18). Since that time, progress on the approvals of the 4S reactor has been disappointingly slow.

As of September, 2012, the NRC has not approved the Toshiba 4S reactor for installation in Galena. Toshiba began a ‘pre-application review process’ in 2007, and according to the latest communication between Toshiba (and its partner, Westinghouse) and the NRC in April, 2012 (38), the review is still in progress.Another report (39) suggests that Toshiba intends to apply for approval for the 4S reactor design mid-2012. The same report suggests that the licensing process for the 4S could extend beyond 2020. Having said this, the NRC is much closer to approving an SMR for construction than is Canada.

The Department of Energy, which manages 21 national laboratories including the Idaho National Laboratory (INL), which is leading the Generation IV International Forum and the Next Generation Nuclear Plant (NGNP) program (31). Another Laboratory, Savannah River Site in North

Carolina is poised to lead a demonstration project of up to 15 small reactors. In the FY 2012, a new DOE program that is focused on SMRs strives to obtain design certification for two light-water SMRs on a cost share basis with industry. In January 2012, DOE allocated $452 million over 5 years to help design and licensing of one or two SMR designs through a cost-sharing initiative with industry. The target is to have a design in commercial operation by 2022 (32).

In the meantime, it is reported (37) that in April 2007, the Russian state nuclear energy company “RosEnergoAtom” … “began building the first of a batch of 35-megawatt nuclear reactors designed to be mounted on barges, towed to where they are needed and hooked up to the local electricity grid”. The idea is to provide nuclear power plants along the remote stretches of the Arctic coastline.

The Canadian Nuclear Safety Commission (CNSC) has been given jurisdiction over all nuclear-related activities and substances in Canada. Its mandate is similar to that of the NRC. A recent report (42) suggests that Canada has a long history of experiences with small nuclear reactors beginning with the Zero Energy Experimental Pile and 1945 up to the 1976 commercial design of the Slowpoke-2 which was provided to eight universities in Canada for research purposes.

The CNSC reports that it has been approached by multiple vendors looking to license reactors in Canada including:

1. Babcock &Wilcox, mPower reactor, 180MWe – 2-reactor module
2. NuScale Power System, 45 MWe – 12-reactor module

Each is in the first phase of a pre-licensing Vendor Design Review.

3. Starcore Power, 10 MWe, static pebble-bed, gas-cooled reactor. Starcore has contacted CNSC to determine how they would deal with a gas-cooled reactor.

The same report notes the flexibility of the CNSC licensing process to the various requirements of vendor applications. But, outside reports do not paint the CNSC in a favourable light. In a 2007 report prepared for the Alberta Government (11), the authors noted that the CNSC has not licensed a new reactor in 30 years and it lacked the resources to undertake an aggressive licensing program for new technologies. It was suggested that the level of CNSC effort required to license a new technology could exceed 500 person years.

To their credit, recent information indicates that the CNSC is attempting to improve their image and their response. One report (6) suggests that the CNSC is currently exploring cooperation with a Russian organization on a 30 Mw reactor concept. And, recent CNSC publications, aimed at licensing review processes (15, 16, 17), suggest that the CNSC will consider reviews of certifications from other countries in the application for approval of new technologies in Canada. It should be noted that the publications do not suggest that successful certifications from other countries will help to reduce the time required for licensing in Canada

7. Nuclear Industry

   Since the design of the first small nuclear reactor, the nuclear industry has been designing new technologies to improve the safety, increase power outputs and reduce the cost of SMRs. In November, 2009, a US Senate committee introduced legislation to provide funding through the DOE for the development of SMRs. Fifty percent of the cost of developing two different technologies of SMRs would be funded by the US Government.

6. CONCLUSIONS

Current technology used to extract bitumen from the oil sands requires the use of large amounts of natural gas and water and produces substantial amounts of Greenhouse gases. Since oil sands production is expected to quadruple within the next 5 years, fossil fuel use and subsequent emissions may not be acceptable to the Canadians or those outside Canada.

Clearly, an alternative approach is needed for oil sands production and needed quickly. Carbon sequestration is a relatively new technology that is expensive, untried and potential dangerous if CO_2 accidently releases from ground cavities. So, the use of GHG free nuclear power may be the answer.

Research indicates that large scale nuclear plants are not practical for use in the oil sands. They require large, permanent installations with large support staffs (13). And, the time currently required to approve, design, construct and commission a conventional nuclear plant can be 10-12 years. They have relatively short maintenance and/or refueling cycles (8). And, the steam that they produce would not be easily adapted to oil sands requirements.

Small modular nuclear reactors (SMR) could be the answer. They areoften factory built to reduce fabrication costs. They are designed to be inherently safe. They are typically installed in the ground, so security is improved. They are simple to operate, so operating staff is minimal. Modular design would ease transportation to the site. And, most technologies have long periods between refueling. But, most importantly, they are very competitive with natural gas.

If they were available today to install in new oil sands operations, their benefits would likely convince most companies to use them over natural gas. But, they are not yet approved for use and may not be available for years in North America. The issue is regulation. The Canadian Nuclear Safety Commission has not licensed a new reactor in 30 years and is not staffed to undertake an aggressive licensing program for SMRs. It is estimated that the level of effort required to license a new technology could exceed 500 person years. Some would argue that vendors and interested nuclear consulting companies could provide the expertise required to perform the licensing function. CNSC could monitor this work with far fewer staff and speed up the process. In addition to the work that could be performed by the nuclear industry, we believe that the CNSC should be looking at sister regulatory organizations outside Canada and monitoring their processes to fast track our own. After all, if our military can accept the work done by the US, Department of Defense on an American madefighter jet in order to accept it for use in Canada;our CNSC should also be able to accept the work performed by the US, DOE for licensing SMRs in Canada.

We believe that if the CNSC, with the help of the Canadian Nuclear Industry, monitored, adapted and applied the data that is currently being collected on SMRs by outside regulatory agencies, an SMR for the oil sands could be approved and constructed in 5 years (2017).

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