Written Submission by Atomic Energy of Canada Limited

To the Saskatchewan Crown & Central Agencies Energy Options Committee

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Introduction to AECL

Established in 1952, Atomic Energy of Canada Limited (AECL) is a full-service nuclear technology company providing services to nuclear utilities around the world. AECL's 5,000 full-time employees deliver world-class nuclear services, research and development support, design and engineering, construction management, specialized technology, life extension, waste management and decommissioning in support of CANDU reactor products.

Canada's nuclear program to date is based on AECL's pressurized heavy water CANDU technology – well respected here and abroad for the quality and safety of its design, competitive capital and operating costs, and longevity. The CANDU reactor designs include the Advanced CANDU Reactor (ACR-1000) and the CANDU 6, one of the world's top performing reactors.

Canada is one of only five countries successfully selling nuclear reactors. In the last 13 years, AECL has contractually delivered seven reactors on time and on budget – in China, South Korea and Romania. In fact, our new builds in China were both delivered under budget and ahead of schedule.

AECL's CANDU reactor life extensions, another important business line, are major undertakings. This process can safely extend the operating life of the reactor by up to 30 years. Similarly, AECL's services business line helps to maintain operating CANDU reactors and provide support for non-CANDU technologies.

CANDU technology is being further developed to incorporate advanced fuel technology. AECL's CANDU reactors have the potential to use alternative fuels such as thorium or recycled uranium from light water reactors. This is important for countries without an abundant supply of uranium resources and would represent a significant breakthrough in nuclear waste reduction. AECL is currently conducting research into alternative fuels in China and Canada.

AECL's major research and development (R&D) efforts take place at the Chalk River Laboratories (CRL). Scientists and engineers perform research and product development to support and advance CANDU nuclear reactor technology and the facility has world-class expertise in physics, metallurgy, chemistry, biology and engineering.

AECL's National Research Universal (NRU) reactor provides knowledge that helps AECL build safer and more efficient CANDU nuclear power plants. It has also been the birthplace of many scientific achievements. Each year more than 200 professors, students and industrial researchers come to the NRU to make use of this national resource. Because neutrons can probe any kind of materials, they can be applied to research in metals, alloys, polymers, biomaterials, glass, ceramics, thin films, cement and minerals. This work is leading to advances in medical, industrial and scientific fields to the benefit of all Canadians. In addition, the NRU reactor at Chalk River supplies 30% of the world's supply of medical isotopes.

AECL is a national asset, guaranteeing future energy independence for Canada through a homegrown Canadian supply sector with a skilled workforce. AECL is ready to be one of the true growth engines of Canada's future economy.

CANDU Products

The **ACR-1000** is an evolutionary technology based on the proven success of the original CANDU design and was specifically designed to meet market demand for competitive pricing and state-of-the-art technology. It is a hybrid, bridging between heavy and light water reactor technologies. The ACR-1000 combines the neutron efficiency of heavy water design with the economic advantages of light water cooling. ACR-1000 units are designed to have a 60-year operating life and a lifetime average annual capacity factor of more than 90 per cent. The design meets or exceeds Generation III+ advanced reactor standards.

The **Enhanced CANDU6 (EC6)** maintains all of the proven features of the highly successful CANDU 6 reactor while delivering a higher plant output and increased safety and security attributes, meeting Generation III standards. It also has the unique potential to utilize advanced fuels, such as recovered uranium and thorium, and may be used to dispose of actinides. AECL estimates that the use of recovered uranium fuel from three light water reactors can keep a CANDU reactor running over its operational life. This presents a very attractive proposition for those countries that have light water reactor-based nuclear programs and access to recovered uranium.

The CANDU Advantage

- The economics of electricity production by an ACR-1000 is cost-competitive with other nuclear technologies.
- The pre-project design review by the Canadian Nuclear Safety Commission (CNSC) concluded there are no fundamental barriers to licensing the ACR-1000 design in Canada.
- AECL and the CNSC recently signed a service agreement to conduct a pre-project design review of the EC6 reactor.
- CANDU technology is designed to stringent Canadian licensing standards and also complies fully with International Atomic Energy Agency licensing and safety requirements.
- The strong operability features of CANDU reactors results in high lifetime capacity factors and best-in-class fuel integrity records. Canadian utilities, some with decades of experience in operating CANDU reactors, can rapidly move up the learning curve on operations and maintenance for the ACR-1000 and EC6.

- AECL employs a low-risk project delivery model that is based on the most up-to-date construct-ability and modularization knowledge and on a strong legacy of on-time and on-budget project management of new build CANDU projects.
- AECL has been building reactors continuously for the past 30 years and has established a strong project management delivery capability and construction program built to international standards.
- The CANDU supply chain and procurement experience is robust and proven through recent new builds, current life-extension projects and scheduled maintenance and services of the existing CANDU fleet worldwide.

Status of the Worldwide Nuclear Renaissance

From an existing base of 436 nuclear reactors around the globe in 2009, there are plans, discussions and work underway to build an estimated 230 new nuclear reactors. Beyond this, there is potential for many more reactors. This opportunity represents a market well in excess of $1 trillion over the next 20 years.

Why is the world looking at nuclear power as a major source of electricity generation? Simply due to the overwhelming evidence that nuclear power can make major contributions towards meetings the world's electricity needs while taking the following into account:

- Nuclear power does not generate air pollution or greenhouse gas emissions
- Nuclear power is proven, baseload technology
- Nuclear power can provide competitively-priced electricity, thus contributing to a nation's economic competitiveness
- Nuclear power contributes to security of supply and to stability of energy prices,
- Nuclear power has renewed interest and acceptance among the general public, based on an unparalleled safety record as well as the resolution of long-term spent fuel storage approaches.

Safety Record of Nuclear Power Plants

All Canadian nuclear plants are equipped with special safety systems whose sole function is to automatically shut down the reactor in the event of any major equipment malfunction. The many safety systems of the CANDU nuclear plant take into account human error, equipment failure, natural risks such as earthquakes, and even the threat of a terrorist attack.

In the event that an accident should occur, CANDU power plants have three means of shutdown, including the normal regulating system and two independent, fast-acting safety shutdown systems that are designed to contain radioactive emissions within multiple containment barriers.

Worldwide, CANDU nuclear power has one of the best safety records in the industry. The nuclear power industry is the most regulated industry in Canada for health, safety and environmental factors.

Environmental Impacts
Nuclear energy does not release carbon dioxide and the air discharges from a nuclear plant are free of contaminants such as heavy metals and organic compounds. CANDU nuclear power plants therefore generate electricity without producing emissions that cause air pollution and smog or contribute to climate change.

The use of CANDU technology to generate nuclear power, in place of generating the same amount of energy from coal, has in the past four decades prevented the release of more than two billion tones of carbon dioxide (CO_2) emissions, 11 million tones of sulphur dioxide and 2.5 million tones of nitrogen oxides.

Recent national health statistics show that about 5,000 deaths a year in Canada can be attributed to poor air quality. Without CANDU nuclear power plants in Ontario, the air quality in southern Ontario would be much worse and annual CO_2 emissions would increase by 15 to 20 per cent.

The Ontario Power Authority assessed the environmental impacts of several methods of power generation, and found that nuclear power plants, such as those using CANDU nuclear technology, have a much smaller environmental "footprint" than other forms of non-renewable energy, scoring much closer to renewable sources.

COMPARISON OF SCORED ENVIRONMENTAL IMPACTS

	GHG/toxic Emissions	CO_2	Radioactivity	Land Use	Water Impacts	Waste Impacts	Resource Availability	**Total Impact (Weighted)**
Hydro (run of river)	0	1	0	0	0	0	1	**21**
Hydro (impoundment)	0	1	0	4	5.5	0	1	**30.5**
Wind	1	1	0	4.5	0	0	0	**34.5**
Biomass	2	1	0	1	4	1	1	**47**
Photovoltaic	2	1	0	1	0	0	0	**41**
Nuclear	1	1	6	1	4.5	1	5.3	**47.8**
Natural gas (single cycle)	2	3	0	1	2	0	8	**91**
Natural gas (combine cycle	2	2	0	1	2	0	8	**71**
Natural gas (cogeneration)	2	2	0	1	2	0	8	**71**
Gasification (no CO_2 removal)	4	6	10	1	2	0	2	**175**
Gasification (with 90% CO_2 removal)	4	2	10	1	2	0	2	**95**
Coal	5	7	10	1	3.5	10	2	**216.5**
Oil	5	10	1	1	5	3	5	**265**

Note: The Total Weighted Impact is calculated by applying a weight of 10 to contaminant emissions, 20 to greenhouse gases, and 1 to all other categories. Source: SENES , OPA)

Long Term Used Fuel Management
Compared to other types of thermal power plants, nuclear plants produce only small amounts of used fuel (waste). A 700 megawatt CANDU nuclear power plant, for example, produces about 0.30 tonnes of used fuel per day, while an equivalent sized coal-fired station produces 1,440 tonnes of solid ash per day and eight tonnes of fly ash. Canada's total inventory of used fuel would fill one soccer field, to the height of a player.

The small amount of used fuel produced by Canadian nuclear power plants is controlled and stored in carefully managed facilities. For the first five years, it is stored in bays at the plant site where radiation is shielded from the outside world by three metres of water. Then placed in dry storage canisters with meter-thick concrete.

On-site storage is considered to be safe and secure for a century or more, and in Canada's 40 years of using nuclear energy, no member of the public has ever been harmed as a result of a radiation leak from a nuclear power plant, or its storage facility.

Long Term Used Fuel Disposal
In the long term a more permanent disposal method is being considered, involving the building of a large underground storage facility. However, no decision has yet been made by the Federal Government on the site for such a facility.

In 2002, the Nuclear Waste Management Organization (NWMO) was established by an Act of Parliament to examine options for the long-term management of used nuclear fuel. NWMO's report, submitted in November 2005, recommended a strategy of "Adaptive Phased Management" with the end goal of centralizing all of Canada's used nuclear fuel in one location, and isolating it deep underground in a suitable geological formation. The strategy allows for public consultation at every step of the process, with the option to modify the strategy as new technologies and uses for used nuclear fuel emerge.

In 2007, the Government of Canada accepted the NWMO's Adaptive Phased Management option as the recommended approach for managing used nuclear fuel in Canada over the long term. This option includes the isolation and containment of used nuclear fuel deep in the earth, with an option for temporary shallow underground storage.

Nuclear Plant Costs
"When one analyzes the nuclear project over sixty years, and takes into account air emission compliance cost, fuel diversity, and fossil fuel dependence concerns … nuclear is generally more cost-effective." (Source: The Cost of New Generating Capacity in Perspective, Nuclear Energy Institute, February 2009)

Recent media attention on the Ontario new build bid selection process has raised questions about the cost of building new nuclear power plants. Although AECL is bound by the communications guidelines of the process and therefore cannot address the context of these media stories, AECL agrees with the Nuclear Energy Institute's conclusion..

AECL's strong competitive position against AREVA's EPR and Westinghouse's AP1000 was demonstrated through the Ontario RFP process – the most thorough and structured review of leading global nuclear Generation III+ technologies performed to-date. The bid evaluation results confirmed that AECL's proposal for two Advanced CANDU Reactor (ACR-1000) units at Darlington was the only compliant bid.

"It is important to recognize that capital costs are only the starting point for any analysis of new generating capacity. A more accurate measure of economic competitiveness, and one that is more important to regulators and consumers, is the cost of electricity produced by a particular project compared to alternative sources of electricity and to the market price of electricity when the power plant starts commercial operation. This generation cost takes into account not only capital and financing costs, but also the operating costs and performance of a project.

Analysis by generating companies, the academic community, and financial experts shows that even at capital costs in the $4,000/kWe to $6,000/kWe range, the electricity generated from nuclear power can be competitive with other new sources of baseload power, including coal and natural gas. …With regional or national programs that put a significant price on carbon emissions, nuclear power becomes even more competitive." (Cost of New Generating Capacity in Perspective, Nuclear Energy Institute, Feb. 2009).

Value Proposition for Saskatchewan

Reliable Baseload Generation – CANDU Performance Record

In Canada, nuclear power contributes about 14% of the total electricity supply. In the province of Ontario in 2008 about 51% of the electricity supply was nuclear (along with 21% hydro, 26% fossil, 2% "other"). The other two provinces with nuclear power, New Brunswick and Québec, receive about 30% and 3%, respectively, of their supply from nuclear. (Source: Canada's Nuclear Energy: Reliable, Affordable and Clean Energy, Canadian Nuclear Association)

Nuclear power is Ontario's main baseload energy source generating 51% of its electricity supply. Although the province is investing in renewable energy sources – primarily wind and solar – and mounting impressive conservation campaigns, there is renewed interest in new nuclear builds in Ontario. This is not only based on the environmental benefits to nuclear power, but also on the fact that nuclear power – particularly CANDU nuclear power – has proven reliability rates and capacity factors that result in Ontario residents having the power they need, when they need it.

The CANDU 6 reactor, the proven workhorse of the CANDU fleet, has been consistently safe, economical and reliable over the past three decades of operation, while achieving excellent performance track records for reliability and capacity factors. Based on the latest International Atomic Energy Agency data available (2007), of the 433 operating reactors worldwide at that time, three-quarters of AECL's international CANDU 6 fleet ranked in the top 10% for their lifetime load factor. This includes holding the top three spots in the global ranking.

The CANDU 6, a pressurized heavy water reactor, is valued for its reliability, efficiency, competitive capital and operating costs and constructability. It has been sold around the world, including in Canada: Quebec (single unit), New Brunswick (single unit); South Korea (four units); Romania (two units); Argentina (single unit) and China (twin unit). The latest project in China, Qinshan, was completed in 2003.

CANDU 6 reactors (600-730 megawatts), when compared to similar size and larger reactors, rank ahead of the competition with an average lifetime performance factor of 88.9% *(Source: CANDU Owners Group, 2007)*. To provide some context to the significance of this high performance, a 1% improvement in the annual capacity factor of a CANDU 6 unit generates an additional $1 million to $2 million in utility revenue, based on average Ontario utility electricity prices.

In the case of South Korea, where the same operator is managing both light water reactors and CANDU plants, the CANDU 6 units have delivered a higher operating capacity factor than the light water units. In Qinshan, AECL was recently advised by the Chinese operator (TQNPC) that the Qinshan 3 units ranked 18^{th} overall in a survey comprised of over 400 operating stations.

AECL and its Team CANDU partners has continuously demonstrated a strong capability for delivering CANDU 6 new build projects on time and on budget.

In Service	Plant	Status
1997	Wolsong Unit 2, South Korea	On budget, on schedule
1998	Wolsong Unit 3, South Korea	On budget, on schedule
1999	Wolsong Unit 4, South Korea	On budget, on schedule
2002	Qinshan Phase III, Unit 1, China	Under budget, 6 weeks ahead of schedule
2003	Qinshan Phase III, Unit 2, China	Under budget, 4 months ahead of schedule

Why build a CANDU Power Plant in Saskatchewan?
As a result of Saskatchewan's growing economic momentum, SaskPower is facing an unprecedented increase in demand for electricity from its customers. Over the next 10 years, load is expected to grow by 34%. Combined with the need to replace generation equipment that is nearing the end of its operating life, Saskatchewan will need a total of approximately 1,700 MW of supply by 2020 and approximately 3,700 MW by 2030.

Bruce Power, with the support of the Saskatchewan Government, undertook a nuclear feasibility study and issued their findings in November 2008. The report identified the North/South Saskatchewan Rivers as a viable water source for a plant and identified the Lloydminster/Prince Albert economic zone as the best region for the province's first nuclear power plant.

Creation of a long-term Saskatchewan-based nuclear supply industry
As already indicated, Ontario relies heavily on nuclear power for baseload electricity generation, and with 20 nuclear units in operation. Ontario is currently the hub of the Canadian nuclear industry today. The Organization of CANDU Industries (OCI), the supply chain of the CANDU nuclear industry, currently has 150 members supplying goods and services for nuclear reactor in domestic and export markets. OCI operates separately from the design authorities and the utilities, but participates with them in the design, manufacture, construction and commissioning of CANDU plants at home and abroad. The majority of OCI members are located in Ontario.

A decision to build new nuclear in Saskatchewan would create similar manufacturing growth in Saskatchewan due to the nature of the nuclear industry. Unlike other industries, nuclear has a much greater demand for the manufacture of higher quality components and technology that can be used in a radioactive environment. As a result, this highly regulated industry requires all manufacturing and fabrication be carefully audited at every stage of the project timeline, resulting in a greater need for the manufacturer to be in close proximity of a new build.

The fact that close, daily interaction with the project vendor is imperative to meet regulatory requirements and intense customer timelines, offers growth opportunities for new and existing Saskatchewan suppliers.

Nuclear R&D in Saskatchewan Universities
The University of Saskatchewan is looking to build on existing excellence to develop a multi-disciplinary and globally competitive research institute for nuclear studies. The concept is to build the University of Saskatchewan Institute for Nuclear Studies around three interconnected themes:

- **Opportunities** – Nuclear initiatives provide an important opportunity for real social and economic progress for Saskatchewan and Canada. These benefits will be in the form of environmental stewardship, stronger community leadership, and new wealth for a greater portion of society. The Institute for Nuclear Studies could help explore the full environmental and social context of nuclear development.

- **Nuclear Cycle** – The nuclear fuel cycle includes exploration and mining to power, isotope production and other value-added linkages, and to safe storage and recycling. The Institute for Nuclear Studies could coordinate various initiatives to advance science across the entire nuclear fuel cycle.
- **Foundations** – The creativity and flexibility of basic research together with applied initiatives in the nuclear cycle is the foundation for public benefits in this and other sectors. The foundation programs are critical for training graduates in a variety of scientific and policy areas related to the nuclear industry including energy, medical and natural resources.

The Institute is envisaged as a partnership among the U of S, the Province, nuclear and other industries, and other national and international research centres. The Institute would provide greater understanding of how to optimally manage the province's uranium resources across the fuel cycle and in relation to northern development, environmental stewardship, and medicine. This will require a foundation of interconnected basic arts and sciences, applied research and community engagement.

Synergy with Saskatchewan Oil Sands Industry – Hydrogen for Bitumen Upgrading
Hydrogen is used in large quantities in the Alberta oil sands, ammonia production and petroleum refineries, and there is a movement to use hydrogen as a fuel in the transportation sector. For example, the Alberta oil sands requires between 2.4-4.3 kg of hydrogen for every barrel of crude bitumen that is upgraded to synthetic crude oil. In 2008, about 2200 tonnes of hydrogen per day was required to upgrade bitumen and heavy oil. According to the Canadian Hydrogen Association/Bruce Power report "Saskatchewan and the Hydrogen Age" (January 2009) the upgrading of heavy oil and bitumen is Canada's fastest growing hydrogen demand sector with annual demand expected to rise to 2.8 Mt/a by 2020. In this time frame there is strong likelihood that hydrogen will also be used in fleet vehicle and heavy vehicle transportation options.

Much of the hydrogen used today is produced by steam-methane reforming, where natural gas is both the feedstock and fuel for the process. Partial oxidation of bitumen residues, such as petroleum coke or asphaltenes, has also been applied for large-scale hydrogen production. Both processes produce large quantities of carbon dioxide and other greenhouse gases.

An alternative hydrogen production process with minimum greenhouse gas emissions is electrolysis where the electricity is produced using wind, hydroelectric or nuclear power. Electrolysis of water is an efficient, well-established process for hydrogen production that can be economically viable in locations with low cost electricity since the cost of electricity comprises 80-90% of the hydrogen cost. Hydrogen production by the electrolysis of steam is a promising new process under development that promises efficiency and economic advantages over conventional electrolysis. The higher operating temperatures of steam electrolysis provide two benefits: increased thermodynamic efficiency and a reduced electricity requirement since thermal energy provides some of the energy required to split water.

Need and Opportunity for Hydrogen Production

The report of the Uranium Development Partnership, released in March 2009, recommends that Saskatchewan create a centre of excellence for nuclear research and training with focussed areas of research on longer-term commercialization prospects. In addition, the University of Saskatchewan has been looking to identify opportunities for training and research in the nuclear area to underpin a new Institute for Nuclear Studies. Research and development to resolve technical challenges and demonstrate hydrogen production using steam electrolysis (also called high temperature electrolysis or HTE) on a prototype scale would meet both of these requirements. The Energy Division of the Saskatchewan Research Council has been working on processes to develop, extract and produce Western Canada's energy resources through joint industry partnerships and on a single client basis. The mandate of the Saskatchewan Research Council is to develop value-added technology in Saskatchewan. SRC is home to a Slowpoke nuclear reactor. In addition the Canadian Light Source is an ideal facility to solve the materials related challenges associated with the high temperature electrolysis.

Hydrogen production using zero GHG nuclear electricity is an effective way to link two important resource industries, uranium and oil sands (bitumen upgrading) through innovative and environmentally sustainable technology. Saskatchewan is therefore an ideal location to conduct research on steam electrolysis and build pilot -scale demonstration plant. The ultimate aim would be to deploy full-scale steam electrolysis facility(ies) in Saskatchewan that are economically viable and help reduce the carbon footprint of the heavy oil and oil sands industries in Saskatchewan and Alberta.

Conclusion – A Unique Opportunity for Saskatchewan

Saskatchewan has both natural resources, one of the world's largest and richest uranium deposits, as well specialized research facilities, the Canadian Light Source that can help solve long term materials challenges related to new nuclear power developments – that provide a unique advantage in enabling the province to play a leadership role in Canadian nuclear technology development and implementation.

Saskatchewan is at the cross roads of an important longer term electricity supply and industrial strategy decision that could involve the introduction of nuclear power generation and related R&D and manufacturing facilities in the province. This decision should consider the environmental, social and financial impacts that an expanded nuclear industry could have on the province and its citizens. The choice of an energy and industrial strategy for Saskatchewan should be based on factual information about nuclear energy and would benefit from an understanding of the experience of other "nuclear provinces" in Canada.

AECL, as Canada's nuclear energy company, is ready to work with Saskatchewan to ensure that the province understands the full range of nuclear options and selects an energy path that is best for its citizens and future generations.