Intervention by the Canadian Nuclear Society (CNS) Before the Canadian Nuclear Safety Commission (CNSC)

Application by Ontario Power Generation (OPG) to renew, for a 13 year term, the operating licence for the Darlington Nuclear Generating Station (Ref 2015-H-04)

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Introduction

The Canadian Nuclear Society (CNS) views with great interest the renewal of the operating licence for the Darlington nuclear power station under review today during Day 2 of the hearings by the Canadian Nuclear Safety Commission (CNSC). In this short paper, the CNS will present its perspective on the importance of the Darlington NGS and the role nuclear power plays in Canada and in the province of Ontario.

We observe that the current application before the CNSC is for the longest duration of any power reactor facility in Canada that has ever come before the CNSC or its predecessor the Atomic Energy Control Board (AECB). It is also one of the most complex licence applications, as it combines two major activities within the licence period: ongoing station operation, and sequential refurbishment of the station's four reactors.

Renewal of the Darlington PROL (power reactor operating licence) also occurs in the wake of one of the most significant events to impact nuclear power operations in recent years, the earthquake and tsunami which interrupted normal station operations at the Fukushima Daiichi nuclear power plant in Japan on March 11, 2011. The consequences of the accident to those four reactors have had some profound implications for all reactor operations worldwide. In Canada, the CNSC and power reactor operators such as OPG have engaged in a process of reassessing the safety of nuclear power operations for protection against beyond design basis accidents. This process has included implementation of measures to reduce or eliminate the reasonable possibility of such events having significant consequences.

This paper will provide the perspective of the CNS on these measures.

The licensing of a nuclear facility is not an abstract activity. To operate, all regulated nuclear facilities in Canada must meet the safety performance requirements of the CNSC. However, all regulated nuclear facilities in Canada exist for important commercial, research, or energy supply reasons. This means that licensing decisions have direct research, technical and commercial consequences. It is the purpose of this paper to provide the views of the CNS on the importance of these licensing decisions.

The CNS is Canada's learned society for the nuclear industry. We are a not-for-profit organization representing more than 1,000 professionals, scientists and other researchers, engineers and other nuclear professionals engaged in various aspects within Canada's nuclear industry. We do not represent any company or other organization within the industry. The CNS believes that the views of Canada's nuclear professionals, as embodied by its learned society, may provide useful assistance to the CNSC in its deliberations.

Refurbishment and Operation of the Darlington NGS

Starting in 2016, OPG will commence a decade-long refurbishment of the Darlington NGS. This will constitute the first time in the history of Canada's nuclear industry in which an owner has prepared and tabled for approval a comprehensive plan for the refurbishment of all reactors at a multi-unit CANDU nuclear power station. There have already been previous refurbishments of CANDU reactors, notably Point Lepreau, Pickering Units 1 and 4, and Bruce Units 1 and 2. But the Darlington project will constitute the first time a Canadian nuclear operator will have formally committed to the refurbishment of an entire multi-unit station.

The scope of such a project spans more than a decade, from 2016 to 2028. It constitutes an investment of billions of dollars in capital, and millions of man-years of work. The importance of this project to Ontario's economic future cannot be understated. As noted below, Darlington produces about 20 per cent of Ontario's electricity supply. It should also be noted that nuclear power produces most of Ontario's lowest cost and lowest emission source of electricity.

OPG has undertaken two previous reconstruction projects, namely Pickering Units 1 and 4. It should be acknowledged that there were some difficulties with these projects with respect to project management, schedule and cost overruns. However, it should also be observed that an evident learning curve was shown in those first two projects a decade ago. The refurbishment of Pickering 1 subsequent to Pickering 4 showed great improvement in adhering to project milestones and in minimizing cost overruns.

It must also be remembered that OPG was not the only utility refurbishing CANDU reactors. Bruce Power completed the reconstruction of Bruce Units 1 and 2, NB Power completed its refurbishment of Point Lepreau, and the Korea Electric Power Company (KEPCO) has recently completed the refurbishment of Wolsong 1. Nuclear utilities do not undertake such projects in isolation. There has been and will continue to be extensive sharing of knowledge and information among them. This comes through various agencies such as information exchanges and research programs such as the CANDU Owners Group (COG), and events such as technical conferences sponsored by the CNS.

Nuclear utilities are not the only ones who have learned and developed through this technical history. There has also been growth and development of the regulatory agencies as well. The CNSC today has far more sophisticated and extensive analytical tools and a far greater institutional knowledge base today upon which to draw than was available to its predecessor the Atomic Energy Control Board (AECB). From a regulator's perspective, the CNSC today can draw upon an extensive body of data and experience, providing it with greater certainty about the consequences of decisions it makes.

It is in this aspect that the CNS perceives the importance of the requested 13-year term of the operating licence. One of the elements critical to any undertaking in the nuclear industry is regulatory certainty. Specifically, the proponent must have a clear understanding of the requirements of the regulator throughout the term of the project. There must also be a clear understanding of the terms and conditions under which such requirements might change. Should such not be the case, then a project is likely to be delayed at considerable cost to the project proponent and its shareholders, in addition to the adverse economic impact to the province in which the project is being carried out.

By extending the term of the operating licence to cover the entire refurbishment period of all four Darlington units, the CNSC adds greatly to the ability of the proponent OPG to meet its project milestones over the decade to come. Such a licence duration adds confidence that there will not be new and unexpected regulatory requirements introduced partway through. There have been specific occurrences of such in the past, and no one wants to repeat such experiences.

It should be noted that mere extension of the operating licence to 13 years does not convey any exemption from all of the other reporting requirements placed upon the operator. Indeed it is the expectation of the CNS that both OPG and the CNSC have thought through comprehensively the workings of day to day regulatory requirements for a plant partly in operation, partly in construction during the term of the licence. It is our understanding that much of the interaction of the CNSC and OPG has been outlined and agreed in the CNSC document *OPG Protocol with the CNSC for Darlington Relicensing and Refurbishment, ccm 2015-000170*.

Post Fukushima Plant Improvements

March 11, 2011 marked the most traumatic event in the history of the world's nuclear industries since Chernobyl on April 26, 1986. The events at Fukushima Daiichi in Japan were initiated by the largest and most severe earthquake and tsunami ever recorded in human history. It should be noted that the events at Fukushima were utterly trivial compared to the human tragedy that emerged all around the plant. Tens of thousands perished primarily in the vast inundation that followed shortly after the earthquake.

However, the effect on the nuclear industry was profound. This was an accident which exceeded the design basis of the plant. With the total loss of both back-up and grid power, the Daiichi units became unmanageable, and almost impossible to monitor.

This in turn compelled nuclear operators and regulators around the world to start looking at their systems and operations to determine what other threats to safe operation existed or could conceivably exist and what could to mitigate such threats. The CNS has observed that Canada was among the very first nations to initiate such investigations and to develop useful plant and personnel upgrades.

We note in the documentation provided by OPG that these upgrades in the case of Darlington were the result of the work by the CNSC Fukushima Task Force and its recommendations to licencees as action items. The priorities were:

- Prevent the occurrence of fuel damage and the release of radiation to the environment by improving defenses and the availability of portable water and power supplies;
- Arrest any progression of fuel and core damage through additional operational measures; and
- Implement timely protective and mitigating actions to respond to beyond design basis accidents.

This has resulted in a large number of upgrades to plant and personnel. For Darlington, the most important measures included:

- Hydrogen (including deuterium) autocatalytic recombiners operating in addition to hydrogen igniters but do not require electrical power, a measure now complete;
- Additional emergency equipment including portable pumps and diesel generators capable of functioning and providing power supplies in the event of loss of both normal and emergency power supplies;
- Construction of a separated storage facility for the new equipment;
- Additional seismic assessments of the station;
- An automated, real time station boundary radiation monitoring system;
- The conducting of both training and simulated exercises testing new equipment and procedures;
- A mutual aid agreement among Canadian nuclear operators.

These are the measures implemented already, and a continuing work program has been agreed with the CNSC.

It is beyond the scope of the CNS to provide a detailed technical assessment of these measures. However, it is the view of the CNS that these measures should diminish greatly the possibility however unlikely that the events of Fukushima involving a total loss of in-plant power and complete loss of cooling to the fuel in the core and in the spent fuel bay could occur at the Darlington NGS.

There is often a tendency to bureaucratic panic in the wake of an event like Fukushima. In the 1980s, the response of Italy was to close without technical justification its five nuclear power reactors. In 2011, the response of the German government was to order the immediate closure of eight of its 17 reactors, with the remainder to close by 2022.

The Canadian response to Fukushima was far different. It is to the credit of the CNSC and Canada's nuclear operators that intelligent, practical responses to avert a replication of a Fukushima Daiichi event were found and are being implemented.

Conclusions

The CNS is therefore of the view that operation of the Darlington nuclear power station must continue, provided that it meets all of the safety requirements of the CNSC. Our reasons are as follows:

1. Nuclear power is essential to Ontario for the supply of base load electricity that cannot be provided economically from any other available source.
2. Electricity supplied by Darlington is an essential part of that base load electricity supply, meeting 20 per cent of Ontario's total electricity demand.
3. Any premature loss of generation from Darlington cannot be met in the short term by either construction of new generating facilities or by increased imports from other jurisdictions.
4. OPG has demonstrated in dialogue with the CNSC a strong response in emergency preparedness and in investment in equipment and personnel.
5. OPG constitutes a strong ongoing source of high technology employment for engineers and skilled trades, providing a solid base for both Ontario industrial capacity and Ontario's academic and apprenticeship training programs.
6. Continuous performance improvement is intrinsic to OPG's nuclear operations.

7. Approval of the application for renewal of the operating licence for a 13-year term will provide certainty for regulators, the operator, and the public of the requirements for operation of the Darlington site throughout the refurbishment project.

Therefore, the Canadian Nuclear Society supports the application by Ontario Power Generation for the renewal of its operating licence for the Darlington nuclear power station.

Appendix

Nuclear Power in Canada

Nuclear technology plays an important role in Canada, and it has done so for more than 70 years. Canada was one of the first nations ever to demonstrate controlled fission with the startup of the ZEEP reactor at Chalk River Laboratories. It was one of the first nations to build a demonstration nuclear power reactor, the NPD reactor at Rolphton, Ontario. With the eight nuclear reactors at Bruce, Canada has the world's largest operating nuclear generating facility.

As a Tier-1 nuclear nation, Canada is one of the very few nations of the world in which all of the following activities take place:

- Design of nuclear reactor technology
- Construction and operation of nuclear power plants
- Uranium mining, fuel fabrication and production
- Medical and industrial isotope production
- Decommissioning, environmental remediation and high level, long term waste management
- Full scope nuclear laboratory services and R&D
- Post-secondary nuclear education up to doctorate level.

Canada is the second largest producer of commercial uranium in the world, with annual production averaging approximately 10,000 tonnes of uranium consistently over the past 40 years. And it has all of the facilities and technology to provide the full spectrum of uranium supply, both to meet Canada's needs and to supply uranium for nuclear power in other nations as well.

The success of Canada's nuclear reactor technology has been shown by its extensive, safe and economic operation in Canada. It has also been acquired by a number of other nations as well, including South Korea, Romania, Argentina and China. In all of these countries, CANDU technology has been shown to be both reliable and economic, providing large quantities of electricity to meet these nations' energy needs. Canada's CANDU technology was also adopted by India and Pakistan, and in the case of India, their heavy water reactor technology is to this day the mainstay of that country's commercial power program.

The following is a list of operating CANDU reactors, both in Canada and around the world.

Table I: CANDU Nuclear Reactor Performance
December 2014

Reactor	In Service	Capacity (MW)	Performance In 2014 (%)	Lifetime Performance (%)
Point Lepreau	1983	680	82.2	76.3
Wolsong 1	1983	622	0*	80.3
Wolsong 2	1997	730	91.5	93.5
Wolsong 3	1998	729	85.7	94.8
Wolsong 4	1999	730	85.1	95.7
Embalse	1984	648	29.9	81.4
Cernavoda 1	1996	706	91.1	90.4
Cernavoda 2	2007	705	98.5	94.5

Qinshan 4	2002	700	98.6	91.8
Qinshan 5	2003	700	92.0	92.3
Pickering 1	1971	542	86.0	64.3
Pickering 4	1973	542	63.3	66.2
Pickering 5	1983	540	95.0	74.2
Pickering 6	1984	540	88.9	78.5
Pickering 7	1985	540	62.0	77.9
Pickering 8	1986	540	53.8	76.0
Bruce 1	1976	825	87.3	84.5
Bruce 2	1977	825	76.8	82.4
Bruce 3	1978	750	64.5	64.6
Bruce 4	1979	750	94.3	65.2
Bruce 5	1985	872	81.6	85.2
Bruce 6	1984	872	94.6	79.5
Bruce 7	1986	872	76.4	84.7
Bruce 8	1987	872	96.0	83.0
Darlington 1	1992	934	75.8	85.2
Darlington 2	1990	934	96.6	79.5
Darlington 3	1993	934	97.8	87.5
Darlington 4	1993	934	95.3	86.4
Total/Average		20,666	80.0	82.0

COG CANDU/PHWR Performance Indicators, December 2014.
**These reactors were under reconstruction during part or all of 2014.*
All capacities in all tables are quoted in gross generation unless otherwise indicated.

In total, these reactors have produced more than 3300 TWh of electricity during their years of operation. To put that in perspective, the US Energy Information Administration (EIA) notes that based on 2013 figures world total electricity production from all sources was:

Table II: 2012-2013 World Electricity Production

	Capacity (GW) (2012)	Energy(TWh) (2013)
Fossil	3606	14,498
Hydro	979	3,646
Nuclear	373	2,364
Wind	268	520
Biomass	87	384
Solar	91	95.8
Geothermal	10	68
Tidal	2.7	0.5
Total	5549	21,531

Note: columns may not add due to rounding.

http://www.eia.gov/cfapps/ipdbproject/IeDIndex3.cfm?tid=2&eyid=2012&syid=2012&reverseAxes=0&cid=&cid=r1&cid=r2&cid=r3&cid=r4&cid=r5&cid=r6&cid=r7&cid=ww&pid=alltypes&aid=7&unit=MK&updateB=UPDATE#

From a historical perspective, it should be noted that the only significant change to world electricity production over the past 50 years has been the emergence of nuclear power and to a lesser degree the use of natural gas. Natural gas has replaced coal. Also appearing in world electricity production has been the various forms of renewable generation. At this time, renewables produce less than 10% of world electrical energy, with much of that coming from biomass. The proportion of electricity generated from hydraulic sources in 1950 was roughly similar to that above. However, starting in the late 1950s, nuclear power began to emerge as a major source of new electricity generation. Its impact over the past half-century has been to displace principally oil-fired generation, and to a considerable extent coal-fired generation particularly for base load applications.

To a considerable extent, nuclear and gas complement each other. Nuclear with its high fixed costs and low operating costs works best as base load generation. Gas, with its low fixed costs and high proportional fuel costs, works best as a peaking power source. (Approximately 90 per cent of the lifetime total cost of a gas-fired CTU comes from fuel purchase and not construction and operation. Nuclear by contrast has much less than 10 per cent of its total lifetime cost in the purchase of fuel.)

For Canada, electricity consumption from all sources is approximately 525 TWh annually. Canada is the seventh largest electricity jurisdiction in the world:

Table III: World's largest electricity jurisdictions (2012)

	Consumption(TWH)
China	4468
USA	3832
Japan	921
Russia	889
India	865
Germany	540
Canada	525
Brazil	483
South Korea	482
France	451
United Kingdom	319
Italy	303

US Energy Information Administration

Canada's nineteen operating nuclear reactors, therefore, have produced the equivalent of approximately six years of Canada's total electricity production from all sources or about 18 months of world annual nuclear production. Nuclear power remains about 17 per cent of Canada's total electric energy production, above the world average noted above.

Canada however is very different from the large nations.

Table IV: Canada's Electricity Sources

	% share
Hydraulic	62.7
Nuclear	17.08
Coal	14.33
Natural Gas	4.52
Wind	1.46
Other	>0.05

The Canadian Nuclear Factbook 2012, CNA

Canada has more than half its electricity produced by low cost hydraulic energy, whereas the dominant form of generation for all of the other large nations is coal. With approximately 80 per cent of Canada's electricity supply coming from hydraulic and nuclear energy, Canada has one of the cleanest large electricity systems in the world. There has been some new hydraulic construction over the past 40 years, principally the La Grande generating complex in Quebec. But the vast majority of new electric generation in Canada over that period was nuclear power.

It is reasonable to draw several conclusions:

1. That Canada's nuclear power stations have absorbed most of the growth in electricity production over the past half-century; and

2. That Canada's nuclear power stations have displaced fossil fuels in Canada, principally coal and oil; and
3. That 80 per cent of Canada's electric generation is free of atmospheric emissions.

It should be noted that Canada is the only nation in the world, with all of the above-mentioned aspects of nuclear technology and infrastructure, which has developed its nuclear industry for purely peaceful purposes.

Nuclear Power in Ontario

Ontario is home to all but one of Canada's 19 operating nuclear power reactors. These reactors are concentrated in two main areas: Durham Region with the Pickering and Darlington nuclear power stations; and Bruce County with the Bruce nuclear power station.

Of all of the provinces in Canada, Ontario's electricity system has perhaps the greatest diversity of electricity sources of any province in Canada. Nuclear generation is only one part of a large system producing and distributing electricity from a variety of sources:

Table V: Ontario's Electricity Production – 2014

	Energy(TWh)	%Share
Nuclear	94.9	62
Hydro	37.1	24
Gas	14.8	10
Wind	6.8	4.0
Coal	0.1	<1
Other	0.32	<1

http://www.ieso.ca/Pages/Power-Data/Supply.aspx

Importance of Darlington NGS in Ontario's electricity supply

At this time, the Darlington nuclear power station consists of eight operating reactors. The performance characteristics of these reactors are shown below:

Table VI: Characteristics of the Darlington Reactors

Reactor	**In Service**	**Capacity (MW)**	**Performance In 2014 (%)**	**Lifetime Performance (%)**
Darlington 1	1992	934	75.8	85.2
Darlington 2	1990	934	96.6	79.5
Darlington 3	1993	934	97.8	87.5
Darlington 4	1993	934	95.3	86.4
		3736	**91.4**	**84.7**

COG CANDU/PHWR Performance Indicators, December 2014.

On a continuing basis, Darlington's four reactors supply about 20 per cent of the province's total electricity requirement.