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

Application by Ontario Power Generation (OPG)
To renew for a five year term and to merge
The operating licences for the Pickering Nuclear Generating Station
(Ref 2013-H-03)

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Introduction

The Canadian Nuclear Society (CNS) views with great interest the renewal of the operating licence for the Pickering 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 some perspective on the importance of the Pickering NGS and the role that nuclear power plays in Canada and in the province of Ontario.

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. And it is the purpose of this paper to provide our Society's views on the importance of these licensing decisions.

The CNS is Canada's learned society for the nuclear industry. We represent more than 1,000 professionals, scientists and other researchers, engineers and other nuclear professionals engaged in various aspects within Canada's nuclear industry. It should be noted that this presentation marks the first intervention the CNS has ever made in a CNSC licensing process. 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.

Nuclear Power in Canada

Nuclear technology plays an important role in Canada, and it has done so for more than 60 years. Canada was one of the first nations ever to demonstrate 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. And it was the second nation in the world to build and operate a multi-unit commercial nuclear power station, Pickering NGS.

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 and 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 one of the very few nations to innovate and deploy nuclear reactor technology. In fact, the Pickering NGS under review for licence renewal today was the first full-scale commercial CANDU nuclear power plant ever built. It was preceded by two nuclear demonstration plants, NPD at Rolphton and Douglas Point on Lake Huron.

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 2012

Reactor	In Service	Capacity (MW)	Performance In 2012 (%)	Lifetime Performance (%)
Point Lepreau	1983	680	0*	55.4
Gentilly 2	1983	675	71.9	76.9
Wolsong 1	1983	622	80.1	87.9
Wolsong 2	1997	730	92.7	94.1
Wolsong 3	1998	729	88.8	94.9
Wolsong 4	1999	730	98.6	96.1
Embalse	1984	648	65.8	83.8
Cernavoda 1	1996	706	87.5	89.7
Cernavoda 2	2007	705	98.8	94.8
Qinshan 4	2002	700	96.3	91.1
Qinshan 5	2003	700	90.5	91.2
Pickering 1	1971	542	64.7	64.2
Pickering 4	1973	542	73.6	65.7
Pickering 5	1983	540	98.0	74.0
Pickering 6	1984	540	96.8	78.6
Pickering 7	1985	540	66.2	77.9
Pickering 8	1986	540	65.6	76.5
Bruce 3	1978	750	51.6	64.0
Bruce 4	1979	750	57.5	64.4
Bruce 5	1985	817	98.4	84.5
Bruce 6	1984	817	99.7	81.5
Bruce 7	1986	817	99.7	84.5
Bruce 8	1987	787	85.6	82.6
Darlington 1	1992	934	94.9	85.1
Darlington 2	1990	934	93.6	79.3
Darlington 3	1993	934	83.3	86.6
Darlington 4	1993	934	98.2	86.8
Total/Average		19,643	81.4	81.2

COG CANDU/PHWR Performance Indicators, December 2012.
**These reactors were under reconstruction during part or all of 2012.*

In total, these reactors have produced more than 3200 TWh of electricity during their years of operation. To put that in perspective, the *OECD 2011-12 Factbook* notes that based on 2009 figures world total electricity production from all sources was:

Table II: 2009 World Electricity Production

	Capacity(GW)	Energy(TWh)	Share(%)
Coal	942.6	8263	41
Oil	126.7	1111	5
Natural Gas	490.7	4301	21
Hydro	375.1	3288	16
Nuclear	311.6	2731	13
Other	64.8	568	3

OECD/NEA Factbook, 2010-11

From an 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. 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. While gas, with its low fixed costs and high fuel costs works best as a peaking power source.

For Canada, electricity consumption from all sources is approximately 550 TWh annually. Canada is the seventh largest electricity jurisdiction in the world:

Table III: World's largest electricity jurisdictions

	Consumption(TWH)
China	4940
USA	3886
Russia	1016
India	906
Japan	858
Germany	607
Canada	550

CIA World Factbook, 2008

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 the cleanest large electricity system 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.

The Importance of Electricity in Ontario

Ontario is home to nearly one-third of all Canadians. It also represents more than one-third of Canada's total GDP. Since the turn of the last century, Ontario has been and remains Canada's industrial heartland. It contains a mix of primary, secondary and tertiary industry.

Ontario is unique in the world as an industrial centre. During the 19th century, industrial centres started to emerge in Europe and the United States. Virtually without exception, all of these emerged close to or within large coal-fields in Britain, France, Germany and the United States. And to this day, proximity to fossil fuels remains a key energy resource for industrial development.

However, Ontario is an exception. Ontario has no significant deposits of fossil fuels. All of these must be imported from outside the province. Its industrial development, in large measure triggered by the Second World War, was based upon the ready supply of low cost electricity. During the 20th century, Ontario went through three phases of development to provide this. Starting at the beginning of the century, Ontario began large scale development of hydraulic generation, principally the Sir Adam Beck station at Niagara Falls.

By 1950 however, it had become apparent that hydraulic development would not be capable of sustaining further expansion of Ontario's industrial base. After the completion of Adam Beck and R.H. Saunders, only much smaller projects remained available, particularly after Ontario rejected development of its rivers flowing into Hudson's Bay. So Ontario turned to coal-fired generation, based on coal imported principally from the Ohio River basin.

The use of coal posed a different set of problems for Ontario. It was dependent upon the availability of US supply and vulnerable to interruptions in lake shipments. It worsened the balance of payments between Canada and the United States. And it was subject to significant labour interruptions.

It was for these reasons that Ontario began its program of nuclear development starting in the 1950s. Initially it was expected to be a supplement to Ontario's then-base load mix of hydraulic and coal. However, the program demonstrated that it was in fact capable of meeting all of Ontario's base load electricity requirements. This resulted in the extensive construction program from the mid-1960s to 1993.

Today, this situation remains unchanged. Nuclear power is the principal base load electricity supply for the province. During 2012, Ontario's nuclear reactors produced more than 90 TWh of electricity during the year, coming close to the 98 TWh produced in Ontario in 1994. And this situation of reliance on nuclear for the bulk of Ontario's electricity supply will not change over the course of at least the next 10 years.

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 Generation – 2012

	MW	**%Share**
Nuclear	12 998	36.2
Gas	9987	27.9
Hydro	7939	22.2
Coal	3293	9.2
Wind	1511	4.2
Other	122	0.3

IESO, http://www.ieso.ca/imoweb/media/md_supply.asp

In total, Ontario has approximately 35,858 MW of installed generating capacity. What this table shows is that two-thirds of Ontario's raw generating capacity comes from energy sources with no gaseous emissions, nuclear, hydraulic and wind. More than half of that generating capacity is found in nuclear, with most of the rest coming from hydraulic generation.

However, actual energy production varies considerably from the proportion of generation shown above.

Table VI: Ontario's Electricity Production – 2012

	Energy(TWh)	%Share
Nuclear	85.6	56.4
Hydro	33.8	22.3
Gas	22.2	14.6
Wind	4.6	3.0
Coal	4.3	2.8
Other	1.3	0.8

http://www.ieso.ca/imoweb/media/md_newsitem.asp?newsID=6323
Ontario's electricity generation

The share of nuclear and hydraulic in actual electricity produced is considerably higher than their share of installed generating capacity. As Ontario's lowest operating cost sources of electricity, they operate largely as base load facilities, running as much of the time as possible at nominal capacity.

Ontario's generating capacity has changed considerably over the past 10 years.

Table VII: Changes to Ontario's Generation – 2003-2012

Station	**Type**	**MW**
2003		
Pickering 4	nuclear	515
Bruce 4	nuclear	770
2004		
Bruce 3	nuclear	782
Brighton Beach	gas	580
Kirkland Lake	gas	32
Beck and Kipling upgrade	hydro	80
2005		
Pickering 1	nuclear	515
Lakeview retirement	coal	(1130)
2006		
Toronto Airport	gas	117
Amaranth	wind	68
Kingsbridge	wind	40
Port Burwell	wind	99
Prince	wind	99
Prince II	wind	90
2007		
Abitibi upgrade	hydro	20
Ripley	wind	76
2008		

Portlands	gas	394
Greenfield	gas	1153
Umbata Falls	hydro	24
Kruger	wind	101
Melancthon II	wind	132
2009		
St. Clair	gas	678
Portlands CC	gas	246
Goreway	gas	942
Beck 7 conversion	hydro	69
Beck 2 upgrade	hydro	68
Enbridge	wind	182
Wolfe Island	wind	198
East Windsor	gas	100
2010		
Thorold	gas	287
Halton Hills	gas	705
Nanticoke, Lambton	coal	(2000)
Fort Frances conversion	biomass	47
Kruger – Chatham	wind	101
2011		
Gosfield	wind	50
Spence	wind	99
Talbot	wind	99
Nanticoke 1,2	coal	(980)
2012		
Greenwich	wind	99
Atikokan	coal	(211)
Bruce 1, 2	nuclear	1552
York	gas	438

http://www.ieso.ca/imoweb/media/md_supply.asp

There are several trends to note from this list. First, over the past 10 years, six nuclear reactors, Pickering 1, 4, and Bruce units 1-4 have been returned to service after their shutdown in the 1990s.

Second, Ontario has retired all but four of its coal-fired units. Lambton, Lakeview and Atikokan have been shut completely, while only half of Nanticoke, units 5-8 remains in service at this time.

Third, while Ontario has introduced approximately 1500 MW of wind generating capacity onto the system, this has been insufficient to compensate for the loss of more than 4,000 MW of coal-fired generation. The gap has largely been covered by the return to service of six idled nuclear power reactors along with the construction of roughly 5500 MW of gas-fired generation.

Under the old Ontario Hydro, nuclear and hydraulic were used for baseload generation. Coal and some very small amounts of oil- and gas-fired generation were used to meet peak demands.

Under the new system however, things look rather different. Nuclear and hydraulic continue to be used for baseload production, while peaking demand is now largely met by gas. It should be noted that wind generation is neither base load or peaking. This is because the low capacity factors for wind mean it cannot fill a meaningful base load role, while its incapacity for dispatch means it cannot fill a peaking requirement either.

In general then, with respect to meeting peak demand, Ontario has replaced about 4000 MW of coal with about 6500 MW of a mix of wind and gas, mostly gas.

This system has resulted in a change to Ontario's electricity import and export balance as well. During the late 1990s, Ontario was importing a net of about 2 TWh annually. For the past five years, however, Ontario has been exporting an average of about 10 TWh annually. Because of the unpredictability of wind generation however, the timing of electricity exports is now occasionally forced rather than voluntary on the part of IESO (Independent Electricity System Operator).

Because wind generation has been given right of way on Ontario's electricity grid, this in turn has resulted in impacts on the operation of some nuclear plants. Operators must now conduct a number of reactor maneuvers not previously a feature of the old Ontario electricity system.

Importance of Pickering NGS in Ontario's electricity supply

At this time, the Pickering nuclear power station consists of six operating reactors, Pickering Units 1 and 4, and Pickering Units 5-8. The performance characteristics of these reactors is shown below:

Table VIII: Characteristics of the Pickering Reactors

Reactor	In Service	Capacity (MW)	Performance In 2012 (%)	Lifetime Performance (%)
Pickering 1	1971	542	64.7	64.2
Pickering 4	1973	542	73.6	65.7
Pickering 5	1983	540	98.0	74.0
Pickering 6	1984	540	96.8	78.6
Pickering 7	1985	540	66.2	77.9
Pickering 8	1986	540	65.6	76.5
		3246	**77.5**	**74.5**

COG CANDU/PHWR Performance Indicators, December 2012.

In total, these reactors have produced

Table IX: Pickering Lifetime Generation

Reactor	Lifetime Gross (TWh)
Pickering 1	103
Pickering 4	105.7
Pickering 5	104.5
Pickering 6	108.1
Pickering 7	103.2
Pickering 8	97.3
	621,8

Nucleonics Week 02/14/13

Given that Ontario consumes approximately 150 TWh of electricity from all sources annually, this means that the Pickering reactors have produced enough electricity by themselves to power the province of Ontario for more than four years. On an annual basis, these reactors produce between 3 and 4.5 TWh each. This total production of 18 to 27 TWh constitutes 12 to 18 per cent of Ontario's total annual electricity consumption.

This amount is at least three to six times the electricity production of Ontario's entire existing fleet of 1500 wind turbines on an annual basis. Replacement of electricity generated by Pickering is thus not possible through renewable sources for either the near or medium term. Approximately an additional 10,000 wind turbines would be required to replace the raw kWh production from the Pickering reactors.

And given that, as noted above, wind cannot produce electricity to meet base load requirements, the loss of Pickering and replacement by wind would result in two signficant effects:

1. A substantial rise in the cost of electricity with the loss of low cost base load generation;
2. Reduced reliability of the electricity supply, given the variable nature of wind generation.

The effect of reduced reliability means that additional generating capacity must be built to provide electricity during those times when the wind does not blow. This backup generation also cannot be provided during the short term and possibly the medium term in the event of the loss of Pickering's generating capacity.

Nor can the deficit of lost generation at Pickering be compensated for by increased imports of electricity from other jurisdictions. Ontario has a total import/export capacity of 4800 MW, including connections to the provinces of Quebec and Manitoba, and the states of New York and Michigan. These interconnections with other utilities are already in extensive use, however. Electricity imports cannot be greatly increased without significant additions, and these certainly cannot be put in place over the short term.

Grid Reliability

Finally it should be noted that Pickering is the closest power station to Ontario's dominat load centre, Metropolitan Toronto. This importance has become even greater in recent years with the closure of the Lakeview coal-fired station in 2005.

Stability of an electric grid is dependent to some degree on proximity between supply and demand. The closer the two, the less likelihood of power interruptions or distortions. The importance of proximity was shown by the great ice storm in 1998. With all of the transmission lines from northern Quebec down, the only supply of electricity into the city of Montreal for nearly three weeks was that from the Gentilly 2 nuclear power station near Trois Rivieres.

Pickering therefore has great value, not just because of its raw electricity production, but because of where that production is located. Pickering fill a vital role in overall reliability of Ontario's electricity system.

Technical Importance of Pickering

For any technology, whether it be nuclear power or any other form of advanced industrial technology, reference plants are important. Industrial systems age over time. Components wear out, usually in highly specific ways and must be replaced. The sheer number of age-related methods of materials degradation is much too large to discuss here in detail.

This is why original reference plants are important. As they age, they provide scientists and engineers enormous quantities of information about age-related degradation common to the technology. This information provides essential guidance in understanding the future maintenance needs of such facilities. By understanding these degradation mechanisms, new material or other solutions can be developed to ameliorate or prevent such degradation.

This applies to nuclear technology. For well over 20 years, the long term maintenance of nuclear facilities has become of great importance to nuclear operators including those in Ontario. This has resulted in a variety of best practices including predictive and preventive maintenance. Specifically, it is a large enhancement to the safety of nuclear facilities when the failure of components can be predicted accurately, allowing them to be replaced in a predictable schedule rather than requiring their replacement during a forced outage.

And this highlights the safety importance of the Pickering reactors. Canada's oldest full scale prototype reactors which used to provide this information were NPD-2 and Douglas Point. Both of these reactors were shut down many years ago and can no longer fill this role. The oldest operating full-scale CANDU reactors are now Pickering Units 1 and 4, after more than 40 years in service. And as such, they provide vital information about the performance characteristics and obstacles that reactor operators need to ensure reliable future performance over the long term for all CANDU reactors.

This reason by itself is not sufficient to continue operation of the Pickering NGS, but it is an important additonal consideration.

Conclusions

The CNS is therefore of the view that operation of the Pickering 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 Pickering is an essential part of that base load electricity supply.
3. Any premature loss of generation from Pickering cannot be met in the short term by either construction of new generating facilities or by increased imports from other jurisdictions.
4. The Pickering reactors provide important technical information on age-related degradation, and its prevention, not available from other sources.

Therefore, the CNS supports the application by Ontario Power Generation (OPG) for the renewal of its operating licence for the Pickering nuclear power station.