Brief presented to

Le Bureau d'audiences publiques sur l'environnement

Modification of Radioactive Waste Storage Facilities and Refurbishment of Gentilly-2 Nuclear Power Plant

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Bécancour, Québec

Nuclear Power in Quebec

Summary

The Canadian Nuclear Association welcomes the opportunity to support the refurbishment of the Gentilly-2 nuclear reactor and participate in the public consultations held by the Bureau d'audiences publiques sur l'environnement (BAPE).

The CNA believes that the Gentilly-2 nuclear reactor provides essential, low-cost base-load electricity supply for Québec. Nuclear electricity is safely produced, free from air emissions and is reliable.

Nuclear power generation from Gentilly-2 serves as a useful complement to Hydro-Quebec's system based primarily upon hydraulic generation. Simply put, Gentilly-2 allows Hydro-Québec to better manage and operate its transmission and distribution systems. The CNA also believes that the renovation of Gentilly-2 by Hydro-Québec is part of the resurgence in the renovation of existing nuclear reactors in developed countries and part of a growing and strengthening nuclear industry at home.

Throughout the past 30 years, nuclear power has been and remains the fastest growing source of large-scale electrical generation throughout the industrialized nations. In this paper, the CNA will address the following issues:

1. The roles of nuclear power in Hydro-Quebec's electricity supply system;

2. The size and importance of Canada's nuclear industry, in which industries in Quebec play a leading role;

3. The development of new nuclear power around the world and the renovation of existing nuclear reactors;

4. The benefits of nuclear power;

5. The three traditional concerns: safety, nuclear waste, and non-proliferation.

This paper will show that, nuclear power offers clear benefits for electric power generation. Nuclear power is reliable, low cost, base load generation and it is a strong environmental performer.

Like hydroelectricity, nuclear power offers strong economic advantages when used to generate electricity. These include low fuel cost.

1. The role of Gentilly-2 and electricity supply in Québec

Gentilly-2 is a 675 MW CANDU-6 nuclear plant owned and operated since 1983 by Hydro-Québec. It provides a continuous base-load supply of reliable, low cost, non-emitting electricity. The plant is located near the large load centers in the St. Lawrence Valley and makes a substantial contribution to the stability and reliability of Hydro-Québec's transmission system. The plant supplies 3% of the electricity generated by Hydro-Québec or about 5 TWh a year. In the 21 years it has operated, Gentilly 2 has maintained a capacity factor that compares favourably to other nuclear plants. It does not depend on rainfall and gravity and is a reliable workhorse for the province.

Like all nuclear power plants operating in Canada, Gentilly-2's operation is highly regulated and carefully monitored. The Canadian Nuclear Safety Commissions (CNSC) regulates the operations. Inspection and monitoring staff from the CNSC are permanently located at the plant.

In addition to maintaining a reliable, safe, profitable facility for the grid, the plant and its refurbishment maintain a high degree of nuclear expertise that is recognized worldwide and applied to the almost 700 workers. The regional economy benefits from the plant. The benefits generated in terms of employment and the purchases of goods and services, and the indirect support for local industry and businesses are important.

Hydro-Québec makes an important contribution to cancer treatment at home in Québec, around the world and to medical sterilization by producing Cobalt-60 at Gentilly-2. Approximately 75 per cent of Cobalt-60, used as a gamma source for both cancer treatment and medical sterilization, is from Canada. There are some 1200 cobalt–60 machines around the world. It is estimated that these machines deliver about 15-million cancer treatment every year. Québec benefits directly from Cobalt-60.

Nuclear power in Québec has had a powerful effect in improving air quality. In the case of the Gentilly-2 nuclear reactor, compared to a coal-fired station producing the same amount of electricity, this unit avoids each day:

- 14,000 tonnes of carbon dioxide;
- 200 tonnes of sulfur dioxide; and
- 700 tonnes of soot and ash.

2. The Nuclear Industry in Canada

In total, the nuclear industry in Canada employs approximately 21,000 workers, with a disproportionately high number having post secondary science or engineering education.

Some of the key economic indicators for Canada's nuclear industry are as follows:

- 21,000 direct employment, 10,000 indirect employment;
- $5 billion revenues annually;
- $1.2 billion annual exports
- 150 companies in nuclear industry in Canada;

In addition to the reactor at Gentilly-2, Canada's nuclear reactor fleet consists of 21 CANDU nuclear reactors: 20 in Ontario and one in New Brunswick. These nuclear reactors and some of their characteristics are outlined in Table 1.

Table 1: Nuclear Reactors in Canada – 2002
CANDU Nuclear Reactor Performance - December 2002

Reactor	Performance In 2002 (%)	Lifetime Performance (%)
Point Lepreau	68	82.9
Gentilly 2	**81.9**	**79.6**
Wolsong 1	99.1	85.6
Wolsong 2	91.6	91.7
Wolsong 3	95.8	92.5
Wolsong 4	94.7	95.4
Embalse	83.6	84.2
Cernavoda 1	89.4	87.5
Pickering 5	59.4	73.7
Pickering 6	89	78.7
Pickering 7	94.7	82
Pickering 8	80.4	76.2
Bruce 5	86.6	82.8
Bruce 6	51	78.6
Bruce 7	69.7	81.7
Bruce 8	96.4	80.7
Darlington 1	85.4	82.7
Darlington 2	94.9	71.3
Darlington 3	81.2	83.2
Darlington 4	97.2	84.7
Average	84.5	82.7

COG Station Performance Oct. 2002-Dec.2002

Each year, Canada's nuclear reactors produce approximately 75 TWh of electricity, or about 16 per cent of Canada's total electrical energy production from all sources. The dependency upon nuclear power varies among the three provinces with nuclear power. Ontario depends upon nuclear power for the majority of its base-load electricity, approximately 45 to 50 per cent of total electrical energy demand. In New Brunswick, nuclear power accounts for 30 to 35 per cent of that province's electricity supply, while in Québec, nuclear power accounts for about 3 per cent of electricity supply.

In the case of uranium for fuel supply, Canada provides about 30 to 35 per cent of the world's commercial uranium. Its uranium reserves are such that Canada is the low cost producer of uranium in the world, thanks to very large, very rich deposits of uranium in Saskatchewan's Athabasca Basin. Fuel for Gentilly-2 will always be available as the supply is from domestic sources.

3. New nuclear power around the world

At the end of 2003, 438 nuclear power reactors were in service in 31 countries around the world. In total, these nuclear reactors represented 360,000 MW of nuclear power generation, producing a total of approximately 2600 TWh during the year. This represents about 17 per cent of the world's electricity supply, or about seven per cent of total primary energy supply.

The world's nuclear reactors are disproportionately concentrated in the OECD nations, where they produce about 25 per cent of those nations' electricity. A list of nations with nuclear power is shown in Table 2.

Table 2:World Reactor Capacity - December 2003

Country	Operating		Planned or Under Construction		Electricity Generation (2002)	
	No	MW	No	MW	%	TWh
Argentina	2	935	1	692	7.2	5.4
Armenia	1	376			41	2.1
Belgium	7	5 728			57	44.7
Brazil	2	1 855	1	1 245	4	13.8
Bulgaria	6	3 538			47	20.2
Canada	16	11 282	4	2 314	13	71
China	8	6 002	7	6 335	1.4	23.5
Czech Republic	6	3 472			25	18.7
Finland	4	2 656	1	1 000	20	21.4
France	59	63 203			78	415.5
Germany	18	20 609			30	162.3
Hungary	4	1 755			36	12.8
India	14	2 550	9	4 168	3.7	17.8
Iran			2	1 900		
Japan	53	44 153	15	19 554	39	313.8
Korea, N			2	1 900		
Korea, S	18	14 870	10	11 100	39	113.1
Lithuania	2	2 370			80	12.9
Mexico	2	1 310			4.1	9.4
Netherlands	1	452			4	9.4
Pakistan	2	425	1	300	2.5	1.8
Romania	1	655	1	655	10	5.1
Russia	30	20 793	6	5 575	16	130
Slovakia	6	2 472			65	18
Slovenia	1	679			41	5.3
South Africa	2	1 842			5.9	12
Spain	9	7 405			26	60.3
Sweden	11	9 460			46	65.6
Switzerland	5	3 170			40	25.7
Taiwan	6	4 884	2	2 600	21	33.9
UK	27	12 082			22	81.1
Ukraine	13	11 195	2	1 900	46	73.4
USA	104	98 622			20	780.1
Total	**438**	**360 074**	**64**	**61 238**	**16**	**2574**

Notes
All figures taken from the World Nuclear Association

As shown in the table, a further 64 nuclear reactors with a total capacity of approximately 61,000 MW are under construction or planned. The majority of these new nuclear reactors are concentrated in rapidly industrializing Asian countries. These numbers do not include the recent announcements by China of a new nuclear building program of 12 new nuclear reactors over the next decade.

Nuclear power is experiencing renewed growth among nations with existing nuclear reactor fleets.

USA

In the United States of America where most of the nation's 104 nuclear reactors are privately owned, utilities are investing in large capital projects to maintain and improve the performance and production from their nuclear plants. The utilities are seeking 20-year licence extensions from the U.S. Nuclear Regulatory Commission (NRC). To date, approximately 30 nuclear reactors have received licence extensions, and the NRC now expects that virtually all of the owners of nuclear reactors will make licence extension applications for their reactors.

The United States government has initiated a program to have one or more new nuclear plants start construction before 2010. This program provides matching funding to applicants to assist in deferring licencing and regulatory costs. Three consortia have been formed thus far, making detailed proposals in May-June, 2004. The U.S. Department of Energy provided its first major funding announcement for these consortia when it approved their project proposals in November 2004. One of the consortia, headed by Dominion Energy, is based upon the Advanced CANDU Reactor technology of Atomic Energy of Canada Limited (AECL).

France

New nuclear development is occurring in other nations with mature nuclear power programs. Électricité de France (EdF) has recently announced its decision to build its new 1600 MW European Pressurized Reactor (EPR) at its Flamanville nuclear power station. The new project is part of a long term plan by EdF to renovate its existing 58 nuclear power reactors, to extend their productive life and to build new nuclear reactors as a bridge to new reactor technology expected to be available by the middle of the 21st century.

Finland

Also building new nuclear capacity is Finland with its decision to build its fifth reactor at Olkiluoto this year. Finland needs more base-load power to compensate for reduced power available for import from Sweden and a need to reduce imported electricity from Russia.

Sweden

A number of European countries have introduced moratoriums or phase-out of nuclear power over the past decade. In many cases, these are now being re-considered. Sweden

closed one nuclear power reactor at Barsebaeck in 1999 and has ordered the second closed in 2005. However, Swedish utilities are engaged in an extensive program to increase generating capacity and prolong the service life of Sweden's 10 remaining nuclear reactors. Swedish government-owned Vattenfal has started a program to generate more than 200 additional megawatts from its four nuclear reactors at its Ringhals nuclear power station.

Belgium
In Belgium, despite the government's official nuclear phase-out policy, the electric utility Electrabel has started planning for new nuclear construction after the government began publicly discussing abandoning the country's phase-out policy.

China
It is in Asia where nuclear power is currently experiencing its strongest growth. More than 30 nuclear reactors are planned or under construction in China, Japan and India. In the case of China, that country has been experiencing electrical load growth of more than 15 per cent annually for each of the past four years, and there is no sign that the rise in demand is slowing at any time in the near future. Complicating matters is that the growth is occurring in central and southern China where lack of transportation and cost prevents the use of large coal supplies from Manchuria to meet demand. In southern China, only nuclear power is capable of meeting the demand for residential and industrial electricity supply. This strong demand is the reason for China's recent announcement of eight new reactors to be built and in service before 2012.

Japan
Unlike China, Japan has a mature, fully developed nuclear power program with 57 nuclear plants in service. A further 15 are under construction or planned. The Japanese government has indicated that increased use of nuclear power will be its principal program to meet its Kyoto Protocol commitment to reduce greenhouse gas emissions.

4. Benefits of Nuclear Power

Nuclear power offers clear benefits for electric power generation:

- reliable, low cost, base load generation
- environmental performance

Like hydroelectricity, nuclear power offers strong economic advantages when used to generate electricity. These include low fuel cost.

Economic Benefits
The fuel of nuclear power plants, uranium, is both plentiful and widely available. Moreover, because nuclear fuel is a very small part of the overall cost of nuclear power generation, large changes in the price of uranium, such as have occurred in the past 10 months, affect the cost of electricity from nuclear power very little. With respect to uranium, low cost supplies of uranium at less than $75 U.S./lb. are expected to be widely

available for most of this century, given current known reserves reported by the OECD/NEA.

The low fuel cost for nuclear power means that, like hydroelectricity, the cost of nuclear power generation remains generally constant throughout the life of the plant. The same cannot be said for fossil fuels, where fuel purchase constitutes as much as 50 per cent of the cost of generation in the case of coal or 90 per cent in the case of natural gas. It is noteworthy that the market price for natural gas has more than doubled over the last two to three years, meaning that the price of electricity from natural gas generation has also doubled. Less noticed is that the recent rise in oil and gas prices has also produced a doubling of the cost of steam coal, with consequent effects on the cost of electricity from this fuel.

For a jurisdiction such as Quebec, which has a relatively high dependency upon electric home heating compared to other regions in Canada, stability and predictability of electricity costs is of great importance. Only hydro and nuclear generation provide that needed long term cost stability.

Environmental Benefits

Nuclear power offers strong advantages over any other thermal source of generation because of the environmental impact of nuclear power. Nuclear power plants emit no carbon dioxide, no sulfur dioxide and no nitrous oxides. Where nuclear power displaces fossil fuels for electricity generation, such as occurred in Ontario and France during the 1970s and 1980s, the result has been a large drop in atmospheric emissions of these gases along with heavy metal and particulate emissions.

Compared to coal-fired electrical generation, each nuclear reactor such as Gentilly-2 avoids approximately 5 million tonnes of carbon dioxide emissions each year. It is true that there may well be some carbon emissions associated with nuclear power on a life cycle basis, principally through construction of the plant or the mining of uranium and manufacturing of its fuel. The Japanese Central Research Institute of the Electric Power Industry calculated the carbon emissions in Table 3. These results are reported in the following table.

Table 3: Carbon Dioxide Emissions (g/kWh)

Coal:	975 g
LNG Thermal:	608 g
LNG Combined Cycle:	519 g
Solar PV:	53 g
Wind:	29 g
Nuclear:	22 g
Hydroelectric:	19 g

It should be noted that this study used enriched fuel and boiling water reactors for their calculations. Because CANDU reactors use natural uranium without enrichment, the life cycle carbon emissions from CANDUs such as Gentilly-2 will be considerably lower than reported in this table.

5. Traditional Concerns being addressed

The public had traditionally found three areas of concern regarding the development of nuclear power: safety, waste and proliferation.

Safety

The safety record of Canada's nuclear industry is flawless: no nuclear plant worker has lost time off the job as a result of a radiation-related accident in the history of nuclear power generation. Even in non-radiation related accidents, the nuclear power generation industry is far safer than conventional industrial practice. The average industrial accident rate is approximately four per 100,000 hours worked, but in the nuclear industry it is typically 0.5/100,000 hours. Moreover, Canada's nuclear industry on average reduces its already low industrial accident rate each year. Quite simply, working in a nuclear power plant is safer than living at home.

The safety of nuclear power plants relative to other forms of electricity generation was demonstrated by the safety study of energy system accidents done by the Paul Scherrer Institut (PSI) for the federal government of Switzerland. PSI maintains one of the world's largest databases on energy system accidents. The results of their study are indicated in the three tables in **Annex 1**.

Waste

Nuclear power is the world's most efficient source of thermal power generation with respect to the quantity of fuel required to produce energy. The following table shows the quantity energy produced from similar amounts of fuel.

Table 4: Electricity from Thermal Generation

1 kg coal	= 3 kWh
1 kg oil	= 4 kWh
1 kg natural gas (1.4 cubic meters)	= 5.8 kWh
1 kg uranium	= 60,000 kWh

Nuclear waste differs from those of fossil fuels in that nuclear fuel results in vastly smaller quantities of waste. However, nuclear waste is all solid, principally in the form of oxidized uranium. The total quantity of nuclear waste from all of Canada's nuclear power reactors operating since the early 1960s is quite small, about 30,000 tonnes. Typically, each nuclear reactor such as Gentilly-2 will use about 20 cubic meters of nuclear fuel annually, approximately 100 tonnes. Historically, that small quantity of waste has produced 1870 TWh of electricity. Producing this quantity of electricity from coal would have resulted in the use of 970 million tonnes of coal or 620 million tonnes of oil.

A further advantage of nuclear waste is that because it is oxidized, it is chemically inert. Its principal hazard is its radioactivity. Nuclear fuel is highly radioactive when first removed from the nuclear reactor, but both its radioactivity and its thermal heat decay

rapidly. After five years in water storage in the nuclear power station, the used fuel can be removed and placed in dry storage containers such as those found at Gentilly-2. The fuel can be stored in this fashion indefinitely or until such time as a decision is made on an option for its long-term management.

For the long-term management of used nuclear fuel, Canada is consulting with the public on approaches for managing nuclear fuel waste. The Nuclear Waste Management Organization (NWMO) will propose approaches to the Government of Canada in late 2005 on managing used nuclear fuel.

Proliferation

Canada has an extensive program to ensure that Canadian nuclear technology is not diverted for use in nuclear weapons. Trade in nuclear technologies is only permitted with those countries with which Canada has a Nuclear Co-operation Agreement. In addition, Canada requires that all countries be signatory to the Non-Proliferation Treaty as a condition of being allowed access to Canadian nuclear technology.

To ensure that used nuclear fuel is not diverted into weapons programs, it is monitored constantly at all nuclear reactors and fuel processing facilities by the IAEA.

Conclusions

- Gentilly-2, a 675 MW CANDU 6 reactor, started to deliver electricity to Hydro-Québec's grid in 1983. Hydro-Québec has been efficiently managing its nuclear program for more than 30 years.

- In 2002, Gentilly-2 performed at 81.9% and has a lifetime performance rate of 79.6%.

- Gentilly-2 generates 3% of Québec's electricity and plays an important in the production of electricity due to its excellent performance, profitability and contribution to the network.

- With a design life expectancy to 2013, Hydro-Québec is currently evaluating the feasibility of refurbishing Gentilly-2 to extend its operating life for an additional 30-40 years.

- The CNA supports the proposal by Hydro-Québec to proceed with refurbishment of Gentilly-2 as it provides low cost, reliable and non-emitting electrical generation near the large load centres in the St. Lawrence Valley.

ANNEX 1

Table 5
Severe accident damage indicators based on worldwide records for the period 1969-1996:

Energy Source	Fatalities per TWa	Injuries per TWa	Evacuees per TWa	Monetary Damage ($ millions U.S. 1996)
Coal	342	70	0	20.4
Oil	418	441	7220	637
Natural Gas	85	213	5900	86.8
LPG	3280	13 900	522 000	1740
Hydro	883	195	34 200	620
Nuclear	8	100	75 700	93 500

Table 6
Severe accident damage indicators based on OECD records for the period 1969-1996:

Energy Source	Fatalities per TWa	Injuries per TWa	Evacuees per TWa	Monetary Damage ($ millions U.S. 1996)
Coal	137	19	0	34.7
Oil	387	439	7410	940
Natural Gas	66	216	4830	110
LPG	1810	7340	481 000	1920
Hydro	4	230	10 100	702
Nuclear	0	0	46 400	1650

Table 7
Severe accident damage indicators based on non-OECD records for the period 1969-1996:

Energy Source	Fatalities per TWa	Injuries per TWa	Evacuees per TWa	Monetary Damage ($ millions U.S. 1996)
Coal	514	113	0	9
Oil	458	444	6980	247
Natural Gas	109	210	7230	58
LPG	7660	33 400	645 000	1200
Hydro	2190	143	70 000	498
Nuclear	53	635	232 000	583 000

CNA has converted the numbers in the study from GWa to TWa so as to provide tables composed of whole numbers.

It should be noted that a TWa (Terawatt-year) is a large quantity of energy. It can be considered to be a quantity of energy approximately equivalent to 15 years of electricity generation in Canada from all sources at current levels.

From this analysis, the PSI drew several conclusions related to the safety of nuclear power as outlined below:

1. Nuclear power is the safest form of energy generation in terms of loss of human life in either OECD or non-OECD nations (pp 291-3).

2. Nuclear power has a high apparent economic cost, but this value is derived from inflated conversion values of Ukrainian currency and is based on two accidents, the 1979 Three Mile Island accident which had no off-site consequences, and the 1986 Chernobyl accident. It should be noted that the cost of the Chernobyl accident is equivalent to the value of about one year's electricity production from the world's 435 nuclear power reactors (p 277).

3. Probabilistic Safety Analyses do not exist for any form of energy generation other than nuclear power. Therefore, the numbers cited for non-nuclear sources must be treated with caution, as actual values may be higher (p 303).

The reason for the high degree of safety in nuclear power generation is very simple. All nuclear power plants are designed with multiple safety systems capable of shutting down the plant under any accident condition. Should these safety shutdown systems all fail, all nuclear power plants are built with overlapping containment systems capable of containing all of the radiation that might be produced under accident conditions. The ruggedness of nuclear containment is perhaps best illustrated by the accident at Three Mile Island in 1979. Despite the scope of the accident, all of the melted nuclear fuel was completely contained within the reactor, there were no injuries or fatalities to plant workers, and there was no measurable release of radiation to the environment.

It should be noted that CANDU reactors such as Gentilly-2 enjoy the strongest protection for safety of any nuclear reactor technology. All CANDU reactors have two independent shutdown systems capable of shutting off the nuclear reaction within seconds.