Canadian Nuclear Association

1960 – 2010

CELEBRATING 50 YEARS:
Seizing Opportunities for Growth

CNA 2010 Factbook
Anniversary Edition

WWW.CNA.CA

2010

Message from the President

On August 26, 1960 the Canadian Nuclear Association (CNA) was created to promote the peaceful use of nuclear technology in Canada. As we celebrate our 50th anniversary, with our proud history and many accomplishments, we look to the future with a vision of maintaining Canada's nuclear leadership role at home and around the world.

Canada is one of the nations that introduced the world to nuclear energy. In the years 1940-1942, George Laurence pioneered the work on the first subcritical reactor at the National Research Council in Ottawa which was one of the first in the world to demonstrate a nuclear chain reaction. This brought international attention to Canada and branded our nation as a leader in cutting-edge science.

Today, Canada's nuclear industry has achieved an unparalleled record of safe, reliable and economic nuclear power generation in three provinces. Nuclear energy is responsible for 15% of Canada's electricity production and for over 55% of Ontario's alone.

To ensure our industry's continued growth, our goals are clear. We want to ensure that:

- Canada remains a global leader in nuclear technology.

- We have a strong research and development program to maintain highly-skilled jobs in Canada and retain our bright young minds at home.
- We are poised to participate in the construction of over 450 reactors in the world creating economic benefits and thousands of high paying jobs for Canadians.
- Nuclear power is recognized as clean and virtually emission-free energy as Canada and the world address the challenges of climate change.

I am pleased to share the CNA's 2010 factbook with you. This edition reflects the most up-to-date information on nuclear energy in Canada and around the world.

I encourage you to learn more about nuclear energy in Canada and to visit our website at www.cna.ca. In addition to facts, news and online publications, you may also view our 50th anniversary video, "Nuclear Technology Working for Canada."

Canada has a unique history of nuclear innovation and achievement. As we build on our past accomplishments, we are seizing opportunities for the future.

Denise Carpenter
President and CEO
Canadian Nuclear Association

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Canada’s Nuclear Industry: Our History

For 62 years, Canada has been a world leader in nuclear research, medicine and electricity production – and renowned for our nuclear know-how. This historic timeline highlights some of our proudest moments.

(1941) In Ottawa, George Laurence was one of the first in the world to demonstrate a nuclear chain reaction.
(1944) The National Research Council built new nuclear research laboratories at Chalk River, Ontario.
(1945) The first major innovation of Chalk River laboratories was called ZEEP, the Zero Energy Experimental Pile. With it, Canada became the second country in the world to use a reactor to control nuclear fission.
(1947) The National Research Experimental reactor commissioned at Chalk River was the world’s most powerful. Its production of isotopes gave Canada the lead in nuclear medicine.
(1951) The first two cancer-treating machines using Cobalt-60 were built by Dr. Harold Johns at the University of Saskatchewan and Roy Errington of Eldorado Mining and Refining.
(1951) The world’s first cancer treatment using Eldorado’s Colbalt-60 machine was performed in London, Ontario.
(1952) Atomic Energy of Canada Limited was created to take over the research labs at Chalk River to pursue nuclear science, technology and commercial applications.

Canada's Nuclear Industry: Our History

(1954) Dr. W.B. Lewis fostered collaboration between Atomic Energy of Canada, Ontario Hydro and Canadian General Electric that led to the development of the CANDU reactors in use around the world today.
(1957) The National Research Universal Reactor was the world's first to refuel while operating at full power.
(1962) The Nuclear Power Demonstration facility was Canada's first electricity-producing reactor.
(1964) Atomic Energy of Canada developed the first commercial sterilizers used to process medical, pharmaceutical and food products.
(1967) The Douglas Point Reactor, on Lake Huron, was Canada's first commercial scale reactor and the forerunner of CANDU.
(1970) The Chalk River labs began conducting ground- breaking research in human cell genetics, significantly advancing medical research programs around the world.
(1973) When Pickering A was completed, it produced more electricity than any other nuclear power station in the world.
(1983) CANDU reactors held 7 of the top 10 places for lifetime performance worldwide.
(1987) The Bruce Nuclear Power Development was the largest nuclear site in the world.
(1987) CANDU was honoured as one of the top 10 Canadian engineering achievements of the past century.



Canada's Nuclear Industry: Our History

(1993) Canada had 22 nuclear reactors in Ontario, Québec and New Brunswick.

(1994) Alberta's Dr. Bert Brockhouse won the Nobel Prize for Physics – for his work on materials research using neutrons at Chalk River.

(1996) The sale of two CANDU reactors by AECL to China was the largest contract between China and Canada.

(2003) The CANDU units in China were delivered four months ahead of schedule and under budget. The project holds the record for the shortest construction schedule ever accomplished for a nuclear power plant in China.

(2005) Pickering A Unit 1 was returned to commercial service following the voluntary lay-up as part of Ontario Hydro's nuclear improvement program.

(2008) New Brunswick Power began refurbishing the Point Lepreau generating station. Prior to the refurbishment, it provided up to 30% of New Brunswick's electricity.

(2008) Hydro-Québec announced the refurbishment of Gentilly-2 nuclear generating station in Bécancour, extending its operation until 2035.

(2009) Nuclear energy generated over 55% of Ontario's total electricity.

(2010) OPG announced plans to proceed with the detailed planning phase for the mid-life refurbishment of Darlington Nuclear.

Canada's Nuclear Industry Today: Facts

- Nuclear energy in Canada is for peaceful purposes – used only for electricity generation, medicine, agriculture, research and manufacturing.
- Nuclear power is safe and one of the highest monitored industries in Canada.
- For 48 years, Canada's nuclear industry has achieved an unparalleled record of safe, reliable and economic power generation in three provinces.
- Canada is one of the world's largest producers of natural uranium.
- Canada's nuclear sector is a $6.6 billion per year industry generating $1.5 billion in federal and provincial revenues from taxes, providing 71,000 jobs (21,000 direct, 10,000 indirect [contractors to the industry] plus 40,000 spin-off jobs). It represents 150 firms and $1.2 billion per year in exports. *(Source: Canadian Energy Research Institute (CERI) 2008).*
- In 2009: 22 CANDU Reactors – 17 in service cleanly and safely generating 14.8% of the country's electricity, – 55.2% in Ontario and 3% in Québec.
- In 2009 in Ontario: 20 reactors – 16 in service providing 55.2% of the province's electricity coming from 12,024 MW (Gross) of installed electrical nuclear capacity *(Source: CANDU Owners Group (COG)/Pressurized Heavy Water Reactor (PHWR)* Performance Indicators, Dec 2009).
- Canada has the world's largest known high-grade natural uranium deposits in Saskatchewan.
- Canada provides over 50% of the global supply of medical isotopes for nuclear medicine used in over 50,000 procedures per day — 5,000 of those in Canada.

Canada is a World Leader in Uranium

- Canada is one of the world's largest producers of natural uranium supplying over 20% of the world's demand *(Source: World Nuclear Association- World Uranium Mining, April 2010).*
- Canadian uranium is used exclusively for the generation of electricity at nuclear power plants with end use strictly enforced by international non-proliferation agreements and export restrictions.
- The two major uranium mining companies in Canada are Cameco Corporation and AREVA Resources Canada Inc.
- Electricity generated from Canadian uranium worldwide avoids nearly 700 million tonnes of CO2 emissions annually (Sources: Canadian Nuclear Association (CNA) & World Nuclear Association (WNA) 2009).
- Uranium is a metal, common and abundant in nature, found in most rocks, soil, rivers, oceans, food and the human body. It is a unique element because of its potential to generate huge amounts of energy.
- Saskatchewan's uranium reserves contain about four times more energy than all known Canadian conventional oil reserves (not including Canada's oil sands).
- Saskatchewan's McArthur River and Cigar Lake deposits are the world's richest with average ore grades of more than 100 times the global average for uranium mines. The energy contained in these deposits is equivalent to 15 billion barrels of oil or more than four billion tonnes of coal.
- Saskatchewan-based Cameco alone accounted for about 16% of the world's uranium production in 2009. Cameco is also involved in exploration projects in Saskatchewan, Nunavut, the Northwest Territories and Québec and operates a uranium refining facility at Blind River, Ontario and conversion and fuel manufacturing facilities at Port Hope and Cobourg, Ontario.

Canada is a World Leader in Uranium

- AREVA Resources Canada based in Saskatoon, mines and mills uranium in Saskatchewan and is exploring for uranium in several provinces as well as in Nunavut. AREVA Resources is part of the AREVA group, the largest miner of uranium in 2009.
- There is ample uranium in the world to fuel nuclear power plants today and in the future.
- The Canadian Energy Research Institute (CERI) has found that the mining and fuel production, operation and waste disposal of nuclear plants produces just 1.8 grams of carbon dioxide per kilowatt-hour (g/kWh), compared to 540 g/kWh for gas-fired plants, and 1,050 g/kWh for coal-fired plants in Ontario. *(Source: Comparative Life-Cycle Assessment of Electricity Generation in Ontario, CERI, 2008).*
- The uranium mining industry in Canada generates direct employment for 5,000 people. *(Source:The Canadian Nuclear Industry: Contributions to the Canadian Economy, CERI, 2008)* and is a leading employer of Aboriginal People.
- Eight pellets of uranium, each smaller than an average adult thumb, contain enough energy to power an average home for about one year.

Nuclear Reactors in Canada

In 2009, 17 nuclear reactors provided 14.8% of Canada's electricity.

2009 Operating Reactors

• Pickering A (ON)	2 reactors	542 MW each	(Gross)
• Pickering B (ON)	4 reactors	540 MW each	(Gross)
• Darlington (ON)	4 reactors	934 MW each	(Gross)
• Bruce A (ON)	2 reactors	805 MW each	(Gross)
• Bruce B (ON)	1 reactor	845 MW	(Gross)
• Bruce B (ON)	3 reactors	872 MW each	(Gross)
• Gentilly-2 (QC)	1 reactor	675 MW	(Gross)

OPG's Five Year Safe Storage Project Completed in 2010

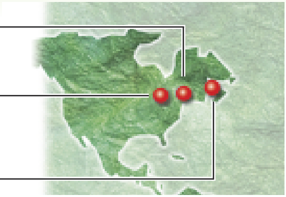
- Pickering A (ON) Units 2 & 3 542 MW each (Gross)

3 CANDU Reactors Being Refurbished 2009

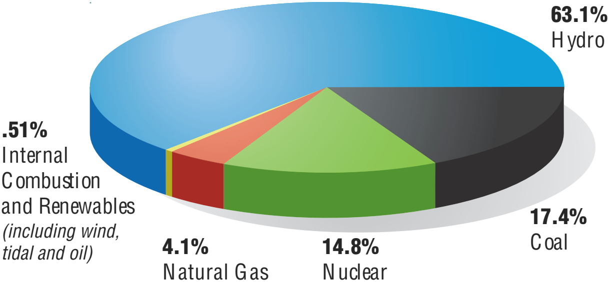
- Bruce A (ON) Units 1 & 2 805 MW each (Gross)
- Point Lepreau (NB) 1 reactor 680 MW (Gross)

CANDU Reactors in Canada 2009

Québec	
Gentilly-2	1 unit
Ontario	
Darlington	4 units
Pickering	8 units
Bruce	8 units
New Brunswick	
Point Lepreau	1 unit



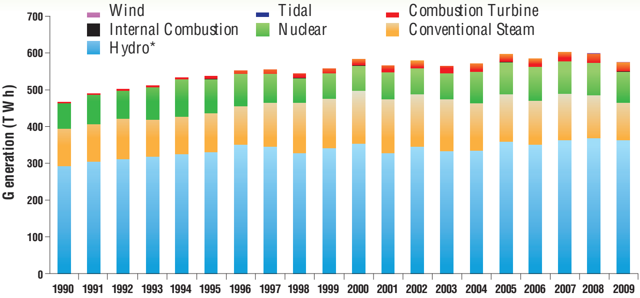
Electricity Generation in Canada 2009



Sources : NRCan, February 2009; Statistics Canada, Energy Statistics Handbook 2009.

Electricity Generation in Canada by Fuel Type, 1990-2009

Total Electricity Generation in Canada, 2008 = 575.2 TWh



*Prior to 2008, wind and tidal generation are included in hydro.
Source: Statistics Canada, *Survey* 2151, 2010

CANDU Nuclear Reactor Performance

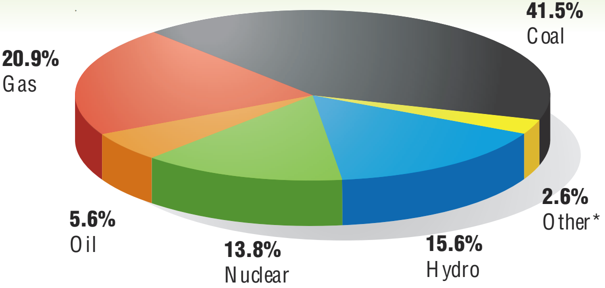
Reactor	In Service	Capacity (MWe)	Performance In 2009 (%)	Lifetime Performance (%)
Point Lepreau*	1983	680	–	76.8
Gentilly 2	1983	675	65.4	78.4
Wolsong 1*	1983	622	23.3	84.1
Wolsong 2	1997	730	94.8	93.6
Wolsong 3	1998	729	95.3	94.9
Wolsong 4	1999	730	92.5	96.0
Embalse	1984	648	98.8	85.4
Cernavoda 1	1996	706	100.1	89.1
Cernavoda 2	2007	705	90.6	93.8
Qinshan 4	2002	700	89.5	91.5
Qinshan 5	2003	700	93.4	89.9
Pickering A-1	1971	542	91.3	64.0
Pickering A-4	1973	542	36.5	65.7
Pickering B-5	1983	540	70.2	73.9
Pickering B-6	1984	540	77.8	77.8
Pickering B-7	1985	540	94.3	78.1
Pickering B-8	1986	540	91.8	76.7
Bruce A-1*	1977	805	–	N/A
Bruce A-2*	1977	805	–	N/A
Bruce A-3	1978	805	78.6	64.0
Bruce A-4	1979	805	74.7	62.9
Bruce B-5	1985	872	95.4	83.5
Bruce B-6	1984	872	84.6	80.8
Bruce B-7	1986	872	90.3	83.7
Bruce B-8	1987	872	75.3	82.7
Darlington 1	1992	934	89.7	84.1
Darlington 2	1990	934	87.9	77.5
Darlington 3	1993	934	74.0	85.4
Darlington 4	1993	934	89.2	86.2
Total/Average		**21,313**	**82.5**	**81.5**

Source : COG CANDU/PHWR, Performance Indicators, December 2009.
**These reactors were under refurbishment during part or all of 2009.*

Nuclear Generation Worldwide

- There were 438 operable nuclear power reactors in 30 countries on February 1, 2010. The world total includes 6 reactors operating in Taiwan.
- As of February 1, 2010, there were 54 nuclear reactors under construction, another 148 being planned and 342 being proposed *(Source: World Nuclear Association, February 1, 2010).*
- Nuclear power is the only large-scale generation option, other than hydro, that does not release greenhouse gas emissions that contribute to global warming.
- Nuclear power produces 13.8% of global electricity and is the world's fourth largest source of electricity *(Source: OECD/IEA, Key World Energy Statistics 2009).*
- Around the world, scientists in more than 50 countries use nearly 300 research reactors to investigate nuclear technologies and to produce radioisotopes for medical diagnosis and cancer therapy.

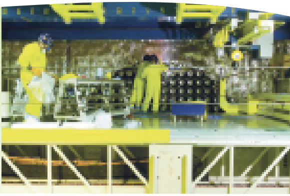
Global Electricity Generation



** Other includes geothermal, solar, wind, combustible renewables & waste, and heat.*
Source: OECD/IEA, Key World Energy Statistics 2009.

CANDU Technology

- Advanced CANDU reactor under development: **ACR-1000®**
- World record for longest non-stop operation: **Pickering 7** (894 days–1994)
- Top lifetime performance by a CANDU: **Wolsong 4** (96.0%)
- Top annual performance by a CANDU in 2009: **Cernavoda 1** (100.1%)



Percentage of electricity generated by CANDUs (2009):

In Canada **14.8%**
In Ontario **55.2%**
In New Brunswick*
In Québec **3.0%**

** In New Brunswick nuclear accounts for up to 30% of electricity generation. As of April 1, 2008 the Point Lepreau Generating Station is under refurbishment.*

- Number of tonnes of emissions of carbon dioxide (CO_2) avoided by CANDU produced nuclear energy in Canada since 1972: **2.4 billion tonnes** *(Source: CNA/CANDU Owners Group (COG)).*
- Number of tonnes of emissions of sulphur dioxide (SO_2) avoided by nuclear energy in Canada since 1972: **48.9 million** *(Source: CNA 2009)*
- Annual production of goods and services: **$6 billion**
- Total annual value of electricity from nuclear: **$5 billion**
- Total direct, indirect and spin-off jobs from nuclear power production in Canada: **71,000 jobs** (full-time equivalent not including 5,000 in uranium mining) *(Source: The Canadian Nuclear Industry: Contributions to the Canadian Economy,*

CANDU Reactors Worldwide 2009

Québec, Canada

Gentilly-2	1 unit

Ontario, Canada

Darlington	4 units
Pickering	8 units
Bruce	8 units

New Brunswick, Canada

Point Lepreau	1 unit

Argentina

Embalse	1 unit

Romania

Cernavoda	2 units

Pakistan

KANUPP	1 unit

India

RAPS	2 units

China

Qinshan	2 units

Republic of Korea

Wolsong	4 units

Nuclear Facts — Ontario

- In 2009, electricity in Ontario was generated from nuclear (55.2%), hydro (25.5%), natural gas (10.3%), coal (6.6%), wind (1.6%) and other alternative sources (0.8%) *(Source: IESO, 2010).*
- By 2020, Ontario will need to replace about 80% of its electricity generation (25,000 MW) because of growth in demand and aging plants, about half of which are nuclear.
- Bruce Power is refurbishing Bruce A (ON) Units 1 & 2 (805 MW each) with a return to service date in 2011 and will refurbish Bruce A Units 3 & 4 upon completion of 1 & 2.
- The top two performing nuclear reactors in Ontario in 2009 were: Bruce 5 (872 MW) with 95.4% performance and Pickering 7 (540 MW) with 94.3% performance.
- OPG continues work on the environmental assessment and licensing activities in support of the Darlington New Nuclear Project on the Darlington Nuclear site.
- In February 2010, OPG announced plans to proceed with the detailed planning for the mid-life refurbishment of Darlington Nuclear. Should OPG proceed with the project, construction will start in about 2016. OPG is investing in the continued safe and reliable performance of its Pickering B station for approximately 10 years. Following this, OPG will begin the long-term decommissioning process of Pickering Nuclear.

Pickering, ON

Darlington, ON

Bruce, ON

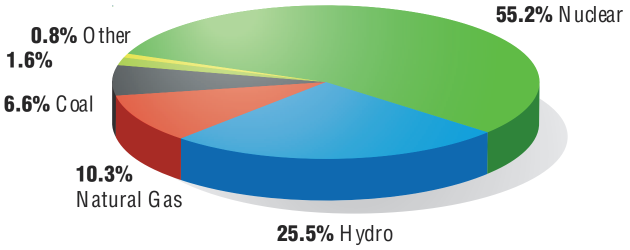
Nuclear Generation in Ontario

Pressurized Heavy Water CANDU reactors provide 55.2% of Ontario's electricity.

Unit	Status	Design Capacity (MWe)	Actual Capacity (MWe) Net	Actual Capacity (MWe) Gross	In-Service Date
Bruce A–1	Restart 2011	905	750	805	09/01/1977
Bruce A–2	Restart 2011	905	750	805	09/01/1977
Bruce A–3	Operational	905	750	805	02/01/1978
Bruce A–4	Operational	905	750	805	01/18/1979
Bruce B–5	Operational	915	817	845	03/01/1985
Bruce B–6	Operational	915	817	872	09/14/1984
Bruce B–7	Operational	915	817	872	04/10/1986
Bruce B–8	Operational	915	817	872	05/22/1987
Darlington 1	Operational	935	878	934	11/14/1992
Darlington 2	Operational	935	878	934	10/09/1990
Darlington 3	Operational	935	878	934	02/14/1993
Darlington 4	Operational	935	878	934	06/14/1993
Pickering A–1	Operational	542	515	542	07/29/1971
Pickering A–2	Safe Storage	542	515	542	12/30/1971
Pickering A–3	Safe Storage	542	515	542	06/01/1972
Pickering A–4	Operational	542	515	542	06/17/1973
Pickering B–5	Operational	540	516	540	05/10/1983
Pickering B–6	Operational	540	516	540	02/01/1984
Pickering B–7	Operational	540	516	540	01/01/1985
Pickering B–8	Operational	540	516	540	02/28/1986
Total Installed Capacity			**13,870**	**14,718**	

Source: CANDU Owners Group (COG), Bruce Power and Ontario Power Generation 2010.

Electricity Generation in Ontario 2009



Source: Independent Electricity System Operator (IESO), 2010.

Nuclear power was Ontario's principal source of electricity in 2009.

Demand for electricity in Ontario declined in 2009 as a result of the economic recession, conservation efforts and mild weather. Ontarians consumed 139,000 GWh (139 TWh) of electricity in 2009, lower than 2008' consumption (148.4 TWh). Ontario exported a net total of 10.3 TWh in 2009.

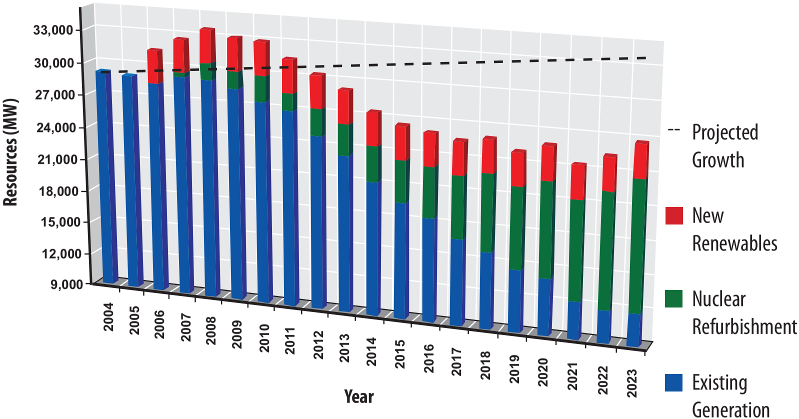
Nuclear facilities continue to be the main electricity suppliers for Ontario at 82.5 TWh, or 55.2% of 2009's total. The portion of Ontario's electricity production from hydroelectric generators increased slightly to 25.5% from 24.1% in 2008.

Sources of electricity in 2009

Nuclear	55.2%	82.5 TWh
Hydro	25.5%	38.1 TWh
Natural Gas	10.3%	15.4 TWh
Coal	6.6%	9.8 TWh
Wind	1.6%	2.3 TWh
Other	0.8%	1.3 TWh

Note: Values are rounded(Source: IESO, January 8, 2010).

Renewable Potential Added to Nuclear Refurbishment or Replacement



Nuclear Facts — Québec

- Hydro-Québec has efficiently managed its nuclear program for more than 30 years.
- In 1971, the 250 MW Gentilly-1, a prototype reactor, came into operation near Trois-Rivières on the south shore of the St. Lawrence River. Built and owned by AECL and operated by Hydro-Québec staff, the reactor had design and operational problems and was not economical. It was taken out of service in 1979.
- Québec has only one nuclear power station in operation: Gentilly-2, owned by Hydro-Québec. Equipped with a 675 MW CANDU 6 reactor, the plant was constructed on the same site as Gentilly-1 and came into commercial operation in 1983.
- In 2009, Gentilly-2 achieved a gross capacity factor (performance rate) of 65.4%; it has a lifetime gross capacity factor of 78.4%.
- In 1995, one of Canada's first dry storage facilities for used nuclear fuel began operation at the Gentilly site.
- Gentilly-2 generates around 3% of the energy in the Hydro-Québec grid and plays an important part given its excellent performance and profitability. Due to its proximity to the main load centers, it also contributes to the stability of the network.
- Hydro-Québec made the decision in 2008 to refurbish Gentilly-2. The work would be carried out in 2012 to allow continued operation until 2035.

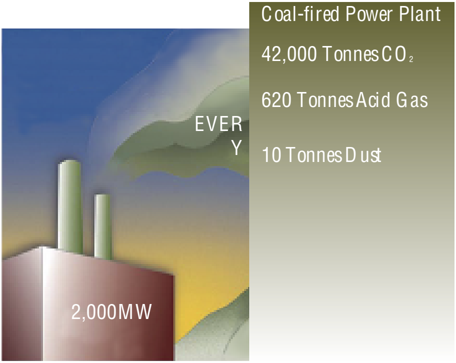
Gentilly-2, QC

Nuclear Facts — New Brunswick

- New Brunswick Power Nuclear Corporation is a subsidiary of New Brunswick Power Corporation (NB Power), the largest electricity utility in Atlantic Canada. It operates Atlantic Canada's only nuclear facility, Point Lepreau Generation Station.
- Point Lepreau started generating nuclear power commercially in February 1983 and was the first CANDU 6 in the world to be licensed for operation with a gross capacity of 680MW.
- The Point Lepreau Generating Station CANDU 6 provides up to 30% of New Brunswick's electricity and is one of the lowest cost generators on NB Power's electrical system.
- On April 1, 2008 NB Power began refurbishment of Point Lepreau to extend the station's life to 2032.
- Since 1983, the station's in-service gross lifetime capacity factor has been 79.5%.
- Point Lepreau became NB Power's first ISO 14001 registered generating station, demonstrating that advanced systems are in place to manage environmental issues.
- In 2006, the Canadian Nuclear Safety Commission approved proposed modifications to the Solid Radioactive Waste Management Facility at Point Lepreau.
- Low and stable uranium fuel costs contribute to a reliable supply of economical electricity for New Brunswick.

Point Lepreau, NB

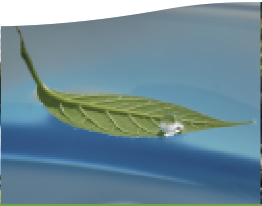
Environment



- Nuclear energy is clean. Canada's nuclear electricity plants release virtually no emissions that cause climate change, smog or acid rain.
- Many countries, such as the U.S. and China, rely on coal for power generation. By relying on nuclear generating stations for 15% of our electricity instead of coal-fired plants, Canada avoids about 90 million tonnes of greenhouse gas emissions per year.
- On a life-cycle basis, nuclear energy also has relatively low carbon dioxide emissions. A number of studies conducted around the world show that nuclear energy's life-cycle emissions are much lower than coal, oil, and natural gas and are similar to those of wind, solar and hydro.

Environment: Domestic and International Commitments

- Canada's energy demand is expected to increase by 34% by 2025, creating higher requirement for reliable, clean electricity.
- The Government of Canada has set the objective that 90% of Canada's electricity needs to be provided by non-emitting sources such as hydro, nuclear, clean coal or wind power by 2020.
- The Government of Canada has committed to reducing Canada's total greenhouse gas emissions by 17% from 2005 levels by 2020.
- Nuclear electricity generation in Canada is clean and can help meet these targets. It avoids about 90 million tonnes of greenhouse gases a year—about 12% of Canada's total emissions.
- The 15th United Nations Conference of the Parties meeting held in Denmark in December 2009 culminated in the Copenhagen Accord, an agreement that endorses the continuation of the Kyoto Protocol.
- Canada and 18 countries. representing over 83% of global emissions, signed the Copenhagen Accord.
- The Government of Canada is working to implement the Copenhagen Accord and to complete negotiations under the United Nations to reach a legally binding international treaty that is fair, effective and comprehensive.



Electricity Generation and Greenhouse Gas Emissions

Life–Cycle Analysis of Base Load Electricity in Ontario (Nuclear, Coal and Natural Gas)

- All forms of electricity generation produce some greenhouse gas emissions (GHG) whether from mining or milling fuel, building electrical plants, transportation, releases of gases or pollutants during the burning of fuel and/or in the disposal of by-products or waste.
- The Canadian Energy Research Institute (CERI) conducted a Life-Cycle Analysis (LCA) to identify and analyze current and potential life-cycle environmental impacts (GHG emission, other air pollutants, water pollutants and radiation) of base load electricity generation from nuclear, coal and natural gas in Ontario.
- Life-Cycle Analysis (LCA) is a systematic approach used to evaluate environmental impacts associated with electricity generation from different sources over their life-cycle (cradle to grave).
- The LCA took a snapshot of electricity generation activities in 2005 and 2006 in Ontario looking at the fuel supply chain and the operations of the electrical facility within the system boundaries.
- This LCA did not include CO_2 from construction of coal, gas or nuclear plants because CO_2 emissions in the construction phase of these various electricity generation technologies are roughly the same for each and proportional to the size of the plant and quantity of materials used.

Construction Emissions of Various Electricity Generation Technologies[1]

Power Generation Technology	Kilo Tonnes of CO_2 per TWh	Ratio of Construction CO_2 to Operations CO_2 (%)
IGCC (coal)	1.10	0.14
SUPC (coal)	1.49	0.18
CCGT (gas)	0.95	0.22
SXC (nuclear)	2.22	6.89

Notes: CCGT: Combined Cycle Gas Turbine, IGCC: Integrated Gasification Combined Cycle, SUPC: Supercritical Coal, SXC: Sizewell C (PWR).
Source: [1]Estimating life-cycle from Table 2 of: S. Andeseta et al., "CANDU Reactors and Greenhouse Gas Emissions".
www.computare.org/Support%20documents/Publications/Life%20Cycle.htm, retrieved October 20, 2008.

Electricity Generation and Greenhouse Gas Emissions

The LCA did consider CO_2 emissions in the construction phase of other electricity generation technologies (hydro, wind, biomass) demonstrated that construction-related emissions are negligible when compared to the emissions related to plant operations and their fuel life-cycles. CERI concluded that the inclusion or exclusion of construction-related CO_2 emissions does not significantly affect the outcome of the LCA.

Material Quantities for Construction of Various Electricity Generation Technologies, circa 1983[2] (Thousands of tonnes per EJ/year)

Generation Technology	Steel	Concrete	Other Metals
Coal - Electric	1,500	5,500	30
Coal - Synfuel	600	*	30
CANDU 900 Mwe (1995)	1,600	14,000	*
LWR	2,500	15,000	125
CANDU 600 Mwe (1995)	1,400	18,000	*
Hydro	3,500	60,000	200
Wind	8,000	35,000	1,000
Biomass	4,500	12,000	*

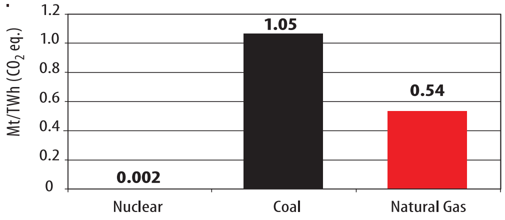
*Notes: * Indicates data not available;; LWR, Light Water Reactor*
Source: [2]Estimating life-cycle from Table 2 of: S. Andeseta et al., "CANDU Reactors and Greenhouse Gas Emissions"
www.computare.org/Support%20documents/Publications/Life%20Cycle.htm, retrieved October 20, 2008.

- Ontario power plants included in this study: three nuclear, four coal-fired and fifty-two natural gas-fired.
- LCA analyses, completed in accordance to international standards (ISO 14040 series), can assist with future electricity generation mix decisions.

Electricity Generation and Greenhouse Gas Emissions

- The study of the complete life-cycle of nuclear power in Ontario found that nuclear power results in the emissions of 1.8 grams of carbon dioxide per kilowatt-hour (g/kWh) of generated electricity. These emissions occur mainly in the mining and refining of uranium fuel, not in the operation of the reactor.
- The study of the complete life-cycle of coal in Ontario results in the emissions of 1050 g/kWh, mostly created by the burning of coal in the power plant.
- The study of the complete life-cycle of natural gas in Ontario to make electricity results in emissions of 540 g/kWh, mostly created by the burning of natural gas in the power plant.

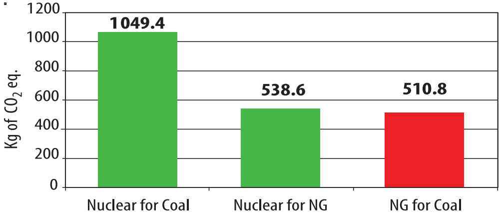
Comparative Life-Cycle GHG Emissions for Ontario Electricity Generation Sector



- This study concludes that life-cycle GHG emissions per one TWh of nuclear electricity are so small, that they are simply not comparable to other types of base load electricity generation.

Electricity Generation and Greenhouse Gas Emissions

GHG Emissions Avoided by Replacing One MWh by Switching Fuels



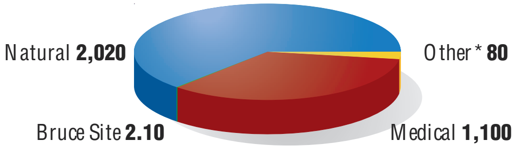
- If one MWh of coal-fired or natural gas-fired electricity capacity is replaced by one MWh of nuclear electricity, Ontario could have avoided 1049 kg or 539 kg of GHG emissions, respectively.

For complete information and the full "Comparative Life-Cycle Assessment (LCA) of Base Load Electricity Generation in Ontario" report please go to **www.cna.ca** under "Studies and Reports".

Radiation

- Radiation is natural and everywhere. Radioactivity has been in rocks, soil, water and air since the earth was formed, and is responsible for the formation of mountains.
- X-rays are invisible and were discovered accidentally in 1895 by Wilhelm Roentgen in Germany when he noticed that a crystal would glow whenever he turned on an electric current in a vacuum tube.
- In France, Henri Becquerel accidentally discovered nuclear radiation in 1896 when he noticed that a photographic plate would darken after he put a piece of uranium rock on it.
- The radiation dose to the public as a result of radioactivity from all nuclear power plants in Canada is much less than regulatory limits and the radiation dose from naturally occurring sources.
- All Canadians are exposed to naturallyoccurring radiation, mostly from the sun and from radon which is found in soil as well as man-made sources such as X-rays and air flight. As an example, a person flying one-way from Toronto to Vancouver will receive about 15 to 20 times the amount of radiation exposure as a person living in the perimeter of a nuclear plant for a whole year.

Breakdown of Radiation Dose to Public in microsieverts (μ Sv) per year

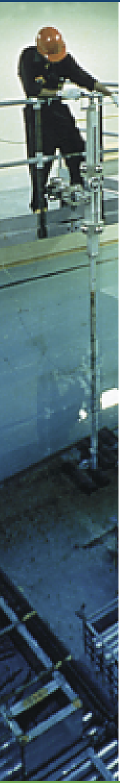


** Includes a number of manufactured goods, technologies, or human activities such as air travel, construction materials, televisions, smoke detectors, luminous dial watches, coal combustion products, etc.*

Nuclear Regulation in Canada

- The Canadian Nuclear Safety Commission (CNSC) is an independent, quasi-judicial regulatory agency that reports to Parliament through the Minister of Natural Resources Canada (NRCan).
- As Canada's nuclear watchdog, the CNSC's mandate is to regulate the use of nuclear energy and materials to protect the health, safety and security of Canadians and of the environment; and to implement Canada's international commitments to the peaceful use of nuclear energy.
- The CNSC regulates all nuclear facilities and activities in Canada including the operation of nuclear power plants, uranium processing and fuel fabrication facilities, research facilities, radioactive waste management facilities, nuclear substance processing facilities, and uranium mines and mills.
- Before any person or company can prepare a site to build, operate, decommission or abandon a nuclear facility, or possess, use, transport or store nuclear substances, they must obtain a license issued by the CNSC.
- The CNSC oversees the refurbishment of existing nuclear power plants and is making preparations for new nuclear projects, including new nuclear power plants and new uranium mines. In terms of regulating these major resource projects, the CNSC is a partner in the federal government's Major Projects Management Office under NRCan.
- CNSC staff is located on-site at each of Canada's five nuclear power plants and AECL's Chalk River Laboratories, and across Canada in four regional offices (Calgary, Saskatoon, Mississauga and Laval).
- The CNSC has a longstanding history of international bilateral and multilateral cooperation. International peer reviews and shared practices are frequently conducted through the International Atomic Energy Agency and the World Association of Nuclear Operators.
- The CNSC strives to be the best nuclear regulator in the world, and is focused on its core regulatory operations, commitment to ongoing improvements, clarity of requirements, capacity for action and communications.

Long-term Care of Canada's Used Nuclear Fuel



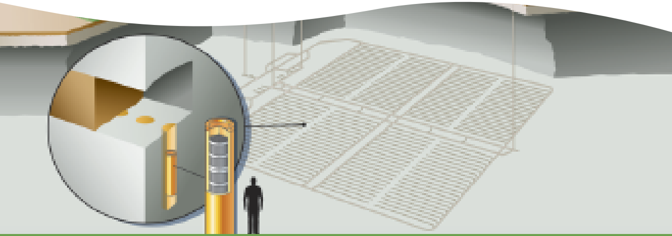
- All of the used fuel (waste) produced by Canadian nuclear power plants is safely managed at licensed interim storage facilities at the reactor's sites.
- Used fuel is initially stored in water-filled bays at the site of the nuclear power plants for 5–10 years and then placed in large concrete and steel containers safely stored on site.
- The total amount of used fuel produced by Canada's nuclear power plants could be stored in six hockey rinks up to the height of the boards.
- In Canada's 48 years of using nuclear energy, no member of the public has been harmed as a result of a radiation leak from a nuclear power plant or waste storage facility.
- The Nuclear Waste Management Organization (NWMO) was established in 2002 to collaboratively develop with Canadians a management approach for the long-term care of Canada's used nuclear fuel.
- In 2007 the Government of Canada accepted the NWMO's recommendation for an **Adaptive Phased Management** approach which incorporates new learning and knowledge at each step to guide a process of phased decision-making. The plan is now being implemented by the NWMO.
- Designs have been developed for a deep underground repository for used nuclear fuel which will be hosted by an informed and willing community. The project will not be imposed on any community.
- In 2006, Ontario Power Generation began the environmental assessment for a deep geological repository to store low and intermediate level waste at the Bruce nuclear site.

Long-term Care of Canada's Used Nuclear Fuel

Adaptive Phased Management involves:

- Ultimate centralized containment and isolation of used nuclear fuel in a deep underground repository in a suitable rock formation;
- Moving to this ultimate goal through a series of steps and clear decision points, which can be adapted over time as may be required;
- Providing opportunities for citizens to be involved throughout the implementation process;
- Allowing for optional temporary shallow storage at the central site, if needed;
- Ensuring long-term stewardship through continuous monitoring of the used fuel and maintaining the ability to retrieve it over an extended period should there be a need to access the waste or take advantage of new technologies which may be developed; and
- Providing financial surety and long-term program funding to ensure the necessary money will be available for the long-term care of used nuclear fuel when it is needed.

To learn more about the Adaptive Phased Management approach and the long-term management of used nuclear fuel in Canada, please visit **nwmo.ca** where you can view the video, "Managing Canada's Used Nuclear Fuel: A Responsible Path Forward."



Advancing Global Health

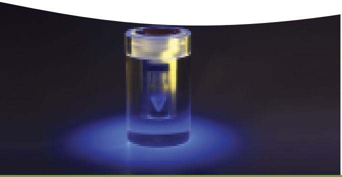
- Global nuclear medicine started mainly in Canada in 1951 when the first two cancer-treatment machines using cobalt-60 (radioisotopes) were built. One was built by Dr. Harold Johns of Saskatoon and one by Eldorado Mining and Refining Ltd. In 2008, Best Theratronics took ownership of the cancer treatment technology.
- Today in Canada, MDS Nordion is a leading provider of innovative technologies for medical imaging and radiotherapeutics, and sterilization technologies benefiting the lives of millions of people in more than 65 countries around the world.
- MDS Nordion produces a comprehensive range of products that are used to manufacture medical imaging radiopharmaceuticals. These are used to diagnose heart disease and forms of cancer.
- MDS Nordion provides innovative targeted cancer treatments for a variety of conditions including liver and brain cancer, and non-Hodgkin's lymphoma. Many of these treatments target cancer from within the body to deliver a higher concentration of treatment to the tumor.
- Canadian-produced medical isotopes for nuclear medicine are used in over 50,000 procedures a day world-wide, with 5,000 in Canada alone.
- Canada's nuclear infrastructure is essential to the global medical isotope supply. MDS Nordion processes materials from Atomic Energy of Canada Limited (AECL) at the Chalk River Laboratories to produce 50% of the world's medical isotopes.

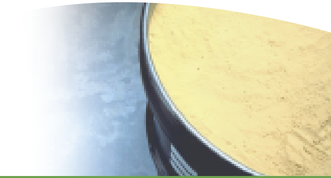
Advancing Global Health

- Through a partnership with the TRIUMF Laboratory and MDS Nordion, medical isotopes are also produced by three cyclotrons on the University of British Columbia campus. Radioisotopes are also produced at McMaster University in Ontario.
- Canada supplies 60% of the world's cobalt-60 used to sterilize more than 40% of the world's single-use medical supplies. This technology is also used to sterilize a vast array of consumer products, such as food packaging materials and cosmetics.
- Canada's cobalt-60 is produced in nuclear reactors at Bruce Power and Pickering in Ontario and Gentilly-2 in Québec.
- Canada is a leader in the development of gamma technology used to eliminate food-borne pathogens, such as harmful E.Coli and Salmonella, to make food safer and as a quarantine treatment for fruits and vegetables to reduce post-harvest losses caused by spoilage, pest infestation and contamination.
- MDS Nordion is collaborating with the University of Ottawa Heart Institute (UOHI), Canada's largest cardiovascular health centre, to establish a Molecular Imaging Centre of Excellence to advance cardiology research. The new centre enables the two organizations to collaborate on joint cardiology research, using the latest in molecular imaging technology.

Nuclear Research and Development

- Canada is a world leader in the peaceful uses of nuclear technologies and in pushing the frontiers of scientific knowledge and innovation using nuclear reactors for research and development (R&D).
- In the 1940s, the National Research Council (NRC) recognized a huge potential for innovation that could be realized from the discovery of nuclear energy and studying atoms, which are the basis of all matter. By improving our understanding of the way matter works we can have positive impacts on every aspect of our lives.
- In 1944, NRC built the Chalk River Laboratories (CRL) on the shores of the Ottawa River, 200 kilometers northwest of Ottawa. The decision to build a national research laboratory is the foundation of Canada's leadership role in nuclear energy, nuclear medicine and matter research.
- In 1952, Atomic Energy of Canada Limited (AECL) was created as a fully-owned federal crown corporation with the broad mandate to develop and apply the peaceful uses of the atom and direct scientific research at the Chalk River Laboratories.
- AECL has since operated as Canada's national nuclear R&D institution contributing its science and engineering research capabilities in developing and supporting commercial CANDU products and service businesses, nuclear medicine and materials research for a wide range of industries.



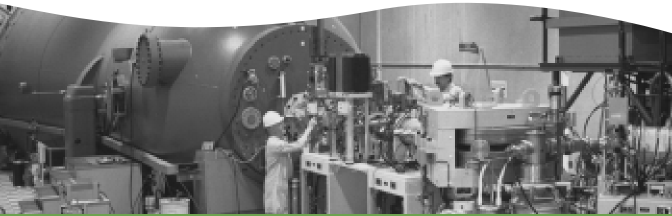


Nuclear Research and Development

- Canada's homegrown nuclear energy technology – CANDU power plants – was developed at CRL. There are now 34 CANDU nuclear reactors worldwide : Canada (22), Argentina (1), Romania (2), South Korea (4), China (2) Pakistan (1) and India (2).
- Canada has been recognized as a world leader in materials research using neutron beams at CRL since the 1950's when Alberta-born Dr. Bert Brockhouse pioneered this field, earning him the 1994 Nobel Prize in physics.
- The National Research Universal (NRU) reactor is the fourth largest research reactor in the world and the largest global producer of isotopes for applications in medicine and industry; its core provides a test environment for fuels and components for nuclear power technologies such as CANDU reactors and it supplies neutrons for the materials research conducted at CRL. The earlier NRX reactor performed similar functions until it was shutdown in 1992.
- With over 50 years of studying materials, Canada has made major scientific and economic contributions to the fields of aerospace, automotive, manufacturing, energy, construction, health, environmental technologies and oil and gas. For example, today's groundbreaking biological research at CRL focuses on how our body really works by determining the roles of cholesterol and proteins in cell membranes. This kind of basic knowledge will open pathways to revolutionary approaches for curing diseases, benefiting Canadians and patients around the world.

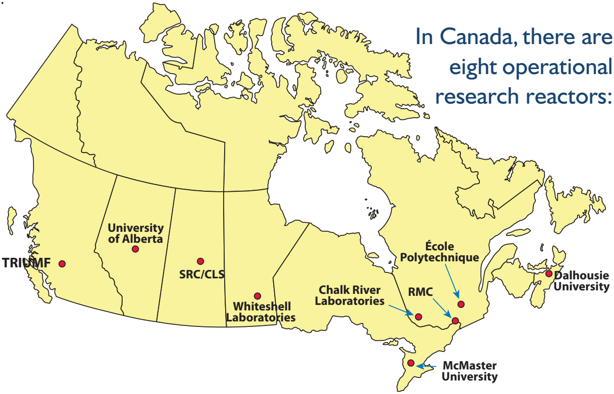
Nuclear Research and Development

- The Chalk River Laboratories were responsible for designing the NRX (42 MW) and NRU (135 MW) research reactors, ZED-2 (0.2 kW) and SLOWPOKE (16 to 20 kW) reactors which are used today across Canada in Saskatchewan, Alberta, Québec, Ontario and Nova Scotia. The SLOWPOKE reactors are primarily tools used for smaller scale research and education.
- The McMaster Reactor (3 MW) is the second largest research reactor in Canada and is used for education and research, medical isotope production and industrial imaging.
- CRL remains Canada's nuclear research laboratory and now employs over 2700 people. It supports a scientific community of over 400 researchers and engineers from the Canadian industry, government and over 50 university departments across Canada, and operates in a global network of neutron beam facilities, attracting collaboration with over 100 institutions from 20 countries.
- Canada's world leadership role in nuclear technology development provides the country with a respected international voice allowing it to participate at forums for future technology development (Generation IV International Forum) and for international nuclear safeguards and non-proliferation.



Nuclear Research and Development

- In 2011, Canada's NRU's operating license will expire as it approaches the end of its useful life after an outstanding performance of over 50 years. AECL plans to apply for a license for another 5 years.
- Canada is currently exploring options for its replacement and reinvestment in nuclear infrastructure to move forward and capitalize on the nuclear renaissance worldwide.



In Canada, there are eight operational research reactors:

Chalk River Laboratories – NRU Reactor 135 MW start date 1957
Chalk River Laboratories – ZED-2 Reactor 0.2 kW start date 1960
Royal Military College – Slowpoke-2 Reactor 20 kW start date 1985
Saskatchewan Research Council – Slowpoke-2 Reactor 16 kW start date 1981
École Polytechnique – Slowpoke-2 Reactor 20 kW start date 1976
University of Alberta – Slowpoke 2 Reactor 20 kW start date 1977
Dalhousie University – Slowpoke 2 Reactor 20 kW start date 1976
McMaster University – McMaster Nuclear Reactor 3 MW start 1959

Resources

American Nuclear Society
www.ans.org

AREVA Canada
www.arevacanada.ca

AREVA Resources Inc.
www.arevaresources.ca

Atomic Energy of Canada Limited
www.aecl.ca

Australian Uranium Association
www.aua.org.au

Bruce Power
www.brucepower.com

Cameco Corporation
www.cameco.com

Canadian Nuclear Association
www.cna.ca

Canadian Nuclear Safety Commission
www.nuclearsafety.gc.ca

Canadian Nuclear Society
www.cns-snc.ca

Canadian Nuclear Workers Council
www.cnwc-cctn.ca

Canadian Institute for Neutron Scattering
www.cins.ca

CANDU Owners Group
www.candu.org

Centre for Energy
www.centreforenergy.com

European Nuclear Society
www.euronuclear.org

Foratom–European Atomic Forum
www.foratom.org

Half-Lives: A Guide to Nuclear Technology in Canada
Hans Tammemagi, David Jackson,
Oxford University Press, 2009
www.cna.ca/english/publications.asp

Hydro-Québec
www.hydroquebec.com

Independent Electricity Systems Operator (IESO)—Ontario
www.ieso.ca

International Atomic Energy Agency (IAEA)
www.iaea.org

International Commission on Radiological Protection
www.icrp.org

Resources

International Energy Agency
www.iea.org

McMaster University
www.mcmaster.ca

MDS Nordion
www.mds.nordion.com

Natural Resources Canada – Nuclear Energy Division
www.nuclear.nrcan.gc.ca

New Brunswick Power
www.nbpower.com

Nuclear Energy Institute (U.S.)
www.nei.org

Nuclear Waste Management Organization
www.nwmo.ca

Ontario Power Generation
www.opg.com

Organization for Economic Co-operation and Development Nuclear Energy Agency
www.nea.fr

Organization of CANDU Industries
www.oci-aic.org

Power Workers' Union
www.pwu.ca

Society of Nuclear Medicine
www.snm.org

United Nations Scientific Committee on the Effects of Atomic Radiation
www.unscear.org

University of Ontario Institute of Technology
www.uoit.ca

Women in Nuclear Canada
www.wincanada.org

World Nuclear Association
www.world-nuclear.org

World Nuclear University
www.world-nuclear-university.org

Nuclear technology
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www.cna.ca

The Voice of Canada's Nuclear Industry

The Canadian Nuclear Association (CNA) is a non-profit organization established in 1960 to represent the nuclear industry in Canada and promote the development and growth of nuclear technologies for peaceful purposes.

Canadian Nuclear Association

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