THE CANADIAN NUCLEAR

FACTBOOK 2019

canadian nuclear association

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The information in this book is based on data available as of October 2018.

SUMMARY

MESSAGE FROM THE PRESIDENT

I am honoured to present the 2019 Canadian Nuclear Factbook.

Over the years, the Factbook has become a highly regarded source of information about nuclear technology in Canada and the world.

Nuclear is essential in the fight against climate change. In Canada, nuclear energy helps avoid 80 million tonnes of CO_2 emissions per year, by displacing the use of fossil fuels—the equivalent of taking 15 million passenger vehicles off the road.

But nuclear technology is about more than just providing clean, safe, reliable and affordable energy; it plays a role in medicine, industry, food and water safety, research and innovation, and so much more.

Nuclear medicine is responsible for saving millions of lives. The radioisotopes produced in Canada's CANDU reactors are used to diagnose and treat various diseases, including cancer.

The Canadian nuclear industry supports 60,000 direct and indirect jobs across the country. These are women and men who mine uranium, design reactors, generate electricity and advance Canadian scientific and technological expertise.

I hope that you find the Factbook information useful and I encourage you to share it widely.

John Barrett, Ph.D.

President and Chief Executive Officer
Canadian Nuclear Association

EXECUTIVE SUMMARY

The 2019 edition of the Canadian Nuclear Factbook is packed full of up-to-date information about nuclear in Canada and around the world. Some of the highlights are listed below.

- There are currently 453 operable nuclear reactors worldwide. Canada is home to 19 power reactors, which provide 14.6% of the country's electricity.
- A total of 57 reactors are under construction worldwide, primarily in emerging economies such as China and India. There are more than 150 reactors on order or planned, while another 335 have been proposed.
- Nuclear power generation helps reduce global CO_2 emissions, which hit a record high of 32.5 billion tonnes in 2017.
- Nuclear is the most efficient power source by land area. It is at least 15 times more efficient than renewable sources like wind and solar.
- Nuclear in Canada generates more than $6 billion in revenues per year. It directly and indirectly supports a total of 60,000 Canadian jobs.
- Canada is a leader in the global supply of uranium. Most Canadian uranium is mined in northern Saskatchewan, which has the highest-grade deposits in the world.
- Canada pioneered one of the first nuclear power reactors, the CANDU. There are currently 46 operable CANDU and CANDU-derived reactors worldwide.
- Nuclear technology is used extensively in medicine and industry. In Canada, over 1.5 million diagnostic scans and 15,000 radiation therapy treatments are performed annually.
- Canada's nuclear industry is among the safest and most strictly regulated industries in the world.

HISTORY OF NUCLEAR IN CANADA

1908 Ernest Rutherford is awarded the Nobel Prize in Chemistry for his work on radioactive decay, performed at McGill University in Montreal, QC.

1930 Gilbert A. Labine discovers Canada's first uranium deposit in Great Bear Lake, NWT.

1940 George C. Laurence designs one of the world's first nuclear reactors at the National Research Council (NRC) in Ottawa, ON.

1944 The NRC begins building a nuclear research facility in Chalk River, ON.

1945 The Zero Energy Experimental Pile (ZEEP) reactor makes Canada the second country to control a nuclear fission reaction.

1946 The Atomic Energy Control Board (AECB) is established as Canada's federal nuclear regulator.

1947 The National Research Experimental (NRX) reactor, then the most powerful reactor in the world, comes into operation at Chalk River.

1951 Two separate teams led by Harold E. Johns and Roy Errington build the world's first two cobalt-60 radiation therapy units. The first external radiation cancer treatment is delivered in London, ON, and the second 11 days later in Saskatoon, SK.

1952 Atomic Energy of Canada Limited (AECL) is created as a federal Crown corporation.

1952 The NRX suffers an accident with reactor core damage—the first accident of this type. The reactor is decontaminated, rebuilt and restarted after 14 months.

1954 Wilfrid B. Lewis initiates the development of the CANDU reactor in collaboration with AECL, Ontario Hydro and Canadian General Electric Company.

1957 The National Research Universal (NRU) reactor comes into operation at Chalk River.

1962 The Nuclear Power Demonstration (NPD) reactor, Canada's first electricity-producing reactor and the prototype for the CANDU design, comes online in Rolphton, ON, at a capacity of 20 MWe.

1964 AECL develops the first commercial cobalt-60 sterilizer for food and medical supplies.

1967 Douglas Point, Canada's first full-scale power reactor, comes online in Kincardine, ON, producing 220 MWe.

1972 The first CANDU outside Canada comes online at Rajasthan-1 in India.

1973 All four units at Pickering A come online at 2,060 MWe, making it the largest nuclear generating station in the world at the time.

1982 Point Lepreau in New Brunswick and Gentilly-2 in Quebec come online at 635 MWe each.

1994 Bertram N. Brockhouse is awarded the Nobel Prize in Physics for his neutron scattering research at Chalk River.

1996 Two CANDU reactors are sold to China—the largest commercial contract between two countries at the time.

2000 The Canadian Nuclear Safety Commission (CNSC) is formed under the new Nuclear and Safety Control Act, replacing the AECB as Canada's nuclear regulator.

2002 The Nuclear Fuel Waste Act is passed, mandating the creation of the Nuclear Waste Management Organization (NWMO). In 2007, the federal government approved the NWMO's Adaptive Phased Management approach for the long-term storage of used nuclear fuel.

2011 AECL's commercial operations are acquired by Candu Energy Inc., a wholly-owned subsidiary of SNC-Lavalin. AECL remains a federal Crown corporation.

2012 Two units at Bruce A come back online after being refurbished, making the Bruce Nuclear Generating Station the largest operating nuclear generating station in the world.

2015 Arthur B. McDonald is awarded the Nobel Prize in Physics for showing that neutrinos have mass at the Sudbury Neutrino Observatory in Sudbury, ON.

2015 The Canadian National Energy Alliance (CNEA), a private-sector organization, is contracted to manage and operate AECL and renames it Canadian Nuclear Laboratories (CNL).

2016 SNC-Lavalin announces a joint venture with the China National Nuclear Corporation (CNNC) and Shanghai Electric Company to build Advanced Fuel CANDU Reactor (AFCR) units in China and internationally.

2016 Ontario begins the process of refurbishing 10 of its 19 nuclear power reactors—currently the largest clean energy project in North America.

2018 The NRU is permanently shut down after more than 60 years of operation.

NUCLEAR POWER
GLOBALLY AND IN CANADA

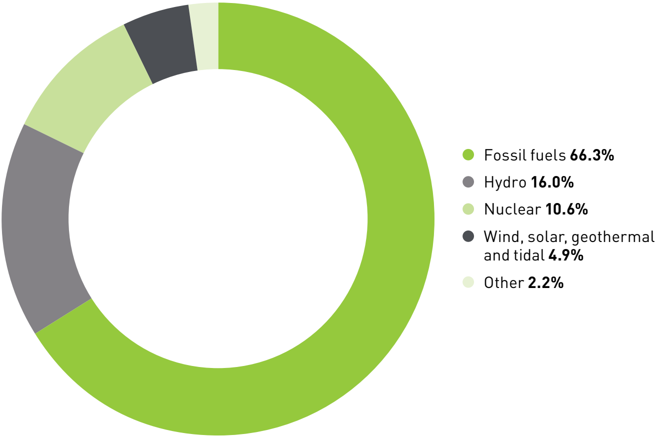
NUCLEAR POWER GLOBALLY

Nuclear generated 10.6% of global electricity in 2017. After hydroelectricity, it is the largest source of low-carbon energy worldwide.

Fossil fuels were the most widely used electricity source by far, at 66.3%. Coal represents about two-thirds of this, and natural gas represents about one-third.

Renewable sources other than hydro, including wind, solar, geothermal and tidal, generated 4.9% combined.

GLOBAL SOURCES OF ELECTRICITY IN 2017



SOURCE • U.S. Energy Information Administration. "International Energy Statistics." 2018. https://www.eia.gov/beta/international/data/browser/.

NUCLEAR REACTORS GLOBALLY

Currently, there are 453 operable power reactors worldwide, with a net generating capacity of approximately 400 GWe.

- This includes 42 Japanese reactors that were taken offline shortly after the 2011 Fukushima accident. As of October 2018, nine have been reconnected to the grid, seven have been earmarked for decommissioning and another 17 have applied for restarts.
- It also includes seven German reactors that were taken offline post-Fukushima. Germany plans to phase out all of its nuclear reactors by 2022.

A total of 57 reactors are under construction worldwide, primarily in emerging economies such as China and India.

There are more than 150 reactors on order or planned, while another 335 have been proposed.

453 OPERABLE POWER REACTORS

57 REACTORS UNDER CONSTRUCTION

150 REACTORS ON ORDER OR PLANNED

335 PROPOSED REACTORS

SOURCE • IAEA Power Reactor Information System. "Operational & Long-Term Shutdown Reactors." 2018. https://www.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx.

CURRENT NUCLEAR POWER REACTORS

COUNTRY	UNITS	NET CAPACITY (MWE)	FUEL SHARE (%)
Argentina	3	1,633	4.5
Armenia	1	375	32.5
Belgium	7	5,918	49.9
Brazil	2	1,884	2.7
Bulgaria	2	1,926	34.3
Canada	19	13,554	14.6
China	42	38,331	3.9
Czech Republic	6	3,930	33.1
Finland	4	2,769	33.2
France	58	63,130	71.6
Germany	7	9,515	11.6
Hungary	4	1,889	50.0
India	22	6,255	3.2
Iran	1	915	2.2
Japan	42	39,752	3.6
Mexico	2	1,552	6.0
Netherlands	1	482	2.9
Pakistan	5	1,318	6.2
Romania	2	1,300	17.7
Russia	37	28,264	17.8
Slovakia	4	1,814	54.0
Slovenia	1	688	39.1
South Africa	2	1,860	6.7
South Korea	24	22,494	27.1
Spain	7	7,121	21.2
Sweden	8	8,622	39.6
Switzerland	5	3,333	33.4
Taiwan	6	5,052	9.3
U.K.	15	8,918	19.3
U.S.	99	99,952	20.1
Ukraine	15	13,107	55.1
Total	**453**	**394,836**	

SOURCE • IAEA Power Reactor Information System. "Operational & Long-Term Shutdown Reactors." 2018. https://www.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx.

NUCLEAR POWER IN CANADA

There are 19 operable power reactors at four nuclear generating stations in Canada.

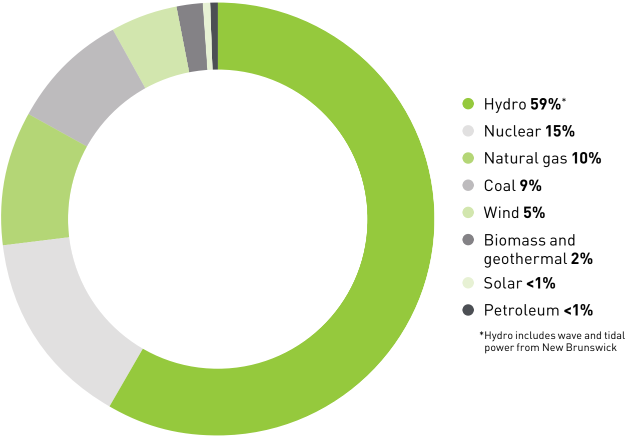
Nuclear power provided approximately 15% of Canada's electricity in 2016.

Hydro power is the most utilized source of electricity in Canada, generating approximately 59% of the electricity in 2016.

While coal was phased out in Ontario in 2014, it continues to be widely used elsewhere in the country.

Non-hydro renewable sources provided approximately 7% of Canada's electricity in 2016.

CANADIAN SOURCES OF ELECTRICITY IN 2016



SOURCE • National Energy Board. "Provincial and Territorial Energy Profiles—Canada." 2018. https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/cda-eng.html.

CANADA'S NUCLEAR POWER REACTORS

FACILITY	STATUS	NET CAPACITY (MWE)	START YEAR
Bruce A: Unit 1	Operable	760	1977
Bruce A: Unit 2	Operable	760	1976
Bruce A: Unit 3	Operable	750	1977
Bruce A: Unit 4	Operable	750	1978
Bruce B: Unit 5	Operable	817	1984
Bruce B: Unit 6	Operable	817	1984
Bruce B: Unit 7	Operable	817	1986
Bruce B: Unit 8	Operable	817	1987
Darlington: Unit 1	Operable	878	1990
Darlington: Unit 2	Operable	878	1990
Darlington: Unit 3	Operable	878	1992
Darlington: Unit 4	Operable	878	1993
Douglas Point	Shut down	206	1967
Gentilly-1	Shut down	250	1971
Gentilly-2	Shut down	635	1983
Pickering A: Unit 1	Operable	515	1971
Pickering A: Unit 2	Shut down	515	1971
Pickering A: Unit 3	Shut down	515	1972
Pickering A: Unit 4	Operable	515	1973
Pickering B: Unit 5	Operable	516	1982
Pickering B: Unit 6	Operable	516	1983
Pickering B: Unit 7	Operable	516	1984
Pickering B: Unit 8	Operable	516	1986
Point Lepreau	Operable	660	1982
Rolphton NPD	Shut down	22	1982

DID YOU KNOW?

CANADA'S NUCLEAR FLEET PRODUCES ENOUGH ELECTRICITY TO POWER OVER 10 MILLION HOMES!

SOURCE • IAEA Power Reactor Information System. "Canada." 2018. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA.

ELECTRICITY SOURCES BY PROVINCE

Electricity sources vary significantly by province.

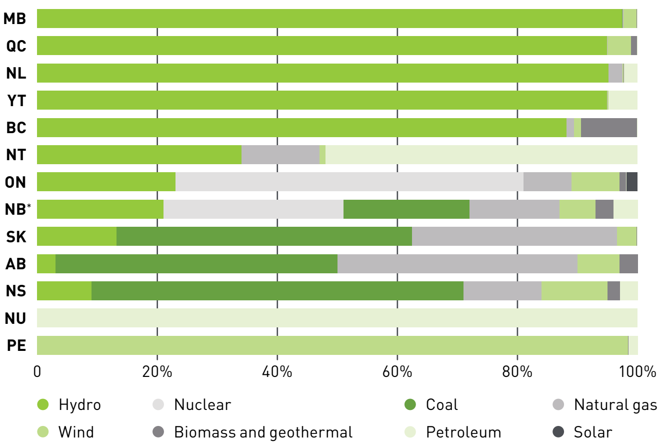
In 2016, nuclear power provided approximately 58% of Ontario's electricity and 30% of New Brunswick's electricity.

Hydro power is the dominant source of electricity in British Columbia, Manitoba, Quebec, Newfoundland and Yukon.

Fossil fuels still provide most of the power in Alberta, Saskatchewan, Nova Scotia, Nunavut and Northwest Territories.

While 98% of power generation in Prince Edward Island is from wind farms, the province still imports about 60% of its electricity from New Brunswick.

SOURCES OF ELECTRICITY BY PROVINCE IN 2016



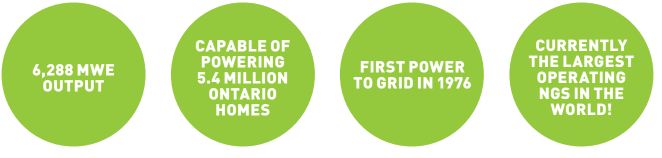
*In New Brunswick, hydro includes wave and tidal power.

SOURCE • National Energy Board. "Provincial & Territorial Energy Profiles." 2018. https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/index-eng.html.

BRUCE NUCLEAR GENERATING STATION

Bruce Nuclear Generating Station (NGS) is the largest operating nuclear power facility in the world. It is located on the shore of Lake Huron, 190 km from downtown Toronto, Ontario, and first delivered power to the grid in 1976.

Currently operating at 6,288 MWe from eight reactors, Bruce NGS generated a record 49 billion kWh in 2017—enough electricity to power 5.4 million Ontario households. (An average Ontario household consumes about 9,000 kWh per year.)



SOURCE • Ontario Energy Board. "Defining Ontario's Typical Electricity Customer." 14 April 2016. https://www.oeb.ca/sites/default/files/uploads/Report_Defining_Typical_Elec_Customer_20160414.pdf.

DARLINGTON NUCLEAR GENERATING STATION

Darlington NGS is Canada's second-largest nuclear facility. It is located on the shore of Lake Ontario, 60 km from downtown Toronto, Ontario.

Currently operating at 3,512 MWe from four reactors, Darlington NGS generated 25.8 billion kWh in 2016—enough to power over 2.8 million Ontario households.

Unit 2 was shut in October 2016 for its mid-life refurbishment. As of October 2018, the refurbishment is over halfway complete—ahead of schedule and under budget.

3,512 MWE OUTPUT

CAPABLE OF POWERING 2.8 MILLION ONTARIO HOMES

FIRST POWER TO GRID IN 1990

PICKERING NUCLEAR GENERATING STATION

When Unit 4 was completed in 1973, Pickering A became the world's largest nuclear generating station at the time. Pickering A and B are located 30 km from downtown Toronto, Ontario.

Now, with a combined six reactors at Pickering A and B producing 3,094 MWe, Pickering NGS produced 21.5 billion kWh in 2016—enough to power 2.4 million Ontario households.

Pickering NGS had eight reactors in total until Units 2 and 3 were shut down in 1997.

The remaining six reactors are scheduled to run until 2024, at which point they will be decommissioned.

3,094 MWE OUTPUT

CAPABLE OF POWERING 2.4 MILLION ONTARIO HOMES

FIRST POWER TO GRID IN 1971

POINT LEPREAU NUCLEAR GENERATING STATION

Point Lepreau NGS is located in New Brunswick, approximately 30 km southwest of Saint John, and was the first CANDU 6 unit to generate electricity commercially.

Point Lepreau underwent refurbishment to extend its operational lifespan and returned to service in November 2012. It currently provides approximately 30% of New Brunswick's electricity.

Point Lepreau operates at 660 MWe, producing 5.2 billion kWh in 2017, or enough to power 300,000 New Brunswick households. (An average New Brunswick household consumes about 17,000 kWh per year.)

660 MWE OUTPUT

CAPABLE OF POWERING 300,000 NEW BRUNSWICK HOMES

FIRST POWER TO GRID IN 1983

SOURCE • National Energy Board. "Provincial and Territorial Energy Profiles—New Brunswick." 2018. https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/nb-eng.html.

CANADA'S NUCLEAR REFURBISHMENT PROJECTS

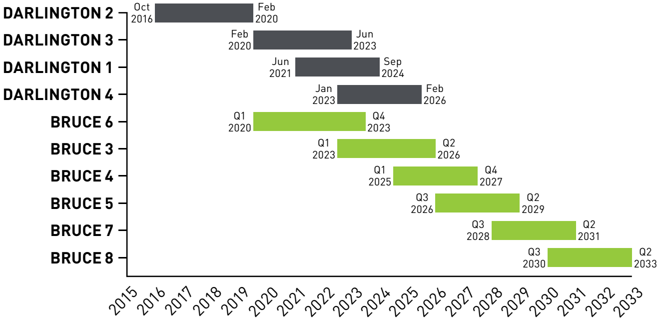
The life of a nuclear reactor can be extended for several decades through refurbishment, a process of modernizing and enhancing major equipment and systems to support long-term operation.

Canada has begun the process of refurbishing 10 of its 19 nuclear reactors to extend their lives for another 30 years. The refurbishment projects are expected to last 15 years and create thousands of jobs.

Point Lepreau and Bruce Units 1 and 2 have already been refurbished. All three reactors returned to service in 2012.

According to a study by the Conference Board of Canada, the economic benefits from refurbishing the four Darlington reactors and from the 30+ years of operation following the project will total $89.9 billion.

NUCLEAR REFURBISHMENT SEQUENCE



SOURCES • Ontario Power Generation. "Darlington Refurbishment Project." 2018, pp. 8. https://www.opg.com/darlington-refurbishment/whats-involved/Documents/DRP_ScopeProgramBook.pdf.

Bruce Power. "BPRIA Backgrounder." 3 December 2015. http://www.brucepower.com/bpria-backgrounder/.

The Conference Board of Canada. "Continued Operation of the Darlington Nuclear Generating Station: An Impact Analysis on Ontario's Economy." 2016, pp. 12.

THE ENVIRONMENT AND THE ECONOMY

ENERGY AND THE ENVIRONMENT

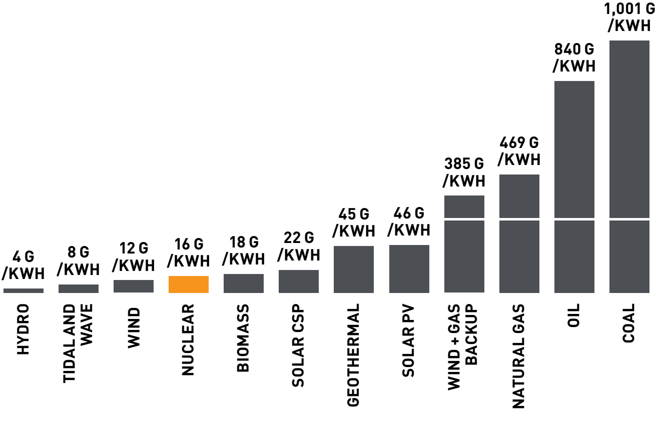
All forms of electricity production generate some level of CO_2 and other greenhouse gases (GHG), even if they do not burn fossil fuels. The construction of the plant or equipment, for example, requires cement production and vehicle use, each having its own carbon footprint.

When considering the entire power generation lifecycle, including construction, mining, operation and decommissioning, nuclear comes out as one of the cleanest technologies available.

Hydro is a low-carbon source of electricity, but it is only feasible in locations with access to large quantities of flowing water.

Solar and wind are low-carbon sources of electricity as well, but to power a grid they would require backup sources about 80% of the time. Backup most often comes from burning natural gas, which increases CO_2 emissions greatly.

LIFECYCLE CO_2 EMISSIONS BY ENERGY SOURCE



SOURCE • Intergovernmental Panel on Climate Change. "Renewable Energy Sources and Climate Change Mitigation." 2011, pp. 190. https://www.ipcc.ch/site/assets/uploads/2018/03/SRREN_Full_Report-1.pdf.

GLOBAL CO_2 EMISSIONS OVER TIME

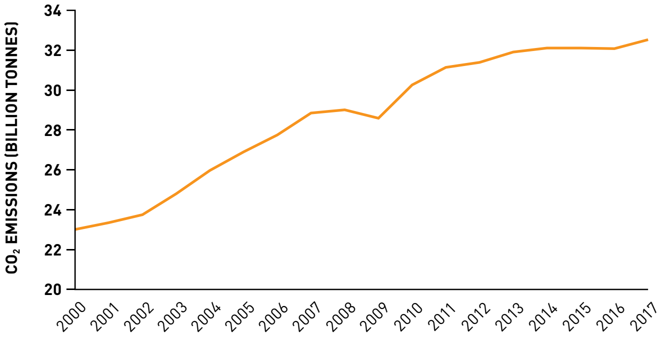
Global CO_2 emissions reached a record high of 32.5 billion tonnes in 2017.

Fossil fuel use is the primary source of CO_2 emissions.

If we replaced all the world's coal and natural gas plants with low-carbon nuclear, we would reduce global CO_2 emissions by nearly 13 billion tonnes annually.

Today, by displacing the use of coal and natural gas, nuclear power helps avoid about 2.2 billion tonnes of CO_2 emissions annually. That's the same as taking about 480 million passenger vehicles off the road—or nearly half of all the passenger vehicles in the world!

GLOBAL CO_2 EMISSIONS SINCE 2000



DID YOU KNOW?

REPLACING COAL AND NATURAL GAS WITH NUCLEAR WOULD TURN BACK THE CLIMATE CLOCK NEARLY TWO DECADES!

SOURCES • International Energy Agency. "Global Energy & CO_2 Status Report." 2018. https://www.iea.org/geco/emissions/.

World Nuclear Association. "Greenhouse Gas Emissions Avoided through Use of Nuclear Energy." 2018. http://www.world-nuclear.org/nuclear-basics/greenhouse-gas-emissions-avoided.aspx.

Natural Resources Canada. "Learn the Facts: Fuel Consumption and CO_2." 2018. http://www.nrcan.gc.ca/energy/efficiency/transportation/cars-light-trucks/buying/16770.

CANADA'S CLIMATE TARGETS

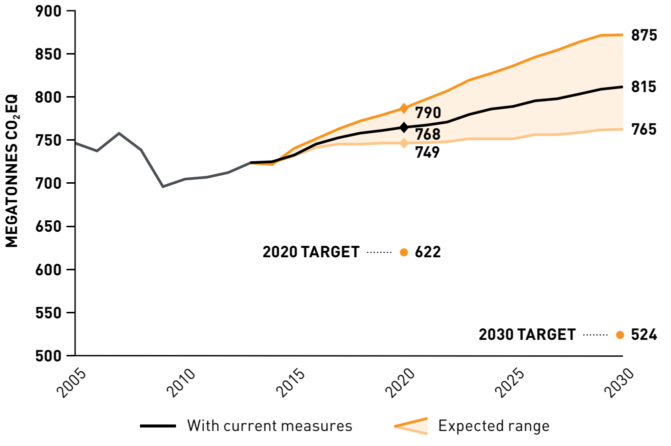
Climate change is one of the greatest threats of our time.

Under the 2015 Paris Agreement, Canada, along with 194 other countries, agreed to transition to a low-carbon economy and meet country-specific GHG reduction targets.

With current measures, Canada is not likely to meet its 2020 or 2030 targets.

To drastically reduce emissions, Canada must embrace all available low-carbon energy sources, including nuclear.

CANADA'S GHG EMISSIONS PROJECTIONS



SOURCE • Environment and Climate Change Canada. "Canada's GHG Emissions." 2018. http://ec.gc.ca/ges-ghg/default.asp?lang=En&xml=8BAAFCC5-A4F8-4056-94B1-B2799D9A2EE0.

NUCLEAR AND THE UN'S SUSTAINABLE DEVELOPMENT GOALS

Canada's nuclear industry contributes to nine of the United Nation's 17 Sustainable Development Goals (SDGs), which were designed to ensure the prosperity of developed countries and improve living conditions in developing countries by 2030.

2: Zero hunger

Nuclear technology helps protect plants from pests and improve crop resilience to disease and climate change.

3: Good health and well-being

Nuclear technology is used to diagnose and treat diseases, including cancer.

6: Clean water and sanitation

Nuclear technology can help clean up wastewater contaminants making the water safe for re-use.

7: Affordable and clean energy

Nuclear is one of the cheapest forms of energy and emits zero GHGs during generation.

9: Industry, innovation and infrastructure

The nuclear industry is pursuing innovative research into future energy options and technology improvements.

13: Climate action

Nuclear energy emits zero GHGs during generation, reducing the impact of human activity on the climate.

14: Life below water

Nuclear technology can provide a window into ocean health so that oceans can be better understood and protected.

15: Life on land

Nuclear technology is used for environmental risk assessments to protect forests and to reverse biodiversity loss.

17: Partnerships for the goals

The nuclear industry has a long history of working with stakeholders to find solutions to global problems.

NUCLEAR'S LAND FOOTPRINT

Nuclear is the most land-efficient means of electricity production, requiring only 2.4 km^2/TWh per year, which includes all aspects of production such as mining and fuel fabrication.

Other low-carbon options, such as solar, hydro and wind, require far more land at 37 km^2/TWh, 54 km^2/TWh and 72 km^2/TWh per year, respectively.

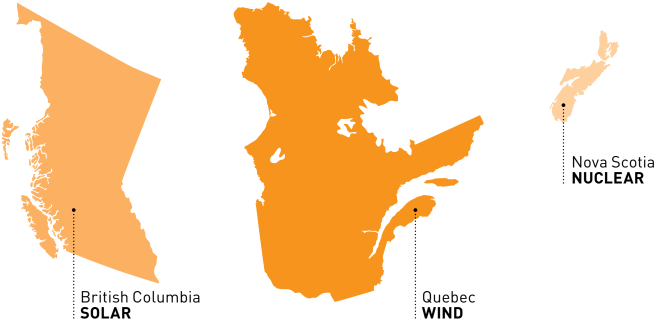
To produce 100% of global electricity with only one source, nuclear would require an area the size of Nova Scotia. Solar would occupy British Columbia and wind would need almost all of Quebec.

As a result of its small land footprint, nuclear has a very minimal impact on natural habitats.

The impact of wind turbines on birds and bats has been well documented, as has the impact of hydro dams on aquatic ecosystems.

Fossil fuel extraction has a devastating impact on forests, grasslands and water supply.

LAND USE REQUIRED TO SUPPLY GLOBAL ELECTRICITY



SOURCE • McDonald, Robert, et al. "Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America." PLoS ONE. 2009, pp. 4. http://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0006802&type=printable.

NUCLEAR AND THE CANADIAN ECONOMY

Nuclear technology is an integral part of any advanced economy. It supports medicine, materials science, advanced manufacturing, food safety and energy production.

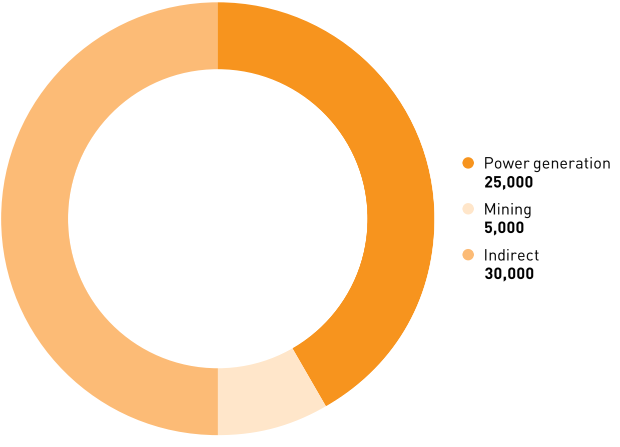
The nuclear industry directly and indirectly supports a total of 60,000 Canadian jobs, many of which are high-tech and well paid.

Nearly 200 Canadian companies supply products and/or services to the nuclear industry.

Opportunities for recent graduates are plentiful. Many nuclear workers in Canada are nearing retirement, so the industry is eager to attract new workers with a variety of backgrounds and skills.

The nuclear industry in Canada has revenues of over $6 billion annually.

JOBS SUPPORTED BY NUCLEAR IN CANADA



SOURCE • Canadian Manufacturers & Exporters. "Nuclear: A Canadian Strategy for Energy, Jobs, and Innovation." 2012, pp. 7.

URANIUM MINE PRODUCTION

Canada is the second largest uranium producer in the world, with Cameco Corporation and Orano Canada as its two primary uranium mining companies.

Canada exports 85% of the uranium it mines.

Uranium exports add $1.2 billion to the Canadian economy annually.

Uranium mining is one of the leading industrial employers of Indigenous people in Saskatchewan.

GLOBAL URANIUM MINE PRODUCTION IN 2016

COUNTRY	TONNES U	GLOBAL SHARE (%)
Kazakhstan	24,575	39
Canada	14,039	23
Australia	6,315	10
Namibia	3,654	6
Niger	3,479	6
Russia	3,004	5
Uzbekistan	2,404	4
China	1,616	3
U.S.	1,125	2
Ukraine	1,005	2
Other	1,152	2

DID YOU KNOW?

CANADA HAS OVER 500,000 TONNES OF PROVEN URANIUM RESERVES!

SOURCES • Natural Resources Canada. "About Uranium." 2018. https://www.nrcan.gc.ca/energy/uranium-nuclear/7695.

Natural Resources Canada. "The Canadian Nuclear Industry and its Economic Contributions." 2018. https://www.nrcan.gc.ca/energy/uranium-nuclear/7715.

World Nuclear Association. "World Uranium Mining Production." 2018. http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx.

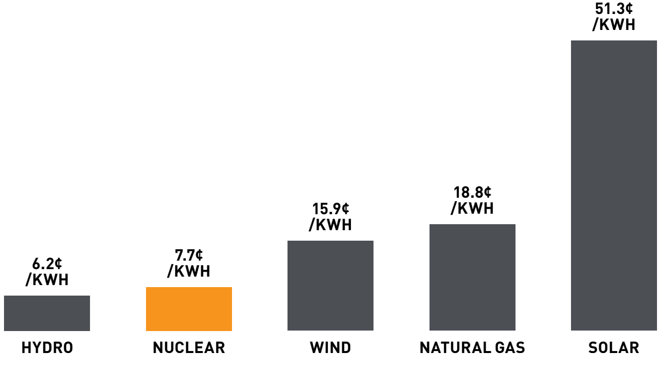
COST OF NUCLEAR POWER

Nuclear remains one of the most affordable electricity sources worldwide.

While nuclear generating stations require high upfront capital investment, their long life and low costs for fuel, operations and maintenance lead to low power costs in the long run.

In Ontario, only hydro has a lower cost per kilowatt-hour than nuclear. Gas and wind are about twice as expensive as nuclear, and solar is more than six times as expensive.

COST OF ENERGY BY SOURCE IN ONTARIO IN 2018



DID YOU KNOW?

MORE THAN HALF OF THE COST OF NUCLEAR IS ATTRIBUTABLE TO FACILITY CONSTRUCTION. ONCE BUILT, NUCLEAR HAS VERY LOW FUEL AND MAINTENANCE COSTS, PROVIDING STABLE ELECTRICITY PRICES OVER THE PLANT'S LIFETIME OF 60+ YEARS.

SOURCE • Ontario Energy Board. "Regulated Price Plan Supply Cost Report." 2018, pp. 16. https://www.oeb.ca/sites/default/files/RPP-Supply-Cost-Report-20180501-20190430-correction.pdf.

URANIUM AND NUCLEAR **REACTORS**

URANIUM

Uranium is a heavy metal and one of many naturally occurring radioactive elements. It exists in most rocks and soils at approximately two to four parts per million—about the same concentration as tin.

Like other elements, uranium occurs in several different forms, known as isotopes.

The most common isotope of uranium is U-238 (99.28%), followed by U-235 (0.71%). The number following the "U" indicates the atomic weight of the isotope.

U-235 is the primary isotope of uranium that is used to generate electricity because it is fissile (i.e., can be easily split or "fissioned"). Fission releases 100 million times more energy per atom than the chemical energy that's released in a combustion reaction.

URANIUM ORE

DID YOU KNOW?

CANDU REACTORS USE U-235 IN ITS NATURAL CONCENTRATION (0.71%), WHEREAS OTHER REACTOR DESIGNS USE FUEL ENRICHED TO 3% U-235 OR HIGHER.

CONVERTING URANIUM ORE INTO CANDU REACTOR FUEL

Mining

Uranium ore is extracted from the ground in one of three ways: open-pit mining, underground mining or in-situ recovery.

Milling

The ore is crushed in a mill and ground to a fine slurry. The slurry is leached in acid to separate the uranium from the minerals, which is then purified to produce uranium oxide powder.

Refining

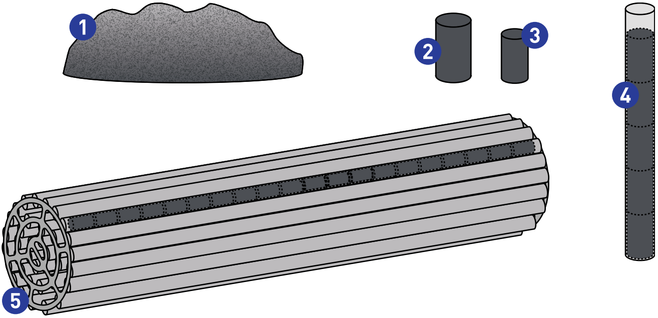
A series of chemical processes separate the uranium oxide from impurities, producing high-purity uranium trioxide.

Conversion

Uranium trioxide is converted to uranium dioxide.

Fuel manufacturing

Uranium dioxide powder (1) is pressed into small cylindrical pellets (2), which are baked at high temperatures and finished to precise dimensions (3). Pellets are loaded into fuel tubes (4), which are then assembled into reactor-ready bundles (5).



URANIUM MINING METHODS

There are three ways of mining uranium:

Open-pit mining is used when uranium deposits are located near the surface. It involves removing a layer of soil and waste rock, and then excavating a pit to access the ore. The walls of the pit are mined in a series of benches to prevent them from collapsing.

Underground mining is the preferred method when deposits are found deep underground. It involves digging a vertical shaft to the depth of the ore, and then cutting a number of tunnels to access the ore directly.

In-situ recovery (or in-situ leaching) is the process of dissolving the uranium ore by pumping mining solutions underground, bringing them back to the surface, and extracting the dissolved uranium. Though not currently used in Canada, in-situ recovery is the fastest-growing mining method.

IMAGE • Cameco

CANADA'S URANIUM INDUSTRY

Most Canadian uranium is mined and milled in northern Saskatchewan, in the Athabasca Basin region.

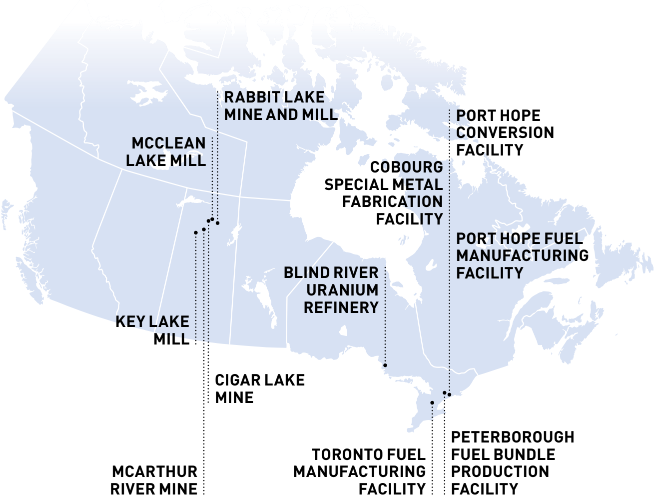
Canada has the world's highest-grade uranium deposits with grades more than 100 times the global average.

Blind River, Ontario, is home to Canada's only uranium refining facility. Owned and operated by Cameco, it is the largest such facility in the world.

Port Hope, Ontario, is home to Canada's only uranium conversion facility, also owned and operated by Cameco.

Plants that process natural uranium powder and assemble CANDU fuel bundles are located in Port Hope (Cameco), as well as in Toronto and Peterborough (BWXT Nuclear Energy Canada), Ontario.

MAP OF CANADIAN URANIUM FACILITIES



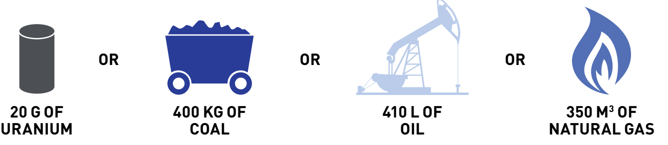
THE POWER OF URANIUM

Nuclear fission is a very energy-dense source of energy, so a nuclear reactor requires very little fuel.

Uranium pellets are approximately 20 grams each, and fewer than 10 are needed to power the average Canadian household for a year.

Providing the same amount of electricity as one 20-gram uranium pellet would require 400 kilograms of coal, 410 litres of oil or 350 cubic metres of natural gas.

FUEL REQUIRED TO PRODUCE THE SAME AMOUNT OF ELECTRICITY



CANDU FUEL BUNDLE

IMAGE • Nuclear Waste Management Organization

HOW FISSION WORKS

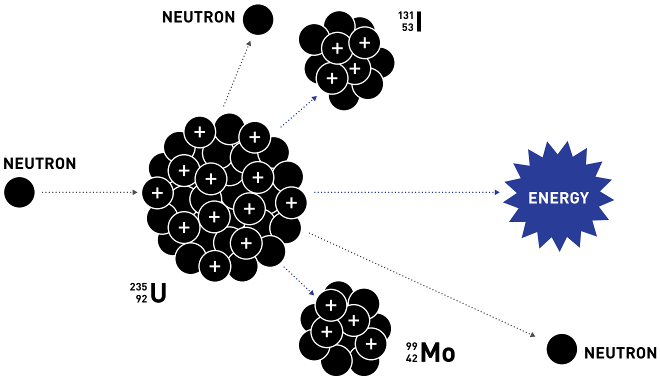
Uranium, in both of its main isotopes, U-235 and U-238, emits very little radiation before it is used in the reactor—so little that unused fuel bundles are safe to handle.

When a neutron collides with a U-235 atom, however, the atom undergoes fission. It splits into several pieces, including two or three extra neutrons, and releases heat that can be converted into electricity.

These extra neutrons then collide with other nearby U-235 atoms, prompting more fission and allowing the effect to continue. Nuclear reactors control this chain reaction to the desired stable state.

This process also produces other smaller isotopes, such as iodine-131, cesium-137 and molybdenum-99, which are useful in medicine and industry.

NUCLEAR FISSION



NUCLEAR REACTORS

A nuclear reactor is a highly sophisticated steam engine that turns an electrical generator. The heat used to generate the steam comes from the energy produced by the fission reaction.

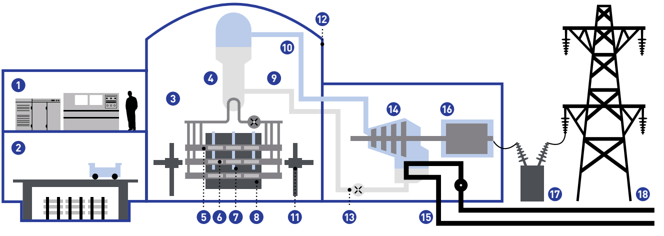
The basic parts of a nuclear reactor are the uranium fuel, the moderator and the coolant.

Depending on the reactor type, the uranium may be natural, of which 0.71% is U-235, or enriched so that the U-235 makes up 3% or more of the total.

The moderator is a light material, such as water, that slows down the neutrons without capturing them. By slowing down the fast neutrons created during fission, the moderator allows further fission.

The coolant is a fluid circulating through the reactor core that is used to absorb and transfer the heat produced by nuclear fission. It also maintains the temperature of the fuel within acceptable limits.

CANDU REACTOR SCHEMATIC



1. Control room
2. Used fuel management
3. Reactor core
4. Steam generator (boiler)
5. Coolant (heavy water)
6. Fuel (uranium)
7. Control rods
8. Moderator (heavy water)
9. Water
10. Steam
11. Fueling machine
12. Shielding
13. Condenser
14. Steam turbine
15. Condenser cooling water
16. Electrical generator
17. Transformer
18. Electrical grid

CANDU REACTORS

CANDU stands for CANada Deuterium Uranium, because it was invented in Canada, uses deuterium oxide (also known as heavy water) as a moderator and coolant, and uses uranium as a fuel.

CANDU reactors are unique in that they use natural, unenriched uranium as a fuel. With some modification, they can also use thorium, recycled uranium and mixed fuels.

CANDU reactors can be refuelled while operating at full power, while most other reactors are designed to be shut down for refuelling.

CANDU reactors are exceptionally safe. The safety systems are independent from the rest of the plant, and each key safety component has three backups. This multiplication of safety measures is often referred to as "redundancy" or "defence in depth." Not only does this increase the overall safety of the system, but it also makes it possible to test the safety systems while the reactor is operating at full power.

CANDU REACTOR FACE AT BRUCE A

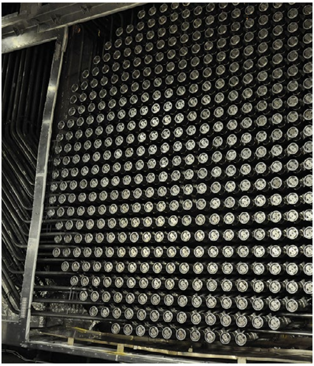


IMAGE • Bruce Power

DID YOU KNOW?

ONE CANDU REACTOR CAN BE POWERED WITH THE RECYCLED URANIUM FROM FOUR LIGHT WATER REACTORS WITHOUT ANY ADDITIONAL FUEL!

CANDU REACTORS GLOBALLY

Canada has exported CANDU reactors to Argentina, China, India, Pakistan, Romania and South Korea. In total, there are 34 CANDU reactors globally, 30 of which are currently operable.

There are also 16 reactors built in India that are based on the CANDU design but are not technically CANDUs.

CERNAVODA (ROMANIA)

EMBALSE (ARGENTINA)

QINSHAN (CHINA)

WOLSONG (SOUTH KOREA)

IMAGES • SNC-Lavalin

CANDU AND CANDU-DERIVED REACTORS GLOBALLY

FACILITY	UNITS	STATUS	NET CAPACITY (MWE)
Bruce Power	8 CANDU reactors	Operable	6,288
Darlington	4 CANDU reactors	Operable	3,512
Pickering	6 CANDU reactors	Operable	3,094
	2 CANDU reactors	Shut down	1,030
Point Lepreau	1 CANDU reactor	Operable	660
Gentilly-2	1 CANDU reactor	Shut down	635
Cernavoda (Romania)	2 CANDU reactors	Operable	1,300
Emblase (Argentina)	1 CANDU reactor	Operable	600
Karachi (Pakistan)	1 CANDU reactor	Operable	90
Kaiga (India)	4 CANDU-derived reactors	Operable	808
Kakrapar (India)	2 CANDU-derived reactors	Operable	404
Madras (India)	2 CANDU-derived reactors	Operable	410
Narora (India)	2 CANDU-derived reactors	Operable	404
Rajasthan (India)	1 CANDU reactor	Operable	187
	1 CANDU reactor	Shut down	90
	4 CANDU-derived reactors	Operable	808
Tarapur (India)	2 CANDU-derived reactors	Operable	980
Qinshan (China)	2 CANDU reactors	Operable	1,354
Wolsong (South Korea)	4 CANDU reactors	Operable	2,576

SOURCE • IAEA Power Reactor Information System. "Country Statistics." 2018. https://www.iaea.org/PRIS/CountryStatistics/CountryStatisticsLandingPage.aspx.

POWER REACTOR DESIGNS GLOBALLY

CANDU reactors are a type of pressurized heavy water reactor (PHWR). They are one of several power reactor designs currently used worldwide.

Different designs use different concentrations of uranium for fuel, different moderators and different coolants in the reactor core.

The most common reactor design is the pressurized water reactor (PWR), representing 297 of the world's 453 currently operable nuclear power reactors.

DIFFERENCES AMONG POWER REACTOR DESIGNS

REACTOR DESIGN	FUEL	MODERATOR	COOLANT	QUANTITY
Pressurized water reactor (PWR)	Enriched UO_2	Water	Water	297
Boiling water reactor (BWR)	Enriched UO_2	Water	Water	75
Pressurized heavy water reactor (PHWR)	Natural UO_2	Heavy water	Heavy water	49
Light water graphite reactor (LWGR)	Enriched UO_2	Graphite	Water	15
Gas-cooled reactor (GCR)	Natural U and enriched UO_2	Graphite	Carbon dioxide	14
Fast breeder reactor (FBR)	PuO_2 and UO_2	None	Liquid sodium	3

DID YOU KNOW?

PRESSURIZED HEAVY WATER REACTORS, OR "CANDU-TYPE" REACTORS, MAKE UP ABOUT 11% OF THE POWER REACTORS IN USE TODAY. THEY ARE MOST COMMON IN CANADA AND INDIA.

SOURCE • World Nuclear Association. "Nuclear Power Reactors." 2018. http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx.

NEXT GENERATION REACTORS AND ADVANCED FUELS

Ongoing innovation ensures that nuclear remains among our best options for clean, reliable and affordable power.

In 2002, the Generation IV International Forum was established to oversee the development of six new reactor technologies:

1. Gas-cooled fast reactor (GFR)
2. Lead-cooled fast reactor (LFR)
3. Molten-salt reactor (MSR)
4. Sodium-cooled fast reactor (SFR)
5. Supercritical water-cooled reactor (SCWR)
6. Very high temperature reactor (VHTR)

All six designs offer improvements over existing reactors, including output flexibility, varying fuel options and reduced waste streams.

Four of the six reactor types are suitable for hydrogen production or other process heat, in addition to power generation.

Advanced fuel options include thorium, reprocessed uranium and mixed oxide fuel (MOX).

Thorium is a naturally occurring element more abundant in nature than uranium. Several types of reactors can already use thorium.

Reprocessed uranium (or recycled uranium) is uranium that has been recovered from used nuclear fuel and treated for re-use. It has the potential to reduce the volume of high-level waste.

MOX is made from plutonium recovered from used nuclear fuel and depleted uranium. MOX also provides a means of using and eliminating weapons-grade plutonium.

SOURCE • The Generation IV International Forum. "Generation IV Systems." 2018. https://www.gen-4.org.

SMALL MODULAR REACTORS

Small modular reactors (SMRs) are relatively small nuclear reactors designed to be built economically in factory-like conditions (rather than fully constructed onsite), with capacities ranging from 1 to 300 MWe.

The potential applications for SMRs in Canada include providing electricity and heat to smaller and/or remote communities, providing process heat for resource industries such as Ontario's Ring of Fire mining and Alberta's oil sands, as well as contributing to existing power grids.

The deployment of SMRs in Canada would reduce greenhouse gas emissions drastically since nuclear would, in many cases, replace fossil fuel generation.

SMRs could also have a positive socio-economic impact on Canada depending on the country's participation in developing and manufacturing the technology.

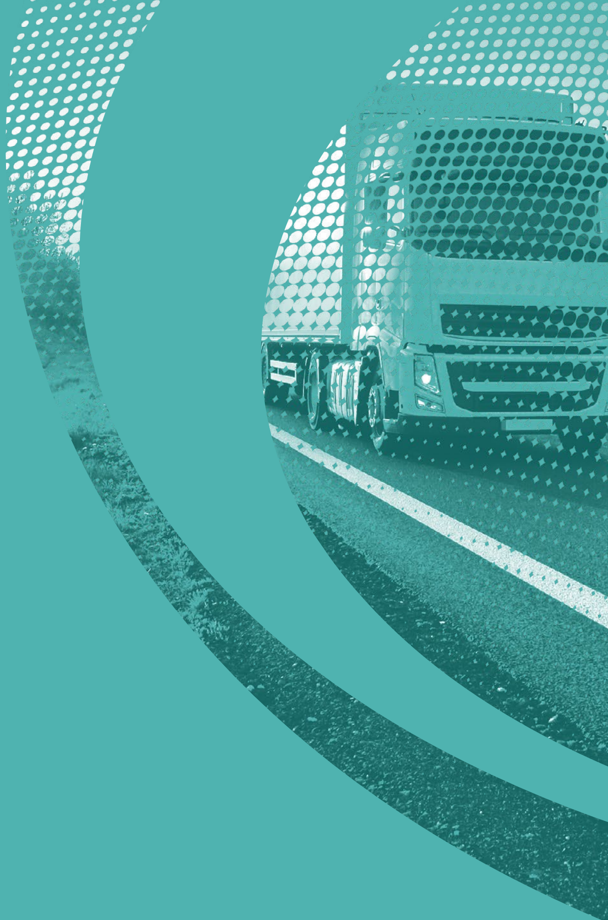
Currently there are more than 45 SMR designs under development, and four SMRs are already under construction in Argentina, Russia and China.

Canada is already recognized internationally as a favourable market and regulatory environment for SMRs. An early leadership position could secure a significant share of the projected $400 to $600 billion global market for SMR technology.

TERRESTRIAL ENERGY SMR SCHEMATIC

IMAGE • Terrestrial Energy

SOURCE • International Atomic Energy Agency. "Small modular reactors." 2018. https://www.iaea.org/topics/small-modular-reactors



RADIOACTIVE WASTE AND TRANSPORTATION

RADIOACTIVE WASTE

Radioactive waste is any post-production solid, liquid or gas that emits radiation.

Industrial activity at uranium mines, mills, nuclear power plants, and research and medical facilities creates radioactive waste.

There are four classes of radioactive waste:

Uranium mine and mill waste consists of waste rock from uranium mining and tailings from uranium milling. Waste rock is the material removed from the mine to gain access to the uranium ore. Tailings are what remain of the ore after the uranium has been removed by a chemical process.

Low-level waste (LLW) includes items such as mop heads, cloths, gloves and other protective clothing that may have been contaminated while being used in the workplace. Over 98% of the nuclear waste in Canada by volume is LLW.

Intermediate-level waste (ILW) includes items that have had more direct contact with radioactive substances such as ion-exchange resins and reactor components.

High-level waste (HLW) is used fuel. It is generated at nuclear power plants and is highly radioactive.

RADIOACTIVE WASTE IN CANADA

WASTE CATEGORY	INVENTORY TO END OF 2016
Waste rock	169,000,000 tonnes
Mill tailings	218,000,000 tonnes
Low-level waste (LLW)	2,359,385 m^3
Intermediate-level waste (ILW)	33,155 m^3
High-level waste (HLW)	11,089 m^3

SOURCE • Natural Resources Canada. "Inventory of Radioactive Waste in Canada." 2016. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/uranium-nuclear/17-0467%20Canada%20Radioactive%20Waste%20Report_access_e.pdf.

USED NUCLEAR FUEL

Used nuclear fuel is the spent fuel that is removed from a nuclear reactor.

Nuclear fuel bundles are removed from reactors when the concentration of U-235 inside the fuel becomes too low to sustain the fission reaction at the desired power level.

Once removed, used fuel is stored in water-filled pools for seven to ten years, giving it time to cool down and reduce its radioactivity.

After about ten years, nuclear fuel bundles emit less than 0.01% of the radioactivity of fuel fresh from the reactor.

Once the bundles have cooled down sufficiently, they are put into dry storage: large concrete containers that protect and cool the bundles and contain the remaining radiation.

Used nuclear fuel may be recycled to become usable again. Although this is not currently practised in Canada, fuel recycling is a part of several successful nuclear programs, including that of France.

USED FUEL BAY AT BRUCE B

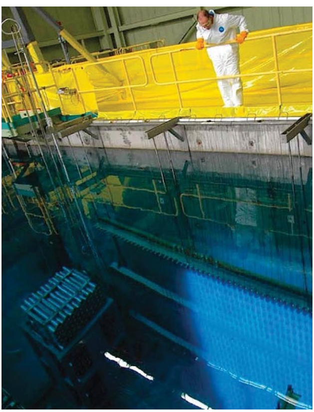


IMAGE • Bruce Power

DID YOU KNOW?

ONLY ABOUT 1% OF THE TOTAL ENERGY IN THE URANIUM IS USED BEFORE FUEL BUNDLES ARE REMOVED FROM THE REACTOR. THAT'S WHY MANY SCIENTISTS PREFER NOT TO REFER TO USED FUEL AS WASTE.

HOW USED NUCLEAR FUEL IS MANAGED

All of Canada's used nuclear fuel is safely managed at licensed storage facilities.

There are strict security measures in place to ensure there is no threat to public health from stored used fuel bundles.

The storage of used nuclear fuel is managed by the utilities and laboratories that own the fuel, and is closely monitored, regulated and licensed by the Canadian Nuclear Safety Commission (CNSC), in direct cooperation with the International Atomic Energy Agency (IAEA).

The long-term care of Canada's used nuclear fuel is managed by the Nuclear Waste Management Organization (NWMO).

USED FUEL STORAGE CONTAINERS

IMAGE • Ontario Power Generation

DID YOU KNOW?

NUCLEAR ENERGY IS SO POWERFUL THAT IF IT SUPPLIED ALL OF THE ELECTRICITY YOU'LL EVER USE, THE WASTE WOULD FIT IN A SODA CAN!

NUCLEAR WASTE MANAGEMENT ORGANIZATION

In 2002, the Nuclear Waste Management Organization (NWMO) was established in response to federal legislation to develop a management approach for the long-term care of Canada's used nuclear fuel.

The NWMO engaged citizens, knowledge specialists and Indigenous peoples across Canada to determine the approach that met the priorities and objectives of Canadians. In 2007, the Government of Canada selected Adaptive Phased Management (APM) as Canada's plan. The NWMO is responsible for implementing this plan.

The end point of APM is the centralized containment and isolation of used nuclear fuel in a deep geological repository. The project will only proceed with the interested community, the local First Nation and Métis communities and the surrounding communities working in partnership to implement it.

The siting process is community-driven and designed to ensure, above all, that the site selected is safe and secure. It involves detailed technical and social studies to progressively narrow down to a single preferred site by 2023.

A safe, secure and socially acceptable transportation plan is also required.

As required by law, the producers of used nuclear fuel are responsible for fully funding the implementation of Canada's plan.

DID YOU KNOW?

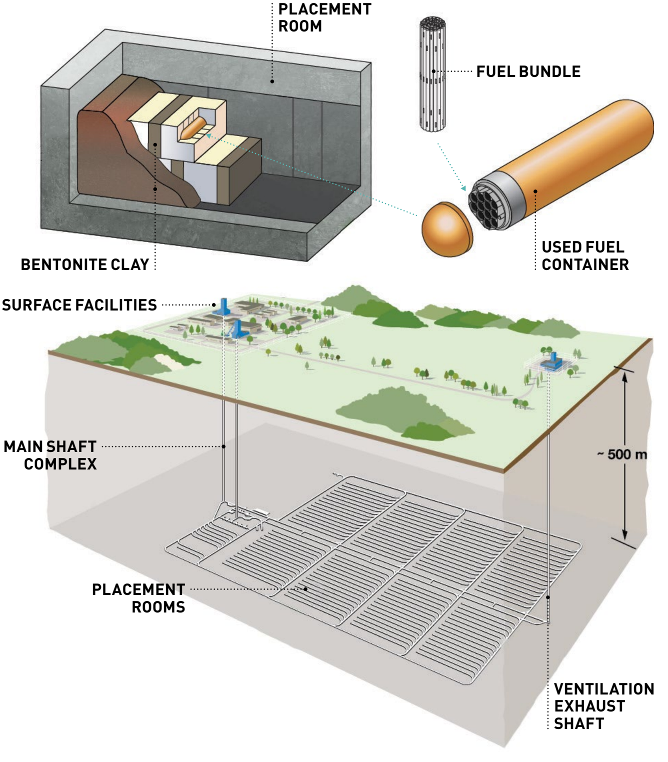
AS WAS MANDATED BY THE NUCLEAR FUEL WASTE ACT, PRODUCERS OF USED NUCLEAR FUEL HAVE ALREADY CONTRIBUTED TO TRUST FUNDS THAT ENSURE THE LONG-TERM MANAGEMENT OF CANADA'S USED FUEL.

DEEP GEOLOGICAL REPOSITORY

Used nuclear fuel stored in a deep geological repository will be placed in secure containers approximately 500 metres underground.

Advanced containers and secure geology will ensure that the public and environment are protected from radiation exposure.

DEEP GEOLOGICAL REPOSITORY SCHEMATIC



SOURCE • Nuclear Waste Management Organization.
"Deep Geological Repository Conceptual Design Report Crystalline / Sedimentary Rock Environment." May 2016.
https://www.nwmo.ca/~/media/Site/Reports/2016/06/08/10/03/APM_REP_00440_0015_R001.ashx?la=en.

TRANSPORTATION

Every year around the world, about 20 million shipments containing radioactive substances are transported on public roads, railways and ships.

Canada has extensive experience in transporting fuel cycle materials, including uranium ore, fuel bundles, tritiated water and used fuel, as well as non-fuel cycle materials such as radioisotopes.

Measures that contribute to the safe management of radioactive substances include

- safe engineering of vehicles and containers;
- qualified personnel receiving sound training;
- inventory tracking and accountability;
- independent, professional regulatory bodies; and
- careful study and analysis of incidents.

The Canadian Nuclear Safety Commission (CNSC) and Transport Canada share the responsibility for the safe transport of nuclear substances.

In Canada's history, there has never been a transportation accident that has resulted in radioactive release causing harm to any individual or the environment.

DID YOU KNOW?

ONLY ABOUT 5% OF RADIOACTIVE SHIPMENTS ARE FUEL CYCLE RELATED. THE REST RELATE TO SUCH SECTORS AS MEDICINE, AGRICULTURE, INDUSTRY AND RESEARCH.

SOURCES • International Atomic Energy Agency. "Transport Security." 2018. https://www.iaea.org/topics/transport-security.

World Nuclear Transport Institute. "Nuclear Power." 2018. https://www.wnti.co.uk/nuclear-transport-facts/facts-figures.aspx.

TYPES OF PACKAGES

For the packaging of radioactive substances, Canada has adopted the standards of the International Atomic Energy Agency (IAEA), which are based on the characteristics of the material they contain.

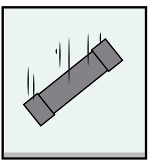
Excepted and industrial packages are sufficient for low-activity materials such as uranium ore.

Type A packages are designed to withstand minor accidents and are used for medium-activity materials such as radioisotopes.

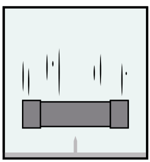
Type B packages are robust and very secure casks for high-activity materials such as used nuclear fuel and radioactive waste. These packages undergo stringent testing, including free-drop testing, puncture testing, thermal testing and immersion testing.

Type C packages offer the greatest protection in accident scenarios. They are used to transport highly hazardous materials such as plutonium and can survive being dropped from an aircraft at cruising altitude.

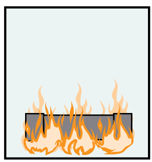
TYPE B PACKAGE TESTS



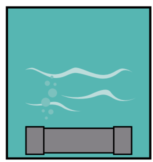
FREE DROP
A 9-metre (30-foot) free-fall onto an unyielding surface



PUNCTURE
A 1-metre (40-inch) free-fall onto a steel rod



THERMAL
A 30-minute, fully-engulfing fire at 800°C (1475°F)



IMMERSION
An 8-hour immersion under water

NUCLEAR SCIENCE AND **TECHNOLOGY**

NUCLEAR SCIENCE AND TECHNOLOGY IN CANADA

Nuclear science and technology (S&T) is an integral part of Canada's manufacturing and engineering capability. That is why the federal government and Canada's nuclear industry have a long history of investing in nuclear S&T.

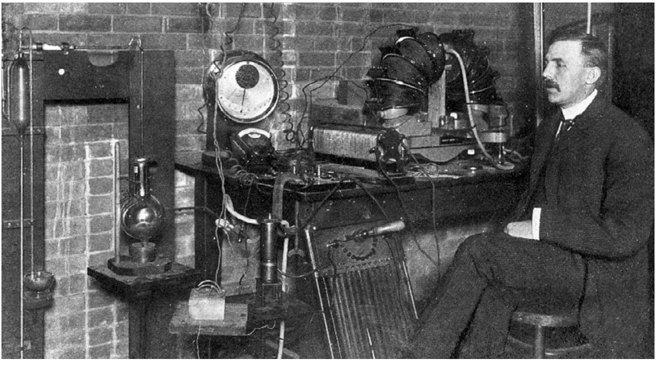
Nuclear research initiatives take place at national laboratories, universities and research reactors across the country.

Canada is a historic leader in nuclear research and is home to four Nobel prizes related to nuclear S&T:

- Ernest Rutherford in 1908 for his work at McGill University on radioactive decay;
- Richard E. Taylor in 1990 for early understandings of quarks in particle physics;
- Bertram N. Brockhouse in 1994 for developing new neutron scattering techniques; and
- Arthur B. McDonald in 2015 for the discovery of neutrino oscillations, showing that neutrinos have mass.

Nuclear technology plays an important role in numerous sectors across Canada, including medicine, food, agriculture, industry, water resources, transportation and consumer products.

ERNEST RUTHERFORD AT MCGILL IN 1905



RADIOISOTOPES AND HALF-LIVES

Nuclear technology is based on the use of radioisotopes—radioactive isotopes of an element.

All isotopes of a given element have the same number of protons in their atomic nuclei but differing numbers of neutrons.

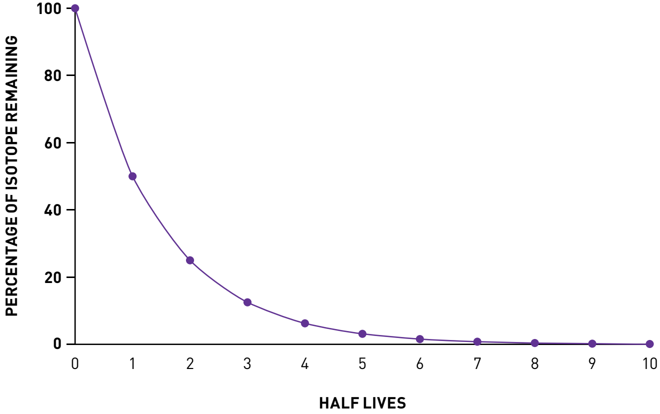
Radioisotopes are isotopes that have an unstable number of neutrons and undergo a change (or "decay") to become stable, emitting radiation in the process.

A half-life is the time it takes for half of a radioisotope to decay. The shorter the half-life, the faster the isotope decays and the more radioactive it is.

The radioisotope of uranium that is used to make fuel, U-235, has a half-life of 704 million years. This is a very long half-life and is why unused fuel bundles can be safely handled by people.

Radioisotopes that are commonly used in medicine include cobalt-60, which has a half-life of 5.27 years, and technetium-99, which has a half-life of six hours.

RADIOACTIVE DECAY



NUCLEAR MEDICINE

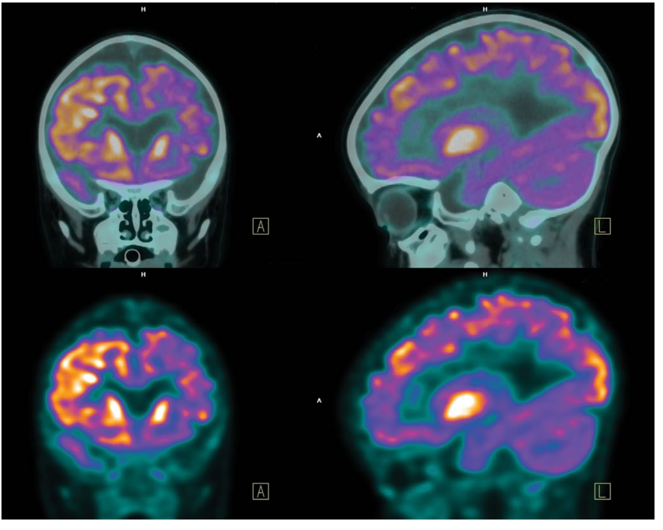
Nuclear medicine uses radiation to diagnose and determine the stages of various diseases, including cancer.

Nuclear medicine works by injecting a radioisotope into the patient. This isotope accumulates in target tissues and emits radiation that is picked up by a detector outside the body.

Over 1.5 million diagnostic scans are performed each year in Canada.

The most common radioisotope used in nuclear medicine is technetium-99, about 35% of which is produced in Canada.

DIAGNOSTIC SCAN OF THE BRAIN



SOURCE • Canadian Institutes of Health Research. "Medical Imaging." 2018. http://www.cihr-irsc.gc.ca/e/40539.html.

RADIATION THERAPY AND STERILIZATION

Radiation therapy is a common technique used to treat cancer. It works by delivering radiation to specific areas of the body to destroy cancer cells.

Radiation therapy can be performed either externally by irradiation or internally by radioisotope injection.

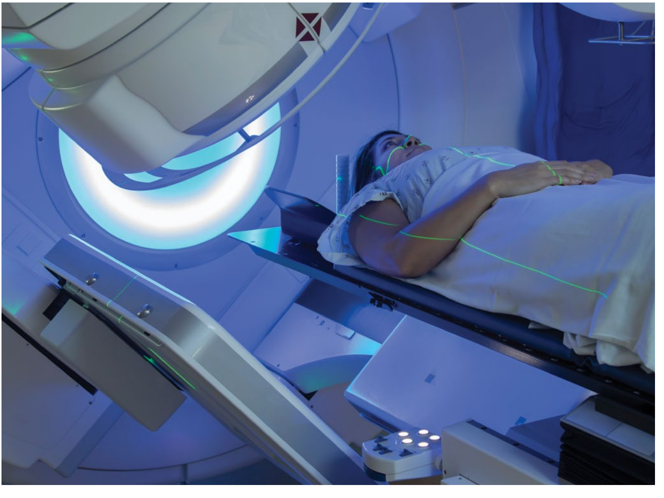
Approximately 15,000 therapeutic doses are administered each year in Canada.

Cobalt-60 is the most common radioisotope used in radiation therapy, and over 70% of the global supply is produced at Canada's nuclear power plants.

Hospitals also use cobalt-60 to sterilize medical equipment such as gowns, gloves, masks, syringes and implants.

Sterilization by radiation is less expensive than traditional heat sterilization, doesn't cause heat damage and is safer because it can be done after the items have been packaged.

PATIENT UNDERGOING RADIATION THERAPY



FOOD IRRADIATION

Food irradiation is the process of using radiation to kill bacteria, insects and parasites that can cause food-borne diseases.

Food irradiation also extends the shelf-life of food by destroying the micro-organisms that cause spoilage and by slowing the ripening process.

More than 60 countries, including Canada, irradiate food products such as meat, fruit, vegetables, grains and spices.

The Canadian firm Nordion has built many of the food irradiators around the world.

IRRADIATOR SCHEMATIC

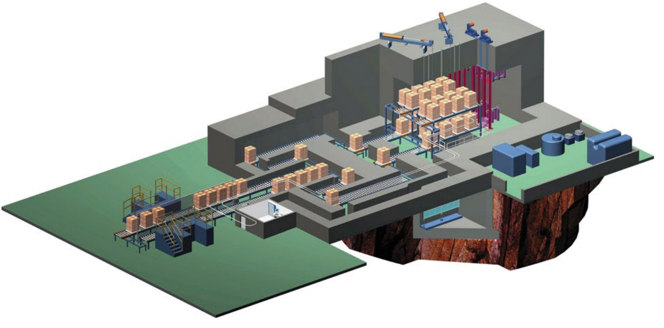


IMAGE • Nordion

DID YOU KNOW?

YEARS OF RESEARCH HAS SHOWN IRRADIATED FOOD TO BE JUST AS SAFE AND NUTRITIOUS AS FOOD PRESERVED BY FREEZING OR CANNING!

AGRICULTURAL APPLICATIONS OF RADIATION

Radiation is used in agriculture to produce more desirable crop varieties and reduce crop losses due to insects.

Crop varieties are produced by exposing seeds to radiation to induce genetic changes, a process known as mutation breeding.

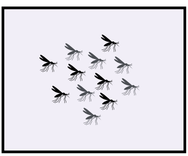
Mutation breeding has been used for several decades to create crops that are more plentiful, nutritional, adaptable to harsh climates and resistant to pests. Over 3,200 crop varieties have been developed this way.

Radiation is used to control insect populations via the Sterile Insect Technique (SIT).

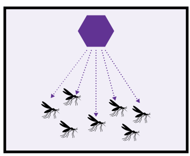
SIT is an environmentally-friendly alternative to pesticides that involves rearing, sterilizing and releasing male insects into the wild where they mate with females but produce no offspring.

Certain fertilizers also contain trace amounts of radioactive elements to determine nutrient absorption rates and improve water and fertilizer management.

STERILE INSECT TECHNIQUE

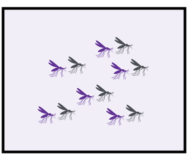


Mosquitoes are mass-reared

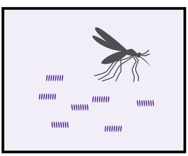


Male mosquitoes are isolated and sterilized

Sterilized males are released into the wild



Sterilized males mate with wild females



Wild females lay infertile eggs

SOURCE • International Atomic Energy Agency. "Mutation Breeding." 2018. https://www.iaea.org/topics/mutation-breeding.

INDUSTRIAL INSPECTIONS

Radioactive materials are used to examine the molecular and macroscopic structure of materials without damaging or changing them. This is a form of non-destructive testing.

Like X-rays, gamma rays pass through objects and create images of them on film, revealing material flaws.

Applications of these nuclear images include

studying critical aircraft components such as rotors, wings and landing gear to reduce their chance of in-flight failure;

examining the structure of automotive engines so that they can be made more reliable and with fewer defects;

improving the surface structure of medical implants such as pacemakers so that they are more compatible with the human body;

analyzing pipes and other oil and gas components to decrease defects, thereby avoiding leaks and benefitting environmental and human health; and

developing sophisticated delivery systems for pharmaceuticals to make them more effective and reduce side effects.

INDUSTRIAL GAUGES AND TRACERS

A nuclear gauge is a device that uses a radioactive source to quickly detect characteristics of an item such as thickness, density or chemical makeup.

There are two main types of gauges: fixed and portable.

Fixed gauges are typically used in production facilities to control and monitor product quality.

Portable gauges are brought to work sites for assorted reasons, including

- analyzing the walls of dug holes to identify mineral deposits;
- searching for underground caves or other formations that could make a building site unstable; and
- determining the density of asphalt in paving mix to optimize road life, rutting resistance and overall durability.

Radioisotopes are used as tracers to study the mixing and flow rates of various liquids, powders and gases, and to locate leaks.

Tracers can help to characterize ground and surface water resources, such as age, origin, distribution and interconnections, as well as to identify discharge and sedimentation rates.

MOISTURE/ DENSITY GAUGE

IMAGE • Humboldt Scientific

DID YOU KNOW?

THE CANADIAN NUCLEAR SAFETY COMMISSION (CNSC) REGULATES THE POSSESSION, USE, PACKAGING, TRANSPORT, STORAGE, IMPORT AND EXPORT OF ALL TYPES OF NUCLEAR SUBSTANCES, INCLUDING NUCLEAR GAUGES.

NUCLEAR DESALINATION

Most Canadians are fortunate to have ready access to fresh water. However, in many parts of the world, potable water is in short supply.

Approximately 19,000 desalination plants have been built in 150 countries to produce safe drinking water.

Most desalination plants are powered by burning fossil fuels, which contributes to increased GHG emissions.

Nuclear desalination plants use the heat from small nuclear reactors to evaporate water, leaving the salt and debris behind.

Though there are several desalination methods available, nuclear desalination offers carbon-free heat and low fuel costs.

There are several small and demonstration nuclear desalination plants in operation, but so far no large-scale commercial deployments.

CHILD DRINKING CLEAN WATER

DID YOU KNOW?

IT IS ESTIMATED THAT ONE-FIFTH OF THE WORLD DOES NOT HAVE ACCESS TO SAFE DRINKING WATER.

SOURCES • International Desalination Association. "Desalination by the Numbers." 2018. http://idadesal.org/desalination-101/desalination-by-the-numbers/.

World Nuclear Association. "Desalination." 2018. http://www.world-nuclear.org/information-library/non-power-nuclear-applications/industry/nuclear-desalination.aspx.

NUCLEAR-POWERED TRAVEL

Space travel

Nuclear power has been used for space travel since 1961.

Radioisotope thermal generators (RTGs) are used in most space missions. The heat generated by the decay of a radioactive source, often plutonium, is used to generate electricity.

The Voyager space probes, the Cassini mission to Saturn, the Galileo mission to Jupiter, the New Horizons mission to Pluto and the Curiosity mission to Mars were all powered by RTGs.

Voyager 2, launched in 1977, is the world's longest-running space mission.

Marine travel

Nuclear power is particularly suitable for vessels that need to be at sea for extended periods of time without refuelling.

Currently, there are over 140 nuclear-powered vessels, the majority of which are submarines.

Road travel

In the future, electricity or heat from nuclear power plants could be used to make hydrogen, which can be used in fuel cells to power cars.

MARS CURIOSITY ROVER

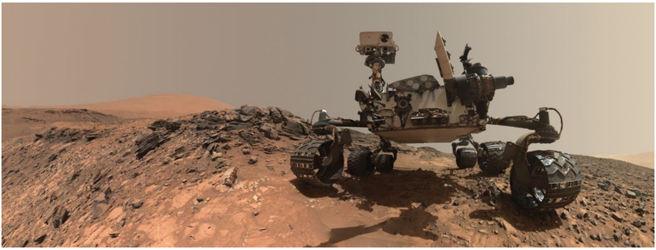


IMAGE • NASA

SOURCE • World Nuclear Association. "The Many Uses of Nuclear Technology." 2018. http://www.world-nuclear.org/information-library/non-power-nuclear-applications/overview/the-many-uses-of-nuclear-technology.aspx.

CONSUMER PRODUCTS

Smoke detectors are the most common consumer products that use nuclear technology. They use the radiation from a small amount of americium-241 to detect the presence of smoke or heat.

Emergency exit signs are powered by tritium, a radioactive isotope of hydrogen. These signs do not require electricity or batteries, and therefore serve an important safety function during power outages.

Tritium is also used in clocks, watches and gun sights to create "light" in the absence of electricity.

Other consumer products that use nuclear technology include

- cosmetics, such as contact lens solutions and hair products, which are sterilized with radiation;
- frying pans, which are often treated with radiation to achieve a non-stick surface; and
- photocopiers, which sometimes use radioactive polonium to prevent static build-up.

HOW SMOKE DETECTORS WORK

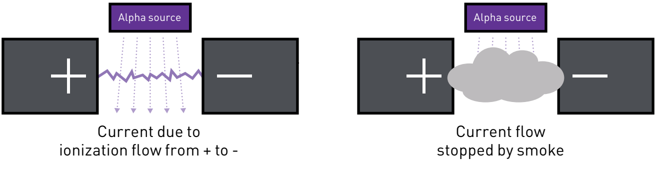


IMAGE • Teaching Advanced Physics

SOURCE • World Nuclear Association. "Radioisotopes in Consumer Products." 2018. http://www.world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-consumer-products.aspx.

OTHER USES OF NUCLEAR TECHNOLOGY

The applications of nuclear technology are vast and, in addition to those already described, include

- preventing the spread of infectious diseases such as Ebola, malaria and Zika;
- measuring magnitudes and sources of soil erosion;
- detecting, monitoring and tracking food contaminants;
- improving livestock health, productivity and nutrition;
- combating malnutrition and childhood obesity;
- analyzing metals, alloys and electronic materials;
- identifying extremely small and diluted forensic materials;
- characterizing archaeological and historical materials;
- carbon dating the age of rocks and organic materials; and
- studying air pollution and aerosols.

SOURCE • International Atomic Energy Association. "Material Analysis." 2018. https://www.iaea.org/topics/material-analysis.

NUCLEAR RESEARCH CENTRES

Nuclear research centres are key facilities for promoting nuclear S&T.

There are several major nuclear research centres in Canada, five of which use research reactors. Other centres rely on particle accelerators, including linear accelerators, cyclotrons and synchrotrons.

Canada's largest nuclear research centre is Chalk River Laboratories (CRL), owned by Atomic Energy of Canada Limited (AECL) and operated by Canadian Nuclear Laboratories (CNL).

CRL boasts several nuclear facilities, such as the ZED-2 Research Reactor and the Co-60 Gamma Irradiation Facility, as well as multiple other facilities and laboratories that support innovation in safety, security, health, the environment and clean energy.

Until it was shut down in 2018, the National Research Universal (NRU) at CRL was Canada's most powerful research reactor and the third most powerful research reactor in the world.

TRIUMF operates the world's most powerful cyclotron, enabling leading Canadian research in atomic physics and new methods of producing radioisotopes.

Canadian Light Source (CLS) operates Canada's only synchrotron.

CHALK RIVER LABORATORIES

IMAGE • Canadian Nuclear Laboratories

NRU REACTOR

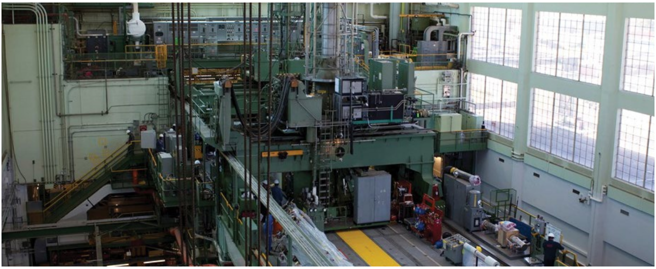


IMAGE • Canadian Nuclear Laboratories

INSIDE THE TRIUMF CYCLOTRON

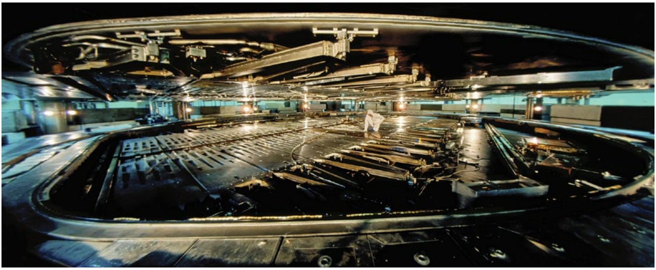


IMAGE • TRIUMF

INSIDE THE CLS SYNCHROTRON

IMAGE • Canadian Light Source

FUSION RESEARCH

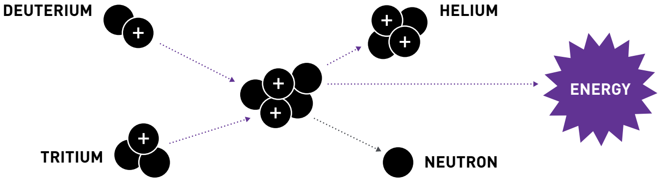
Fusion is a form of nuclear energy with the potential to create massive amounts of heat by forcing atomic nuclei together. It is essentially the opposite of fission, which involves splitting atoms apart.

In the sun, gravity creates the conditions for fusion. Here on earth, the challenge is to create these same conditions by using magnetic fields and inertia.

One of the most efficient fuels for fusion power is a mix of heavy hydrogen isotopes (deuterium and tritium), which means that water could become a primary fuel source.

In addition to having an abundant fuel source, fusion has the potential for even cleaner operation and shorter-lived radioactive waste compared to fission.

NUCLEAR FUSION



FUSION REACTOR PROTOTYPE

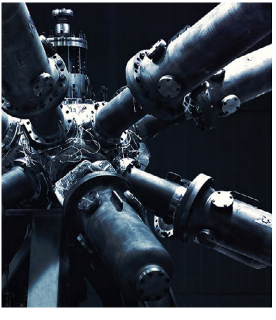


IMAGE • General Fusion

DID YOU KNOW?

ONE CUBIC KILOMETRE OF WATER CAN PRODUCE MORE FUSION ENERGY THAN ALL OF THE COAL, OIL AND GAS EVER FOUND IN ALL OF HUMAN HISTORY!

RADIATION,
NUCLEAR SAFETY AND SECURITY

RADIATION

Radiation is energy that travels in the form of waves or particles. It can be found everywhere in the universe, including in rocks on the earth and in deep space.

Some types of radiation that can be directly sensed by humans are sound, light and heat. Other types can only be observed indirectly, such as microwaves, radio waves and ionizing radiation.

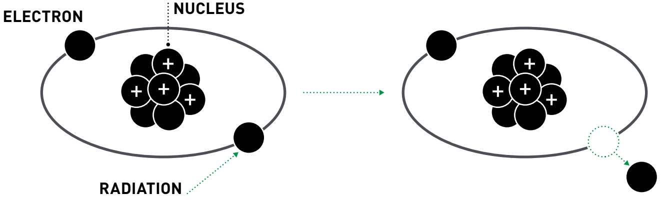
When radiation is discussed in the context of nuclear energy, it is typically referring to ionizing radiation.

Ionizing radiation is released when atoms decay. It is a highly energetic type of radiation that can detach electrons from atoms in the irradiated material.

Ionizing radiation occurs naturally and can be found all around us. The normal level of radiation at any given location is called background radiation.

Within the context of nuclear safety and human health, the most relevant types of radiation are alpha particles, beta particles and gamma rays.

IONIZING RADIATION



BACKGROUND RADIATION

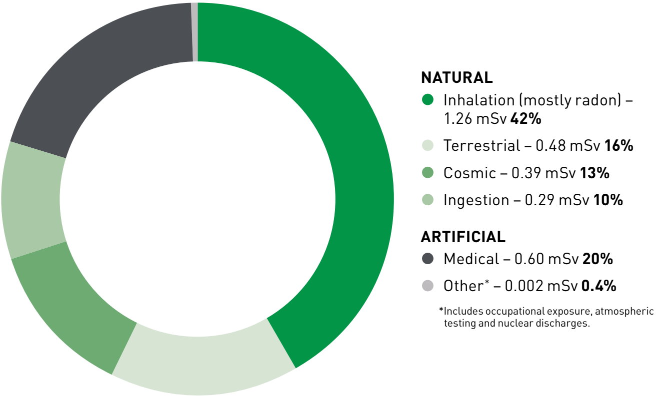
Background radiation is made up of natural and artificial (man-made) sources.

Natural background radiation worldwide is on average 2.4 mSv/year, though local variations can be significant. In some places, such as Ramsar, Iran, natural radiation levels can reach 260 mSv/year—over five times the dose limit for Canadian nuclear energy workers.

Canadians, on average, are naturally exposed to about 1.8 mSv/year. Local levels vary from about 1.3 mSv in Vancouver to about 4.1 mSv in Winnipeg. Most of this radiation comes from rocks in the ground and from naturally occurring radon gas.

Radiation from nuclear power produces less than 0.1% of our natural background radiation.

GLOBAL SOURCES OF RADIATION



SOURCES • Canadian Nuclear Safety Commission. "Radiation Doses." 2018. http://www.nuclearsafety.gc.ca/eng/resources/radiation/introduction-to-radiation/radiation-doses.cfm.

United Nations Scientific Committee on the Effects of Atomic Radiation. "Sources and Effects of Atomic Radiation: UNSCEAR 2008 Report." 2010, pp. 4. http://www.unscear.org/docs/publications/2008/UNSCEAR_2008_Report_Vol.I.pdf.

RADIATION DOSES AND EFFECTS

There are many different ways of measuring radiation. Alpha, beta and gamma radiation can be counted with a Geiger counter. Accumulated radiation dose can be measured over time with a personal dosimeter.

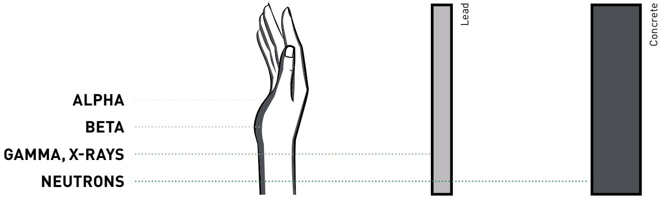
Different types of ionizing radiation have different biological effects. To account for these differences, the biological effects of ionizing radiation are generally measured in units called millisieverts (mSv).

Ionizing radiation cannot make non-radioactive material radioactive. This is why it is safe to use in sterilizing food and medical supplies.

High doses of ionizing radiation, however, can damage healthy tissues and cause serious illness.

While a safe level of radiation has not been conclusively established, research shows that radiation doses of up to 100 mSv/year have no measurable health effects in humans.

THE PENETRATING POWER OF DIFFERENT TYPES OF RADIATION



EFFECTS OF RADIATION ON THE BODY

While the low doses we receive naturally and through medical procedures pose little risk to our health, high doses received in a short time (called acute doses) can be very dangerous.

Doses at these magnitudes occur only in extreme circumstances, such as in the case of emergency workers after the Chernobyl accident. No event producing doses of this magnitude has ever occurred in Canada.

RADIATION DOSES AND EXAMPLES

MSV	EXAMPLE
10,000	Acute dose that would be fatal within weeks
6,000	Acute dose to some Chernobyl emergency workers
5,000	Acute dose that would be fatal to half of those exposed within months
1,000	Acute dose that would cause radiation sickness, but not death
600	Maximum hourly dose recorded at Fukushima on 14 March 2011
350	Dose to Chernobyl residents who were relocated
150	Annual dose to astronauts on the International Space Station
50	Annual dose limit for nuclear energy workers
10	Dose from a full-body CT scan
1.8	Annual dose to Canadians from natural background radiation
1.0	Average annual dose to nuclear energy workers
0.1	Dose from a chest x-ray
0.01	Dose from a dental x-ray
0.001	Annual dose from living near a Canadian nuclear power plant

DID YOU KNOW?

LIFE ON EARTH EVOLVED IN A RADIATION FIELD, AND SOME RESEARCH SHOWS THAT OUR CELLS HAVE THE ABILITY TO REPAIR DAMAGE DONE BY RADIATION!

NUCLEAR SAFETY

Canada's nuclear power program has an exemplary safety track record with over 60 years of occupational and public health and safety, and is a leader in the industry worldwide.

There are many layers of protection between nuclear facilities and the communities in which they operate. These layers of protection ensure the safety of workers, communities and the environment against any potential incident that could be caused by human error, equipment failure or external forces such as earthquakes.

Nuclear power generation is the only energy technology for which there is an international oversight agency at the United Nations: the International Atomic Energy Agency (IAEA).

Because of stringent monitoring and regulation at the national and international levels, nuclear power generation is one of the safest energy technologies.

IAEA DIRECTOR GENERAL YUKIYA AMANO

DID YOU KNOW?

NUCLEAR POWER TECHNOLOGY HAS THE LOWEST RATE OF FATALITIES AND INJURIES PER UNIT OF GENERATED ELECTRICITY!

NUCLEAR REGULATION

The Canadian Nuclear Safety Commission (CNSC) is Canada's nuclear regulator.

The CNSC is an independent agency that reports to Parliament through the Minister of Natural Resources. The CNSC has quasi-judicial powers, similar to a court of law, and can impose legal penalties such as fines on individuals and organizations.

The CNSC is responsible for regulating the use of nuclear energy and materials to protect the health, safety and security of Canadians and the environment.

The CNSC monitors and regulates the entire nuclear fuel cycle and other uses of nuclear material, including uranium mines, mills, processing facilities, fuel fabrication plants, nuclear power facilities, radioactive waste management facilities, nuclear research facilities and nuclear substances processing facilities.

Any person or organization that wants to possess, use, transport or store nuclear material—or build, operate, decommission or abandon a nuclear facility, including a nuclear power facility—must first obtain a licence issued by the CNSC.

The CNSC also implements Canada's international commitments on the peaceful use of nuclear energy.

The CNSC has a long-standing history of international bilateral and multilateral cooperation. International peer reviews and shared practices are conducted often through the IAEA and the World Association of Nuclear Operators (WANO).

WHAT THE CNSC IS DOING

The CNSC is currently assessing proposed new nuclear projects, including a deep geological repository for nuclear waste at the Bruce site, a near-surface waste disposal facility at Chalk River Laboratories, the in-situ decommissioning of the Nuclear Power Demonstration reactor in Rolphton, Ontario, and the in-situ decommissioning of the WR-1 reactor at Whiteshell Laboratories in Pinawa, Manitoba.

The CNSC works collaboratively with the federal government's Major Projects Management Office under Natural Resources Canada in regulating these major resource projects.

CNSC INSPECTION AT A NUCLEAR GENERATING STATION

IMAGE • Canadian Nuclear Safety Commission

DID YOU KNOW?

CNSC STAFF ARE LOCATED AT EVERY CANADIAN NUCLEAR GENERATING STATION, AS WELL AS AT CHALK RIVER LABORATORIES AND AT FIVE REGIONAL OFFICES ACROSS CANADA.

SITE SECURITY

Nuclear security in Canada is regulated by the CNSC, which sets out detailed security requirements for licensed nuclear facilities.

The security requirements are designed to safeguard nuclear facilities against the possibility of infiltration or attack, and to ensure that nuclear material stays in the right hands.

The main security requirements include

- annual threat and risk assessments;
- on-site armed response forces available 24 hours a day, seven days a week;
- enhanced security screenings of employees and contractors involving background, police and security checks;
- enhanced access controls to nuclear facilities;
- design basis threat analyses for nuclear facilities;
- uninterrupted power supplies in place for alarm monitoring and other security systems; and
- contingency planning, drills and exercises.

BRUCE POWER RESPONSE FORCE

IMAGE • Bruce Power

SOURCE • Canadian Nuclear Safety Commission. "Emergency management and nuclear security." 2018. http://suretenucleaire.gc.ca/eng/resources/emergency-management-and-safety/index.cfm

CYBER SECURITY

Cyber security is the practice of protecting systems, networks and programs from digital attacks.

Every critical infrastructure, including that of a power plant, relies on effective cyber security measures to protect against attacks.

The CNSC imposes strict cyber security regulations, which are updated regularly to account for new and emerging threats.

The safety and control systems of Canadian nuclear reactors and other vital plant components are not connected to business networks or the Internet. This makes a cyber attack affecting safety or operations next to impossible.

There has never been a cyber attack against a nuclear power plant in Canada that has threatened public safety.

HEADS OF STATE AT THE 2016 NUCLEAR SECURITY SUMMIT

RESOURCES

TEST YOUR KNOWLEDGE

1 How many nuclear power reactors are there in Canada?

a. 13
b. 19
c. 25
d. 31

2 Nuclear power emits carbon dioxide (CO_2) during operation.

a. True
b. False

3 Which of the following accomplishments is thanks to nuclear technology?

a. The production of medical isotopes to diagnose and treat cancer and other diseases
b. The destruction of food pathogens that cause food poisoning and early spoilage
c. The ability to study the integrity of aircraft components such as rotors and wings
d. All of the above

4 Nuclear power is expensive compared to other energy sources.

a. True
b. False

5 Nuclear power plants emit dangerous amounts of radiation.

a. True
b. False

6 Which Canadian provinces use nuclear power?

a. British Columbia and Alberta
b. Saskatchewan and Ontario
c. Ontario and New Brunswick
d. New Brunswick and Nova Scotia

7 How many people does the Canadian nuclear industry employ, both directly and indirectly?

a. 10,000
b. 20,000
c. 40,000
d. 60,000

8 Canada has a solution for the disposal of nuclear waste.

a. True
b. False

9 Nuclear power produces a large amount of waste compared to other energy sources.

a. True
b. False

10 What percentage of the world's supply of cobalt-60 is produced in Canada?

a. 10%
b. 30%
c. 50%
d. 70%

Answers: 1) b, 2) b, 3) d, 4) b, 5) b, 6) c, 7) d, 8) a, 9) b, 10) d

CANADIAN UNIVERSITIES WITH NUCLEAR PROGRAMS

Algonquin College	**algonquincollege.com**
Brock University	**brocku.ca**
Carleton University	**carleton.ca**
McMaster University	**mcmaster.ca**
Polytechnique Montréal	**polymtl.ca**
Queen's University	**queensu.ca**
Royal Military College of Canada	**rmc.ca**
University of Calgary	**ucalgary.ca**
University of Guelph	**uoguelph.ca**
University of New Brunswick	**unb.ca**
University of Ontario Institute of Technology	**uoit.ca**
University of Saskatchewan	**usask.ca**
University of Toronto	**utoronto.ca**
University of Waterloo	**uwaterloo.ca**
University of Western Ontario	**uwo.ca**
University of Windsor	**uwindsor.ca**

Should your school be listed here?

If we've missed a program with nuclear-related education, let us know at info@cna.ca.

MCMASTER NUCLEAR REACTOR CORE

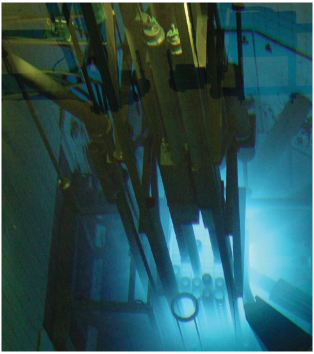


IMAGE • McMaster University

DID YOU KNOW?

THE REACTOR CORE AT MCMASTER UNIVERSITY IS AMONG THE FEW WORLDWIDE THAT ARE VISIBLE AND ACCESSIBLE DURING OPERATION!

OTHER RESOURCES

Bruce Power .... **brucepower.com**
Cameco .... **cameco.com**
Canadian Electricity Association .... **electricity.ca**
Canadian Nuclear Isotope Council .... **canadianisotopes.ca**
Canadian Nuclear Laboratories .... **cnl.ca**
Canadian Nuclear Safety Commission .... **nuclearsafety.gc.ca**
Canadian Nuclear Society .... **cns-snc.ca**
Canadian Nuclear Workers Council .... **cnwc-cctn.ca**
CANDU Owners Group .... **candu.org**
Energy Council of Canada .... **energy.ca**
General Fusion .... **generalfusion.com**
Hydro-Québec .... **hydroquebec.com**
Independent Electricity Systems Operator .... **ieso.ca**
International Atomic Energy Agency .... **iaea.org**
International Commission on Radiological Protection .... **icrp.org**
International Energy Agency .... **iea.org**
Natural Resources Canada—Nuclear Energy .... **nuclear.nrcan.gc.ca**
New Brunswick Power .... **nbpower.com**
Nordion .... **nordion.com**
North American Young Generation in Nuclear .... **naygn.org**
Nuclear Energy Institute .... **nei.org**
Nuclear Industry Association .... **niauk.org**
Nuclear Waste Management Organization .... **nwmo.ca**
OECD Nuclear Energy Agency .... **oecd-nea.org**
Ontario Power Generation .... **opg.com**
Ontario's Nuclear Advantage .... **ontariosnuclearadvantage.com**
Organization of Canadian Nuclear Industries .... **ocni.ca**
Saskatchewan Mining Association .... **saskmining.ca**
SNC-Lavalin—Nuclear .... **snclavalin.com/nuclear**
Society for the Preservation of Canada's Nuclear Heritage .... **nuclearheritage.ca**
Statistics Canada .... **statcan.gc.ca**
Sylvia Fedoruk Canadian Centre for Nuclear Innovation .... **fedorukcentre.ca**
TRIUMF .... **triumf.ca**
United Nations Scientific Committee on the Effects of Atomic Radiation .... **unscear.org**
U.S. Energy Information Administration .... **eia.gov**
Women in Nuclear Canada .... **canada.womeninnuclear.org**
World Health Organization—Ionizing radiation .... **who.int/ionizing_radiation**
World Nuclear Association .... **world-nuclear.org**
World Nuclear Transport Institute .... **wnti.co.uk**

ABOUT THE CNA

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.

The CNA works to

- create and foster a political environment and reasonable regulatory framework for advancing the nuclear industry in Canada;
- encourage cooperation among various industries, utilities, educational institutions, government departments and agencies, and other authoritative bodies that have a common interest in the development of economic uses for nuclear power and radioisotopes; and
- provide a forum for the discussion and resolution of issues of concern to members, industry or the Canadian public.

About the Canadian Nuclear Factbook

The Canadian Nuclear Factbook has been published regularly since 2004 by the Canadian Nuclear Association. Every year, 30,000 copies are distributed to schools, universities, information centres at nuclear facilities, industry associations, parliamentarians and many other groups. Thousands of copies are distributed free of charge nationally and internationally to individuals and organizations on request. If you wish to order one or more copies of the Canadian Nuclear Factbook free of charge for yourself or an organization, or to access an electronic version, send us an email at info@cna.ca.

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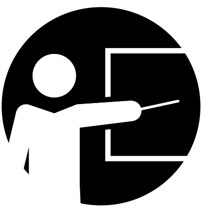
youtube.com/TalkNuclear

COME TO OUR ANNUAL CONFERENCE
cna.ca/conference



WANT TO TALK AND TEACH NUCLEAR? CHECK OUT OUR COMPLETE CURRICULUM RESOURCES AT TEACHNUCLEAR.CA.

1610-130 Albert Street, Ottawa, Ontario K1P 5G4
613 237 4262 info@cna.ca cna.ca

THE CANADIAN NUCLEAR

FACTBOOK 2019

canadian nuclear association