
THE CANADIAN NUCLEAR
FACTBOOK
cna
canadian
nuclear
association

TABLE OF CONTENTS

SUMMARY 1

2 Message from the President
3 Executive Summary
4 History of Nuclear in Canada

NUCLEAR POWER GLOBALLY AND IN CANADA 11

12 Nuclear Power Globally
13 Nuclear Reactors Globally
16 Nuclear Power in Canada
19 Electricity Sources by Province
20 Bruce Nuclear Generating Station
22 Darlington Nuclear Generating Station
24 Pickering Nuclear Generating Station
26 Point Lepreau Nuclear Generating Station
27 Canada's Nuclear Refurbishment Projects

THE ENVIRONMENT AND THE ECONOMY 29

30 Energy and the Environment
31 Global CO^2 Emissions Over Time
32 Canada's Climate Targets
33 Nuclear and the UN's Sustainable Development Goals
35 Nuclear's Land Footprint
36 Nuclear and the Canadian Economy
38 Uranium Mine Production
39 Cost of Nuclear Power

URANIUM AND NUCLEAR REACTORS 41

42 Uranium
43 Converting Uranium Ore into CANDU Reactor Fuel
44 Uranium Mining Methods
45 Canada's Uranium Industry
46 The Power of Uranium
47 How Fission Works
48 Nuclear Reactors
50 CANDU Reactors
51 CANDU Reactors Globally
54 Power Reactor Designs Globally
55 Next-Generation Reactors and Advanced Fuels
56 Small Modular Reactors
57 SMRs, the Environment, and the Economy
58 Advancing SMRs in Canada

RADIOACTIVE WASTE AND TRANSPORTATION 61

62 Radioactive Waste
63 Used Nuclear Fuel
64 How Used Nuclear Fuel Is Managed
65 Nuclear Waste Management Organization
66 Deep Geological Repository
68 Low and Intermediate Level Waste
70 Transportation
71 Types of Packages

NUCLEAR SCIENCE AND TECHNOLOGY 73

74 Nuclear Science and Technology in Canada
75 Radioisotopes and Half-Lives
76 Nuclear Medicine
77 Medical Isotopes
83 Radiation Therapy and Sterilization
84 Enabling the Hydrogen Economy
85 Canada and the Hydrogen Economy
86 Food Irradiation
87 Agricultural Applications
88 Industrial Inspections
89 Industrial Gauges and Tracers
90 Nuclear Desalination
91 Nuclear-Powered Travel
93 Consumer Products
94 Other Uses of Nuclear Technology
95 Nuclear Research Centres
99 Fusion Research

RADIATION, NUCLEAR SAFETY, AND SECURITY 101

102 Radiation
103 Radiation Doses and Effects
104 Background Radiation
105 Effects of Radiation on the Body
107 Nuclear Safety
108 Nuclear Regulation
109 CNSC's Safety and Control Areas
112 Site Security
113 Cybersecurity

RESOURCES 115

116 Canadian Universities and Colleges with Nuclear Programs
117 Other Resources
120 About the CNA

SUMMARY

MESSAGE FROM THE PRESIDENT

The Canadian Nuclear Association Factbook is a helpful resource that highlights the rich history, current role, and future applications of nuclear technology in Canada and globally. This useful resource can facilitate informative discussions with anyone seeking to learn more about nuclear technology and its applications.

For over 60 years, our vibrant nuclear industry has provided reliable, affordable, and low-carbon electricity, as well as life-saving medical isotopes, for Canada and beyond. As the world continues to face geopolitical and climate challenges, nuclear technology offers the energy security, clean air, high-paying jobs, economic growth and innovation needed for nations such as Canada to remain strong and resilient.

Drawing on our rich heritage of designing and operating research and power reactors, as well as engineering and constructing new technologies, including small modular reactors, Canada is at the forefront of nuclear innovation worldwide. Nuclear technology offers a wide range of benefits, including cancer treatment, food safety, spacecraft propulsion, and support for the emerging hydrogen economy.

It's an exciting time for the nuclear industry, and we hope you find this Factbook useful in broadening your knowledge about our many accomplishments and the exhilarating future ahead of us.



George Christidis
President and Chief Executive Officer
Canadian Nuclear Association

EXECUTIVE SUMMARY

This 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 440 operable nuclear reactors worldwide. Canada is home to 17 power reactors, which provide about 13.5% of the country's electricity.
- More than 75 reactors are under construction worldwide, primarily in emerging economies such as China and India. Approximately 115 are planned, while 300 or more have been proposed.
- Nuclear power generation helps reduce global CO^2 emissions, which hit a record high of 37.8 billion tonnes in 2024.
- Nuclear in Canada contributes $22 billion to Canada's GDP every year. It directly and indirectly supports a total of 89,000 Canadian jobs, a remarkable 17% increase in the industry since 2019.
- Canada is a leader in the global supply of uranium. Most Canadian uranium is mined in northern Saskatchewan, which has the highest-grade ore 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 million diagnostic scans and thousands of radiation therapy treatments are performed annually.
- Canada's nuclear industry is among the safest and most strictly regulated industries in the world.

® Registered trademark of Atomic Energy of Canada, Ltd. (AECL), used under exclusive licensed by Candu Energy Inc., a member of the AtkinsRéalis Group Inc. (previously known as SNC-Lavalin Group Inc.)

SOURCE: Canadian Nuclear Association. Canadian Nuclear Industry: A Powerhouse of Job Creation and Economic Growth. https://cna.ca/2024/09/24/canadian-nuclear-industry-a-powerhouse-of-job-creation-and-economic-growth/

HISTORY OF NUCLEAR IN CANADA

1900–1910

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

1921–1930

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

1931–1940

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

1941–1950

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

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

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

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

1951–1960

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.

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

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.

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

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

1961–1970

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.

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

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

1971–1980

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

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.

AECL designs and builds the first SLOWPOKE research reactor.

1981–1990

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

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

1991–2000

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

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

2001–2010

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.

The assets of AECL's CANDU Reactor Division are acquired by Candu Energy Inc., a wholly owned subsidiary of AtkinsRéalis (then SNC-Lavalin). AECL remains a federal Crown corporation.

2011–2020

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.

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

AECL establishes a government-owned, contractor-operated arrangement whereby its sites and facilities are managed and operated by Canadian Nuclear Laboratories.

Ontario begins the process of refurbishing 10 of its 18 nuclear power reactors—currently the largest clean energy project in North America.

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

The Prime Minister of Canada announces a new Institute for Advanced Medical Isotopes in the TRIUMF facility at the University of British Columbia.

A diverse group of federal, provincial, industry, and research stakeholders collaborate to produce

Call to Action: A Canadian Roadmap for Small Modular Reactors.

The premiers of Saskatchewan, Ontario, and New Brunswick sign a memorandum of understanding to develop small modular reactors, to help fight climate change. In 2021, Alberta signs the memorandum as well.

2021–PRESENT

Natural Resources Canada coordinates the creation and launches of the national Small Modular Reactor Action Plan.

During the 28th United Nations Climate Change Conference (COP28) in 2023, 22 world leaders from four continents signed a declaration to increase efforts to triple nuclear energy by 2050. The Declaration acknowledges the pivotal role of nuclear energy in attaining global net-zero greenhouse gas emissions by 2050 and maintaining the 1.5-degree goal within reach. Endorsing countries include Armenia, Bulgaria, Canada, Croatia, Czech Republic, Finland, France, Ghana, Hungary, Jamaica, Japan, Republic of Korea, Moldova, Mongolia, Morocco, Netherlands, Poland, Romania, Slovakia, Slovenia, Sweden, Ukraine, United Arab Emirates, United Kingdom, and the United States.

At COP29, six more countries added their support to the declaration, including El Salvador, Kazakhstan, Kenya, Kosovo, Nigeria and Turkey. At COP30, Rwanda and Senegal had joined the declaration, bringing the number of countries endorsing the declaration to 33.

The Nuclear Waste Management Organization (NWMO) has chosen the Wabigoon Lake Ojibway Nation and Ignace area as the site of Canada's first-ever Deep Geological Repository. This decision followed extensive technical studies, community engagement, and confirmation from residents that they were willing to host the project.

Ontario Power Generation (OPG) is collaborating with GE Vernova Hitachi Nuclear Energy to deploy four

Small Modular Reactors (SMRs) at the Darlington nuclear site. In 2025, the Ontario government approved the construction of the first SMR at this location.

SaskPower has selected GE Vernova Hitachi Nuclear Energy's small modular reactor as a potential deployment option in the province for the mid-2030s. The selection follows an independent and comprehensive assessment process that also included close collaboration with Ontario Power Generation, with a focus on the potential for a pan-Canadian, fleet-based deployment of nuclear power.

In 2025, the Province of Ontario approved the refurbishment of Pickering "B" units 5-8, which will allow them to run for up to 38 years.

The Ontario government has asked OPG to explore opportunities for new nuclear energy generation at the Wesleyville site after receiving interest from the Municipality of Port Hope and the Williams Treaties First Nations.

In 2025, the Ontario government and Bruce Power initiated a federal Impact Assessment as part of a plan to expand their existing plant, adding 4,800 megawatts of output to power approximately 4.8 million homes. The expansion will nearly double the plant's current production, and once built, it will be the first new large-scale nuclear plant construction in Canada in three decades.

In January, 2026, OPG submitted the Initial Project Description for New Nuclear at Wesleyville in Port Hope to the Impact Assessment Agency of Canada.





NUCLEAR POWER GLOBALLY AND IN CANADA

NUCLEAR POWER GLOBALLY

Nuclear generated 9% of global electricity in 2024.

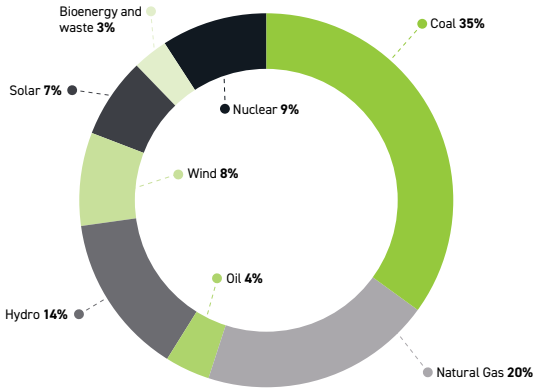
After hydroelectricity, it is the largest source of low-carbon energy worldwide.

Fossil fuels were the most widely used electricity source by far, at 60%. Coal represents about two-thirds of this, and natural gas represents about 20% of total generation.

In 2024, renewable and nuclear energy together accounted for nearly 40% of global electricity generation.

For the first time, power generation from renewables and nuclear sources accounted for two-fifths of total global generation in 2024. Renewables collectively accounted for one-third of electricity generation, led by hydropower (14% of total electricity generation), wind (8%), solar PV (7%), and bioenergy and waste (3%).

GLOBAL ELECTRICITY GENERATION IN 2024



SOURCE: International Energy Agency. "Global Energy Review 2025: Electricity." 2025. https://www.iea.org/reports/global-energy-review-2025/electricity

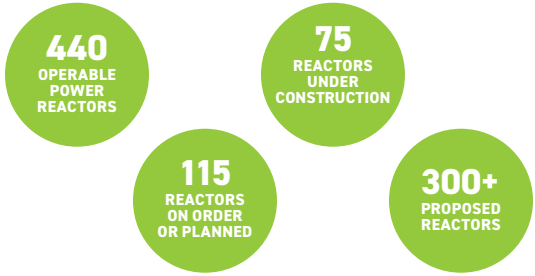
NUCLEAR REACTORS GLOBALLY

Currently, there are about 440 operable power reactors worldwide, with a net generating capacity of approximately 400 gigawatts (GWe).

- In recent years, the commissioning of new nuclear plants has been nearly offset by the retirement of older ones. Over the past 20 years, 111 reactors have been retired, while 101 new units have come online.
- Approximately 30 countries are considering, planning or starting nuclear power programs.

About 75 reactors are under construction worldwide, primarily in emerging economies such as China and India.

There are approximately 115 reactors on order or planned, while 300+ more have been proposed.



SOURCES: World Nuclear Association. "Plans for New Reactors Worldwide." 2024. https://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx
IAEA Power Reactor Information System. "Operational & Long-Term Shutdown Reactors." 2024. https://www.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx

CURRENT NUCLEAR POWER REACTORS

COUNTRY	UNITS	NET CAPACITY (MWE)	ELECTRICITY PRODUCTION SHARE (%)
Argentina	3	1,641	7.4
Armenia	1	416	30.8
Belarus	2	2,220	36.4
Belgium	2	2,056	42.2
Brazil	2	1,884	2.3
Bulgaria	2	2,006	41.6
Canada	17	12,714	13.4
China	59	57,654	4.5
Czech Republic	6	3,963	40.2
Finland	5	4,369	39.1
France	57	63,000	67.3
Hungary	4	1,916	47.1
India	21	7,550	3.3
Iran	1	915	1.7
Japan	14	12,631	9.9
Mexico	2	1,552	4.8
Netherlands	1	482	2.8

COUNTRY	UNITS	NET CAPACITY (MWE)	ELECTRICITY PRODUCTION SHARE (%)
Pakistan	6	3,262	16.7
Romania	2	1,300	19.8
Russia	34	27,969	18.1
Slovakia	5	2,302	60.6
Slovenia	1	696	35
South Africa	2	1,854	3.9
South Korea	26	25,609	31.7
Spain	7	7,123	19.9
Sweden	6	7008	29.1
Switzerland	4	2,973	27
Ukraine	15	13,107	55
UAE	4	5,348	21.8
UK	9	5,883	12.3
US	94	96,952	18.2
TOTAL	**414**	**378,355**	

SOURCE: IAEA Power Reactor Information System. "Operational & Long-Term Shutdown Reactors." 2025. https://www.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx

NUCLEAR POWER IN CANADA

There are 17 operable power reactors at four nuclear generating stations in Canada.

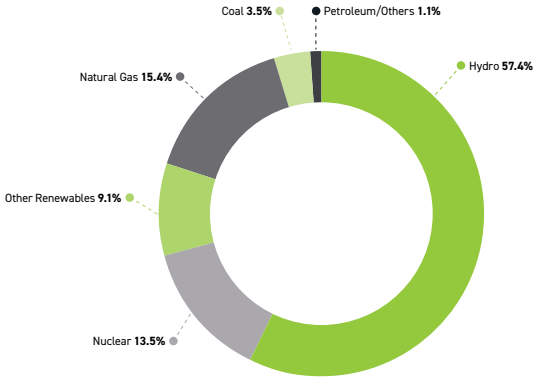
Nuclear power provided 13.5% of Canada's electricity in 2023.

Hydro power is the largest source of electricity in Canada, generating 57.4% of electricity in 2023.

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

Non-hydro renewable sources provided approximately 9.1% of Canada's electricity in 2023.

CANADIAN SOURCES OF ELECTRICITY IN 2023



SOURCE: Natural Resources Canada Energy Factbook. https://energy-information.canada.ca/sites/default/files/2025-11/energy-fact-book-2025-2026.pdf

CANADA'S NUCLEAR POWER REACTORS

FACILITY	STATUS	NET CAPACITY (MWE)	START YEAR
Bruce A: Unit 1	Operable	833	1977
Bruce A: Unit 2	Operable	830	1976
Bruce A: Unit 3	Operable	809*	1977
Bruce A: Unit 4	Operable	798*	1978
Bruce B: Unit 5	Operable	826	1984
Bruce B: Unit 6	Operable	837	1984
Bruce B: Unit 7	Operable	828	1986
Bruce B: Unit 8	Operable	823	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

FACILITY	STATUS	NET CAPACITY (MWE)	START YEAR
Gentilly-1**	Shut down	250	1971
Gentilly-2	Shut down	635	1982
Pickering A: Unit 1	Shut down	515	1971
Pickering A: Unit 2	Shut down	515	1971
Pickering A: Unit 3	Shut down	515	1972
Pickering A: Unit 4	Shut down	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	663	1982
Rolphton Nuclear Power Demonstration**	Shut down	22	1962

***UNIT 3/4** capability as noted immediately before entering respective Major Component Replacements ****Prototype**

SOURCE: IAEA Power Reactor Information System. "Canada." 2024. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA

ELECTRICITY SOURCES BY PROVINCE

Electricity sources vary significantly by province.

In 2024, nuclear power provided approximately 49% of Ontario's electricity and currently provides over 35% of New Brunswick's electricity.

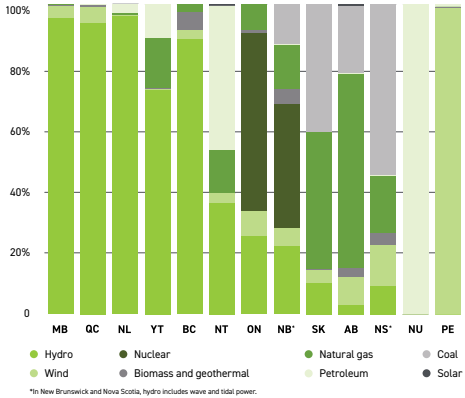
Hydro power is the dominant source of electricity in British Columbia, Manitoba, Quebec, Newfoundland, and Yukon.

In 2024, gas-fired generation accounted for 74.7% of Alberta's total generation, up from 68.9% in 2023, as it fully replaced coal generation during the year. Wind, solar and hydro generation provided 19% of Alberta's generation in 2024, up from 16.5 percent in 2023.

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

While 99% 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 2021



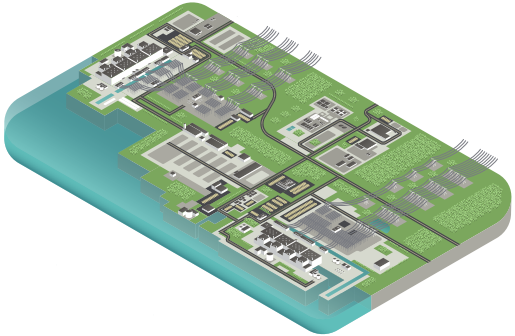
*In New Brunswick and Nova Scotia, hydro includes wave and tidal power.

SOURCES: Canada Energy Regulator. "Provincial & Territorial Energy Profiles." 2024. https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/index.html
AESO 2024 Annual Market Statistics. https://www.aeso.ca/assets/Uploads/market-and-system-reporting/Annual-Market-Stats-2024.pdf
Statistics Canada. https://www.statcan.gc.ca/o1/en/plus/8487-nuclear-energy-canada-past-present-and-future

BRUCE NUCLEAR GENERATING STATION

With eight reactors and a net peak output of 6,580 megawatts, Bruce Power provides 30 percent of Ontario's electricity, while also producing cancer-fighting medical isotopes for patients around the world. It is located on the shore of Lake Huron —within the Saugeen Ojibway Nation Territory —approximately 200 km from Toronto, Ontario, and first delivered power to the grid in 1976.

In 2016, Bruce Power began its Life-Extension Program, which involves the gradual replacement of older systems in the company's eight reactor units during regularly scheduled maintenance outages. As part of the Life-Extension Program, Bruce Power is carrying out its Major Component Replacement (MCR) Project, which focuses on the replacement of key reactor components in Units 3-8. Bruce Power's Life-Extension Program and Major Component Replacement Project is Canada's largest privately financed electricity infrastructure project.



6,584
MWE OUTPUT

FIRST POWER TO GRID IN 1976

GENERATES 30% OF ONTARIO'S ELECTRICITY

The first of these (Unit 6) was taken offline for its MCR in January 2020 and declared operational again in September 2023, ahead of schedule and on budget. Unit 3 MCR started in early 2023 in tandem with Unit 6, and was followed by Unit 4's MCR which kicked-off in early 2025, and will be followed by Units 5, 7, and 8. The life extension of each unit will add more than 30 years of operational life to the units.

In addition to its Life-Extension Program, Project 2030 is Bruce Power's long-term program to increase the net peak output of its existing units to upwards of 7,000 megawatts for the 2030s. The additional output from the existing units will be roughly equivalent to adding a large-scale reactor to its site with existing infrastructure.

To support the Ontario's growing electricity needs, the Ontario government advanced pre-development work to add up to 4,800 megawatts of new nuclear generation at the Bruce site in 2023. This Project, known as Bruce C is currently undergoing federal integrated Impact Assessment, and would make Bruce Power the largest nuclear generator in the world with a capacity of 12,000 megawatts.

In addition to producing nuclear power, Bruce Power produces medical isotopes used in medical sterilization and to fight cancer worldwide. For nearly four decades, Bruce Power has been a reliable supplier of cobalt-60, which sterilizes 40 per cent of the world's single-use medical devices. In 2019, Bruce Power began producing medical-grade cobalt-60, used worldwide in cancer treatment and radiation therapy for complex brain conditions. Bruce Power also became the first commercial nuclear operator in the world to produce lutetium-177 in October of 2022 using the Isotope Production System (IPS) installed in Unit 7, which was developed with Isogen (a Kinectrics and Framatome company). Bruce Power's isotope program is supported through the Gamzook'aamin aakoziwin partnership with Saugeen Ojibway Nation.

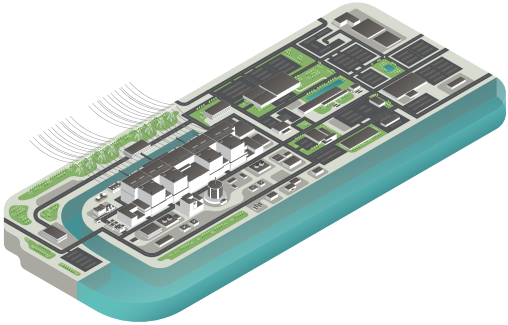
SOURCES: IAEA Power Reactor Information System. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA
Bruce Power. https://www.brucepower.com/publications/the-future-is-nuclear-bruce-powers-2024-annual-review/

DARLINGTON NUCLEAR GENERATING STATION

Darlington NGS is Canada's second-largest nuclear facility. It is located on the shore of Lake Ontario, 70 km from downtown Toronto, Ontario.

Operating at 3,512 MWe from four reactors, Darlington NGS generates enough electricity to power more than 20% of Ontario's electricity needs, or 2 million Ontario households.

Unit 2 was shut down in October 2016 for mid-life refurbishment and was completed ahead of schedule and under budget in June of 2020. Shortly after, the refurbishment of Unit 3 began and was completed ahead of schedule in July of 2023. The refurbishment of Unit 1 started in February 2022 and was competed in November of 2024. Unit 4's refurbishment began in July 2023, incorporating lessons-learned from the previous three refurbishments, and completed construction in February of 2026, ahead of schedule and under budget.



3,512
MWE OUTPUT

GENERATES OVER 20% OF ONTARIO'S ELECTRICITY

FIRST POWER TO GRID IN 1990

Darlington's Unit 1 is producing life-saving cobalt-60 which is used to sterilize 40% of the world's single-use medical devices and certain food products. Darlington Nuclear is also currently harvesting molybdenum-99 and will soon be producing yttrium-90 and lutetium-177. Refer to pages 77-82 for more information on the applications for these life-saving medical isotopes.

In July 2023, the Ontario government announced that it was working with Ontario Power Generation (OPG) to begin the planning and licensing process for four small modular reactors (SMRs) at the Darlington nuclear site. Once deployed, these four reactors are expected to generate a total of 1,200 megawatts of electricity, which is enough to power approximately 1.2 million homes.

This initiative aims to meet the growing demand for electricity resulting from electrification and to support the province's strong economic growth.

In May 2025, the Province of Ontario approved the construction of the first of four BWRX-300 SMRs from GE Vernova Hitachi Nuclear Energy at the Darlington New Nuclear Project site, which is planned to be operational by the end of 2030.

SOURCES: Ontario Power Generation. "Darlington Refurbishment." 2024. https://www.opg.com/strengthening-the-economy/our-projects/darlington-refurbishment/
Ontario Energy Board. "Darlington Refurbishment Program Annual Report 2023." 2024. https://www.oeb.ca/sites/default/files/opg-11.0-2023-DRP%20Annual%20Reporting.pdf
Ontario Government. "Ontario Building More Small Modular Reactors to Power Province's Growth." 2023. https://news.ontario.ca/en/release/1003248/ontario-building-more-small-modular-reactors-to-power-provinces-growth
Ontario Power Generation. "OPG ready to begin building North America's first Small Modular Reactor." 2025. https://www.iea.org/reports/global-energy-review-2025/electricity
IAEA Power Reactor Information System. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA
Ontario Power Generation. https://www.opg.com/reporting/darlington-refurbishment-reports/news/darlington-refurbishment-performance-update-q2-2025/

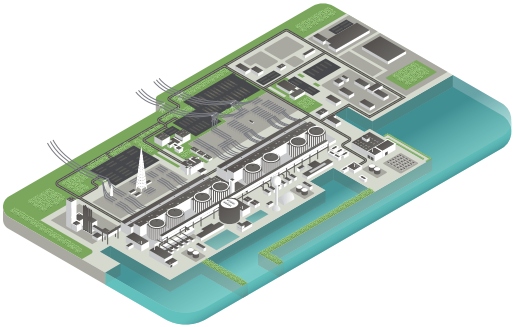
PICKERING NUCLEAR GENERATING STATION

The Pickering Nuclear Generating Station is situated on the north shore of Lake Ontario in Pickering, Ontario. It is one of the world's oldest nuclear power stations and the third largest in Canada, featuring eight CANDU reactors. The facility was constructed in phases between 1965 and 1986 by Ontario Hydro, a provincial Crown corporation, with significant completion of Station A scheduled for 1971.

Currently, Pickering A, which includes Units 1 to 4, has been permanently shut down.

Pickering B, comprising Units 5 to 8, has a total output of 2,064 megawatts, supplying approximately 10% of Ontario's electricity needs.

In 2025, the Ontario government approved the refurbishment of the "B" units of the Pickering Nuclear Generating Station, extending its operation for up to 38 years. Once refurbished, Pickering is projected to produce up to 2,200 megawatts of electricity, enough to power 2.2 million homes



2,064
MWE OUTPUT

GENERATES 10% OF ONTARIO'S ELECTRICITY

FIRST POWER TO GRID IN 1971

for up to 38 years, thereby helping to meet the increasing demand driven by electrification and the province's rapid economic growth. This refurbishment project is also anticipated to have a significant economic impact by creating approximately 30,500 jobs during refurbishment and sustaining 6,700 jobs through the station's operation. Additionally, the refurbishment and ongoing operation will increase Canada's GDP by $41.6 billion.

Planning for the refurbishment has already commenced and is expected to take several years to complete. OPG will undertake procurement and pre-requisite activities to ensure readiness when planning is finalized. The shutdown of all units is scheduled for the end of 2026, pending approval from the Canadian Nuclear Safety Commission (CNSC).

Subject to final approval from the Canadian Nuclear Safety Commission, OPG plans to enter the Project Execution Phase for the refurbishment of Pickering B Units 5 to 8 in early 2027, with work expected to conclude in the mid-2030s.

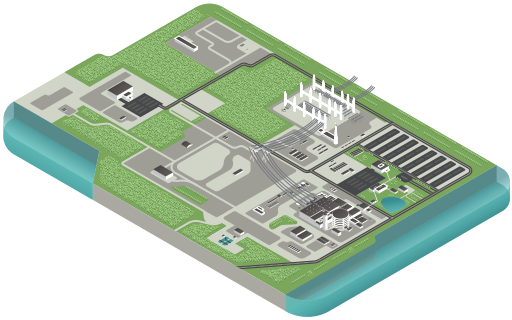
SOURCES: Ontario Power Generation. "Pickering Nuclear Generating Station." 2024. https://www.opg.com/powering-ontario/our-generation/nuclear/pickering-nuclear-generation-station/
Ontario Government. "Ontario Advancing Plan to Refurbish Pickering Nuclear Generating Station." 2025. https://news.ontario.ca/en/release/1005620/ontario-advancing-plan-to-refurbish-pickering-nuclear-generating-station
Ontario Power Generation. "OPG's Pickering Nuclear ready to keep providing low-carbon power for Ontario." 2025. https://www.opg.com/stories/pickerings-innovative-bird-habitat-a-first-for-north-america/story/opgs-pickering-nuclear-ready-to-keep-providing-low-carbon-power-for-ontario
IAEA Power Reactor Information System. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA
Ontario Government. https://news.ontario.ca/en/release/1006772/ontario-greenlights-pickering-nuclear-generating-station-refurbishment-to-create-nearly-37000-jobs

POINT LEPREAU NUCLEAR GENERATING STATION

The Point Lepreau Nuclear Generating Station (NGS) is a CANDU 6 reactor located in New Brunswick, approximately 30 km southwest of Saint John. It was the first CANDU 6 unit to enter commercial operation in Canada. The station has a net electrical output of 663 MWe, contributing over 35% of New Brunswick's electricity.

Point Lepreau underwent refurbishment to extend its operational lifespan for an additional 25 to 30 years and returned to service in November 2012.

The station continues to deliver reliable, low-carbon base-load power, with a strong focus on nuclear safety, regulatory compliance, and operational performance.



663
MWE OUTPUT

GENERATES 35% OF NEW BRUNSWICK'S ELECTRICITY

FIRST POWER TO GRID IN 1983

SOURCES: Canada Energy Regulator. "Provincial and Territorial Energy Profiles—New Brunswick." 2024. https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-new-brunswick.html

New Brunswick Power Corporation. "Annual Report 2023/24". 2024. https://www.nbpower.com/media/1493290/nbp_annual-report_2024_english-1.pdf

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 17 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 underwent refurbishment, with all three reactors returning to service in 2012.

The Bruce Power Life-Extension Program and Major Component Replacement Project entails the refurbishment of Units 3-8. The program is expected to inject billions into Ontario's economy, securing approximately 22,000 jobs both directly and indirectly, along with an additional 5,000 jobs each year.

Unit 6 was the first to be refurbished and was declared operational in September 2023. OPG's Darlington Refurbishment project, involving all four of its units, helped create 14,200 jobs per year, while contributing $89 billion to the economy. In February of 2026, OPG announced it had completed its four-unit refurbishment of Darlington which is forecast to be delivered four months ahead of schedule and $150 million under budget.

The refurbishment project at Pickering is anticipated to create a significant economic impact of over $19 billion during the refurbishment. Additionally, this project is projected to boost Canada's GDP by $41.6 billion, and create approximately 30,500 jobs during refurbishment and sustain 6,700 throughout the station's operation.

SOURCES: Ontario Power Generation. "Darlington Refurbishment." 2023. https://www.opg.com/strengthening-the-economy/our-projects/darlington-refurbishment/
Bruce Power. "Life-Extension Program & MCR Project." 2023. https://www.brucepower.com/life-extension-program-mcr-project/.
Ontario Power Generation. https://www.opg.com/news-resources/newsroom/our-stories/story/opg-celebrates-green-light-for-pickering-refurbishment-heres-whats-next/
Ontario Power Generation: Ontario. https://news.ontario.ca/en/release/1005620/ontario-advancing-plan-to-refurbish-pickering-nuclear-generating-station
Ontario Government. https://news.ontario.ca/en/release/1006772/ontario-greenlights-pickering-nuclear-generating-station-refurbishment-to-create-nearly-37000-jobs



THE ENVIRONMENT AND THE ECONOMY

ENERGY AND THE ENVIRONMENT

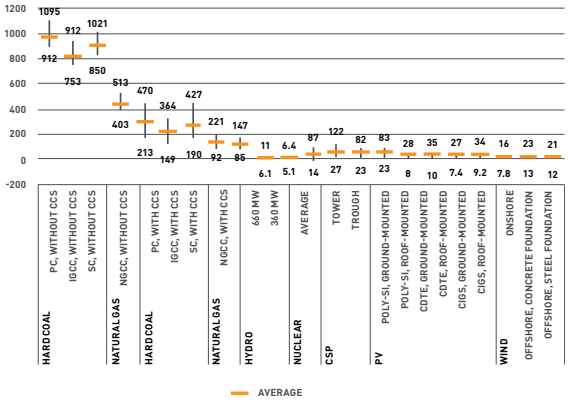
All forms of electricity production generate some level of CO_2 and other greenhouse gases (GHGs), even if they do not burn fossil fuels. The construction of the plant or equipment, for example, requires cement production and vehicle use, each having its own carbon footprint.

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

Hydro also 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 exclusively power a grid they would require backup sources most of the time. Backup most often comes from burning natural gas, which increases CO_2 emissions greatly.

LIFECYCLE GHG EMISSIONS, IN G CO_2 EG. PER KWH, REGIONAL VARIATION, 2020



SOURCE: United Nations Economic Commission for Europe (UNECE). https://unece.org/sites/default/files/2022-04/LCA_3_FINAL%20March%202022.pdf

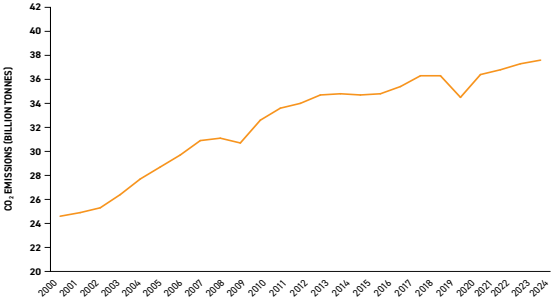
GLOBAL CO_2 EMISSIONS OVER TIME

Global energy-related CO_2 emissions increased by 0.8% in 2024, hitting a high of 37.8 gigatonnes of CO_2. This increase was driven by natural gas and coal, whose emissions rose by approximately 2.5% and 0.9%, respectively, in 2024.

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 14 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 a third of all the world's cars off the road!

GLOBAL CO_2 EMISSIONS SINCE 2000



SOURCES: International Energy Agency (IEA). "Global CO2 emissions from energy combustion and industrial processes and their annual change, 1900-2023." 2025. https://www.iea.org/data-and-statistics/charts/global-co2-emissions-from-energy-combustion-and-industrial-processes-and-their-annual-change-1900-2023

IAEA C02 Emissions. https://www.iea.org/reports/global-energy-review-2025/co2-emissions

U.S. EPA. https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

CANADA'S CLIMATE TARGETS

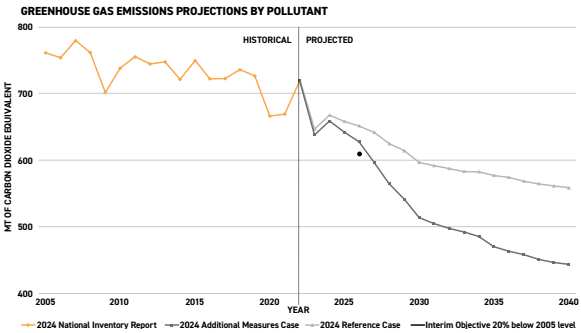
Climate change is one of the greatest threats of our time.

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 2030 targets. Only under scenarios where additional action is taken (including projects that have been announced but not fully implemented) do the greenhouse gas projections take a more positive turn.

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

CANADA'S GHG EMISSIONS PROJECTIONS



SOURCE: Government of Canada. "Greenhouse gas emissions projections." 2025. https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/projections.html

NUCLEAR AND THE UN'S SUSTAINABLE DEVELOPMENT GOALS

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

NUCLEAR CONTRIBUTES DIRECTLY TO:



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, and to eliminate pathogens from food products and medical supplies.



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. For example, nuclear technology is used to analyze seawater to trace pollutants to their sources and to detect algal blooms.



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 clean electricity production, requiring only 103 acres per million-megawatt hours.

Other low-carbon options, such as solar, and wind, require far more land at 3,200 acres per million-megawatt hours and 17,800 acres per million-megawatt hours 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 serious impacts on forests, grasslands, and water supply.

LAND USE REQUIRED TO SUPPLY GLOBAL ELECTRICITY



SOURCES: Nuclear Energy Institute. "Nuclear Needs Small Amounts of Land to Deliver Big Amounts of Electricity" 2023. https://www.nei.org/news/2022/nuclear-brings-more-electricity-with-less-land
McDonald, Robert, et al. "Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America." PLoS ONE. 2009. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0006802

NUCLEAR AND THE CANADIAN ECONOMY

Nuclear technology can be an integral part of any advanced economy. It supports medicine, materials science, advanced manufacturing, food safety, and energy production. In addition, nuclear energy plays a vital role in Canada's efforts to become a leader in clean hydrogen production.

The nuclear industry directly and indirectly supports a total of 89,000 Canadian jobs, with a total impact on the Canadian GDP of $22 billion per year.

Nearly 200 Canadian companies supply products or services to the nuclear industry. While the bulk of these jobs are related to power generation, mining uranium is also a major source of employment —and the medical isotope industry alone creates 8,500 jobs. The industry is also supported by a strong supply chain of over 1,000 construction, manufacturing, engineering, materials, people, and logistic companies as well as a national laboratory and university research and development network.

Jobs in nuclear generally require advanced skills and are well-paid. The economic benefits of the sector are growing as major work is underway to extend the existing fleet and more projects are planned, including:

- Refurbishment of Ontario's nuclear fleet, extending the lives of these reactors.
- The SMR project at Darlington station in Ontario to be in service in 2030, with plans for three more.
- Significant investments made by the Government of Canada, including $304 million to AtkinsRéalis toward the next generation of CANDU; $80 million to Saskatchewan's Crown Investment Corporation for the development of SMRs in Saskatchewan, and a $2 billion investment through the Canada Growth Fund for the Darlington SMR project. Ontario also invested $1 million toward the project through the Building Ontario Fund.

- Plans to explore two new large nuclear build-outs in Ontario (Bruce C and Wesleyville).
- Canada's investment to expand lutetium-177 production at Bruce Power.

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

THE INDUSTRY'S ANNUAL GDP

$22B

Marking a **30% GROWTH** from 2019

The Canadian nuclear energy industry employs approximately

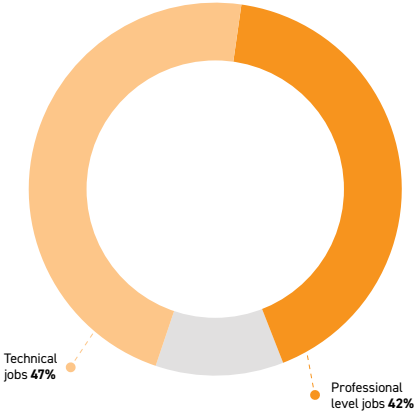
89,000 PEOPLE

indicating **17% GROWTH** since 2019



THE NUCLEAR INDUSTRY PROVIDES HIGH-QUALITY JOBS TO CANADIANS

89% HIGH-JOB SKILL CATEGORY



SOURCE: Canadian Nuclear Association. Canadian Nuclear Industry: A Powerhouse of Job Creation and Economic Growth. https://cna.ca/2024/09/24/canadian-nuclear-industry-a-powerhouse-of-job-creation-and-economic-growth/

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. All of Canada's uranium exports are for peaceful applications.

In 2018, Canadian uranium exports were valued at approximately $600 million, with the majority shipped to the United States, Europe, and Asia.

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

DID YOU KNOW?

CANADA HAS MORE THAN 588,000 TONNES OF KNOWN URANIUM RESERVES—THE THIRD LARGEST IN THE WORLD!

GLOBAL URANIUM MINING PRODUCTION IN 2024

COUNTRY	TONNES U	GLOBAL SHARE (%)
Kazakhstan	23,270	39%
Canada	14,309	24%
Namibia	7,333	12%
Australia	4,598	8%
Uzbekistan	4,000	7%
Russia	2,738	5%
China	1,600	3%
Niger	962	2%
India	500	1%
Other	155	2%

Percentages are rounded and may therefore not sum to exactly 100%.

SOURCES: Natural Resources Canada. https://natural-resources.canada.ca/energy-sources/nuclear-energy-uranium/uranium-canada
World Nuclear Association. "World Uranium Mining Production." 2024. https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx
Natural Resources Canada. "Uranium and nuclear power facts." 2024. https://natural-resources.canada.ca/our-natural-resources/minerals-mining/mining-data-statistics-and-analysis/minerals-metals-facts/uranium-and-nuclear-power-facts/20070

COST OF NUCLEAR POWER

Nuclear remains one of the most affordable electricity sources worldwide.

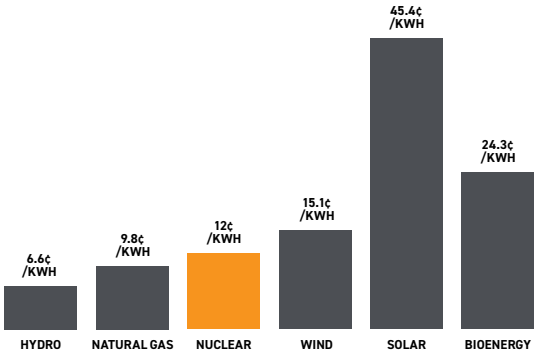
While nuclear generating stations require high upfront capital investment, their long life and low costs for fuel, operations and maintenance lead to low power costs in the long run.

In Ontario, hydro is the lowest-cost source, followed by natural gas and then nuclear, which offers the added benefit of being non-emitting like hydro.

DID YOU KNOW?

MORE THAN HALF THE COST OF NUCLEAR IS ATTRIBUTED TO FACILITY CONSTRUCTION—AN AREA THAT MODULARIZATION COULD GREATLY IMPROVE. ONCE BUILT, NUCLEAR HAS VERY LOW FUEL AND MAINTENANCE COSTS, PROVIDING STABLE ELECTRICITY PRICES OVER THE PLANT'S LIFETIME OF 60+ YEARS.

COST OF ENERGY BY SOURCE IN ONTARIO IN 2025



SOURCE: Ontario Energy Board. https://oeb.ca/sites/default/files/rpp-price-report-20251017.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.



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

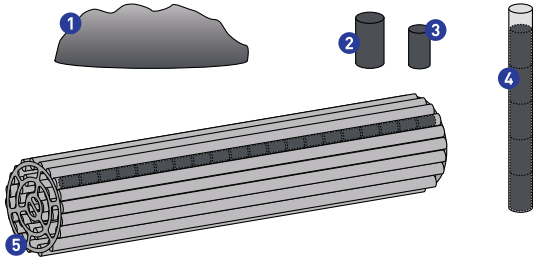
The ore is crushed in a mill and ground to a fine slurry. The slurry is leached in acid to separate the uranium from the minerals, which is then purified to produce uranium oxide powder.

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 to mine 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.

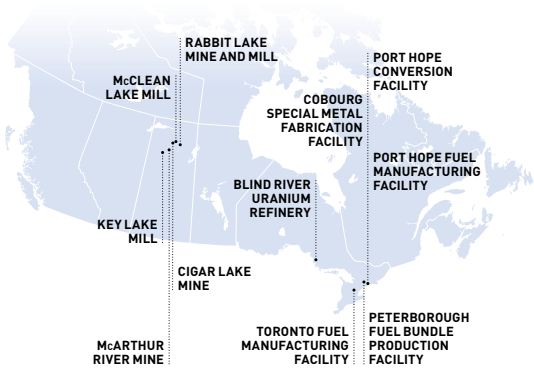
Canada has the world's highest-grade uranium deposits, with grades more than 100 times the global average.

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



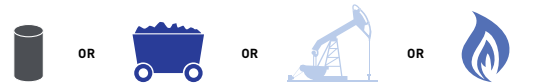
THE POWER OF URANIUM

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

Uranium pellets are approximately 20 g each, and approximately eight are needed to power the average Canadian household for a year.

Providing the same amount of electricity as one 20 g uranium pellet would require 400 kg of coal, 410 L of oil or 350 m^3 of natural gas.

FUEL REQUIRED TO PRODUCE THE SAME AMOUNT OF ELECTRICITY



CANDU FUEL BUNDLE



IMAGE: NUCLEAR WASTE MANAGEMENT ORGANIZATION

HOW FISSION WORKS

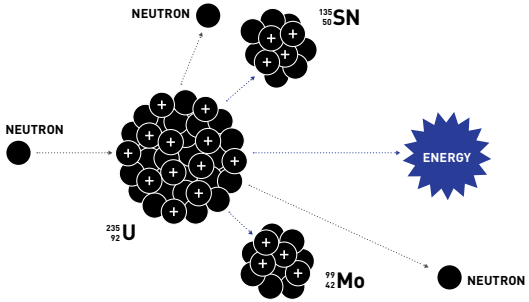
Uranium, in both of its main isotopes, U-235 and U-238, emits very little radiation before it is used in the reactor—so little that unused fuel bundles are safe to handle.

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.

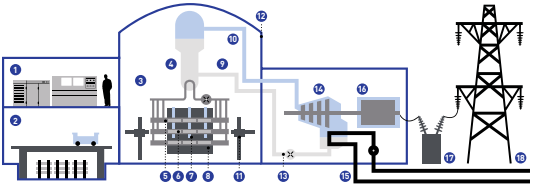
The basic parts of a nuclear reactor are the uranium fuel, the moderator and the coolant.

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

Nuclear reactors use the energy produced by a chain reaction in nuclear fuel to generate electricity. In a CANDU reactor, the steps for generating electricity are as follows:

1. Operators load natural uranium into a reactor core. When there is enough fuel concentrated in the core, neutrons from the uranium start a chain reaction.
2. The neutrons in the chain reaction travel at many speeds, but the slow ones are the best at splitting uranium atoms. The core sits in a moderator (heavy water, in the case of CANDU) that slows the neutrons down.
3. Reactor operators in the control room keep the reaction controlled and steady, so that the reactor generates heat without getting too hot. They move control rods in and out of the reactor core. The rods are made of materials that absorb neutrons and can slow or stop fission as needed.
4. The reactor could get very hot. So, a coolant (also heavy water for CANDU reactors) circulates through the reactor core to cool it down.
5. The coolant also gets hot, but this is useful heat. Despite its name, the coolant boils into high-pressured steam. The pressure pushes the steam to turn turbines. The coolant is then circulated back into the reactor to be re-used.
6. The energy of the spinning turbines drives an electrical generator, which converts the movement into electricity—very much the way a wind turbine works. That electricity powers the electrical grid.

CANDU REACTORS

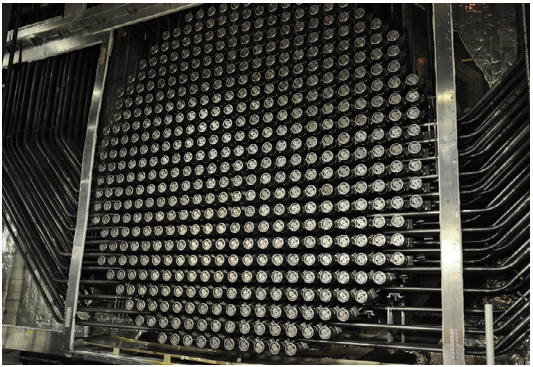
CANDU stands for CANada Deuterium Uranium, because it was invented in Canada, uses deuterium oxide (also known as heavy water) as a moderator and coolant, and uses uranium as a fuel.

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



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, 26 of which are currently operable.

There are also 19 reactors built in India that are based on the CANDU design but are not technically CANDUs.

CERNAVODA (ROMANIA)



QINSHAN (CHINA)



EMBALSE (ARGENTINA)



WOLSONG (SOUTH KOREA)



IMAGES: ATKINSRÉALIS

CANDU AND CANDU-DERIVED (PWHR) REACTORS GLOBALLY

COUNTRY	FACILITY	UNITS	STATUS	NET CAPACITY (MWE)
Argentina	Embalse	1 CANDU reactor	Operable	608
Canada	Bruce Power	8 CANDU reactors	Operable	6,478
	Darlington	4 CANDU reactors	Operable	3,512
	Gentilly	1 CANDU reactor	Permanent Shut Down	635
	Pickering	4 CANDU reactors	Operable	2,064
		4 CANDU reactors	Permanent Shut Down	2,060
	Point Lepreau	1 CANDU reactor	Operable	660
China	Qinshan III	2 CANDU reactors	Operable	1,334
India	Kaiga	4 PHWR reactors	Operable	808
	Kakrapar	4 PHWR reactors	Operable	1,664
	Madras	1 PHWR reactor	Operable	202

COUNTRY	FACILITY	UNITS	STATUS	NET CAPACITY (MWE)
India	Madras	1 PHWR reactor	Operations Suspended	202
	Narora	2 PHWR reactors	Operable	404
	Rajasthan	1 CANDU reactor	Operable	187
		1 CANDU reactor	Permanent Shut Down	134
		5 PHWR reactors	Operable	1,438
	Tarapur	2 PHWR reactors	Operable	868
Pakistan	Karachi	1 CANDU reactor	Permanent Shut Down	90
Romania	Cernavoda	2 CANDU reactors	Operable	1,300
South Korea	Wolsong	3 CANDU reactors	Operable	1,735
		1 CANDU reactor	Permanent Shut Down	661

SOURCE: World Nuclear Association. "Reactor Database." 2025. https://world-nuclear.org/nuclear-reactor-database/

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 310 of the world's 438 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	310
Pressurized heavy water reactor (PHWR)	Natural UO_2	Heavy water	Heavy water	47
Boiling water reactor (BWR)	Enriched UO_2	Water	Water	60
Light water graphite reactor (LWGR)	Enriched UO_2	Graphite	Water	10
Advanced gas-cooled reactor (AGR)	Natural U and enriched UO_2	Graphite	Carbon dioxide	8
Fast neutron reactor (FNR)	PuO_2 and UO_2	None	Liquid sodium	2
High temperature gas-cooled reactor (HTGR)	Enriched UO_2	Graphite	Helium	1

SOURCES: IAEA Power Reactor Information System. "Country Statistics." 2024. https://www.iaea.org/PRIS/CountryStatistics/CountryStatisticsLandingPage.aspx
World Nuclear Association. "Nuclear Power Reactors." 2025. https://world-nuclear.org/nuclear-reactor-database

NEXT-GENERATION REACTORS AND ADVANCED FUELS

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

In 2001, 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." 2024. https://www.gen-4.org

SMALL MODULAR REACTORS

Designs of small modular reactors (SMRs) range between less than 1 megawatt to 300 megawatts, with the largest fitting in a school gym. They're also modular: they can be mass-produced, saving on costs and allowing for shipment to remote locations. A small city could use an SMR until it reaches capacity, then add another as the city grows. A mine could ship an SMR to help with its production, then move it when operations shut down.

The potential applications for SMRs in Canada include providing electricity to small and remote cities, providing process heat for resource industries such as Ontario's Ring of Fire 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, as nuclear power would, in many cases, replace fossil fuel generation.

There are currently 127 SMR designs around the world and 51 designs are currently undergoing pre-licensing or licensing reviews in 15 countries. There are roughly 85 ongoing discussions between SMR developers and site owners worldwide.

In 2020, the first working prototype SMR, Akademik Lomonosov, started generating energy at Russia's northeastern port town of Pevek and in March 2024, the HTR-PM at the Shidaowan Nuclear Power Plant site in Shandong province, China, was connected to a local district heating system after first connecting to the grid in 2021.

SOURCES: International Atomic Energy Agency. "What are Small Modular Reactors (SMR)? Nuclear Explained. 2023. https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs
Nuclear Energy Agency. https://www.oecd-nea.org/jcms/pl_108326/the-nea-small-modular-reactor-dashboard-third-edition

SMRS, THE ENVIRONMENT, AND THE ECONOMY

Adding small modular reactors (SMRs) to the Canadian power mix could bring about several benefits.

Greener cities—SMRs could power smaller grids, especially in remote and northern communities normally powered by fossil fuels. As approximately 1 megawatt can power approximately 750 homes, an SMR could easily power a small city. Some designs could also add intermittent power, making wind and solar more feasible.

Hydrogen production—Many SMRs run hot enough to enable efficient generation of hydrogen, with enormous potential for low-carbon energy for transport.

Greener industry—Resource industries such as mining and the oil sands are a significant part of Canada's economy, but they are often remote and off-grid and require a large amount of heat and power to operate. This normally means burning fossil fuels. SMRs could lower the carbon emissions of these industries substantially.

Reliable electricity—SMR designs also allow for "islanding" parts of the electrical grid, meaning that a blackout in one region would be less likely to affect another if it is powered by a nuclear reactor. An SMR could also be used to re-power a grid after a blackout, as it does not need another power source to restart.

District heating—Off-grid power, district heating currently relies almost exclusively on diesel fuel, which has several limitations (e.g. cost, emissions). These needs may be addressed by very small SMRs.

SOURCES: EnviroEconomics and Navius Research. https://www.naviusresearch.com/publications/small-modular-reactors-2021/

Natural Resources Canada. "Canada Outlines Next Steps for Progress on Small Modular Reactor Technology." 2025. https://www.canada.ca/en/natural-resources-canada/news/2020/12/canada-outlines-next-steps-for-progress-on-small-modular-reactor-technology.html

International Energy Agency. https://www.iea.org/reports/global-energy-review-2025/electricity

ADVANCING SMRS IN CANADA

With its large uranium reserves, extensive nuclear experience, and robust regulation, Canada has the potential to be a leader in the development, use, and sale of SMR technologies.

Over the last five years, government support for SMRs has risen across the country. In December 2019, the premiers of Saskatchewan, Ontario, and New Brunswick signed a memorandum of understanding (MOU) to advance the development and deployment of SMRs; Alberta joined the MOU in April 2021. The MOU encourages cooperation among the involved provinces and with industry. This included a feasibility study prepared by four provincial utilities which found that SMRs have the potential to be economically competitive.

In 2022, the four provinces released "A Strategic Plan for the Deployment of Small Modular Reactors," which was soon followed by the announcement that Saskatchewan was considering the deployment of an SMR in the early 2030s. Later that year, the Canada Infrastructure Bank struck a $970 million deal with Ontario Power Generation to build the country's first SMR at its Darlington site. The federal government then announced $55 million in funding from Environment and Climate Change Canada's Future Electricity Fund (FEF) to advance the deployment of GE Vernova Hitachi Nuclear Energy's BWRX-300 Small Modular Reactors (SMRs) for the Darlington SMR project.

After receiving approval to commence construction in 2025, the province of Ontario and the Government of Canada collectively invested $3 billion to advance the Darlington SMR project, which entails the deployment of four BWRX-300 SMRs, the first of which is expected to be connected to the grid in 2030. When all four SMRs are built, they will generate a combined 1,200 megawatts of electricity—enough to supply power to about 1.2 million homes.

In 2025 the FEF also increased program funding from $24 million to $80 million to the Saskatchewan Government's Crown Investments Corporation in support of SaskPower's SMR pre-development work. This funding will support pre-engineering work, technical studies, environmental assessments, regulatory studies, and community and Indigenous engagement.

In addition, the government announced a total investment of $52.4 million for various projects supporting the development and deployment of SMRs and CANDU reactors and decarbonization efforts in Saskatchewan, Alberta, and Ontario. This includes $11.4 million from the Enabling SMRs Program for three projects and $41 million for four projects under Natural Resources Canada's Electricity Predevelopment Program.

DARLINGTON NEW NUCLEAR PROJECT CONSTRUCTION SITE



IMAGE: ONTARIO POWER GENERATION



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 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 low-level waste.

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

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

RADIOACTIVE WASTE IN CANADA

WASTE CATEGORY	INVENTORY TO END OF 2019
Waste rock	167,000,000 tonnes
Mill and mine tailings	218,000,000 tonnes
Low-level waste	2,524,670 m^3
Intermediate-level waste	15,681 m^3
High-level waste	12,718 m^3

SOURCE: Natural Resources Canada. "Canada's radioactive waste." 2023. https://www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/nuclear-energy-uranium/radioactive-waste/7719
Natural Resources Canada. Natural Resources Canada (NRCan). https://www.canada.ca/en/natural-resources-canada/news/2023/03/government-of-canadas-modernized-policy-for-radioactive-waste-and-decommissioning-for-canada.html

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 practiced in Canada, fuel recycling is a part of several successful nuclear programs, including that of France.

USED FUEL BAY AT BRUCE B

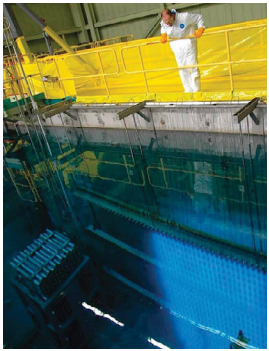


IMAGE: BRUCE POWER

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 that 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?

IF NUCLEAR ENERGY SUPPLIED ALL OF THE ELECTRICITY YOU'LL EVER USE IN YOUR LIFETIME, THE WASTE WOULD FIT IN A POP 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 would meet 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 proceed only with the interested community, the local First Nation and Métis communities and the surrounding communities working in partnership to implement it.

The NWMO began its community-driven site selection process for used nuclear fuel in 2010, emphasizing safety standards and community consent.

In November 2024, Wabigoon Lake Ojibway Nation and the Township of Ignace agreed to move forward to the regulatory process for Canada's deep geological repository. The project promises long-term benefits, including job creation and investments in community wellbeing, over its 175-year timeline. As it moves into the regulatory phase, Canada aims to ensure environmental protection while advancing energy security and climate change goals.

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

Canada's deep geological repository for used nuclear fuel will employ a multiple-barrier system made of natural and engineered barriers designed to safely contain and isolate used nuclear fuel over the long term. Located at a depth of 650-800 meters below ground, the repository will comprise a network of storage rooms for used nuclear fuel.

Above ground, facilities will receive, inspect, and repackage the used fuel into purpose-built Used Fuel Containers (UFC), which are then encased in bentonite clay buffer boxes before being transferred to the main shaft for underground placement, utilizing Canadian shield bedrock to safely isolate and contain the used nuclear fuel. Additional facilities will manage administration, security, processing of sealing materials, quality control, and ongoing operation and monitoring of the site.

The repository will include a centralized services area that will allow for underground ventilation through three shafts located within a single, secure location.

The rock at the site is crystalline. The construction of the deep geological repository will primarily involve controlled drilling and blasting for rock excavation. However, rock boring technology may be used based on the final design and site conditions.

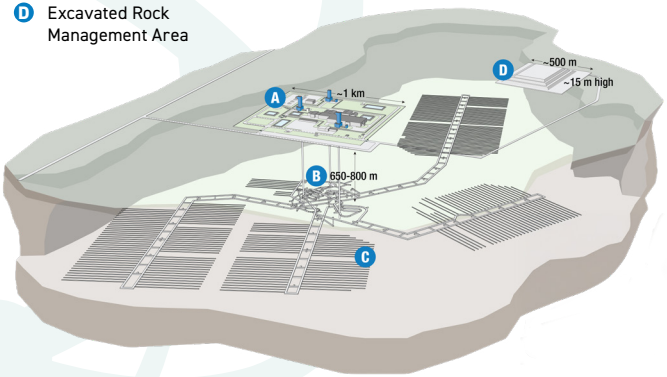
An extensive environmental and operational monitoring program will be implemented for ground and surface water, radiation, air quality, fire, and other relevant parameters. This monitoring will begin prior to construction and continue throughout the operational phase. An extended monitoring period will follow the placement of used nuclear fuel to ensure the repository is performing as expected.

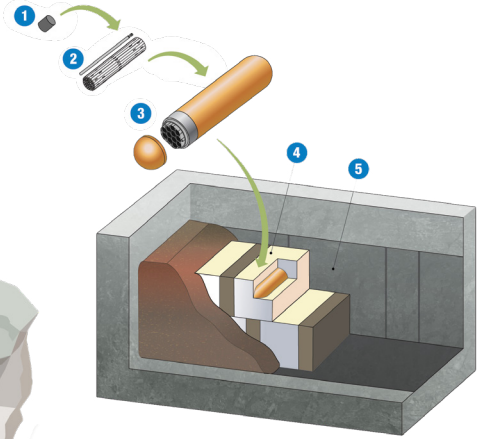
SOURCE: Nuclear Waste Management Organization. https://www.nwmo.ca/

DEEP GEOLOGICAL REPOSITORY SCHEMATIC

LEGEND

- **A** Surface facilities
- **B** Central services area
- **C** Placement rooms
- **D** Excavated Rock Management Area





LEGEND

1. The nuclear fuel pellet
2. The fuel element and the fuel bundle
3. The used nuclear fuel container
4. Bentonite clay
5. The geosphere

LOW AND INTERMEDIATE LEVEL WASTE

The Canadian Nuclear Safety Commission (CNSC) oversees all aspects of radioactive waste management to ensure the safety, health, and security of individuals, as well as to protect the environment.

In Canada, low-and intermediate-level radioactive waste accounts for 99.5% of the country's radioactive waste output, with nearly three-quarters of this waste consisting of contaminated soil, resulting from historical practices.

The CNSC defines low-level waste (LLW) as materials containing radionuclides that exceed established clearance levels and exemption quantities but generally have limited long-lived radioactivity. LLW typically does not require significant shielding during handling and temporary storage, although it does need to be isolated and contained for periods of up to a few hundred years. Examples of LLW include contaminated materials, rags, protective clothing, and waste from the early operations of Canada's radium industry.

Intermediate-level waste (ILW), on the other hand, is characterized by levels of radiation that require shielding during handling and interim storage. While ILW typically does not require significant provisions for heat dissipation during these processes, some may necessitate heat management in the short term, such as refurbishment waste, due to its overall radioactivity. Examples of ILW include ion exchange resins and certain radioactive sources used in radiation therapy.

According to Canada's Radioactive Waste Policy Framework, the owners of radioactive waste are responsible for funding, organizing, developing, and managing their respective waste, including the operation of long-term waste management facilities.

In 2024, Canadian Nuclear Laboratories (CNL) was awarded a licence to construct the first nuclear waste disposal facility in the country. The purpose of the Near Surface Disposal Facility (NSDF) is to permanently dispose of solid LLW in an engineered facility designed to contain the waste and isolate it from both people and the environment.

Learn more about the NSDF at: www.cnl.ca/NSDF

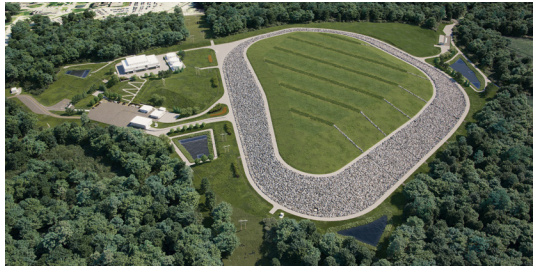


IMAGE: CANADIAN NUCLEAR LABORATORIES

SOURCES: World Nuclear Association. "Radioactive Waste Management." 2025. https://world-nuclear.org/information-library/nuclear-fuel-cycle "nuclear-waste/radioactive-was" e-management.

Canadian Nuclear Safety Commission (CNSC). "Radioactive Waste." 2025. https://www.cnsc-ccsn.gc.ca/eng/waste/.

Canadian Nuclear Laboratories (CNL). "Near Surface Disposal Facility." 2025. https://www.cnl.ca/environmental-stewardship/near-surface-disposal-facility-nsdf/.

Natural Resources Canada (NRCan). (2023 March 27). NOW LIVE: Government of Canada's Modernized Policy for Radioactive Waste and Decommissioning for Canada. https://www.canada.ca/en/natural-resources-canada/news/2023/03/government-of-canadas-modernized-policy-for-radioactive-waste-and-decommissioning-for-canada.html

Canadian Nuclear Safety Commission (CNSC). "Update on the Near Surface Disposal Facility Project." 2025. https://www.cnsc-ccsn.gc.ca/eng/resources/news-room/feature-articles/spring-2023-update-nsdf-project.

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 transportation 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 RELATED TO THE FUEL CYCLE. THE REST RELATE TO SUCH SECTORS AS MEDICINE, AGRICULTURE, INDUSTRY AND RESEARCH.

SOURCES: International Atomic Energy Agency. "Transport Security." 2024. https://www.iaea.org/topics/transport-security
World Nuclear Transport Institute. "Nuclear Power." 2024. 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.

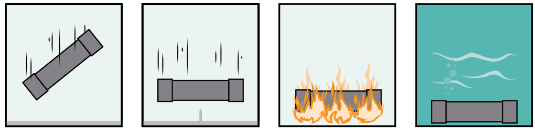
Excepted and industrial packages are sufficient for low-activity materials such as uranium ore.

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 m (30 foot) free-fall onto an unyielding surface

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

THERMAL
A 30 minute, fully engulfing fire at 800°C (1,475°F)

IMMERSION
An 8 hour immersion under water



NUCLEAR SCIENCE AND TECHNOLOGY

NUCLEAR SCIENCE AND TECHNOLOGY IN CANADA

Nuclear science and technology is an integral part of Canada's manufacturing and engineering capability. As such, the federal government and Canada's nuclear industry have a long history of investing in nuclear science and technology.

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

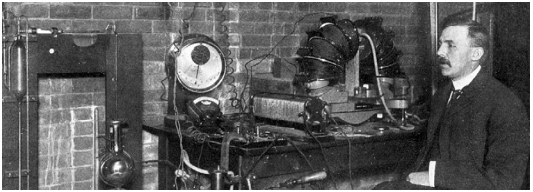
Canada is a historic leader in nuclear research and is home to four Nobel prizes related to nuclear science and technology:

- 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.

Harriet Brooks was Canada's first female nuclear physicist, known for her pioneering research in nuclear transmutation and radioactivity, which led to the discovery of radon in 1901.

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.

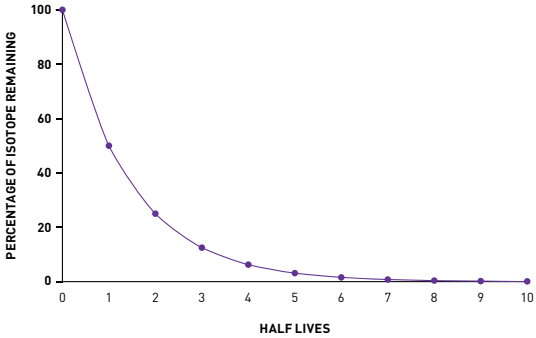
Radioisotopes are isotopes that have an unstable number of neutrons and undergo a change (or "decay") to become stable, emitting radiation in the process.

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.

Uranium-235 (U-235) is used to make fuel. U-235 has a very long half-life of 704 million years, which is why unused fuel bundles can be safely handled by people.

Radioisotopes that are commonly used in medicine include fluorine-18, which has a half-life of just under two hours, and technetium-99, which has a half-life of six hours.

RADIOACTIVE DECAY

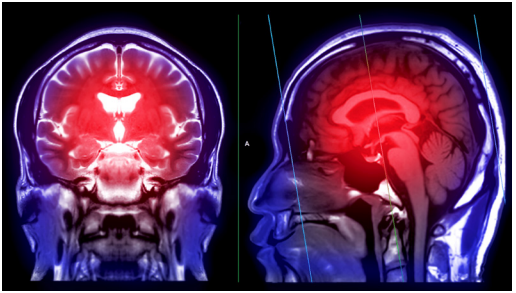


NUCLEAR MEDICINE

Nuclear medicine uses radiation to diagnose and determine the stages of various diseases, including cancer, and to treat illness, particularly by destroying tumours with radiation therapy. Much of 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.

In Canada, over one million diagnostic scans and thousands of radiation therapy treatments are performed annually. Canada has a history as a world leader in medical isotopes, contributing most of the world's raw materials until the closure of the National Research Universal Reactor in 2018. However, in the same year, Canada announced the Institute for Advanced Medical Isotopes (IAMI) at the TRIUMF facility in the University of British Columbia, with plans to produce a variety of medical isotopes. IAMI expects to be operational in 2026.

DIAGNOSTIC SCAN OF THE BRAIN



SOURCES: Canadian Institutes of Health Research. "Medical Imaging." 2015. https://www.cihr-irsc.gc.ca/e/40539.html
Natural Resources Canada. "Medical Isotopes." 2020. https://www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/nuclear-energy-uranium/medical-isotopes/23060
World Nuclear News. "Canada to build advanced medical isotope centre." 2018. https://www.world-nuclear-news.org/Articles/Canada-to-build-advanced-medical-isotope-centre
Canadian Nuclear Isotope Council. "Isotopes." 2024. https://www.canadianisotopes.ca/wp-content/uploads/2020/05/190471A_PolicyMag_IsotopeArticle_R000.pdf
TRIUMF. https://www.triumf.ca/wp-content/uploads/2025/04/TRIUMF-5Y-Implementation-Plan-2025-2030-pages.pdf

MEDICAL ISOTOPES

The production of medical isotopes is achieved by using two overarching technologies: nuclear reactors and particle accelerators (linear accelerators, cyclotrons). Canada is home to five research reactors, (one of which produces a large volume of medical isotopes), three nuclear power stations, twenty-five cyclotrons, and two linear accelerators.

Medical isotopes allow clinicians to see what is happening inside the body noninvasively and in real-time at a molecular level. The global nuclear medicine market was valued at USD 17.77 billion in 2024 and is expected to grow to USD 34.51 billion by 2030.

TYPES OF MEDICAL ISOTOPES

REACTOR-PRODUCED ISOTOPES	FUNCTION	HALF-LIFE
Bismuth-213	Used for targeted alpha therapy (TAT), especially cancers, as it has a high energy (8.4 MeV).	46 minutes
Caesium-131	Used for brachytherapy, emits soft X-rays.	9.7 days
Caesium-137	Used for low-intensity sterilization of blood and in brachytherapy.	30 years
Chromium-51	Used to label red blood cells for monitoring, and to quantify gastro-intestinal protein loss or bleeding.	28 days

SOURCES: Natural Resources Canada. https://natural-resources.canada.ca/climate-change/medical-isotopes
World Nuclear Association. "Radioisotopes in Medicine." 2023. https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx
Grand View Research. https://www.grandviewresearch.com/industry-analysis/nuclear-medicines-market

Cobalt-60	Formerly used for external beam radiotherapy, now almost universally used for sterilizing. Canada supplies 50% of the world's supply of cobalt-60, used to sterlize 40% of the world's single-use medical devices. High-specific-activity (HSA) Co-60 is used for brain cancer treatment.	5.27 years
Dysprosium-165	Used as an aggregated hydroxide for synovectomy treatment of arthritis.	2 hours
Erbium-169	Used for relieving arthritis pain in synovial joints.	9.4 days
Holmium-166	Being developed for diagnosis and treatment of liver tumours. Administered as microspheres.	26 hours
Iodine-125	Used in cancer brachytherapy (prostate and brain), also diagnostically to evaluate the filtration rate of kidneys and to diagnose deep vein thrombosis in the leg. It is also widely used in radioimmuno-assays to show the presence of hormones in tiny quantities.	60 days
Iodine-131*	Widely used in treating thyroid cancer and in imaging the thyroid; also in diagnosis of abnormal liver function, renal (kidney) blood flow, and urinary tract obstruction. A strong gamma emitter, but used for beta therapy.	8 days
Iridium-192	Supplied in wire form for use as an internal radiotherapy source for cancer treatment (used then removed), e.g. for prostate cancer. Strong beta emitter for high dose-rate brachytherapy.	74 days
Iron-59	Used in studies of iron metabolism in the spleen.	46 days

***FISSION PRODUCT**

SOURCE: World Nuclear Association. "Radioisotopes in Medicine." 2023. https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx

Lead-212	Used in TAT for cancers or alpha radioimmunotherapy, with decay products Bi-212 (1 h) and Po-212 (0.3 µs) delivering the alpha particles. Used especially for melanoma, breast cancer and ovarian cancer. Demand is increasing. Used in peptide receptor radionuclide therapy (PRRT).	10.6 hours
Lutetium-177	Lu-177 is increasingly important as it emits just enough gamma for imaging while the beta radiation does the therapy on small (eg endocrine) tumours. Its half-life is long enough to allow sophisticated preparation for use. It is usually produced by neutron activation of natural or enriched lutetium-176 targets or indirectly by neutron irradiation of Yb-176.	6.7 days
Molybdenum-99*	Used as the 'parent' in a generator to produce technetium-99m.	66 hours
Palladium-103	Used to make brachytherapy permanent implant seeds for early stage prostate cancer. Emits soft x-rays.	17 days
Phosphorus-32	Used in the treatment of polycythemia vera (excess red blood cells). Beta emitter.	14 days
Potassium-42	Used for the determination of exchangeable potassium in coronary blood flow.	12 hours
Radium-223	Used for TAT brachytherapy, lodges in bone, emits soft X-rays.	11.4 days
Rhenium-186	Used for pain relief in bone cancer. Beta emitter with weak gamma for imaging.	3.8 days
Rhenium-188	Used to beta irradiate coronary arteries from an angioplasty balloon.	17 hours
Samarium-153	Sm-153 is very effective in relieving the pain of secondary cancers lodged in the bone, sold as Quadramet. Also very effective for prostate and breast cancer. Beta emitter.	47 hours

***FISSION PRODUCT**

SOURCE: World Nuclear Association. "Radioisotopes in Medicine." 2023. https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx

Scandium-47	Sc-47 has similar properties to Lu-177 and may be used for therapy or diagnosis. It is produced by irradiating calcium-46 to produce Ca-47 which decays to Sc-47.	4.5 days
Selenium-75	Used in the form of seleno-methionine to study the production of digestive enzymes.	120 days
Sodium-24	For studies of electrolytes within the body.	15 hours
Strontium-89*	Very effective in reducing the pain of prostate and bone cancer. Beta emitter.	50 days
Technetium-99m	Used to image the skeleton and heart muscle in particular, but also for brain, thyroid, lungs (perfusion and ventilation), liver, spleen, kidney (structure and filtration rate), gall bladder, bone marrow, salivary and lacrimal glands, heart blood pool, infection, and numerous specialized medical studies. Produced from Mo-99 in a generator. The most common radioisotope for diagnosis, accounting for over 80% of scans.	6 hours
Thorium-227	Used for TAT, decays to Ra-223.	18.7 days
Xenon-133*	Used for pulmonary (lung) ventilation studies.	5 days
Ytterbium-169	Used for cerebrospinal fluid studies in the brain.	32 days
Ytterbium-177	Progenitor of Lu-177, through neutron irradiation of Yb-176.	1.9 hours
Yttrium-90*	Used for cancer brachytherapy and as silicate colloid for the relieving the pain of arthritis in larger synovial joints. Pure beta emitter and of growing significance in therapy, especially liver cancer.	64 hours

***FISSION PRODUCT**

SOURCES: World Nuclear Association. "Radioisotopes in Medicine." 2023. https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx
TRIUMF. https://triumf.ca/research/life-sciences/
Natural Resources Canada. "Medical Isotopes." 2024. https://www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/nuclear-energy-uranium/medical-isotopes/23060

CYCLOTRON-PRODUCED ISOTOPES	FUNCTION	HALF-LIFE
Actinium-225	Used for targeted alpha therapy (TAT) especially prostate cancers.	10 days
Astatine-211	Used for TAT.	7.2 hours
Bismuth-213	Used for TAT.	46 minutes
Carbon-11, Nitrogen-13, Oxygen-15, Fluorine-18	These are positron emitters used in PET for studying brain physiology and pathology, in particular for localizing epileptic focus, and in dementia, psychiatry, and neuropharmacology studies. They also have a significant role in cardiology. F-18 in FDG (fluorodeoxyglucose) has become very important in detection of cancers and the monitoring of progress in their treatment, using PET.	various
Cobalt-57	Used as a marker to estimate organ size and for in-vitro diagnostic kits.	272 days
Copper-64	Used to study genetic diseases affecting copper metabolism, such as Wilson's and Menke's diseases, for PET imaging of tumours, and also cancer therapy.	13 hours
Copper-67	Beta emitter, used in therapy.	2.6 days
Fluorine-18 as FLT (fluorothymidine), F-miso (fluoromisonidazole), 18F-choline	It decays with positron emission, so used as tracer with PET, for imaging malignant tumours.	110 minutes

SOURCE: World Nuclear Association. "Radioisotopes in Medicine." 2023. https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx

Gallium-67	Used for tumour imaging and locating inflammatory lesions (infections).	78 hours
Gallium-68	Positron emitter used in PET and PET-CT units. Derived from germanium-68 in a generator.	68 minutes
Germanium-68	Used as the 'parent' in a generator to produce Ga-68.	271 days
Indium-111	Used for specialist diagnostic studies, e.g. brain studies, infection and colon transit studies. Also for locating blood clots, inflammation and rare cancers.	2.8 days
Iodine-123	Increasingly used for diagnosis of thyroid function, it is a gamma emitter without the beta radiation of I-131.	13 hours
Iodine-124	Tracer, with longer life than F-18, one-quarter of decays are positron emission so used with PET. Also used to image the thyroid using PET.	4.2 days
Krypton-81m from rubidium-81	Kr-81m gas can yield functional images of pulmonary ventilation, e.g. in asthmatic patients, and for the early diagnosis of lung diseases and function.	13 seconds /4.6 hours
Rubidium-82	Convenient PET agent in myocardial perfusion imaging.	1.26 minutes
Strontium-82	Used as the 'parent' in a generator to produce Rb-82.	25 days
Thallium-201	Used for diagnosis of coronary artery disease and other heart conditions such as heart muscle death and for location of low-grade lymphomas.	73 hours

SOURCE: World Nuclear Association. "Radioisotopes in Medicine." 2023. https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx

RADIATION THERAPY AND STERILIZATION

Nuclear medicine includes a common set of techniques used to treat cancer. They work by delivering radiation to specific areas of the body to destroy cancer cells.

Over 10,000 hospitals worldwide use radioisotopes in medicine, and about 90% of the procedures are for diagnosis.

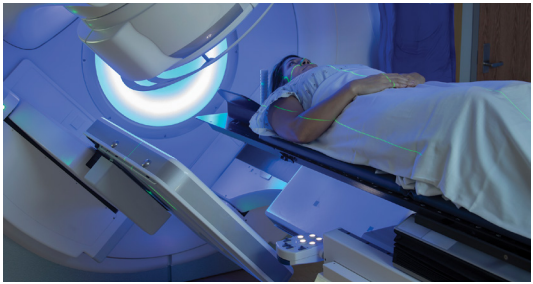
Radiation therapy can be performed either externally by irradiation or internally by radioisotope injection.

Thousands of therapeutic doses are administered each year in Canada. This can be done by external beam radiation, which focuses radiation directly on cancerous tissue, or by brachytherapy, which involves placing a radiation source inside or next to the affected tissue.

Hospitals also use radioisotopes such as cobalt-60, which is produced in nuclear power plants in Ontario, 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. Nor does it cause the sterilized equipment to become radioactive—it's perfectly safe to handle right away.

PATIENT UNDERGOING RADIATION THERAPY



SOURCES: World Nuclear Association. "Radioisotopes in Medicine." 2023. https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx

ENABLING THE HYDROGEN ECONOMY

Hydrogen promises enormous advantages for powering Canadian industry. When combined with oxygen freely available in the air, it releases energy, which can be turned into electricity—and the only waste product is water. Hydrogen has the potential to transform Canada's economy.

- Hydrogen fuel cells could power vehicles with no carbon emissions.
- Hydrogen could power heavy industry in remote locations without burning fossil fuels.
- Hydrogen could store energy from intermittent power sources such as wind or solar, then supply electricity at night or when the wind isn't blowing.

The main method for production worldwide depends on using natural gas, a fossil fuel. Hydrogen can also be produced by electrolyzing (splitting) water molecules. This uses electricity, but the process itself uses some of the energy, so it's more carbon-intensive than the electricity used to produce it.

As nuclear power releases less carbon than almost any other source of electricity, it is possible to use it to make relatively "green" hydrogen.

Another process, called "methane pyrolysis" uses heat to strip the hydrogen atoms from methane, producing hydrogen gas. It also leaves carbon as a by-product, but this carbon is solid, so it does not enter the atmosphere.

This method needs high temperatures (500-1000°C), which can be achieved by Generation-IV nuclear reactors, including some small modular reactor designs. This shows potential as a cost-effective way to produce hydrogen without high carbon emissions.

Transforming the economy will require a lot of hydrogen: to do this in the European Union, the European Commission wants to produce 10 million tonnes of renewable hydrogen by 2030.

CANADA AND THE HYDROGEN ECONOMY

Canada is well placed to help supply hydrogen for its own market and internationally, being already one of the top 10 hydrogen producers in the word and a top-tier nuclear nation.

The federal government recognizes Canada's potential as both a supplier and a leader in hydrogen technology. In December 2020, it launched the Hydrogen Strategy for Canada as part of its commitment to net-zero emissions by 2050. The Strategy, for which a progress report was issued in 2024, explicitly recognizes the potential of the nuclear industry in a hydrogen economy.

Nuclear electricity can be harnessed to produce clean hydrogen at a competitive price via an electrolysis process using off-peak nuclear electricity. Large reactors can be suitable for large-scale centralized hydrogen production.

In contrast, high-temperature thermal processes or coupling with small modular reactors are viable in the longer term and are more appropriate for distributed hydrogen production. Hydrogen, with its unique properties, can also play a crucial role in the daily and seasonal storage of variable renewable resources. This capability reassures us about the grid's stability, enabling higher penetration of intermittent renewables. Efforts are underway to study the economics of nuclear hydrogen production in Ontario, providing us with a comprehensive understanding of its feasibility and potential benefits.

SOURCES: Natural Resources Canada. https://natural-resources.canada.ca/sites/nrcan/files/environment/hydrogen/NRCan_Hydrogen%20Strategy%20for%20Canada%20Dec%2015%202200%20clean_low_accessible.pdf
Nuclear Energy Association, Nuclear Energy Institute and Idaho National Laboratory. "Nuclear-Hydrogen Digest: Nuclear Energy in the Hydrogen Economy." 2022. https://www.nice-future.org/docs/nicefuturelibraries/default-document-library/nuclear-hydrogen-digest.pdf
Natural Resources Canada. https://natural-resources.canada.ca/energy-sources/clean-fuels/hydrogen-strategy/hydrogen-strategy-canada-progress-report

FOOD IRRADIATION

Food irradiation is the process of using radiation to kill bacteria, harmful pathogens like e. coli or salmonella, and insect pests 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. For food irradiation in Canada, the source of irradiation could be gamma from a cobalt-60 irradiator, electron beams or x-rays. This process does not cause the food itself to become radioactive: radiation simply passes through the food.

Food that has been irradiated in Canada, the United States and most other jurisdictions, must display a symbol called the Radura accompanied by explanatory wording such as "Treated by Irradiation." Since many bulk spices used in the restaurant and food packaging industry are irradiated and are only added in small quantities to prepared foods, it is not required to label the prepared foods or foods served in restaurants with the symbol.

More than 55 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.

DID YOU KNOW?



AROUND 500,000 TONNES OF FOOD PRODUCTS ARE COMMERCIALLY IRRADIATED EACH YEAR.

YEARS OF RESEARCH HAS SHOWN IRRADIATED FOOD TO BE JUST AS SAFE AND NUTRITIOUS AS FOOD PRESERVED BY DRYING AND FREEZING.

SOURCE: Nordion. "Facts about food irradiation." 2017. https://www.nordion.com/wp-content/uploads/2017/04/Nordion-Food-Irradiation-Fact-Sheet-2017.pdf

AGRICULTURAL APPLICATIONS

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.

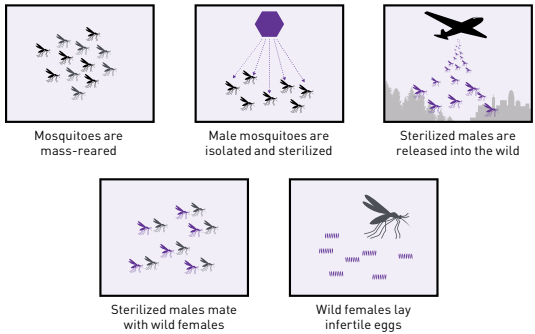
Mutation breeding has been used for several decades to create crops that are more plentiful, nutritious, adaptable to harsh climates, and resistant to pests. Over 3,200 crop varieties have been developed this way.

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



SOURCE: International Atomic Energy Agency. "Mutation Breeding." 2019. 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.

For ground and surface water resources, tracers can help determine characteristics such as age, origin, distribution and interconnections, and 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, TRANSPORTATION, STORAGE, IMPORTING AND EXPORTING 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.

There are currently more than 21,000 desalination plants worldwide, producing approximately 99 million cubic metres of drinking water daily. The global installed capacity for the production of desalinated water has increased at an average rate of 7% per year since 2010, driven by the rising demand for clean water solutions in response to increasing water scarcity challenges.

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

Nuclear desalination plants utilize heat from small nuclear reactors to evaporate water, leaving behind salt and debris. In addition to desalinating brackish or seawater, the treatment of urban wastewater is increasingly being carried out.

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

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

DID YOU KNOW?

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



SOURCES: International Desalination Association. "Fusion Power and the Future of Desalination: A Game-Changer for Energy and Water Security?." 2025. https://idrawater.org/news/fusion-power-and-the-future-of-desalination-a-game-changer-for-energy-and-water-security/
World Nuclear Association. "Desalination." 2020. https://www.world-nuclear.org/information-library/non-power-nuclear-applications/industry/nuclear-desalination.aspx
William Blair: Tapping Into the World of Water. https://www.williamblair.com/-/media/downloads/eqr/2025/williamblair_tapping-into-the-world-of-water.pdf

NUCLEAR-POWERED TRAVEL

SPACE TRAVEL

Since its pioneering use in 1961, nuclear power has been a key player in advancing space travel.

Space nuclear propulsion is a technology that draws energy from fission instead of traditional chemical reactions. Thus, it provides virtually unlimited energy density and opens the door for crewed missions to Mars and opens up new frontiers in deep space science. NASA is looking at two types of nuclear propulsion systems: thermal and electric.

Nuclear thermal propulsion, with its high thrust and double the propellant efficiency of chemical rockets, represents a promising future for space travel. The system operates by transferring heat from the reactor to a liquid propellant, which then converts into a gas. This expanding gas provides the necessary thrust to propel a spacecraft.

The Voyager space probes, the Cassini mission to Saturn, the Galileo mission to Jupiter, and the New Horizons mission to Pluto are all powered by nuclear or RTGs (radioisotope thermal generators). The Spirit and Opportunity Mars rovers have used a mix of solar panels for electricity and RTGs for heat. The latest Mars rover, Curiosity, uses RTGs for heat and electricity.

DID YOU KNOW?

VOYAGER 2, LAUNCHED IN 1977, IS THE WORLD'S LONGEST-RUNNING SPACE MISSION.

SOURCES: NASA. "Space Nuclear Propulsion." 2024. https://www.nasa.gov/tdm/space-nuclear-propulsion/#:~:text=Nuclear%20thermal%20propulsion%20provides%20high,thrust%20and%20propel%20a%20spacecraft
Nuclear Energy Institute. "Nuclear Taking Us Faster & Father into Space" 2023. https://www.nei.org/news/2021/nuclear-taking-us-faster-and-farther-into-space

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 160 ships powered by more than 200 small nuclear reactors. Most of these are submarines, but there are also nuclear-powered icebreakers and aircraft carriers.

Apart from naval use, nuclear power seems most immediately promising for the following:

- Large bulk carriers that go back and forth constantly on few routes between dedicated ports—e.g. China to South America and NW Australia. They could be powered by a reactor delivering 100 megawatt thrust.
- Cruise liners, which have demand curves like a small town. A 70 MWe unit could give base-load and charge batteries, with a smaller diesel unit supplying the peaks. (The largest afloat today —Oasis class, with 100,000 t displacement—has about 60 megawatt shaft power derived from almost 100 megawatt total power plant.)
- Nuclear tugs, to take conventional ships across oceans.
- Some kinds of bulk shipping, where speed may be essential.

In October 2020, Canadian Nuclear Laboratories was awarded a contract by Transport Canada to develop the Marine-Zero Fuel (MaZeF) assessment tool. This tool analyzes the energy ecosystem of marine transport and helps reduce greenhouse gas emissions in line with the IMO 2018 target of a 50% reduction by 2050, compared to 2008 levels. The assessment tool will incorporate various technologies for the production, storage, and handling of hydrogen for marine vessels.

SOURCES: World Nuclear Association. "The Many Uses of Nuclear Technology." 2020. https://www.world-nuclear.org/information-library/non-power-nuclear-applications/overview/the-many-uses-of-nuclear-technology.aspx
World Nuclear Association. "Nuclear-Powered Ships." 2023. https://world-nuclear.org/information-library/non-power-nuclear-applications/transport/nuclear-powered-ships.aspx

CONSUMER PRODUCTS

Smoke detectors are the most common consumer products that use nuclear technology. The ionization type of smoke detectors 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, which is generated in CANDU-type fission reactors, 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 IONIZATION SMOKE DETECTORS WORK

Alpha radiation from an americium source ionizes the air between two electrodes (+ and -). This allows current to flow from one electrode to another. When there is smoke in this space, the ions do not flow, and the current stops. This triggers the smoke detector to set off an alarm.

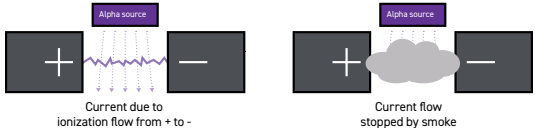


IMAGE: TEACHING ADVANCED PHYSICS

SOURCE: World Nuclear Association. "Radioisotopes in Consumer Products." 2018. https://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;



combatting malnutrition and childhood obesity;



analyzing metals, alloys and electronic materials;



identifying extremely small and diluted forensic materials;



characterizing archaeological and historical materials;



carbon-dating rocks and organic materials; and



studying air pollution and aerosols.

SOURCE: International Atomic Energy Association. "Material Analysis." 2019. https://www.iaea.org/topics/material-analysis

NUCLEAR RESEARCH CENTRES

Nuclear research centres are key facilities for promoting nuclear science and technology. Canada has been a leading country in nuclear energy research and development for many years.

Canadian Nuclear Laboratories (CNL) is Canada's leading organization in nuclear science and technology. For 75 years, CNL has been at the forefront of nuclear innovation in areas such as energy, health, environmental protection, and safety and security.

CNL has a rich history of developing nuclear technologies, including the CANDU reactor, which now supplies carbon-free energy to six out of ten homes in Ontario. Additionally, CNL's researchers have played a pioneering role in nuclear medicine, notably in the development of molybdenum-99 and cobalt-60 radioisotopes, both of which are essential in medical diagnostics and the fight against cancer. CNL is also leading Canada's efforts to safely address several legacy nuclear liabilities, including the decommissioning of prototype reactors, clean-up of historic wastes, and the construction of Canada's first low-level waste disposal facility.

CNL currently operates the Chalk River Laboratories, which is Canada's largest nuclear research centre. The Chalk River Laboratories boasts multiple licence-listed nuclear facilities, including the Zero Energy Deuterium (ZED-2) Research Reactor, the Biological Research Facility, and the Tritium Facility, as well as more than 120 other research facilities and laboratories.

Enabled by investments from the Government of Canada, the campus has seen significant revitalization. This includes the establishment of a new hydrogen laboratory and a new materials science laboratory complex. Construction is underway on the Advanced Nuclear Materials Research Centre (ANMRC), a cutting-edge research facility and the largest nuclear research center ever constructed in Canada.

Once operational, it will form the core of CNL's research and development infrastructure. Covering 10,000 square metres, the complex will house 23 laboratories, 12 shielded cells, support 160 staff members, and bring together essential capabilities from across the campus.

MCMASTER UNIVERSITY

McMaster University is home to a 5 megawatt multi-purpose reactor that provides neutrons for research and medical isotope production. It is Canada's most powerful research reactor and the nation's only major neutron source. The McMaster Nuclear Reactor (MNR) is an open-pool type Materials Test Reactor (MTR) with a core of low-enriched uranium (LEU) fuel, moderated and cooled by light water.

The MNR conducts hundreds of thousands of neutron irradiations each year, many of which support various industries, such as mining exploration and environmental sampling. It is a world leader in the production of iodine-125, a radioactive isotope used in the treatment of prostate cancer, producing hundreds of doses each week. Additionally, the MNR is used for quality assurance testing of turbine blades for jet engines, leveraging the neutron radiography facility at one of the beam ports. Research activities at the MNR are continually expanding, with a new neutron diffractometer installed in 2009 and a state-of-the-art positron beam facility currently in the design phase.

MCMASTER NUCLEAR REACTOR CORE

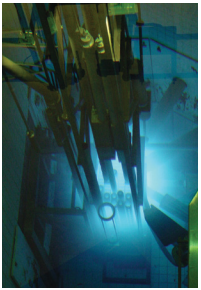


IMAGE: MCMASTER UNIVERSITY

DID YOU KNOW?

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

SLOWPOKE-2 RESEARCH REACTORS

The AECL designed the SLOWPOKE-2 reactor (Safe LOW-POwer Kritical Experiment) as a low-energy, cost-effective source of neutrons for research purposes. This reactor is primarily used for practical applications, such as material quality control. It acts as an analytical tool, comparable to a gas chromatograph or an X-ray machine. The reactor can analyze the elemental composition of materials with high precision and can also produce images, including those of aircraft components. The reactor is also used as an educational resource to teach nuclear science and technology. Currently, only the Royal Military College of Canada in Ontario and École Polytechnique de Montréal in Quebec are licensed by the Canadian Nuclear Safety Commission (CNSC) to operate SLOWPOKE-2 reactors.

PARTICLE ACCELERATOR FACILITIES

Canada is also home to Class 1B nuclear facilities that have particle accelerators.

- TRIUMF Inc. is a large particle accelerator research facility located in Vancouver, British Columbia. In addition to conducting research, TRIUMF produces radioisotopes for industrial and medical applications, including advanced cancer diagnostics and treatments. The facility also tests computer hardware, avionics, and communications equipment for their resistance to ionizing radiation.
- Another significant facility is the Canadian Light Source, situated at the University of Saskatchewan. This national research facility features an operating Class IB synchrotron with an energy level of 2.9 giga-electronvolts (GeV) and a Class II linear accelerator operating at 43 mega electronvolts (MeV).

SOURCES: Canadian Nuclear Laboratories. "Future Vision for the Chalk River Laboratories." 2025. https://www.cnl.ca/about-cnl/future-vision-for-the-chalk-river-laboratories/
Canadian Nuclear Laboratories. "Vision 2030—A Strategy for a Sustainable CNL." September 2022. https://www.cnl.ca/wp-content/uploads/2022/09/Strategy_Final_EN.pdf. Accessed on August 2025
McMaster University. "McMaster Nuclear Reactor." 2025. https://nuclear.mcmaster.ca/facilities-equipment/facility-list/mcmaster-nuclear-reactor/
Canadian Nuclear Safety Commission (CNSC). "Research Reactors." 2025. https://www.cnsc-ccsn.gc.ca/eng/reactors/research-reactors/
Atomic Energy of Canada Limited (AECL). "1944—2020 AECL Historical Timeline." 2025. https://www.aecl.ca/aecl-historical-timeline/
Royal Military College of Canada. "SLOWPOKE Nuclear Reactors in Canada." 2025. https://www.rmc-cmr.ca/en/chemistry-and-chemical-engineering/slowpoke-nuclear-reactors-canada
Polytechnique de Montréal. "SLOWPOKE." 2025. https://www.polymtl.ca/phys/en/slowpoke
Canadian Nuclear Safety Commission (CNSC). "Particle accelerator facilities." 2025. https://www.cnsc-ccsn.gc.ca/eng/nuclear-substances/particle-accelerator-facilities/

Synchrotrons generate bright, focused light by accelerating electrons to very high energies and then redirecting them using magnetic devices.

Scientists utilize synchrotron light to capture images of samples, analyze their chemical composition, and gain insights into the structure of various materials.

TRIUMF'S 520 MEV CYCLOTRON



IMAGE: TRIUMF

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.

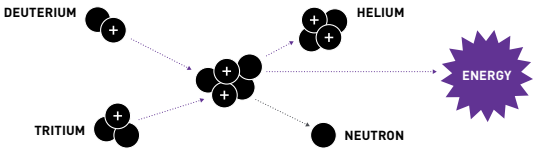
One of the most efficient fuels for fusion power is a mix of heavy hydrogen isotopes (deuterium and tritium), which means that water could become a primary fuel source.

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

General Fusion, a Canadian company based in British Columbia, successfully formed a magnetized plasma in its Magnetized Target Fusion demonstration, Lawson Machine 26 (LM26) in March of 2025.

In 2025, a partnership between the Government of Canada, the Government of Ontario, Atomic Energy of Canada Limited, Canadian Nuclear Laboratories, Ontario Power Generation and Stellarex announced it would establish the Centre for Fusion Energy.

NUCLEAR FUSION



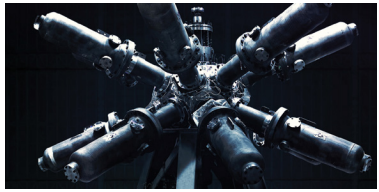


IMAGE: GENERAL FUSION



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.

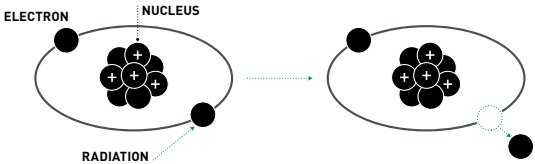
When radiation is discussed in the context of nuclear energy, it is typically referring to ionizing radiation.

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



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.

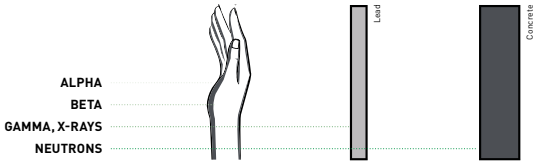
Different types of ionizing radiation have different biological effects. To account for these differences, the biological effects of ionizing radiation are generally measured in units called millisieverts (mSv).

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



WORKER WEARING PERSONAL DOSIMETER

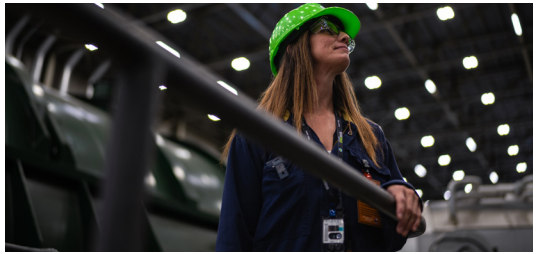


IMAGE: ONTARIO POWER GENERATION

BACKGROUND RADIATION

Background radiation is made up of natural and artificial (human-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 in 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 background radiation.

Natural radiation is all around us, including in cosmic rays, the air we breathe, plants in the environment, water, rocks and soil, the food we eat, and even from our own bodies.

NATURAL RADIATION IS EVERYWHERE



Adapted from Canadian Nuclear Safety Commission, Natural Background Radiation (accessed March 2026); image recreated by author.

SOURCES: Canadian Nuclear Safety Commission. https://www.cnsc-ccsn.gc.ca/eng/resources/radiation/radiation-doses/
Canadian Nuclear Safety Commission. https://www.cnsc-ccsn.gc.ca/eng/resources/radiation/types-and-sources-of-radiation/
United Nations Scientific Committee on the Effects of Atomic Radiation. https://www.unscear.org/unscear/en/publications/radiation-effects-and-sources.html

EFFECTS OF RADIATION ON THE BODY

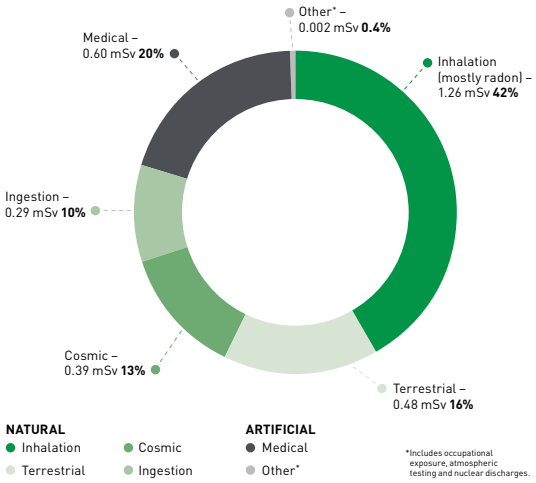
While the low doses we receive naturally and through medical procedures pose little risk to our health, high doses received in a short time (called acute doses) can be very dangerous.

Doses at these magnitudes occur only in extreme circumstances, such as in the case of emergency workers after the Chernobyl accident. Canada has never had any event producing doses of this magnitude.

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!

GLOBAL SOURCES OF RADIATION



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

mSv	EXAMPLE
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
.1	Dose from a chest X-ray
.02	Dose from typical cross-Canada flight
.005	Dose from a dental X-ray
.001	Annual dose from living near a Canadian nuclear power plant

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.

DID YOU KNOW?

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

NUCLEAR REGULATION

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

As an independent agency, the CNSC reports to Parliament through the Minister of Natural Resources. It holds quasi-judicial powers, akin to those of a court, which allow it to impose legal penalties, including fines, on individuals and organizations.

The CNSC's primary responsibility is to regulate the use of nuclear energy and materials, protecting the health, safety, and security of people and the environment.

To fulfill its mandate, the CNSC oversees a diverse range of activities within the nuclear fuel cycle and other applications of nuclear material. This includes regulating uranium mines, mills, processing facilities, fuel fabrication plants, nuclear power plants, radioactive waste management facilities, nuclear research facilities, and sites that handle nuclear substances.

Any person or organization that wants to possess, use, transport or store nuclear material—or build, operate, decommission or shut down a nuclear facility, including a nuclear power facility—must first obtain a licence issued by the CNSC. Additionally, the CNSC conducts compliance activities, including inspections, to ensure that licensees adhere to all conditions and requirements outlined in their licenses.

The CNSC also upholds Canada's international commitments regarding the peaceful use of nuclear energy.

With a long-standing history of international cooperation, the CNSC collaborates closely with the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA). The CNSC actively participates in and sometimes leads various IAEA and NEA committees, working groups, and forums aimed at sharing lessons learned and best practices. The CNSC also hosts and participates in IAEA international peer reviews.

CNSC'S SAFETY AND CONTROL AREAS

The CNSC evaluates how well licensees meet regulatory requirements and expectations by using 14 safety and control areas, which are technical topics it applies to assess, review, verify, and report on regulatory compliance and performance across all regulated facilities and activities.

MANAGEMENT

- **Management System**—The framework that establishes the processes and programs required to ensure the organization achieves its safety objectives, continuously monitors its performance against these objectives, and fosters a healthy safety culture.
- **Human Performance Management**—The activities that enable effective human performance through the development and implementation of processes to ensure that licensees have sufficient staff in all relevant job areas and they have the necessary knowledge, skills, tools and procedures in place to safely carry out their duties.
- **Operating Performance**—A safe and secure operation of the regulated facility with adequate regard for health, safety, security, environmental protection and international obligations. This includes an overall review of the conduct of the licensed activities and the activities that enable effective performance.

FACILITY AND EQUIPMENT

- **Safety Analysis**—A systematic evaluation of the potential hazards associated with the conduct of a proposed activity or facility that considers the effectiveness of preventative measures and strategies in reducing the effects of such hazards.
- **Physical Design**—Relates to the activities that impact the ability of structures, systems and

SOURCE: Canadian Nuclear Safety Commission. https://www.cnsc-ccsn.gc.ca/eng/resources/publications/reports/powerindustry/safety-and-control-areas/

components to meet and maintain their design basis given, new information arising over time and taking changes in the external environment into account.

- **Fitness for Service**—The activities that affect the physical condition of structures, systems and components to ensure that they remain effective over time. This includes programs that ensure all equipment is available to perform its intended design function when called upon.

CORE CONTROLS AND PROCESSES

- **Radiation Protection**—The implementation of a radiation protection program in accordance with the Radiation Protection Regulations. This program must ensure that contamination and radiation doses received by individuals are monitored, controlled and maintained ALARA (As Low As Reasonably Achievable).
- **Conventional Health and Safety**—The implementation of a program to manage workplace safety hazards and to protect workers.
- **Environmental Protection**—Programs that identify, control and monitor all releases of radioactive and hazardous substances and effects on the environment from facilities or as the result of licensed activities.
- **Emergency Management and Fire Protection**—The emergency plans and emergency preparedness programs that exist for emergencies and for non-routine conditions. This also includes any results of exercise participation.
- **Waste Management**—The internal waste-related programs that form part of the facility's operations up to the point where the waste is removed from the facility to a separate waste management facility. Also covers the planning for decommissioning.

SOURCE: Canadian Nuclear Safety Commission. https://www.cnsc-ccsn.gc.ca/eng/resources/publications/reports/powerindustry/safety-and-control-areas/

- **Security**—The programs required to implement and support the security requirements stipulated in the regulations, in the licence, in orders or in expectations for the facility or activity.
- **Safeguards and Non-Proliferation**—The programs required for the successful implementation of the obligations arising from the Canada/International Atomic Energy Agency Safeguards Agreement, as well as all other measures arising from the Treaty on the Non-Proliferation of Nuclear Weapons.
- **Packaging & Transport**—Programs that manage the safe packaging and transport of nuclear substances and radiation devices to and from a licensed facility.

CNSC INSPECTION AT A NUCLEAR GENERATING STATION



IMAGE: CANADIAN NUCLEAR SAFETY COMMISSION

SOURCE: Canadian Nuclear Safety Commission. https://www.cnsc-ccsn.gc.ca/eng/resources/publications/reports/powerindustry/safety-and-control-areas/

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 at high-security sites;
- 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." 2014. https://suretenucleaire.gc.ca/eng/resources/emergency-management-and-safety/index.cfm

CYBERSECURITY

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

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

The CNSC requires nuclear power plant licensees to have a cyber security program that meets the requirements of CSA N290.7-14, *Cyber security for nuclear power plants and small reactor facilities*. It conducts inspections to confirm compliance and program adequacy.

The safety and control systems of Canadian nuclear reactors and other vital plant components are not directly connected to business networks or the Internet.

HEADS OF STATE AT THE 2016 NUCLEAR SECURITY SUMMIT



IMAGE: BEN SOLOMON/U.S. DEPARTMENT OF STATE



RESOURCES

CANADIAN UNIVERSITIES AND COLLEGES WITH NUCLEAR PROGRAMS

Algonquin College	algonquincollege.com
Carleton University	carleton.ca
Loyalist College	loyalistcollege.com
McMaster University	mcmaster.ca
Ontario Tech University	ontariotechu.ca
Polytechnique Montréal	polymtl.ca
Queen's University	queensu.ca
Royal Military College of Canada	rmc-cmr.ca/en
Southern Alberta Institute of Technology	sait.ca
Northern Alberta Institute of Technology	nait.ca
University of Alberta	ualberta.ca
University of Calgary	ucalgary.ca
University of Guelph	uoguelph.ca
University of British Columbia	ubc.ca
Université Laval	ulaval.ca
University of New Brunswick	unb.ca
University of Saskatchewan	usask.ca
University of Toronto	utoronto.ca
University of Waterloo	uwaterloo.ca
Western University	uwo.ca
University of Windsor	uwindsor.ca
University of Ottawa	uottawa.ca
University of Regina	uregina.ca
University of Manitoba	umanitoba.ca
Saskatchewan Polytechnic	saskpolytech.ca
Humber Polytechnic	humber.ca
Georgian College	georgiancollege.ca
Southeast College	southeastcollege.org

SHOULD YOUR SCHOOL BE LISTED HERE?

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

OTHER RESOURCES

AtkinsRéalis	atkinsrealis.com
Atomic Energy of Canada Limited	aecl.ca
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
Conexus	conexusnuclear.org
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	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 Innovation Institute	nuclearinnovationinstitute.ca
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
Society for the Preservation of Canada's Nuclear Heritage	nuclearheritage.com
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—Radiation	who.int/health-topics/radiation
World Nuclear Association	world-nuclear.org
World Nuclear Transport Institute	wnti.co.uk

ABOUT THE CNA

The Canadian Nuclear Association (CNA) has been the national voice of the Canadian nuclear industry since 1960. Working with our members and all communities of interest, the CNA promotes the industry nationally and internationally, works with governments on policies affecting the sector, and endeavours to increase awareness and understanding of the value nuclear technology brings to the environment, economy, and daily lives of Canadians.

The Canadian Nuclear Factbook has been published regularly since 2004 by the Canadian Nuclear Association.

FOLLOW CNA ONLINE

Follow us on LinkedIn: LinkedIn.com/company/Canadian-Nuclear-Association

Watch us on YouTube: YouTube.com/CanadaNuclear

Join us at CNA Conferences:

CNA Annual Conference:
conference.cna.ca

CNA West Conference:
cnawest.cna.ca

340 Albert St., Suite 1120,
Ottawa ON,
K1R 7Y6

613 237 4262

info@cna.ca

cna.ca




THE CANADIAN NUCLEAR
FACTBOOK
cna
canadian
nuclear
association