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Inventory of RADIOACTIVE WASTE in CANADA 2016

Canada

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Inventory of RADIOACTIVE WASTE in CANADA

2016

Canada

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RADIOACTIVE II

1.0 INVENTORY OF RADIOACTIVE WASTE IN CANADA OVERVIEW

The *Inventory of Radioactive Waste* provides an overview of the production, accumulation and projections of radioactive waste in Canada as of December 31, 2016. Information and data on Canada's radioactive waste inventory is compiled from information provided by the waste owners for their waste management facilities.

In preparing this report, information and some excerpts were used from the sixth ***Canadian National Report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management***.

The previous edition of the *Inventory of Radioactive Waste* (named *Inventory Summary Report*) is available from the Canadian Nuclear Laboratories (CNL) website at **cnl.ca/site/media/Parent/2013-CNL_LLRW-Summary-Report-Eng.pdf**. Older editions are available upon request.

The following table presents a summary of the inventory of radioactive waste in Canada as of December 31, 2016, and the amount of waste generated in 2016.

Table 1. Inventory summary of radioactive waste

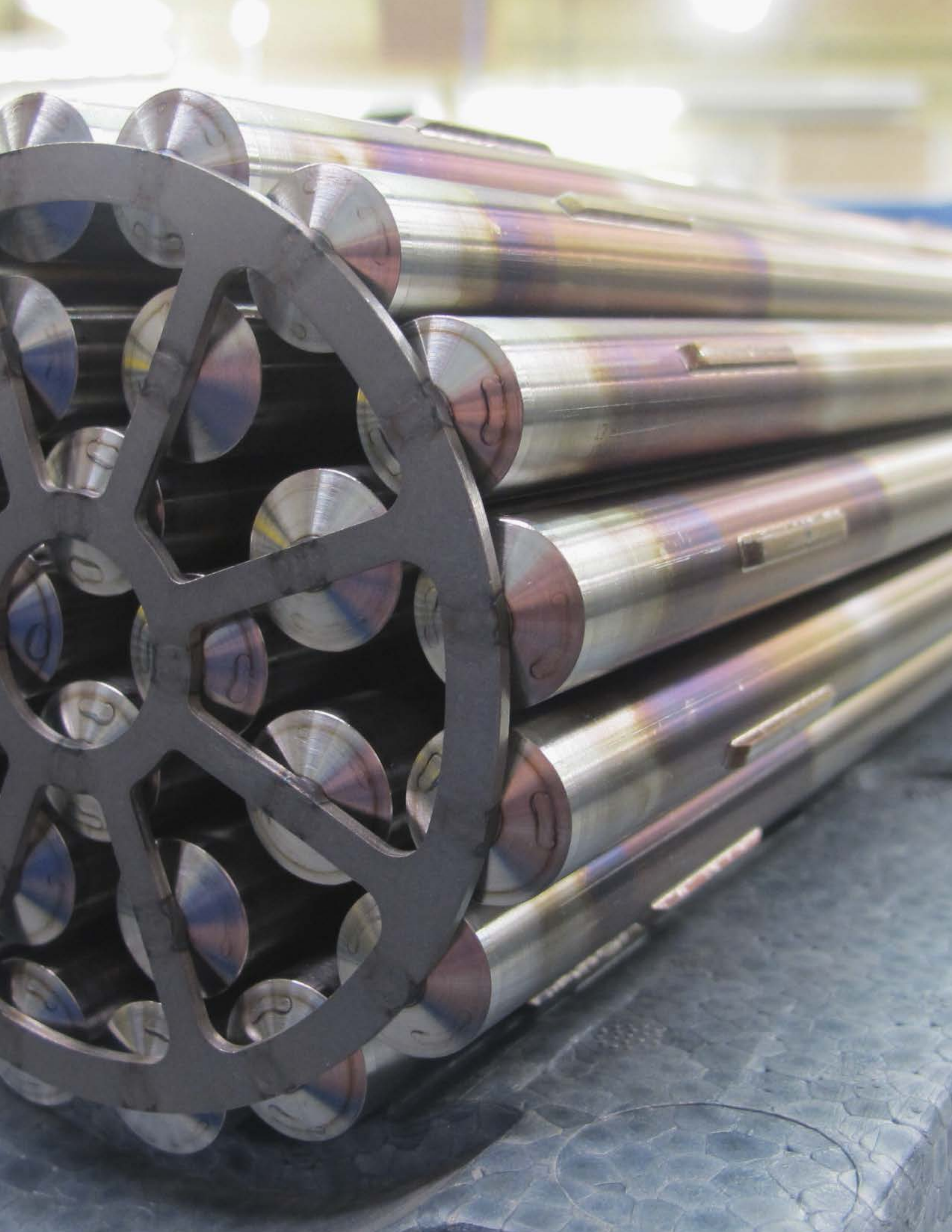
Waste category	Waste inventory to the end of 2016	Waste generated in 2016
High-level radioactive waste	11,089 m^3 (0.5%)	341 m^3
Intermediate-level radioactive waste	33,155 m^3 (1.4%)	249 m^3
Low-level radioactive waste	2,359,385 m^3 (98.1%)	5,268 m^3
Total	2,403,629 m^3 (100%)	5,858 m^3
Uranium mill tailings	218 million tonnes	0.35 million tonnes
Uranium waste rock	169 million tonnes	N/A*
Total	387 million tonnes	0.35 million tonnes

* The accumulation rate of waste rock varies significantly depending on the mining method as well as on the ratio of ore to waste, which is dependent on fluctuations in uranium prices. As a result, the annual generation of waste rock is not highly indicative of the accumulation rate of waste rock. The cumulative total inventory of waste rock is used to provide a more representative value.

Most of Canada's radioactive waste (98.1%) is low-level radioactive waste, with almost three quarters in the form of contaminated soil generated from past practices. This is in keeping with the global trend that, for most countries, larger volumes of lower hazard radioactive waste exist in comparison to the much smaller volumes of intermediate- or high-level radioactive waste. These amounts are the result of work practices that seek to minimize the production of radioactive waste and limit the contamination of equipment, materials and land.

As the level of radioactivity of the waste increases, so does the associated level of hazard. This creates a need for greater design efforts for handling, interim storage and long-term management to ensure the protection of workers, the public and the environment. For example, low-level radioactive waste generally requires minimal isolation and shielding whereas intermediate- and high-level radioactive waste require greater shielding for handling, interim storage and long-term isolation.

Note that in this report, because of rounding, numbers presented may not add up precisely to the totals provided, and percentages may not precisely reflect the absolute figures.

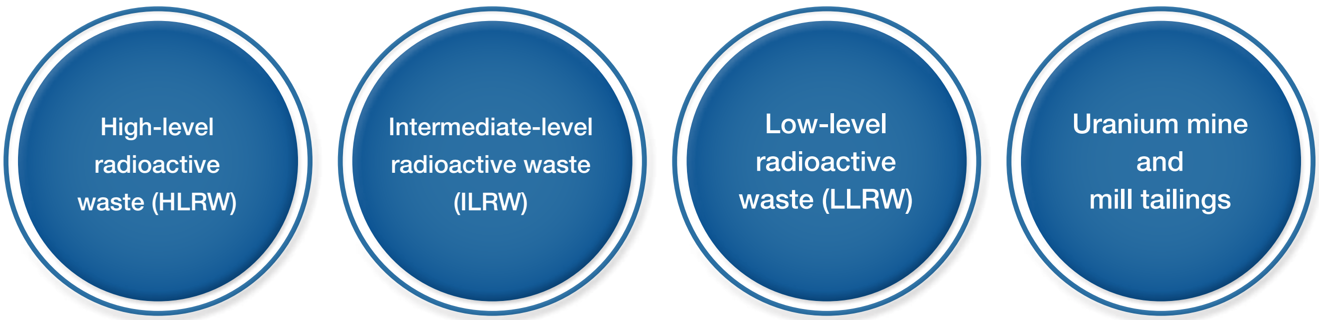


1.1 Radioactive waste definitions and categories

Radioactive waste is any material (liquid, gas or solid) that contains a radioactive nuclear substance (as defined in section 2 of the *Nuclear Safety and Control Act*) and that the owner has determined to be waste.

The Government of Canada is committed to the ongoing management of radioactive waste, by relevant responsible parties, in a safe and environmentally responsible manner.

There are four broad categories of radioactive waste in Canada defined in CSA Standard N292.0 14.



Government and industry stakeholders compiled the standard to provide technical requirements for sound waste management practices. It went into force in May 2014.

The radioactive waste classification system is organized according to the degree of containment and isolation required to ensure safety in the short term and long term. It also considers the hazard potential of the various types of radioactive waste.

A precise boundary between LLRW and ILRW cannot be provided. This is because limits on the acceptable level of activity concentration will differ between individual radionuclides or groups of radionuclides and will be dependent on short- and long-term safety management considerations. For example, a contact dose rate of 2 millisieverts per hour (mSv/h) has been used in some cases to distinguish between LLRW and ILRW.

Sections 2.0, 3.0, 4.0 and 7.0 of this report provide a detailed summary and inventory for the four main categories of radioactive waste.

1.1.1 Processes that generate radioactive waste in Canada

Radioactive waste is a by-product of Canada's use of nuclear technology. Radioactive waste is generated during various stages of the nuclear fuel cycle, including uranium mining, refining and conversion, nuclear fuel fabrication, nuclear power and research reactor operations, and decommissioning.

Figure 1. Processes that generate radioactive waste

Uranium ore mining and processing

Milling (processing) of *uranium ore* produces *uranium concentrate*.

Uranium mining and milling waste

Waste rock (mineralized) mill tailings

Mine decommissioning
Mine shut down

Waste rock and uranium tailings exist at operating uranium mine and mill sites. Because of the large volumes and low activity levels, tailings and waste rocks are decommissioned in place.

Historic LLRW (1930s–1970s)
Waste from handling, transporting, processing and use

Refining

During refining, the ore concentrate from uranium milling operations is upgraded to *uranium trioxide*.

Conversion

The uranium trioxide is then converted to *ceramic grade uranium dioxide* for fabrication into fuel for CANDU reactors or converted into uranium hexafluoride for foreign light water reactors.

Low-level (Refining)

Incinerable waste
Scrap lumber, pallets, rags, paper, cardboard, rubber and plastic

Non-incinerable waste
Air filters, fibreglass, PVC ductwork, floor sweepings, sandblast sand, insulation, sample bottles, scrap metal anodes

Other waste
Recyclable scrap metal, radioactive drain waste

Historic LLRW (1930s–1970s)
Waste from handling, transporting, processing and use

Low-level (Conversion, Fuel fabrication)

Other waste
Rags, paper, gloves, oil and oil sludges, equipment and construction materials, filters and dust collectors

Fuel fabrication and fuel bundle production

During fuel fabrication, uranium dioxide is formed into pellets. *Fuel pellets* are used in the manufacture of *fuel bundles* for reactors.

Nuclear reactor

Fuel bundles are loaded into power reactors for the production of *electricity* or into research reactors for *research and development* and the production of radioisotopes.

About 15% of the uranium mined in Canada is used for domestic nuclear electricity production.

Low and intermediate (Nuclear reactor operation)

Incinerable waste
Paper, plastic, rubber, cotton, wood, organic liquids

Compactible waste
Paper, plastic PVC suits, rubber, fibreglass, metal pieces, empty drums

Non-processable waste
Filters, light bulbs, cable, used equipment, metals construction debris, absorbents (sand vermiculite, sweeping compound), ion exchange resins, reactor core components, retube waste

Processable liquids
Radioactive drain waste, chemical cleaning solutions

Low and intermediate (Nuclear reactor decommissioning)

Nuclear reactor decommissioning

1 PHASE

Incinerable waste
Paper, plastic, rubber, cotton, wood

Compactible waste
Paper, plastic PVC suits, rubber, fibreglass, metal pieces

Non-processable waste
Filters, used equipment, ion exchange resins, absorbents (sand, vermiculite, sweeping compound)

Processable liquids
Radioactive drain waste, Decontamination solutions

2 PHASE

Small quantity of L&ILRW

3 PHASE

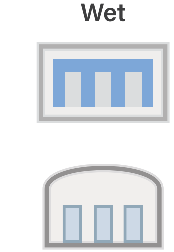
Waste
Same as Phase 1
+ Active systems (e.g. fuel channel components, calandria, reactor and shield tanks, piping, boilers)

+ Active structures (e.g. biological shield, fuel bay)

High-level

(Nuclear fuel waste) interim storage

Wet



Dry

1.1.2 Disused radioactive sealed sources

A wide variety of organizations, including universities, hospitals, industrial facilities and government departments, use radioactive sealed sources. They are used for industrial, medical, commercial, academic and research applications.

Most radioactive sealed sources are physically small, but their radioactivity may range from tens to billions of becquerels. When radioactive sealed sources are no longer required or have decayed beyond their useful life and are not intended to be used for the practice for which authorizations have been granted, they become disused radioactive sealed sources. They may then be returned to the manufacturer in Canada or to their country of origin. They may also be sent to a licensed waste management facility.

In Canada, some source manufacturers recycle radioactive sealed sources at the end of their useful life by reusing decayed sources for other applications, re-encapsulating them or reprocessing them for other useful applications.

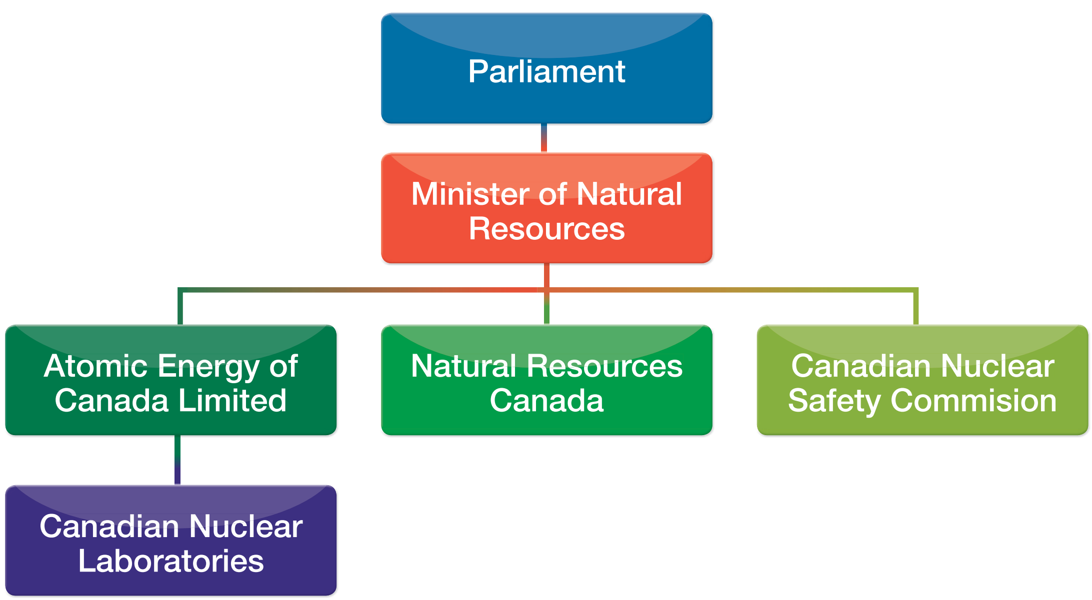
1.2 Responsibility for radioactive waste

Natural Resources Canada (NRCan) is the lead federal government department responsible for developing and implementing uranium, nuclear energy and radioactive waste management policies in Canada.

In accordance with Canada's Radioactive Waste Policy Framework, the owners of radioactive waste are responsible for the funding, organization, development and management of their respective waste in addition to the operation of long-term waste management facilities, as required.

In the case of historic LLRW, the Government of Canada has taken responsibility for its management on a case by case basis.

Figure 2. Federal responsibilities for managing radioactive waste



1.2.1 Regulation of radioactive waste

Radioactive waste in Canada is managed in a safe, secure and environmentally responsible manner in accordance with the requirements of Canada's independent nuclear regulator, the Canadian Nuclear Safety Commission (CNSC).

Although federal departments and agencies have specific roles and responsibilities for the safe management of radioactive waste, it is the CNSC that is responsible for regulation of radioactive waste in Canada. The CNSC's mandate includes:

- regulating the use of nuclear energy and materials to protect health, safety, security and the environment
- implementing Canada's international commitments on the peaceful use of nuclear energy
- disseminating objective scientific, technical and regulatory information to the public

The CNSC regulates and monitors Canada's radioactive waste management facilities to ensure they are operated safely. It imposes rigorous reporting requirements on the operators of radioactive waste management facilities and verifies that facilities comply with safety requirements through inspections and audits.

The CNSC makes regulatory decisions in a fully independent manner. In addition, the nuclear industry is subject to the provincial and territorial acts and regulations where nuclear-related activities are carried out. Where there is an overlap of jurisdictions and responsibilities, the CNSC takes the lead in harmonizing regulatory activities, including the formation of joint regulatory groups involving provincial and territorial regulators.

1.2.2 Key policy and legislation governing radioactive waste in Canada

Radioactive Waste Policy Framework (1996)

Nuclear Safety And Control Act

Nuclear Fuel Waste Act (2002)

Radioactive Waste Policy Framework

Radioactive waste in Canada is managed in accordance with Canada's 1996 Radioactive Waste Policy Framework. The framework's principles govern the institutional and financial aspects for disposal of radioactive waste by waste producers and owners. In summary, the principles include:

- The federal government will ensure that radioactive waste disposal is carried out in a safe, environmentally sound, comprehensive, cost-effective and integrated manner.
- The federal government has the responsibility to develop policy, to regulate, and to oversee producers and owners to ensure that they comply with legal requirements and meet their funding and operational responsibilities in accordance with approved waste disposal plans.

- The waste producers and owners are responsible, in accordance with the principle of “polluter pays,” for the funding, organization, planning, development and operation of disposal and other facilities required for their waste. This recognizes that arrangements may be different for HLRW, ILRW, LLRW, and/or uranium mining and milling waste.

Nuclear Safety and Control Act

- The Government of Canada established the *Nuclear Safety and Control Act* (NSCA) to govern the development, production and use of nuclear energy and the production, possession and use of nuclear substances, equipment and information. The CNSC, Canada’s independent nuclear regulator, is established in the NSCA.

- The CNSC regulatory framework consists of regulations and associated regulatory policies, standards and guides that apply to all nuclear industries including, but not limited to, nuclear power reactors; non-power nuclear reactors including research reactors; nuclear substances and radiation devices used in industry, medicine and research; the nuclear fuel cycle, from uranium mining through to waste management; and the import and export of controlled nuclear and dual-use substances, equipment and technology identified as a proliferation risk.

Nuclear Fuel Waste Act

- The *Nuclear Fuel Waste Act* (NFWA) governs the long-term management of nuclear fuel waste (HLRW) in Canada. This act sets out responsibilities for both the federal government and the nuclear fuel waste owners. It required the nuclear energy corporations to establish a waste management organization to develop and implement a long-term solution for the nuclear fuel waste produced in Canada.

- The Nuclear Waste Management Organization (NWMO) was created in 2002 to carry out this work. Under the NFWA, an important responsibility of the government was to select an approach for the long-term management of nuclear fuel waste that is in the best interest of Canadians and the environment.

- On June 14, 2007, the Government of Canada announced that it had selected the Adaptive Phased Management (APM) approach, as recommended by the NWMO, for the long-term management of nuclear fuel waste in Canada. The NWMO is now required to implement the Government’s decision pursuant to the NFWA and other relevant legislation.

- The Minister of Natural Resources is responsible for administering the NFWA to ensure that the nuclear energy corporations and the NWMO comply with its requirements.

1.3 Radioactive waste locations

The map shows all the major sites for storage of radioactive waste in Canada, according to waste classification.

1.4 Radioactive waste projections

To assess future requirements for managing radioactive waste, inventory projections to the end of 2019, 2050 and 2100 are provided.

The year 2019 was selected because the next survey of radioactive waste will be conducted that year and will be a benchmark for assessing the accuracy of the projections overall. The year 2050 was selected because it is forecasted as the approximate end of operation for the Bruce Power and Darlington generating station power reactors. The projections for the year 2100 were requested by waste owners so that waste from the decommissioning of all reactors would be captured in this reporting cycle.

Table 2. Future waste volumes (projections to 2019, 2050 and 2100)

Waste category	Waste inventory to the end of 2016	Waste inventory projected to 2019	Waste inventory projected to 2050	Waste inventory projected to 2100
HLRW	11,089 m^3	12,437 m^3	20,262 m^3	21,835 m^3
ILRW	33,155 m^3	35,934 m^3	58,430 m^3	82,824 m^3
LLRW	2,359,385 m^3	2,361,541 m^3	2,768,635 m^3	3,095,035 m^3
Uranium mill tailings	218 million tonnes	N/A*	N/A*	N/A*
Uranium waste rock	169 million tonnes	N/A*	N/A*	N/A*

*N/A No projections for uranium mill tailings and waste rock inventory are provided as any inventory increase is dependent on production levels that are subject to market price fluctuations for uranium. See section 7.4.

1.5 Waste generated by ongoing operations

Any waste that is generated from ongoing operations is considered operations waste. It usually consists of any form of disposable material that has been contaminated in the process of its use. For example, operations waste may exist as rags, gloves, paper, cardboard and plastic suits.

Operations waste accumulates on a regular basis and is the responsibility of its producer. Owners or producers of ongoing waste are responsible for its current and long-term management.

1.6 Waste generated by decommissioning activities

Within the nuclear industry, decommissioning refers to those actions taken, in the interest of health, safety, security and protection of the environment, to retire a licensed activity or facility permanently from service.

Decommissioning of nuclear facilities, research and power reactors is considered complete once the planned decommissioning activities have been executed and all materials, waste, equipment and structures have been safely managed, including the remediation of associated land. This ensures all risks to personnel, the public and the environment have been reduced or eliminated prior to releasing the site or area from regulatory control requirements.

Table 3 provides an overview of the life cycle of existing reactor operations in Canada. Dates identified indicate the time cycle for the production of used nuclear fuel, operations and decommissioning waste.

Table 3. Reactor start of operation and shutdown date

Company – site name	Reactor status as of December 2016	Start of operation	Date of planned shutdown
POWER REACTORS			
OPG – Bruce A[1]	Operating	1977–1979	2044–2064
OPG – Bruce B[1]	Operating	1984–1987	2059–2065
OPG – Darlington[1]	Operating	1990–1993	2050–2057
OPG – Pickering A[1]	Units 1 and 4 operating; Units 2 and 3 shutdown/ decommissioning	1971–1973	Reactor 2 and 3: Dec. 1997; Reactor 1 and 4: 2022
OPG – Pickering B[1]	Operating	1983–1986	2024
Hydro-Québec – Gentilly-2	Shutdown / decommissioning	November 1983	December 2012
NB Power – Point Lepreau	Operating	January 1983	2041
PROTOTYPE, DEMONSTRATION AND RESEARCH REACTORS			
AECL – Douglas Point	Shutdown and partially decommissioned	September 1968	May 1984
AECL – Gentilly-1	Shutdown and partially decommissioned	May 1972	May 1977
AECL – NRU	Operating	November 1957	March 2018
AECL – NRX	Shutdown and partially decommissioned	July 1947	April 1993
AECL – WR-1	Shutdown and partially decommissioned	November 1965	May 1985
McMaster University – Nuclear Reactor[2]	Operating	May 1959	June 2024[2]
École Polytechnique (SLOWPOKE-2)	Operating	January 1976	June 2023[2]
Saskatchewan Research Council (SLOWPOKE-2)	Operating	March 1976	June 2023[2]
University of Alberta (SLOWPOKE-2)	Ongoing decommissioning	May 1977	June 2017
Royal Military College of Canada (SLOWPOKE-2)	Ongoing decommissioning	September 1985	June 2023[2]

[1] Multi-reactors sites are provided with intervals rather than dates.
[2] end date of current operating licence, subject to renewal pending CNSC approval

Decommissioning waste

Decommissioning nuclear reactors and their supporting facilities creates a significant quantity of waste. It ranges from LLRW to ILRW. The LLRW is primarily mildly contaminated building materials while the ILRW is associated with reactor core components.

The fuel bundles are removed from the reactor core prior to the decommissioning so the associated HLRW is not considered decommissioning waste.

Phases of decommissioning a nuclear reactor

Based on current plans submitted to the CNSC, nuclear reactors will be decommissioned in three major phases:

- Phase 1 (shutdown and stabilization)

  Phase 1 will begin with the reactor shutdown and last up to 10 years. The purpose of Phase 1 is to isolate and stabilize the remaining reactor components for a long-term storage period to allow time for radioactivity levels to decay. The effect will be that radiation doses to workers and the volume of radioactive waste generated by final decommissioning will be reduced. This phase is expected to produce several hundred cubic metres of low and intermediate-level radioactive waste (L&ILRW[1] per reactor).

- Phase 2 (storage with surveillance)

  This phase may last up to 65 years during which a very small amount of waste is generated.

- Phase 3 (dismantling)

  This phase may last up to 20 years and will generate the majority of the radioactive waste from decommissioning. At the end of Phase 3, the site would be suitable for either restricted or unrestricted use.

Decommissioning status of reactors and facilities

Power reactors

Hydro-Québec's Gentilly-2 power reactor commenced Phase 1 of decommissioning in 2012. Final decommissioning plans, including estimated waste volumes, are being developed; to date no decommissioning waste has been reported as produced. Ontario Power Generation Inc. (OPG) Reactor Units 2 and 3 at the Pickering Nuclear Generating Station are in Phase 2 decommissioning (storage with surveillance).

Research and prototype reactors and facilities

There are three prototype power reactors in Canada. The Douglas Point and Nuclear Power Demonstration (NPD) reactors are in Ontario, at Douglas Point and Rolphton, respectively. The Gentilly-1 reactor is in Bécancour, Quebec.

Each of these facilities has been partially decommissioned and is in Phase 2 decommissioning (storage with surveillance). In situ decommissioning has been proposed by CNL for the NPD reactor.

Decommissioning projects are ongoing at the Atomic Energy of Canada (AECL) research facilities at Chalk River Laboratories (CRL) in Ontario and Whiteshell Laboratories in Manitoba. The WR-1 reactor at Whiteshell (Pinawa, Manitoba) completed Phase 1 decommissioning in 1994 and is currently in Phase 2. In situ decommissioning has also been proposed for the WR-1 reactor.

The University of Toronto completed decommissioning its sub-critical nuclear assembly in 2000. The Dalhousie University SLOWPOKE nuclear reactor was decommissioned in 2011. The University of Alberta is expected to complete decommissioning its SLOWPOKE nuclear reactor by 2018.

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[1] The abbreviation L&ILRW is used when the distinction between the two types is not strictly relevant for our purpose (e.g. waste emplaced in the OPG DGR in section 6.2).

Decommissioning projects at AECL sites

In addition to the reactor decommissioning taking place at the AECL Chalk River and Whiteshell laboratories, other facilities and infrastructure on those sites are being decommissioned. These can include dismantling supporting facilities such as research or storage buildings that have become contaminated and redundant. These activities will generate both LLRW and ILRW.

Section 5.0 provides a summary of future decommissioning waste to be generated.

1.7 Long-term waste management facilities

One of the objectives of the triennial inventory report is to provide a snapshot of the current and future waste inventories in order to properly plan for their long-term management. This is of particular interest because long-term management projects require extended planning periods to consider environmental, socio-economic and cultural impacts.

Under Canada's Radioactive Waste Policy Framework (1996), waste owners are responsible for the funding, organization, planning, development and operation of the waste management facilities required for their waste.

Several initiatives are underway to implement long-term solutions for nuclear fuel and radioactive waste. Canada does not reprocess its used fuel and is progressing on a national solution for nuclear fuel waste that involves disposal.

The NWMO is implementing a voluntary siting process to find a willing and informed community with a suitable site to host a deep geological repository for the long-term management of nuclear fuel waste. As of January 1, 2018, five communities in Ontario are engaged in the process. See section 6.1.4 for further details.

CNL is addressing federal responsibilities for historic radioactive waste across Canada. In particular, the Port Hope Area Initiative is underway, which is addressing the bulk of Canada's historic low-level radioactive waste. Under the Initiative, CNL will retrieve and complete the transfer of approximately 1.7 million cubic metres (m^3) of largely contaminated soils to two new long-term waste management facilities by 2023. More information is available in section 6.1.3

There are also four proposed long-term management facilities for LLRW and ILRW that are undergoing environmental assessments:

- OPG has proposed a deep geological repository for its L&ILRW at the Bruce nuclear site.
- CNL has proposed three projects:
  - a near surface disposal facility at the CRL site to dispose of its LLRW
  - in situ decommissioning for two of its shutdown reactors – NPD and WR-1

Sections 6.1.1, 6.1.2, 6.1.5 and 6.1.6 provide additional information on these projects.


ONTARIO POWER GENERATION
Liftking
400-006

2.0 HIGH-LEVEL RADIOACTIVE WASTE

2.1 HLRW definition

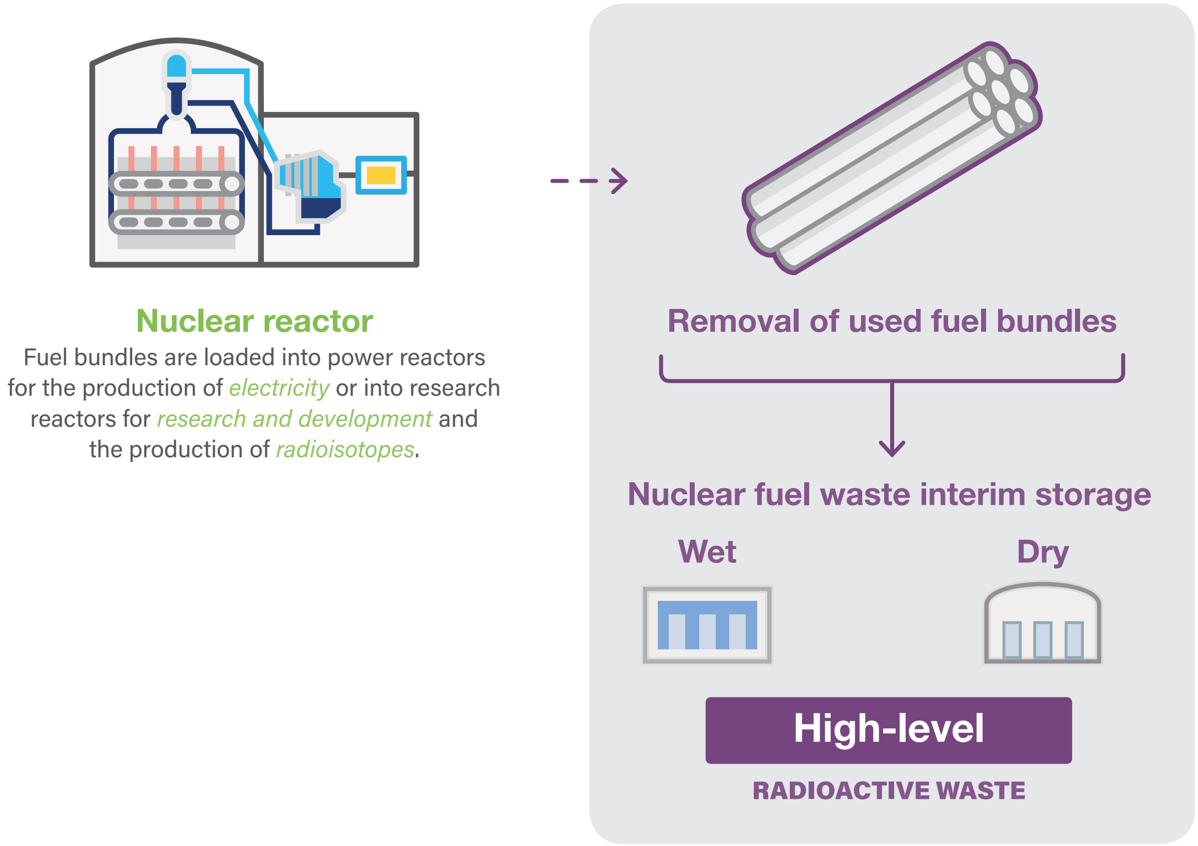
The CSA standard N292.0-14 defines HLRW as used (irradiated) nuclear fuel that has been declared to be radioactive waste and/or waste that generates significant heat (typically more than 2 kilowatts per cubic metre) via radioactive decay.

Some countries and agencies refer to this waste as “spent fuel.” However, in this report it is called HLRW because the discharged fuel is considered a waste material even when it is not fully spent.

In this report, all HLRW listed is considered nuclear fuel waste as defined by Canadian legislation – the *Nuclear Fuel Waste Act*. The NFWA defines nuclear fuel waste as irradiated fuel bundles removed from a commercial or research nuclear fission reactor. However, the nuclear industry in Canada uses the term used nuclear fuel, which is consistent with the CSA standard. Therefore, HLRW is used nuclear fuel resulting from the nuclear fuel cycle and includes waste from nuclear power plants, prototype and demonstration power reactors, and research and isotope production reactors.

HLRW is generated when nuclear fuel is removed from the reactors during operations or prior to decommissioning activities.

Figure 3. How HLRW is generated



2.2 HLRW locations

Almost all nuclear generating stations and research reactor sites store HLRW (nuclear fuel waste) on site in either wet or dry interim storage (see Table 4). This map shows the HLRW storage sites in Canada.

2.3 HLRW inventory

As of December 31, 2016, the inventory of HLRW in Canada was 11,089 m³ (or 2,738,564 nuclear fuel bundles). The HLRW inventory to the end of 2016 for power reactors was approximately 10,806 m³ or 2,697,307 bundles.

Of the remaining HLRW as of December 31, 2016, 122 m³ (30,355 bundles) are associated with the three shutdown prototype/demonstration reactors (Douglas Point, Gentilly-1 and NPD). The balance of the inventory consists of 161 m³ of HLRW (10,902 bundles, research rods, assemblies, units and items) from the AECL Chalk River and Whiteshell research reactors, as well as from the McMaster Nuclear Reactor (MNR).

Table 4. HLRW inventory – 2016

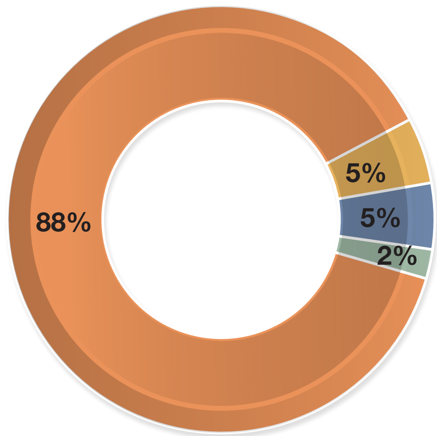
Company – site name	Reactor status as of December 2016	Nuclear fuel waste generated in 2016 (2016 accumulation rate)		On-site nuclear fuel waste inventory to December 31, 2016[1]				
				Dry storage	Wet storage	Total storage		
		Fuel bundles	Est. vol. (m^3)	Fuel bundles	Fuel bundles	Fuel bundles	Est. vol. (m^3)	Uranium (kg)[5]
POWER REACTORS								
OPG – Bruce A[6]	Operating	18,439	74	168,576	335,654[2]	504,230	2,017	9,550,620
OPG – Bruce B[6]	Operating	22,344	89	321,782	349,442[2]	671,224	2,685	12,824,406
OPG – Darlington[6]	Operating	21,669	87	192,314	332,514[2]	524,828	2,099	10,066,201
OPG – Pickering A[6]	2/4 units operating	5,260	21	75,461	263,709[2]	339,170	1,357	6,739,308
OPG – Pickering B[6]	Operating	11,600	46	251,451	137,128[2]	388,579	1,554	7,721,065
Hydro-Québec – Gentilly-2[6]	Shutdown / decommissioning	0	0	107,400	22,525	129,925[9]	531	2,471,173
NB Power – Point Lepreau[6]	Operating	4,684	19	102,598	36,753	139,351	564	2,654,637
Subtotal - power reactors		83,996	336	1,219,582	1,477,725	2,697,307	10,806	52,027,410
PROTOTYPE, DEMONSTRATION AND RESEARCH REACTORS								
AECL – Douglas Point	Shutdown and partially decommissioned	0	0	22,256	0	22,256	89	299,827
AECL – Gentilly-1	Shutdown and partially decommissioned	0	0	3,213	0	3,213	13	67,595
AECL – Chalk River Laboratories (items)[3]	Operating	280	5	7,979	584	8,563	131	40,742[4]
AECL – Chalk River Laboratories (bundles)[8]	Shutdown and partially decommissioned	0	0	4,886	0	4,886	20	65,395
AECL – Whiteshell Laboratories	Shutdown and partially decommissioned	0	0	2,301[7]	0	2,301[7]	29	21,540
McMaster University – Nuclear Reactor[3]	Operating	0	0	0	38	38	1	40
Subtotal - research reactors		280	5	40,635	622	41,257	283	495,139
TOTAL high-level radioactive waste		**84,276**	**341**	**1,260,217**	**1,478,347**	**2,738,564**	**11,089**	**52,522,549**

[1] The number of fuel bundles in this table may differ from Canada's sixth Joint Convention Report because of the reporting approach of the inventory (for example, the exclusion of partial fuel bundles in this report).
[2] The volume of wet bundles has decreased since 2013 because of a higher rate of transfers to dry storage containers than production.
[3] Inventory is reported as the number of irradiated fuel assemblies, units and items.
[4] Total inventory of uranium includes depleted uranium, enriched uranium, U-235, natural uranium, as well as thorium and plutonium fuel rods.
[5] Reported as uranium content in fuel prior to irradiation.
[6] Mass of uranium reported for power reactor operators is approximately 19 kg per bundle. It ranges from 18.941 to 19.106 kg per bundle depending on the reactor.
[7] The number of bundles was incorrectly reported in 2013 and has been revised. The total mass of uranium was verified to be the same.
[8] The number of bundles includes 4,825 bundles from NPD as well as partial bundles from Pickering, Bruce and Douglas Point.
[9] The bundle decrease at Gentilly-2 was due to reclassification of 16 bundles previously thought to be used fuel bundles to the fresh fuel stockpile.

HLRW generated in 2016

The operating power reactors generated 83,996 used nuclear fuel bundles or 336 m³ of HLRW in 2016, while 280 used nuclear fuel assemblies – 5 m³ of HLRW – were generated at CRL as HLRW from research reactors.

Figure 4. HLRW – Inventory 2016



Reactor waste

Power reactors

In Canada, there are 22 nuclear power reactors owned by three provincial electric utilities. OPG owns 20 reactors while Hydro-Québec and New Brunswick Power each own one reactor. OPG's reactors 2 and 3 at Pickering and Hydro-Québec's Gentilly-2 reactor are currently in safe shutdown. The 19 operating reactors have a total generation capacity of 15,000 megawatts of electricity.

HLRW, a by-product of nuclear power generation, is currently safely managed in facilities licensed for interim storage at nuclear reactor sites in Ontario, Quebec and New Brunswick. The waste will remain at these sites until a suitable long-term solution becomes operational.

Prototype and research reactors

Chalk River Laboratories, Chalk River, Ontario

There are two operating nuclear power reactors at CRL:

- National Research Universal (NRU) reactor[2]
- Zero Energy Deuterium (ZED-2) reactor

Research and development activities at these reactors support all aspects of nuclear science, such as reactor development, environmental science and the production of medical isotopes.

The used fuel from the past operation of the NPD reactor is also being managed at CRL.

[2] shut down on March 31, 2018

Whiteshell Laboratories, Pinawa, Manitoba

Whiteshell Laboratories (WL) is shut down and undergoing decommissioning. The AECL-WL decommissioning licence was renewed in December 2008 for 10 years.

The WR-1 reactor has been partially decommissioned (currently in storage with surveillance). The HLRW (nuclear fuel bundles) was removed prior to the decommissioning of the reactor and is safely managed on the WL site. In situ decommissioning is the proposed long-term management solution for the WR-1 reactor.

The SLOWPOKE demonstration reactor at the WL site has been fully decommissioned.

University reactors

A small amount of fuel waste is also stored at the research reactor at McMaster University in Hamilton, Ontario. Other university reactors, listed in Table 5, do not store HLRW on site.

Table 5. Fuel waste at universities

Licensee	Location	Type and capacity
McMaster University	Hamilton, Ontario	Pool-type 5 MW(t)
École Polytéchnique	Montréal, Quebec	SLOWPOKE-2, 20 kW(t)
University of Alberta[1]	Edmonton, Alberta	SLOWPOKE-2, 20 kW(t)
Saskatchewan Research Council	Saskatoon, Saskatchewan	SLOWPOKE-2, 20 kW(t)
Royal Military College of Canada	Kingston, Ontario	SLOWPOKE-2, 20 kW(t)

[1] Reactor operations ceased on June 30, 2017, and the reactor core was subsequently removed and shipped to the United States.

2.4 HLRW projections

HLRW projections for 2019, 2050 and 2100 are 12,437 m³, 20,262 m³ and 21,835 m³, respectively, based on life expectancy of existing nuclear reactors, including announced refurbishment and life extension plans.

The projected HLRW (nuclear fuel waste) inventory to 2050 and 2100 for the prototype/demonstration and research reactors owned by AECL is approximately 298 m³ in both cases.

Figure 5. HLRW – Projections 2050

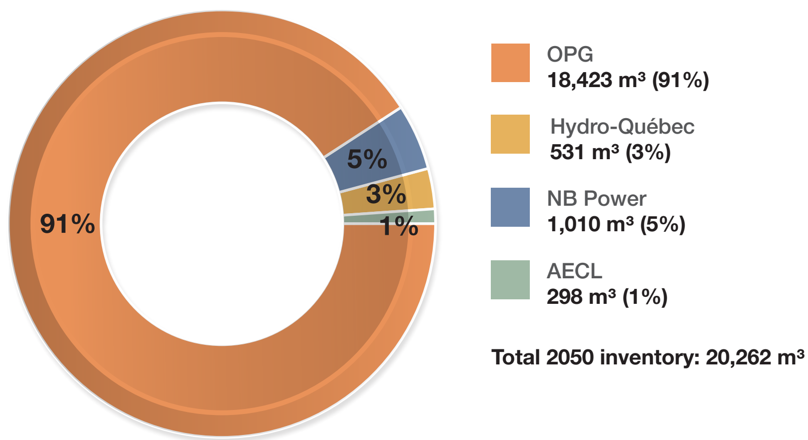


Figure 6. HLRW – Projections 2100

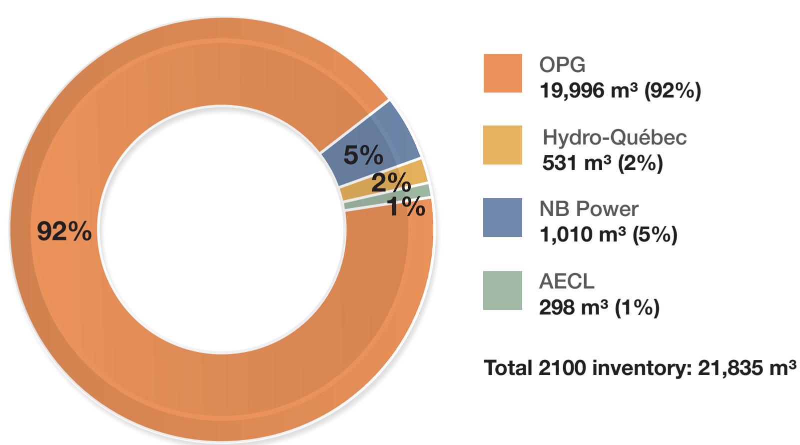


Table 6. HLRW projections – 2019, 2050, 2100

Company – site name	HLRW inventory 2019			HLRW inventory 2050			HLRW inventory 2100		
	Fuel bundles	Est. vol. (m3)	Mass (kg)	Fuel bundles	Est. vol. (m3)	Mass (kg)	Fuel bundles	Est. vol. (m3)	Mass (kg)
POWER REACTORS									
OPG – Bruce A[1]	588,773	2,355	11,151,949	1,141,400	4,566	21,619,257	1,242,398	4,970	23,532,261
OPG – Bruce B[1]	759,571	3,038	14,512,364	1,411,201	5,645	26,962,406	1,661,142	6,645	31,737,779
OPG – Darlington[1]	593,323	2,373	11,379,935	1,170,007	4,680	22,440,734	1,212,280	4,849	23,251,530
OPG – Pickering A[1]	363,885	1,456	7,230,395	379,487	1,518	7,540,407	379,487	1,518	7,540,407
OPG – Pickering B[1]	443,149	1,773	8,805,371	503,527	2,014	10,005,081	503,527	2,014	10,005,081
Hydro-Québec – Gentilly-2[1]	129,925	531	2,471,173	129,925	531	2,471,173	129,925	531	2,471,173
NB Power – Point Lepreau[1]	153,151	619	2,917,527	249,751	1,010	4,757,757	249,751	1,010	4,757,757
Subtotal - power reactors	3,031,777	12,145	58,468,714	4,985,298	19,964	95,796,815	5,378,510	21,537	103,295,988
PROTOTYPE, DEMONSTRATION AND RESEARCH REACTORS									
AECL – Douglas Point	22,256	89	299,827	22,256	89	299,827	22,256	89	299,827
AECL – Gentilly-1	3,213	13	67,595	3,213	13	67,595	3,213	13	67,595
AECL – Chalk River Laboratories (items)[2]	8,936	140	N/A	9,123	147	N/A	9,123	147	N/A
AECL – Chalk River Laboratories (bundles)[3]	4,886	20	65,395	4,886	20	65,395	4,886	20	65,395
AECL – Whiteshell Laboratories	2,301	29	21,540	2,301	29	21,540	2,301	29	21,540
McMaster University – Nuclear Reactor[2][4]	20	1	22	--	--	--	--	--	--
Subtotal - research reactors	41,612	292	454,379	41,779	298	454,357	41,779	298	454,357
TOTAL high-level radioactive waste	**3,073,389**	**12,437**	**58,923,093**	**5,027,077**	**20,262**	**96,251,172**	**5,420,289**	**21,835**	**103,750,345**

N/A means Not Available.
[1] The mass of uranium reported for power reactor operators is approximately 19 kg per bundle, but differs between owners and facilities.
[2] Inventory is reported as the number of irradiated fuel rods, fuel assemblies, units and items.
[3] The number of bundles includes 4,825 bundles from NPD as well as partial bundles from Pickering, Bruce and Douglas Point.
[4] McMaster University Reactor fuel bundles are planned to be repatriated to the United States, so projections do not account for foreign waste.

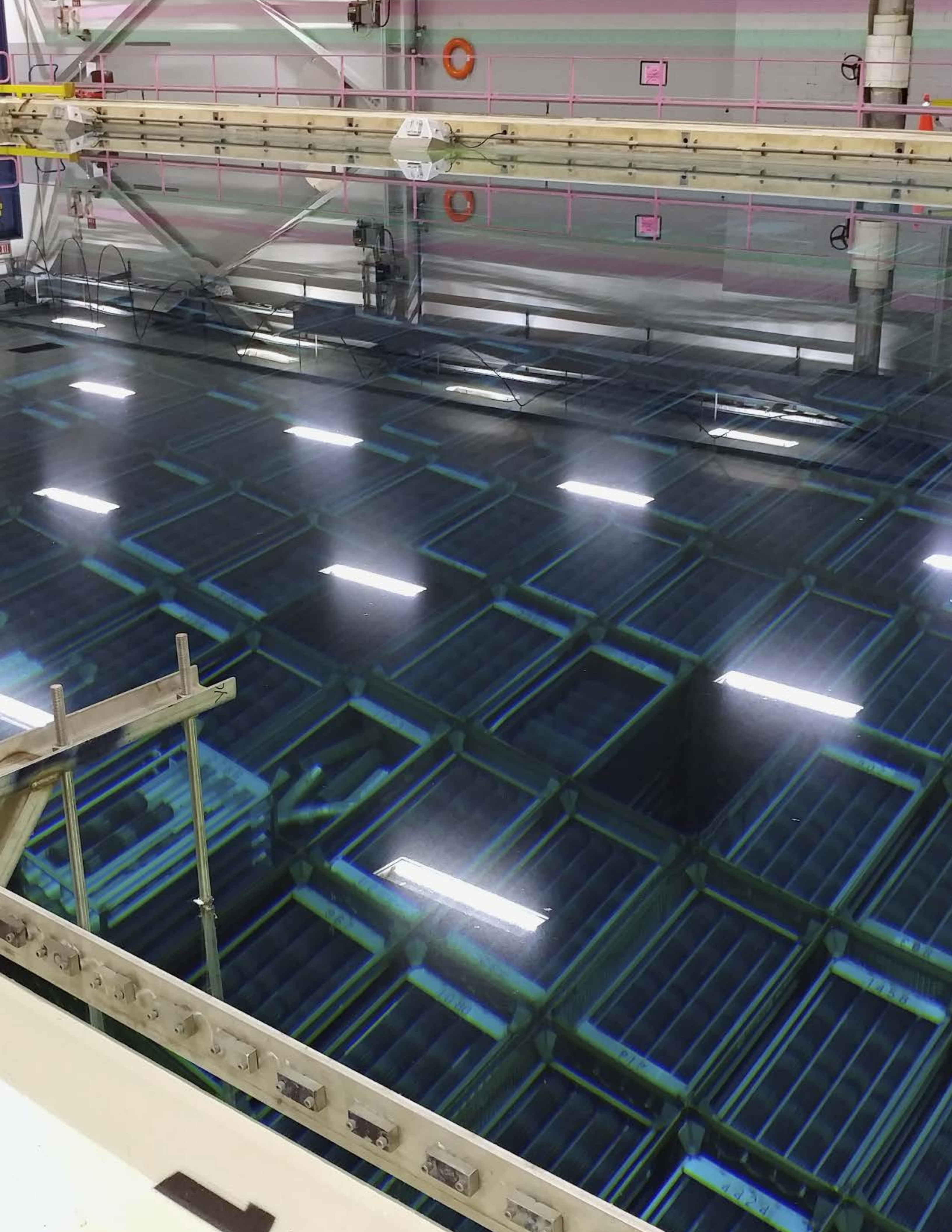
Canada's plan for the long-term management of HLRW

Currently, Canada's HLRW is safely stored on an interim basis at licensed facilities. The HLRW will remain at these sites until a suitable solution becomes available for its long-term management.

When HLRW (nuclear fuel waste) is removed from a reactor, it remains a potential health risk for many hundreds of thousands of years and must be safely isolated from living organisms indefinitely.

The NWMO was established in 2002, in accordance with the NFWA, to assume responsibility for long-term management of Canada's nuclear fuel waste. In 2007, the Adaptive Phased Management (APM) approach was selected by Canada for the long-term management of this waste.

The APM approach is both a technical method and a management system with an emphasis on adaptability that provides containment and isolation of this waste in a deep geological repository. The end point of this plan is to identify a safe site, within a willing host community, for a repository for managing the waste over the long term. This high-technology national infrastructure initiative will unfold over many decades and will be subject to extensive regulatory approvals and oversight. More information is available at **www.nwmo.ca**.



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3.0 INTERMEDIATE-LEVEL RADIOACTIVE WASTE

3.1 ILRW definition

The CSA standard N292.0-14 defines ILRW as waste that typically exhibits sufficient levels of penetrating radiation to warrant shielding during handling and interim storage.

This type of radioactive waste generally requires little or no provision for heat dissipation during its handling, transportation and long-term management. However, some ILRW (e.g. refurbishment waste) may require heat management in the short term because of its total radioactivity level. ILRW includes ion-exchange resins and filters.

3.2 ILRW locations

This map shows the ILRW storage sites in Canada.

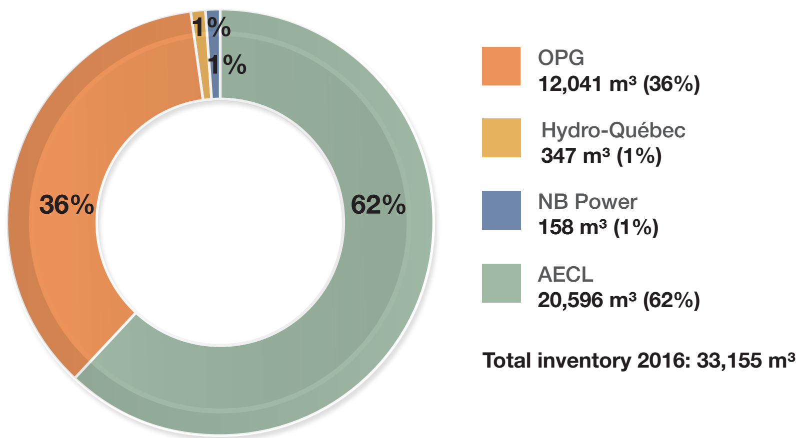
3.3 ILRW inventory

At the end of 2016, there was about 33,155 m³ of ILRW stored in Canada. This includes approximately 340 m³ of liquid ILRW stored in tanks at CRL. ILRW is safely managed throughout the country at interim storage facilities. The ILRW generated in 2016 was approximately 249 m³.

Table 7. ILRW inventory summary – 2016

Category	ILRW inventory to December 31, 2016 (m³)
From operations	32,890
From decommissioning	265
Grand total	33,155

Figure 7. ILRW inventory – 2016



3.3.1 ILRW generated by ongoing operations

The ILRW inventory from operations at the end of 2016 was 32,893 m³. Power reactors account for 12,546 m³ of that total.

Table 8. ILRW inventory from operations – 2016

Site name	Responsible party	ILRW accumulation rate in 2016 (m³)	ILRW inventory to December 31, 2016 (m³)
NUCLEAR FUEL CYCLE AND ISOTOPE PRODUCTION			
Western Waste Management Facility	OPG	102	11,024
Darlington Waste Management Facility	OPG	0	0
Pickering Waste Management Facility	OPG	0	1,012[1]
Radioactive Waste Operations Site-1	OPG	0	5
Bruce Power	OPG	N/A	3[2]
Gentilly-2	Hydro-Québec	0	347
Point Lepreau	NB Power	1	158[3]
Port Hope Conversion Facility	Cameco Corp.	0	0
Blind River Refinery	Cameco Corp.	0	0
Cameco Fuel Manufacturing	Cameco Corp.	0	0
BWXT Toronto	BWXT	0	0
BWXT Peterborough	BWXT	0	0
Nordion Kanata	Nordion	31	12[4]
Best Theratronics Kanata	Best Theratronics	0	1
	Subtotal - nuclear fuel cycle	135	12,562
RESEARCH AND DEVELOPMENT			
Douglas Point	AECL	0	0
Gentilly-1	AECL	0	0
Chalk River Laboratories[6]	AECL	107	19,468
Whiteshell Laboratories[6]	AECL	0	863
	Subtotal - nuclear research and development	107	20,331
	Subtotal - operations	242	32,893

N/A means not available.
[1] The volume has been reduced since 2013 because of a reassessment of the ILRW container count.
[2] disused cobalt 60 sealed sources
[3] The volume has been reduced since 2013 because of waste volume minimization initiatives involving incineration/metal melting.
[4] includes the volume of the flask where applicable
[5] As of December 31, 2016, CRL Radioisotope Production and Use data has been integrated into the Chalk River Laboratories volumes. In previous inventory reports, this was captured as a separate line item.
[6] Volumes for ILRW and LLRW are based on the method of storage and do not necessarily represent the actual breakdown of waste into ILRW and LLRW.

Power reactors

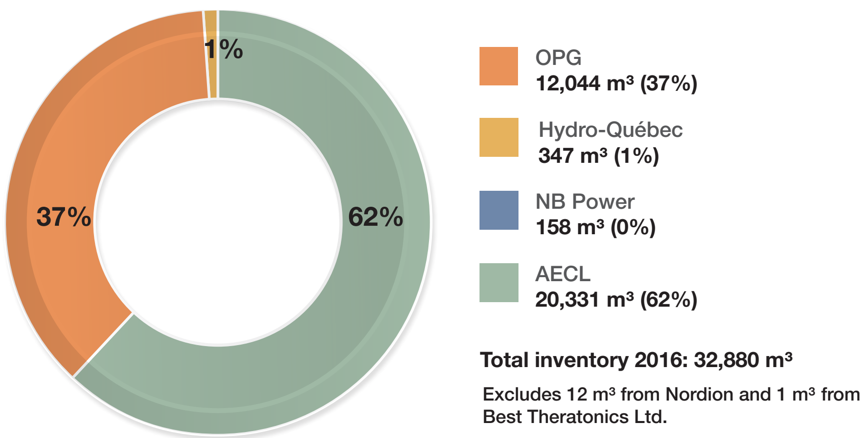
In 2016, about 242 m³ of ILRW was generated from operational activities. The 19 operating power reactors in Canada generated 104 m³ of that volume.

OPG and Bruce Power together operated 18 reactors and generated 102 m³ of the ILRW from operations in 2016. Hydro-Québec and New Brunswick Power did not generate any ILRW from operations in 2016. No ILRW was generated in 2016, as reported by the uranium refining and conversion companies and nuclear fuel fabrication facilities.

Nuclear research and development

Nuclear research and development activities at AECL generated 107 m³ of ILRW in 2016.

Figure 8. Operations ILRW inventory – 2016



3.3.2 ILRW generated by decommissioning activities

As of December 31, 2016, the total inventory of ILRW from decommissioning activities is 265 m³, including from power and prototype reactors. The waste generation rate for 2016 was 7 m³ of ILRW.

No nuclear power plants have been decommissioned in Canada yet, so there has not been any ILRW generated by the nuclear fuel cycle. The entire volume of ILRW from decommissioning activities currently in inventory is owned by AECL.

Table 9. **ILRW inventory from decommissioning – 2016**

Site name	Responsible party	ILRW accumulation rate in 2016 (m³)	ILRW inventory to December 31, 2016 (m³)
RESEARCH AND DEVELOPMENT			
Douglas Point	AECL	0	60[1]
Gentilly-1	AECL	0	58[2]
NPD	AECL	0	0[3]
Chalk River Laboratories[4]	AECL	7[5]	125
Whiteshell Laboratories	AECL	0	22
	Subtotal - decommissioning	242	32,890
	Subtotal - operations	249	33,155
	TOTAL intermediate-level radioactive waste	**249**	**33,155**

[1] comprised of ion-exchange resin, fuel transfer tunnels, booster flow tubes, ram extensions, empty flasks and pool debris
[2] comprised of ion-exchange resin
[3] included in volumes reported for Chalk River Laboratories
[4] As of December 31, 2016, CRL Radioisotope Production and Use data has been integrated into the Chalk River Laboratories volumes. In previous inventory reports, this was captured as a separate line item.
[5] Annual accumulation rate includes 1 m³ from NPD.

3.4 ILRW projections

The waste owners provided projections for ILRW for 2019, 2050 and 2100.

The year 2019 was selected because a new waste survey will be conducted that year and will be a benchmark for assessing the accuracy of the projections overall.

The year 2050 was selected as a future reference because it is forecasted as the approximate end of operation for the power reactors at Bruce Power and the Darlington generating station.

Projections at 2100 were requested from waste owners so that waste from the decommissioning of all reactors would be captured in this reporting cycle.

ILRW projections from operations

The ILRW inventory projected to 2050 from operations and decommissioning is 58,430 m³. For 2100, that volume rises to 82,824 m³.

Future operations ILRW

The inventory of ILRW operations waste as of 2016 is 32,890 m³. The projected inventory of ILRW operations waste to 2050 and 2100 is 47,472 m³ and 47,880 m³, respectively.

Waste from operations will continue to be a major contributor to the ILRW inventory until about 2040. At that time, Phase 3 decommissioning begins for some of the operating power reactors (Bruce B, Gentilly-2 and Pickering A&B) as well as for some research/prototype reactors (Gentilly-1 and Douglas Point).

Projection of ILRW volumes is based on two assumptions. The first is that no new major nuclear facilities, including new nuclear power reactors, will be commissioned before 2050 and that, consequently, there will be no new sources of ILRW from ongoing operations. The second assumption is that the 2016 waste generation rates will remain constant in the future unless otherwise forecasted by the producers (e.g. electric utilities).

Table 10. ILRW projections from operations – 2019, 2050 and 2100

Site name	Responsible party	ILRW inventory 2019 (m³)	ILRW inventory 2050 (m³)	ILRW inventory 2100 (m³)
NUCLEAR FUEL CYCLE AND ISOTOPE PRODUCTION				
Western Waste Management Facility	OPG	11,829	18,737	19,270
Darlington Waste Management Facility	OPG	1,643	6,704	6,704
Pickering Waste Management Facility	OPG	1,012	1,012	1,012
Radioactive Waste Operations Site-1	OPG	5	5	5
Gentilly-2	Hydro-Québec	350	350	350
Point Lepreau	NB Power	162	193	2[1]
Port Hope Conversion Facility	Cameco Corp.	0	0	0
Blind River Refinery	Cameco Corp.	0	0	0
Cameco Fuel Manufacturing	Cameco Corp.	0	0	0
BWXT Toronto	BWXT	Data not requested		
BWXT Peterborough	BWXT			
Nordion Kanata	Nordion			
Best Theratronics Kanata	Best Theratronics			
Subtotal - nuclear fuel cycle		15,001	27,000	27,343
RESEARCH AND DEVELOPMENT				
Douglas Point	AECL	0	0	0
Gentilly-1	AECL	0	0	0
Chalk River Laboratories[2]	AECL	19,512	19,609	19,674
Whiteshell Laboratories[2]	AECL	863	863	863
Subtotal - nuclear research and development		20,375	20,472	20,537
Subtotal - operations		35,376	47,472	47,880

[1] The significant reduction in projected volume was due to incineration (reduction rate of 80:1) and a return shipment of corresponding ash/non-processable waste.

[2] Volumes for ILRW and LLRW are based on the method of storage and do not necessarily represent the actual breakdown of waste into ILRW and LLRW.

ILRW generated by future decommissioning activities

The inventory of ILRW from decommissioning is projected to rise to 10,958 m³ by 2050, and then rise to 34,944 m³ by 2100.

The waste owners provided projected inventories, which were based on decommissioning plans submitted to the CNSC. Preliminary decommissioning plans exist for many sites and include uncertainties about timing and waste volumes.

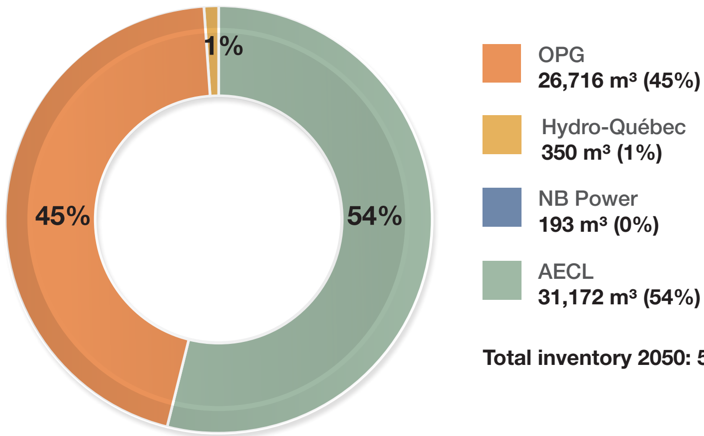
Table 11. ILRW projections from decommissioning – 2019, 2050 and 2100

Site name	Responsible party	ILRW inventory 2019 (m³)	ILRW inventory 2050 (m³)	ILRW inventory 2100 (m³)
NUCLEAR FUEL CYCLE				
Western Waste Management Facility	OPG	0	0	0
Bruce A Nuclear Generating Station	OPG	0	14	3,457
Bruce B Nuclear Generating Station	OPG	0	0	3,544
Darlington Waste Management Facility	OPG	0	0	0
Darlington Nuclear Generating Station	OPG	0	8	3,547
Pickering Waste Management Facility	OPG	0	0	0
Pickering A Nuclear Generating Station	OPG	0	17	2,862
Pickering B Nuclear Generating Station	OPG	0	219	3,240
Radioactive Waste Operations Site-1	OPG	0	0	0
Gentilly-2	Hydro-Québec	0	0	1,237
Point Lepreau	NB Power	0	0	11
Port Hope Conversion Facility	Cameco Corp.	0	0	0
Blind River Refinery	Cameco Corp.	0	0	0
Cameco Fuel Manufacturing	Cameco Corp.	0	0	0
Subtotal - nuclear fuel cycle		0	258	17,898
RESEARCH AND DEVELOPMENT				
Douglas Point	AECL	60	60	202
Gentilly-1	AECL	58	58	202
NPD	AECL	0[1]	0[1]	0[1]
Chalk River Laboratories[2]	AECL	362	9,889	15,949
Whiteshell Laboratories	AECL	78	693	693
Subtotal - nuclear research and development		558	10,700	17,046
Subtotal - decommissioning		558	10,958	34,944
Subtotal - operations		35,376	47,472	47,880
TOTAL intermediate-level radioactive waste		**35,934**	58,430	**82,824**

[1] 96 m³ included in volumes reported for Chalk River Laboratories

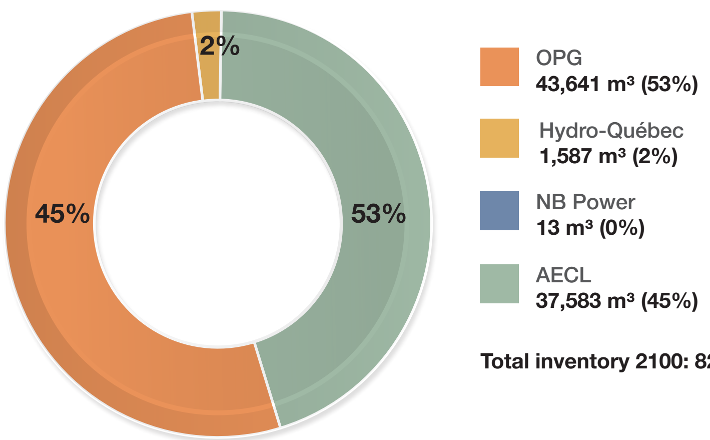
[2] As of December 31, 2016, CRL Radioisotope Production and Use data has been integrated into the Chalk River Laboratories volumes. In previous inventory reports this was captured as a separate line item.

Figure 9. ILRW Projections – 2050



Total inventory 2050: 58,430 m³

Figure 10. ILRW Projections – 2100



Total inventory 2100: 82,824 m³


HYSTER
GARRETT
270
ONTARIO POWER GENERATION

4.0 LOW-LEVEL RADIOACTIVE WASTE

4.1 LLRW definition

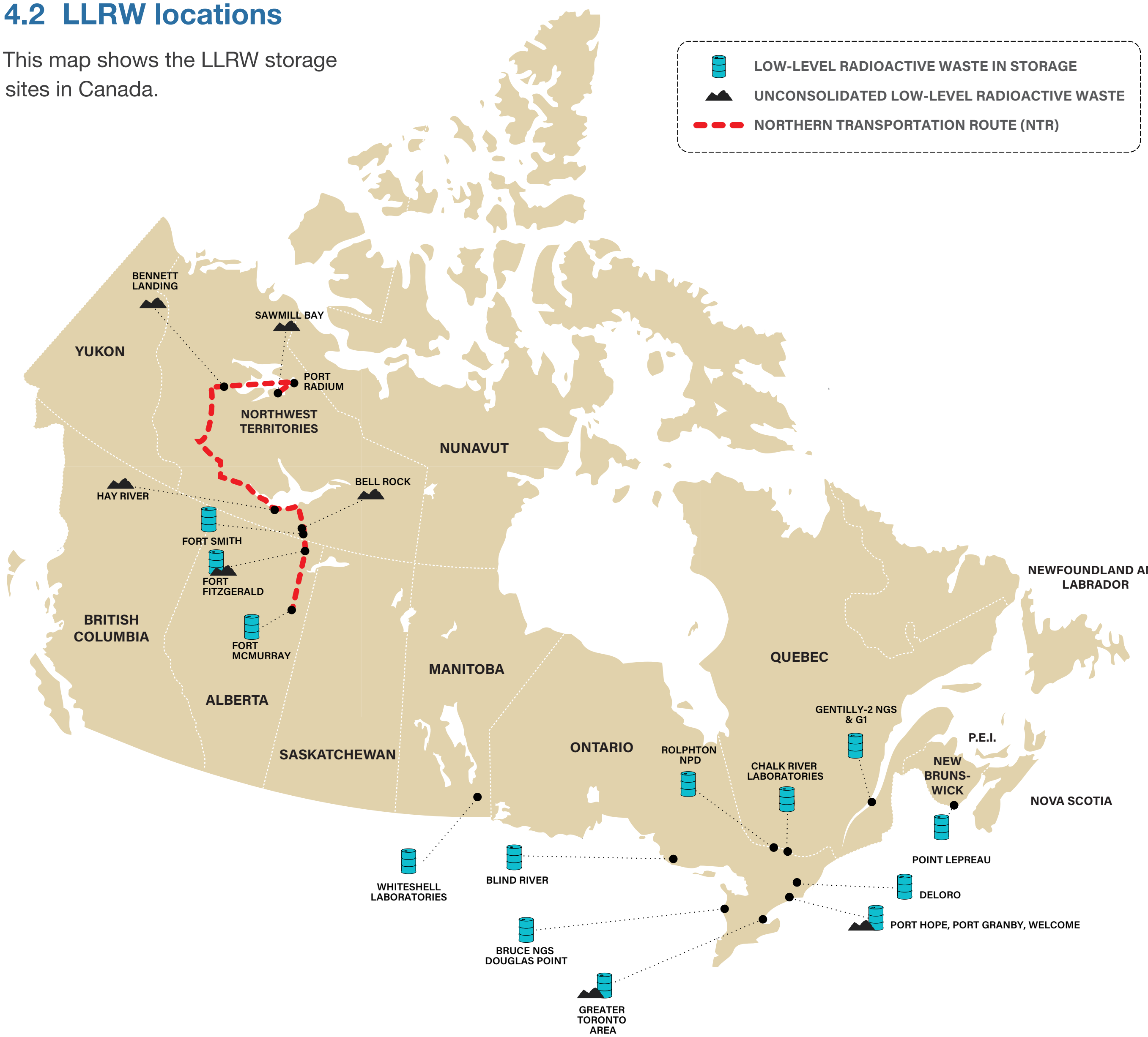
The CSA standard N292.0-14 defines LLRW as waste that contains material that has radionuclide content above established clearance levels and exemption quantities and has generally limited amounts of long-lived radioactivity.

LLRW generally does not require significant shielding during handling and interim storage. LLRW requires isolation and containment for up to a few hundred years. However, longer periods are required for LLRW that contains long-lived radium or longer-lived uranium.

LLRW includes contaminated materials, rags, protective clothing, contaminated soil and related waste resulting from the very early operations of Canada's radium industry.

4.2 LLRW locations

This map shows the LLRW storage sites in Canada.



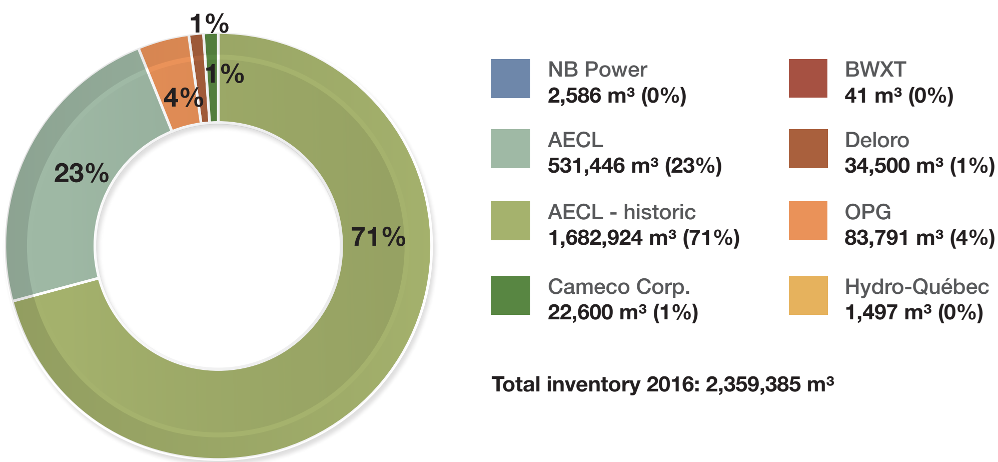
4.3 LLRW inventory

At the end of 2016, there were about 2.36 million m³ of LLRW stored in Canada. Most of Canada's LLRW is characterized as historic waste – mainly contaminated soils. Only 27% of Canada's LLRW comes from ongoing operations and decommissioning activities. At present, LLRW is safely managed throughout the country either in situ or at interim storage or long-term management facilities.

Table 12. LLRW inventory summary – 2016

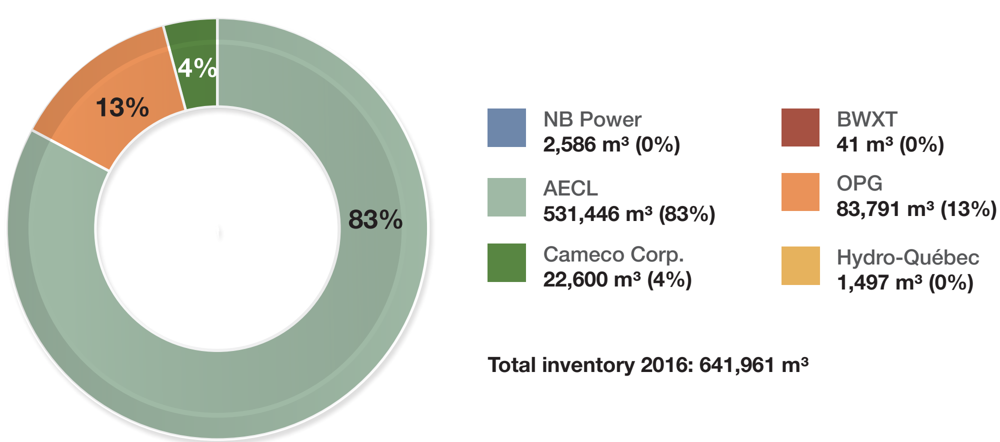
Category	LLRW inventory to December 31, 2016 (m³)
Total for Historic and Deloro waste	1,717,424
Total from operations	630,833
Total for decommissioning	11,128
Grand total	2,359,385

Figure 11. LLRW inventory – 2016



As of December 31, 2016, the total LLRW inventory, excluding historic waste, was 641,961 m³. The LLRW generated in 2016 was approximately 5,268 m³.

Figure 12. LLRW inventory (exculding historic waste) – 2016



4.3.1 Historic waste

CNL, on behalf of the federal government, is responsible for the cleanup and long-term management of historic waste in Canada.

In some instances, remedial actions are required on contaminated properties whose original owner no longer exists. In these situations, the federal government may decide to accept responsibility for management of this waste on a case-by-case basis.

In March 2001, the Government of Canada and the local municipalities in the Port Hope area of southern Ontario entered into an agreement on community-developed proposals. The proposals address the cleanup and long-term management of the bulk of Canada's historic waste, thereby launching the Port Hope Area Initiative (PHAI). In 2012, the Government of Canada announced $1.28 billion in funding to implement the PHAI. As of December 2016, the cleanup had begun with waste retrievals and transfers taking place in one of the communities.

For more information, visit the project's website at **phai.ca.**

Historic waste exists in various sites across Canada including in Ontario, Alberta and the Northwest Territories. At many of these sites, materials have been placed in interim storage pending the development and implementation of a long-term management approach. At other sites, the waste is in long-term storage. Ongoing site monitoring, inspection and maintenance are conducted at all storage and in situ sites by CNL.

The waste at some of these sites includes artifacts or surface-contaminated building materials. Other sites contain large volumes of radium-contaminated soil that has low radioactivity. Larger volumes of contaminated soil that cannot be accommodated at CNL facilities are managed at or near the source.

Table 13. Historic and Deloro LLRW inventory – 2016

Site name	Responsible party	TOTAL (m^3)
Port Hope	AECL	720,000
Welcome	AECL	454,380
Port Granby	AECL	438,200
Northern Transportation Route	AECL - LLRWMO	54,403
Greater Toronto Area - including Peterborough	AECL - LLRWMO / Regional Municipality of Peel, Ontario	15,941
Deloro	Ontario Ministry of the Environment	34,500[1]
TOTAL historic and Deloro low-level radioactive waste		**1,717,424**

[1] A revised volume estimate for Young's Creek has reduced the Deloro Mine site total volume by approximately 3,000 m^3 since 2013.

Origin of historic LLRW

Historic LLRW originated from past handling, transportation and use of uranium ore. In the 1930s, uranium (pitchblende ore) was discovered at Port Radium, Northwest Territories. By 1932, Eldorado Gold Mines Limited had established a mine in Port Radium and a refining facility in Port Hope, Ontario.

As the ore was shipped to southern Ontario, it first traveled along the Northern Transportation Route (NTR), a 2,200 kilometre route comprised of waterways and portages between Port Radium, Northwest Territories, and Fort McMurray, Alberta. From there, the ore travelled by rail to Port Hope, Ontario, to be refined.

Between the 1930s and the 1960s, some spillage occurred at the transfer points along the route when the ore was transferred to planes, boats, trucks and trains and then to the refinery.

These instances of contamination were first found in the early 1970s. Formal identification of contamination continued along the NTR; at the refinery in Port Hope and surrounding area; and at other areas in southern Ontario associated with radium recovery operations and radium dial painting.

Inventory of historic LLRW

The total inventory of historic LLRW in Canada is approximately 1,682,924 m³ (as of December 31, 2016).

Port Hope area

The majority (more than 93%) of historic LLRW in Canada is in the Port Hope, Ontario, area. That amount is 1,612,580 m³:

- Some of it (454,380 m³) is managed at the Welcome Waste Management Facility (Municipality of Port Hope).
- Another portion (438,200 m³) is managed at the Port Granby Waste Management Facility (Municipality of Clarington).
- Another 720,000 m³ of material is at consolidated and unconsolidated locations throughout the Municipality of Port Hope.

Northern Transportation Route

The NTR from the Northwest Territories to Alberta has 54,403 m³ of historic waste.

Part of that waste, 43,282 m³, is in the Beacon Hill Mound section of the Beacon Hill municipal landfill in Fort McMurray, Alberta. The rest of the waste is consolidated and unconsolidated wastes at locations in the Sahtu and South Slave regions of the Northwest Territories and northern Alberta.

Greater Toronto Area

The Greater Toronto Area (GTA) volume of 15,941 m³ of historic waste includes 9,077 m³ at a temporary waste storage mound in Scarborough, Ontario. This mound was created from historic waste removed from contaminated properties in the Scarborough neighbourhood of Malvern. The rest of the total volume is consolidated and unconsolidated wastes at other locations in Toronto, Mississauga, Mono Mills and Peterborough, Ontario

Deloro waste

Deloro waste is LLRW that was produced from reprocessing uranium mill tailings to extract cobalt at Deloro, Ontario.

Although the waste is the result of past practices for which the original owner cannot be reasonably held responsible, the federal government has not accepted responsibility for the waste. Therefore, it is listed as a separate volume under LLRW resulting from historic practices because it does not meet the full criteria for definition as “historic waste.”

The Government of Ontario has accepted responsibility for this waste, and the Ontario Ministry of the Environment is responsible for the cleanup of the former Deloro Mine site. There is approximately 34,500 m^3 of LLRW contaminated soil and historic tailings at the site.

4.3.2 LLRW generated by ongoing operations

LLRW accumulates on a regular basis as the result of ongoing nuclear-related operations, both at power and research reactors. Owners or producers of ongoing waste are responsible for its current and long-term management.

The total inventory of LLRW from ongoing operations at the end of 2016 was 630,833 m^3. Nuclear fuel fabrication facilities and power reactors accounted for 104,515 m^3 of that total.

Nuclear fuel fabrication facilities and power reactors

In 2016, a total of 4,261 m³ of LLRW was generated during operations activities, with the 19 operating nuclear power reactors in Canada generating 3,310 m³ of this volume.

OPG and Bruce Power together operated a total of 18 reactors and generated 3,217 m³ of LLRW in 2016. Hydro-Québec generated 4 m³ of LLRW in 2016 from operations, and NB Power generated 89 m³ of LLRW from ongoing operations. Roughly 40 m³ of LLRW was generated in 2016 from uranium refining, conversion and nuclear fuel fabrication.

Table 14. LLRW inventory from operations – 2016

Site name	Responsible party	LLRW accumulation rate in 2016 (m³)	LLRW inventory to December 31, 2016		
			Waste (m³)	Cont. soil (m³)	Total (m³)
NUCLEAR FUEL CYCLE AND ISOTOPE PRODUCTION					
Western Waste Management Facility	OPG	3,217	83,466[1]	0	83,466[1]
Darlington Waste Management Facility	OPG	0	0	0	0
Pickering Waste Management Facility	OPG	0	0	0	0
Radioactive Waste Operations Site-1	OPG	0	325	0	325
Gentilly-2	Hydro-Québec	4	1,497	0	1,497
Point Lepreau	NB Power	89	2,586[2]	0	2,586[2]
Port Hope Conversion Facility	Cameco Corp.	0	10,000	0	10,000
Blind River Refinery	Cameco Corp.	0	5,600	0	5,600
Cameco Fuel Manufacturing	Cameco Corp.	0	1,000	0	1,000
BWXT Toronto	BWXT	28	5	0	5
BWXT Peterborough	BWXT	12	36	0	36
Nordion Kanata	Nordion	0	0	0	0
Best Theratronics Kanata	Best Theratronics	0	0	0	0
	Subtotal - nuclear fuel cycle	3,350	104,515	0	104,515
RESEARCH AND DEVELOPMENT					
Douglas Point	AECL	0	0	66	66
Gentilly-1	AECL	0	0	1	1
Chalk River Laboratories[3][4]	AECL	911	123,709	382,842	506,551
Whiteshell Laboratories[3]	AECL	0	19,700[5]	0	19,700[5]
	Subtotal - nuclear research and development	911	143,409	382,909	526,318
	Subtotal - operations	4,261	247,924	382,909	630,833

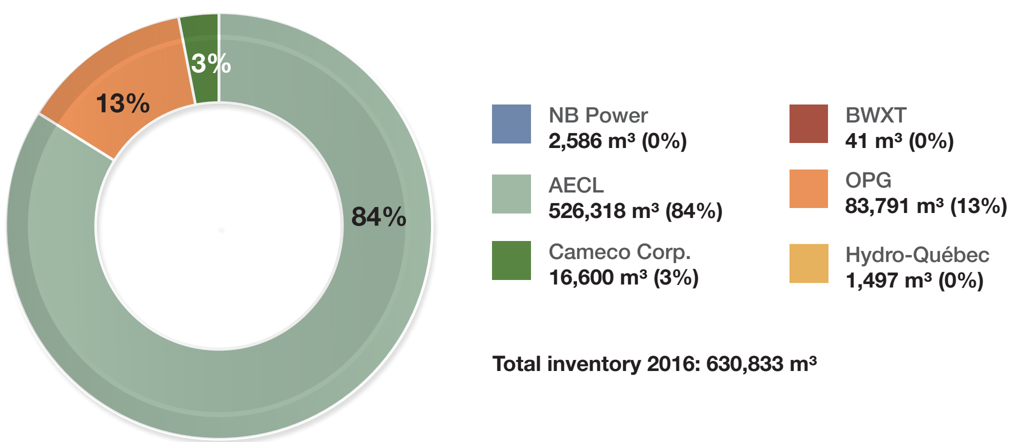
[1] The volume has reduced since 2013 as a result of waste minimization initiatives.
[2] The volume has reduced since 2013 as a result of waste volume minimization initiatives involving incineration and metal melting.
[3] The volumes for ILRW and LLRW are based on the method of storage and do not necessarily represent the actual breakdown of waste into ILRW and LLRW.
[4] As of December 31, 2016, CRL Radioisotope Production and Use data has been integrated into the Chalk River Laboratories volumes. In previous inventory reports, this was listed as a separate line item.
[5] The volume has reduced since 2013 as a result of re-packaging, during which some materials were deemed to be clean wastes and were removed.

Nuclear research and development

The total LLRW inventory produced from nuclear research and development, as of December 31, 2016, was 526,318 m³. AECL indicates that it is managing roughly 382,909 m³ of contaminated soil resulting from its long history of nuclear research and development.

This soil also includes waste that was removed from various locations across Canada including several sites within Ontario in the 1970s. In addition, some LLRW from other producers is managed at AECL's Chalk River Laboratories. On an ongoing basis, nuclear research and development activities at AECL generated 911 m³ of LLRW in 2016.

Figure 13. Operations LLRW inventory – 2016



4.3.3 LLRW generated by decommissioning activities

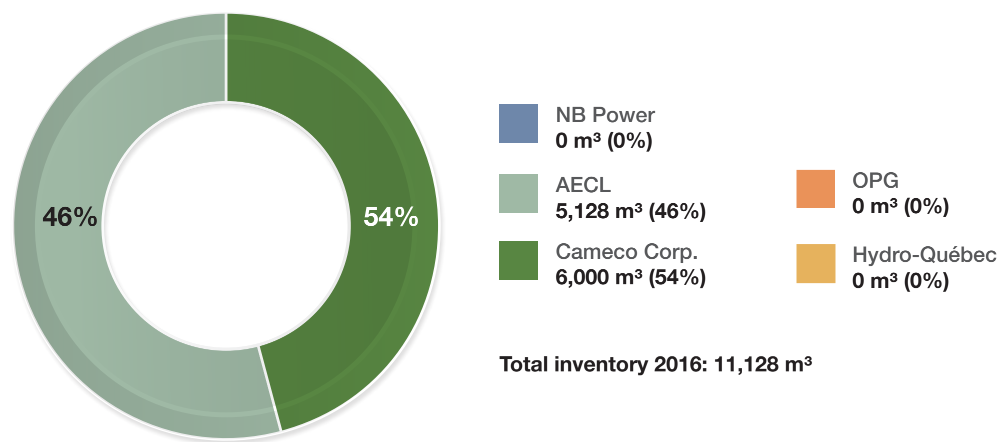
As of December 31, 2016, the total inventory of LLRW in Canada generated by all decommissioning activities was 11,128 m^3. The amount of LLRW generated in 2016 was 1,007 m^3.

Table 15. LLRW inventory from decommissioning – 2016

Site name	Responsible party	LLRW accumulation rate in 2016 (m^3/yr)	LLRW inventory to December 31, 2016		
			Waste (m^3)	Cont. soil (m^3)	Total (m^3)
NUCLEAR FUEL CYCLE					
Western Waste Management Facility (WWMF)	OPG	0	0	0	0
Bruce A Nuclear Generating Station	OPG	0	0	0	0
Bruce B Nuclear Generating Station	OPG	0	0	0	0
Darlington Waste Management Facility	OPG	0	0	0	0
Darlington Nuclear Generating Station	OPG	0	0	0	0
Pickering Waste Management Facility	OPG	0	0	0	0
Pickering A Nuclear Generating Station	OPG	0	0	0	0
Pickering B Nuclear Generating Station	OPG	0	0	0	0
Radioactive Waste Operations Site-1	OPG	0	0	0	0
Gentilly-2	Hydro-Québec	0	0	0	0
Point Lepreau	NB Power	0	0	0	0
Port Hope Conversion Facility	Cameco Corp.	0	3,000	3,000	6,000
Blind River Refinery	Cameco Corp.	0	0	0	0
Cameco Fuel Manufacturing	Cameco Corp.	0	0	0	0
Subtotal - nuclear fuel cycle		0	3,000	3,000	6,000
RESEARCH AND DEVELOPMENT					
Douglas Point[1]	AECL	15	32	2	35
Gentilly-1[1]	AECL	1	423	184	607
NPD[2]	AECL	30	12	0	12
Chalk River Laboratories[3]	AECL	311	2,700	176	2,876
Whiteshell Laboratories	AECL	650	1,373	225	1,598
Subtotal - nuclear research and development		1,007	4,540	588	5,128
Subtotal - decommissioning		1,007	7,540	3,588	11,128
Subtotal - operations		4,261	247,924	382,909	630,833
Total low-level radioactive waste		**5,268**	**255,464**	**386,497**	**641,961**

[1] The volume has decreased since 2013 as a result of off-site supplier processing services or transfers to Chalk River Laboratories.
[2] For the most part, waste has been transferred to Chalk River Laboratories. The volume is the current best estimate and may not reflect material that has been shipped to Chalk River Laboratories recently.
[3] As of December 31, 2016, CRL Radioisotope Production and Use data has been integrated into the Chalk River Laboratories volumes. In previous inventory reports, this was listed as a separate line item.

Figure 14. Decomissioning LLRW inventory – 2016



4.4 LLRW projections

Projections for LLRW were reported by the waste owners, for 2019, 2050 and 2100.

As stated in the overview section, the year 2019 was selected because a waste survey will be conducted that year and will serve as a benchmark to assess the accuracy of the projections overall.

The year 2050 is selected as a future reference because it is forecasted as the approximate end of operation for the Bruce Power and Darlington Generating station power reactors.

Projections to 2100 were requested from waste owners so that waste from the decommissioning of all reactors would be captured this reporting cycle. Because of anticipated waste reduction activities, including incineration, waste volumes are projected to decrease in some instances.

The LLRW inventory projected to 2050 from operations and decommissioning is 1,051,177 m^3 and is 1,377,527 m^3 for 2100.

Figure 15. LLRW – Projections 2050

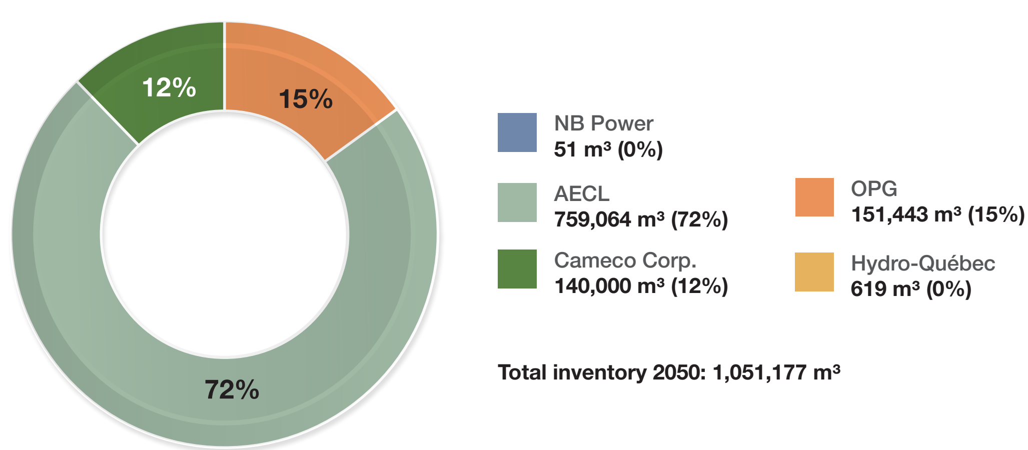
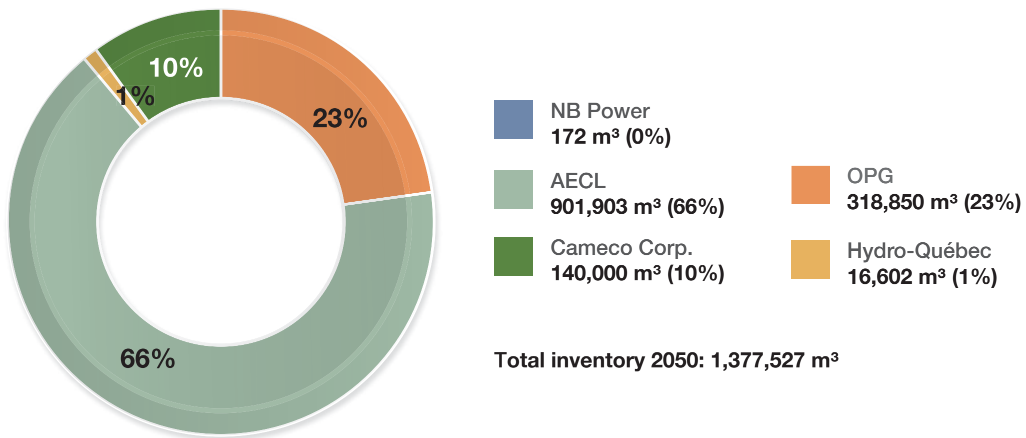


Figure 16. LLRW – Projections 2100



Future operations LLRW

The total LLRW inventory from ongoing operations as of December 31, 2016, is 630,833 m³. The LLRW volume will increase to approximately 689,108 m³ by 2050 and to 709,984 m³ by 2100.

Waste from operations will continue to be a major contributor to the LLRW inventory until approximately 2040. At that time, Phase 3 decommissioning begins for some of the operating power reactors (Bruce B, Gentilly-2 and Pickering A&B) and some research/prototype reactors (Gentilly-1 and Douglas Point).

The projection of LLRW volumes is based on two assumptions. The first is that no new major nuclear facilities, including new nuclear power reactors, will be commissioned before 2050 and, that, consequently, there will be no new sources of LLRW from ongoing operations. The second assumption is that the 2016 waste generation rates will remain constant in the future unless otherwise forecasted by the producers (e.g. electric utilities).

Table 16. LLRW projections from operations – 2019, 2050 and 2100

Site name	Responsible party	LLRW inventory 2019 (m^3)	LLRW inventory 2050 (m^3)	LLRW inventory 2100 (m^3)
NUCLEAR FUEL CYCLE AND ISOTOPE PRODUCTION				
Western Waste Management Facility	OPG	93,811	141,215	147,417
Darlington Waste Management Facility	OPG	0	0	0
Pickering Waste Management Facility	OPG	0	0	0
Radioactive Waste Operations Site-1	OPG	325	325	325
Gentilly-2	Hydro-Québec	1,413	619	619
Point Lepreau	NB Power	2,336	50[1]	50
Port Hope Conversion Facility	Cameco Corp.	1,400	0	0
Blind River Refinery	Cameco Corp.	700	0	0
Cameco Fuel Manufacturing	Cameco Corp.	25	0	0
BWXT Toronto	BWXT	Data not requested		
BWXT Peterborough	BWXT			
Nordion Kanata	Nordion			
Best Theratronics Kanata	Best Theratronics			
Subtotal - nuclear fuel cycle		100,010	142,209	148,411
RESEARCH AND DEVELOPMENT				
Douglas Point	AECL	66	66	66
Gentilly-1	AECL	1	1	1
Chalk River Laboratories[2][3]	AECL	509,747	527,132	541,806
Whiteshell Laboratories[2]	AECL	19,700	19,700	19,700
Subtotal - nuclear research and development		529,514	546,899	561,573
Subtotal - operations		629,524	689,108	709,984

[1] The significant reduction in the projected volume is due to incineration (reduction rate of 80:1) and the return shipment of corresponding ash/non-processable waste.

[2] The volumes for ILRW/LLRW are based on the method of storage and do not necessarily represent the actual breakdown of waste into ILRW and LLRW.

[3] As of December 31, 2016, CRL Radioisotope Production and Use data has been integrated into the Chalk River Laboratories volumes. In previous inventory reports, this was listed as a separate line item.

LLRW generated by future decommissioning activities

The projected inventories of LLRW from decommissioning to 2050 and 2100 are 362,069 m^3 and 667,543 m^3, respectively.

The waste owners provided projected inventories of decommissioning LLRW, which were based on decommissioning plans submitted to the CNSC. Preliminary decommissioning plans exist for many sites and include uncertainties about timing and waste volumes.

Table 17. LLRW projections from decommissioning – 2019, 2050 and 2100

Site name	Responsible party	LLRW inventory 2019 (m^3)	LLRW inventory 2050 (m^3)	LLRW inventory 2100 (m^3)
NUCLEAR FUEL CYCLE AND ISOTOPE PRODUCTION				
Western Waste Management Facility	OPG	0	0	4,947
Bruce A Nuclear Generating Station	OPG	0	1,858	27,692
Bruce B Nuclear Generating Station	OPG	0	0	29,049
Darlington Waste Management Facility	OPG	0	0	123
Darlington Nuclear Generating Station	OPG	0	909	47,042
Pickering Waste Management Facility	OPG	0	0	191
Pickering A Nuclear Generating Station	OPG	0	2,425	33,509
Pickering B Nuclear Generating Station	OPG	0	4,711	28,504
Radioactive Waste Operations Site-1	OPG	0	0	51
Gentilly-2	Hydro-Québec	0	0	15,983
Point Lepreau	NB Power	0	1	122
Port Hope Conversion Facility	Cameco Corp.	1,000	0	0
Blind River Refinery	Cameco Corp.	0	140,000	140,000
Cameco Fuel Manufacturing	Cameco Corp.	0	0	0
	Subtotal - nuclear fuel cycle	1,000	149,904	327,213
RESEARCH AND DEVELOPMENT				
Douglas Point[1]	AECL	35	35	6,544
Gentilly-1[1]	AECL	607	607	7,115
NPD[2]	AECL	12	2,048	2,048
Chalk River Laboratories[3]	AECL	9,618	190,637	305,785
Whiteshell Laboratories	AECL	3,318	18,838	18,838
	Subtotal - nuclear research and development	13,590	212,165	340,330
	Subtotal - decommissioning	14,590	362,069	667,543
	Subtotal - operations	629,524	689,108	561,573
	TOTAL low-level radioactive waste	**644,114**	**1,051,177**	**1,377,527**

[1] The volume has decreased since 2013 because of off-site supplier processing services or transfers to Chalk River Laboratories.
[2] For the most part, waste has been transferred to Chalk River Laboratories. The volume is the current best estimate and may not reflect material that has been shipped to Chalk River Laboratories recently.
[3] As of December 31, 2016, CRL Radioisotope Production and Use data has been integrated into the Chalk River Laboratories volumes. In previous inventory reports, this was listed as a separate line item.

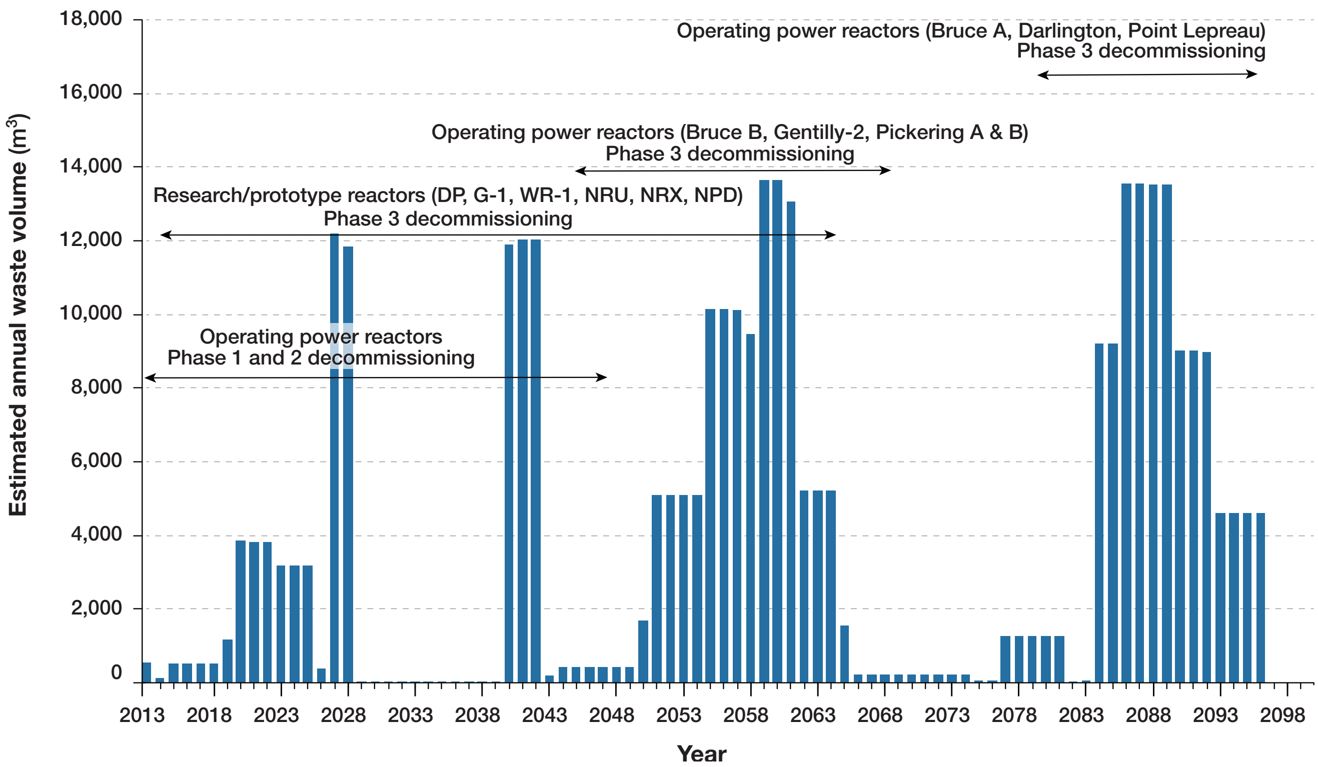
5.0 DECOMMISSIONING SCHEDULE AND ASSOCIATED L&ILRW GENERATION

As per sections 3.4 and 4.4, projected inventories of LLRW and ILRW from decommissioning were provided by waste owners and determined based on decommissioning plans submitted to the CNSC.

The following chart depicts the projected annual decommissioning waste volumes for the power reactors, prototype/demonstration power reactors, and the Whiteshell and CRL facilities through 2100.

This timeline was selected to include complete Phase 3 decommissioning of all currently operating power reactors. It also provides an overview of planned decommissioning activities that would generate large volumes of L&ILRW. Various assumptions, including uncertainties with respect to timing and waste volumes, were considered for these estimates.

Figure 17. Radioactive waste from decommissioning, 2013–2100




1407
967
1363
1364
1393
27

6.0 LONG-TERM MANAGEMENT

Radioactive waste volumes depicted in this inventory provide an understanding of the timeline for the generation of the various types of radioactive waste. This helps explain at a national level the need for long-term radioactive waste management facilities.

The following sections provide an overview of the planned, long-term waste management facilities in Canada for HLRW and L&ILRW.

6.1 Proposed long-term radioactive waste management projects

6.1.1 NWMO's proposed deep geological repository

The NWMO is currently in the process of selecting a community that is willing to host its facility and possesses the necessary technical features for a deep geological repository. The facility is expected to be built about 500 metres (m) underground. This facility would contain and isolate all of Canada's nuclear fuel waste, according to current forecasts.

For more information, visit **nwmo.ca.**

6.1.2 OPG's proposed Deep Geologic Repository

To dispose of its existing and future L&ILRW, OPG has proposed a deep geologic repository project to be located at Kincardine, Ontario. The proposal is for a repository 680 m underground and located on the Bruce nuclear site.

For more information, visit **opg.com/dgr.**

6.1.3 CNL's proposed Near Surface Disposal Facility

CNL, on AECL's behalf, has submitted a proposal to the CNSC for a near surface disposal facility at its Chalk River Laboratories to address its existing and future LLRW. The project would be an engineered containment mound comprising 10 separate cells. The total capacity of the near surface disposal facility is expected to be 1,000,000 m^3.

For more information, visit **cnl.ca.**

6.1.4 Long-term management facilities for historic waste

The Port Hope Area Initiative involves the development of two long-term waste management facilities in the Port Hope area of southeastern Ontario. They are both near surface disposal facilities consisting of engineered containment mounds for historic waste.

The facility in Port Hope will have a storage capacity of 1,200,000 m^3. The other facility in neighbouring Clarington, Ontario, will have a capacity of 450,000 m^3.

Completion of both facilities is expected by 2023. The bulk of this waste is soil that was contaminated through waste management practices stemming from the 1930s at uranium processing facilities in Port Hope.

For more information, visit **phai.ca.**

6.1.5 In situ decommissioning of the WR-1 and NPD reactors

CNL, on AECL's behalf, has submitted proposals to the CNSC for in situ decommissioning (management below grade, on site) of two reactors. The proposals are for the decommissioning of the WR-1 reactor at Whiteshell Laboratories in Pinawa, Manitoba, and the NPD reactor at Rolphton, Ontario.

These projects involve dismantling the above-grade structure and putting it in the underground section as backfill. The below-grade area would then be grouted in place with an engineered cap to prevent water infiltration. The intent is that after the decommissioning is complete, the sites would be considered to be licensed disposal facilities by the CNSC.

Waste owners are making progress in the long-term management of their L&ILRW. Of the total volume of LLRW projected by 2100, 99% has a planned long-term solution. For ILRW, most of the projected volume is set to be managed by 2100 through one of the proposed projects, and waste owners will continue to develop long-term solutions for the remaining ILRW. Used nuclear fuel will be entirely managed under the NWMO's APM plan to site and build a deep geological repository.

6.2 Waste emplacement projections for long-term waste management facilities

Table 18 provides an overview of the volumes of waste to be emplaced in long-term waste management facilities by 2050 and 2100. Based on current proposed facilities (subject to environmental assessment and regulatory review), by 2050, Canada would have made significant progress on the long-term management of the vast majority of the projected L&ILRW and HLRW.

Table 18. Long-term management emplacement projections to 2100

Facility	Emplacement by 2019		Emplacement by 2050		Emplacement by 2100	
Waste from operations	**Fuel bundles**	**Volume** (m^3)	**Fuel bundles**	**Volume** (m^3)	**Fuel bundles**	**Volume** (m^3)
NWMO Deep Geological Repository	0	0	840,000	52,500[1]	5,420,289	338,768[1]
Waste from operations and decommissioning	**Volume** (m^3)		**Volume** (m^3)		**Volume** (m^3)	
OPG Deep Geologic Repository	0		200,525[2]		396,975[2]	
AECL Near Surface Disposal Facility	0		756,307		886,129	
WR-1 reactor In Situ Decommissioning	0		2,620		2,620	
NPD reactor In Situ Decommissioning	0		2,132		2,132	
Historic waste	**Volume** (m^3)		**Volume** (m^3)		**Volume** (m^3)	
Port Hope Long-Term WMF	531,380		1,174,380		1,174,380	
Port Granby Long-Term WMF	438,200		438,200		438,200	

[1] based on the assumed use of a 48 bundle container in a 1 m x 1 m x 3 m bentonite buffer box
[2] according to OPG's reference plan, which accounts for a future expansion plan to the DGR; as emplaced volume

7.0 URANIUM MINING AND MILLING WASTE

7.1 Uranium mining and milling waste definition

This waste is LLRW that was generated from uranium mining and milling activities and includes both mill tailings and waste rock.

Uranium mill tailings

Uranium mill tailings are a specific type of LLRW that is generated during the milling (processing) of uranium ore to produce uranium concentrate. Uranium concentrate, once refined and converted, is used to make fuel for Canadian and foreign power reactors.

Today, tailings are placed in mined-out, open pits converted to tailings management facilities (TMF). However, this was not always the case. Historically, tailings were placed in natural containment areas such as lakes or valleys, disposed of as backfill in underground mines, or placed in engineered surface containment areas.

At all of the newer operations in Saskatchewan, tailings are managed in TMFs that feature hydraulic containment during operation (so that all groundwater flow is toward the tailings facility) and passive long-term containment following decommissioning. Details of each facility can be found in the annual reports prepared for the CNSC by the waste owners.

Waste rock

Waste rock is the non-ore material that is removed during mining to access the ore. Today, waste rock is separated into mineralized and non-mineralized waste rock depending on the relative concentration of uranium present in the material.

Historically, waste rock was stored on the surface or used as backfill in underground mines. However, in the past, inventories of waste rock were not consistently tracked and often mineralized and non-mineralized waste was stockpiled together.

Mineralized waste rock can include sub-economical concentrations of uranium in addition to elevated levels of other elements such as sulphur, arsenic or nickel that could potentially cause adverse environmental effects. Non-mineralized waste rock has very low concentrations of uranium and levels of other elements below applicable standards.

Because of the potential for contaminant transport, when mineralized waste rock is exposed at the surface, it is typically used as mine backfill or stored in mined-out pits that have been converted to TMFs. However, there are no special long-term storage requirements for non-mineralized waste rock.

Figure 18. How uranium mining and milling waste is generated

Uranium ore mining and processing

Milling (processing) of *uranium ore* produces *uranium concentrate*.

Uranium mining and milling waste

Waste rock (mineralized) mill tailings

Mine decommissioning

Mine shut down

Waste rock and uranium tailings exist at operating uranium mine and mill sites. Because of the large volumes and low activity levels, tailings and waste rocks are decommissioned in place.

7.2 Uranium mining and milling waste locations

This map shows the sites of uranium mining and milling waste in Canada.

7.3 Uranium mining and milling waste inventory

Uranium mill tailings are presented as mass in tonnes because this is how the mining industry commonly tracks and reports materials. Waste amounts can be converted to volume (m^3), using assumed or measured densities. A typical dry density for tailings would be 1.0 to 1.5 tonnes/m^3. However, tailings densities vary significantly from site to site and with location or depth at a specific site.

Table 19. Uranium mine and mill tailings accumulation rate and inventory – 2016

Mine or mill	Principal source company or reponsible party	Territory or province	Tailings facility	Accumulation rate (tailings) in 2016 (tonnes/yr)	Total tailings as of Dec. 31, 2016 (tonnes)	Tailings facility status
OPERATING SITES						
Key Lake	Cameco Corp.	Saskatchewan	Deilmann tailings management facility	207,821	5,978,820[1]	Operating since 1995
Rabbit Lake	Cameco Corp.	Saskatchewan	Rabbit Lake In-Pit tailings management facility	74,172	9,124,938	Operating since 1985
McClean Lake	AREVA Resources Canada Inc.[2]	Saskatchewan	JEB tailings management facility	67,368	1,953,300[3]	Operating since 1999
McArthur River	Cameco Corp.	Saskatchewan	No tailings on site	0	0	N/A – no tailings facility ore is milled at Key Lake
Cigar Lake	Cameco Corp.	Saskatchewan	No tailings on site	0	0	N/A – no tailings at facility, ore is milled at McClean Lake (AREVA)
			Sub-total operating sites	349,361	17,057,058	
CLOSED OR DECOMMISSIONED SITES						
Cluff Lake	AREVA Resources Canada Inc.[2]	Saskatchewan	Tailings management area (TMA)	0	3,230,000	Decommissioned since 2006/ ongoing monitoring
Key Lake	Cameco Corp.	Saskatchewan	Surface tailings (old tailings pond)	0	3,579,781[4]	Closed since 1996/ ongoing monitoring
Rabbit Lake	Cameco Corp.	Saskatchewan	Surface tailings	0	6,500,000	Closed since 1985/ ongoing monitoring
Beaverlodge	Cameco Corp.	Saskatchewan	Surface, sub-areal and sub-aqueous tailings	0	5,700,000[5]	Decommissioned since 1982/ ongoing monitoring
Gunnar	Saskatchewan Research Council	Saskatchewan	Surface tailings	0	4,400,000	Closed since 1964
Lorado	Saskatchewan Research Council	Saskatchewan	Surface tailings	0	360,000	Closed since 1960
Port Radium	Indigenous and Northern Affairs Canada	Northwest Territories	Surface tailings – four areas	0	907,000	Decommissioned since 1984/ ongoing monitoring
Rayrock	Indigenous and Northern Affairs Canada	Northwest Territories	North and South tailings pile	0	71,000	Closed since 1959/ ongoing monitoring
Quirke 1 and 2 - Elliot Lake	Rio Algom Ltd.	Ontario	Quirke Mine TMA	0	46,000,000	Decommissioned / ongoing monitoring
Panel - Elliot Lake	Rio Algom Ltd.	Ontario	Panel Mine TMA, Main Basin and South Basin	0	16,000,000	Decommissioned / ongoing monitoring

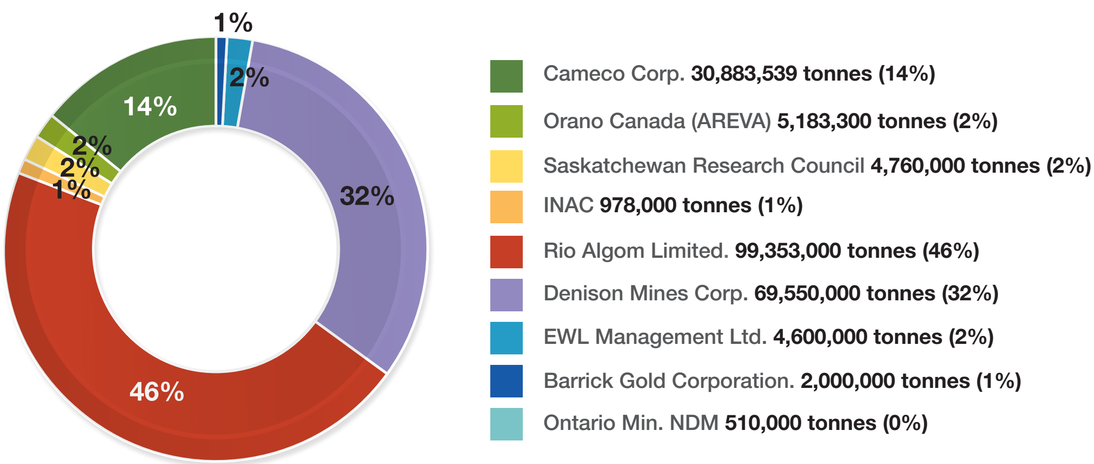
Mine or mill	Principal source company or reponsible party	Territory or province	Tailings facility	Accumulation rate (tailings) in 2016 (tonnes/yr)	Total tailings as of Dec. 31, 2016 (tonnes)	Tailings facility status
Denison - Elliot Lake	Denison Mines Corp.	Ontario	Denison tailings management area (TMA1,TMA2)	0	63,800,000	Decommissioned/ ongoing monitoring
Spanish-American - Elliot Lake	Rio Algom Ltd.	Ontario	Spanish American TMA	0	450,000	Decommissioned/ ongoing monitoring
Stanrock/Can-Met - Elliot Lake	Denison Mines Corp.	Ontario	Stanrock TMA	0	5,750,000	Decommissioned/ ongoing monitoring
Stanleigh - Elliot Lake	Rio Algom Ltd.	Ontario	Stanleigh TMA	0	19,953,000	Decommissioned/ ongoing monitoring
Lacnor - Elliot Lake	Rio Algom Ltd.	Ontario	Lacnor Waste Management Area (WMA)	0	2,700,000	Decommissioned/ ongoing monitoring
Nordic - Elliot Lake	Rio Algom Ltd.	Ontario	Nordic WMA	0	12,000,000	Decommissioned/ ongoing monitoring
Milliken - Elliot Lake	Rio Algom Ltd.	Ontario	Milliken	0	150,000	Decommissioned/ ongoing monitoring
Pronto - Elliot Lake	Rio Algom Ltd.	Ontario	Pronto WMA	0	2,100,000	Decommissioned/ ongoing monitoring
Agnew Lake Mines - Espanola	Ontario Ministry of Northern Development and Mines	Ontario	Dry TMA	0	510,000	Decommissioned since 1990/Ongoing Monitoring
Dyno - Bancroft	EWL Management	Ontario	Surface tailings	0	600,000	Decommissioned/ ongoing monitoring
Bicroft - Bancroft	Barrick Gold Corp.	Ontario	Bicroft TMA	0	2,000,000	Decommissioned/ ongoing monitoring
Madawaska - Bancroft	EWL Management	Ontario	Surface tailings – two Areas	0	4,000,000	Decommissioned/ ongoing monitoring
			Sub-total Decommissioned Sites	0	200,760,781	
			TOTAL		**217,817,839**	

[1] includes tailings accumulated from the processing of ores from McArthur River
[2] AREVA Resources Canada Inc. changed its name to Orano in January 2018.
[3] includes tailings accumulated from the processing of ores from Cigar Lake
[4] based on monthly production reports between 1983 and 1996. In 1996, tailings placement switched to the Deilmann TMF.
[5] Tailings volume does not include 4,300,000 tonnes that have been used as backfill.

Uranium mill tailings

The total inventory of tailings is 217,817,839 tonnes. As of December 31, 2016, the inventory of tailings at closed and decommissioned sites was about 201 million tonnes and about 17 million tonnes were from the operating sites. The tailings generated in 2016 were approximately 0.35 million tonnes.

Figure 19. Tailings inventory – 2016



Waste rock

The total inventory of mineralized waste rock as of December 31, 2016 is 36,454,876 tonnes. Non-mineralized waste rock accounted for 132,818,060 tonnes as of December 31, 2016.

The accumulation rate of waste rock varies significantly depending on the mining method as well as on the ratio of ore to waste, which is dependent on fluctuations in uranium prices. All the mines currently operating are underground mines and do not produce large quantities of waste rock. Some of this waste rock is used for backfilling or construction purposes. At the Key Lake mill, mineralized waste rock is used to down-blend high-grade ore before processing. As a result, the annual generation of waste rock is not highly indicative of the accumulation rate of waste rock. The cumulative total inventory of waste rock is used to provide a more representative value.

Table 20 summarizes the mass of the waste rock inventory and the site status for operating, closed, decommissioned and development sites in Canada as of December 31, 2016. The 2016 inventory of waste rock is rounded to the nearest 100 tonnes.

Table 20. Waste rock inventory – 2016

Mine or mill	Principal source company or responsible party	Province of the source company	Waste rock inventory		Waste rock site status as of December 2016
			Mineralized (tonnes)	Non-mineralized (tonnes)	
Key Lake	Cameco Corp.	Saskatchewan	1,146,585[1]	68,057,937	Operating since 1995
Rabbit Lake	Cameco Corp.	Saskatchewan	1,161,802[2]	12,571,572[3]	Suspended July 2016
McClean Lake	AREVA Resources Canada Inc.	Saskatchewan	10,200,000	51,700,000	Operating since 1999
McArthur River	Cameco Corp.	Saskatchewan	120,951	426,217[4]	Operating since 1999
Cigar Lake	Cameco Corp.	Saskatchewan	625,538	62,334[4]	Operating since 2014
		Subtotal Operational Sites	13,254,876	132,818,060	
Cluff Lake[5]	AREVA Resources Canada Inc.	Saskatchewan	18,400,000		Decommissioned since 2006/Ongoing Monitoring
Beaverlodge[5]	Cameco Corp.	Saskatchewan	4,800,000		Decommissioned since 1982/Ongoing Monitoring
		TOTALS	**36,454,876[6]**	**132,818,060**	

[1] The volume has been reduced since 2013 because of the processing of mineralized waste rock and a 2013 reporting error.
[2] The volume has been reduced since 2013 because of a 2014 survey update and the processing of mineralized waste rock.
[3] The volume has been reduced since 2013 because the reclamation of the B-zone waste rock pile was completed in 2014 and the A-zone, D-zone and North waste rock piles were reclaimed before 2013.
[4] The volume has been reduced since 2013 because of the re-classification of potentially acid-generating waste rock as mineralized.
[5] Work on these sites predated current waste segregation practices and as a result, this volume includes non-mineralized waste rock.
[6] Unsegregated waste rock is counted as mineralized waste rock for the totals because it requires monitoring.

7.3.1 Decommissioning waste (uranium mining and milling waste)

Owing to the large volumes of generated waste and low activity levels, uranium mine sites are decommissioned in place. Decommissioning of surface tailings sites usually includes improvement or construction of dams to provide long-term containment, flooding or covering of tailings to reduce acid generation and the release of gamma radiation and radon gas, and management/monitoring of tailings and effluent.

Waste rock and uranium tailings exist at operating uranium mine and mill sites in northern Saskatchewan and at closed or decommissioned sites in Saskatchewan, Ontario and the Northwest Territories.

7.4 Uranium mining and milling waste projections

The known resources of uranium ore at mines that are currently in operation will be exhausted prior to 2050. No projections of uranium mine tailings or waste rock are provided due to the uncertainty associated with estimating the volume of waste from potential projects. The following sections provide a brief qualitative assessment of factors affecting future uranium mining and milling waste.

Status of future uranium mining and milling waste

Operating sites

Future uranium production rates could increase depending on timing and market conditions. Ore grades from Cigar Lake will be higher (15% uranium) and, as a result, will reduce the tailings production rates at the McClean Lake Mill relative to uranium production. Cameco Corporation will continue to blend Key Lake special waste with high grade ore from McArthur River. At Rabbit Lake, mixing of tailings with waste rock or till prior to deposition is also being considered. Due to these possibilities, it is difficult to forecast the final tailings mass from the operating mill sites.

Closed or decommissioned sites

Decommissioning of uranium mill tailings generally involves management in place. The current mass of tailings at all inactive or decommissioned sites is approximately 201 million tonnes and is assumed to remain unchanged through 2050.

8.0 REFERENCES

High-level radioactive waste

Ontario Power Generation Inc. – Memo, February 23, 2018

Hydro-Québec – Email and associated documentation, February 20, 2017 and June 5, 2017

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NB Power – Email and correspondence, June 1, 2017

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Uranium mining and milling waste

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Ontario Power Generation Inc. – Memo, February 23, 2018

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