SpentFUEL
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THE LATEST DEVELOPMENTS IN SPENT FUEL MANAGEMENT AND TRANSPORTATION

Canada's Strategic Plan and Nuclear Waste Inventory

Canada's Nuclear Waste Management Organization (NWMO), which is responsible for implementing Canada's Adaptive Phased Management (APM) plan for the long-term management of spent fuel generated at Canadian nuclear reactors, has released its annual strategic plan, titled, *Implementing Adaptive Phased Management 2018 to 2022*. The plan calls for a deep geological repository for the permanent disposal of spent fuel, and a Center of Expertise for technical, environmental, and community studies.

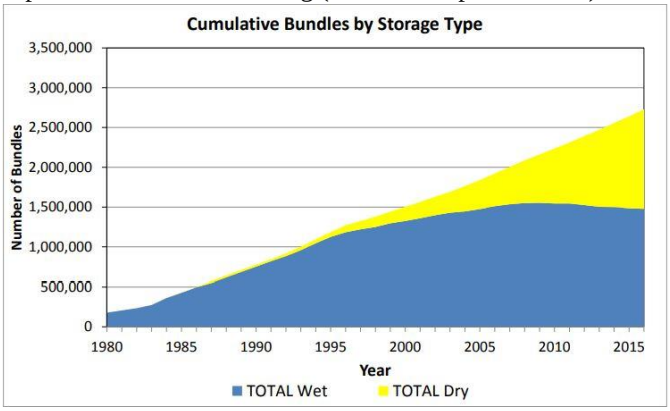
The NWMO is currently in the site selection phase of implementing the APM plan and is working to narrow its focus to one preferred site for a repository that has suitable rock and an informed, willing host community. The repository, which will accept only spent fuel generated from Canada's reactors, will be built at a depth of about 500 meters, depending on the geology of the selected site. It will consist of a network of placement rooms for the spent fuel. The spent fuel will be loaded at the reactor sites into transportation packages and transported to the repository where it will be repackaged into corrosion-resistant containers for placement. In the repository, the spent fuel containers will be placed into a bentonite buffer box in the Used Fuel Packing Plant (UFPP). These boxes will be stacked two high in the horizontal placement room, with spaces backfilled with bentonite pellets. The spent fuel will be monitored to ensure safe management and retrievability throughout the entire life of the repository. Once a decision has been made to close the facility, NWMO will obtain appropriate regulatory approvals prior to decommissioning. Equipment will be removed, and the access tunnels and shafts will be backfilled and sealed.

One of NWMO's areas of focus over the next five years continues to be siting a repository, which will involve working with potentially interested communities as they move through the phases of the siting process. Twenty-two communities initially expressed interest. By the end of 2017, five communities remained in the site selection process, and initial borehole drilling began as part of field studies in these communities. Through 2022, the narrowing down process and subsurface field studies will continue. NWMO expects to have a single preferred site identified by 2023. In 2024, the detailed site characterization will begin, as will construction of the Center of Expertise. The schedule calls for license applications to be submitted in 2028, and a construction license granted in approximately 2032. Operations of the repository are scheduled to begin between 2040 and 2045.

The document states that "From 2018 to 2022, engagement will focus on strengthening established relationships to sustain program momentum." Field studies will continue, including limited borehole drilling to gain knowledge of the geoscientific, engineering, environmental, and safety factors. The number of study areas will be narrowed down, with areas that have relatively low potential to be suitable for the project screened out.

Over the next five years, the NWMO will conduct testing of the engineered-barrier system (EBS) to demonstrate that it meets or exceeds the regulatory requirements of the Canadian Nuclear Safety Commission (CNSC), as well as "all applicable federal and provincial regulatory standards and requirements for protecting the health, safety, and security of humans and the environment." All through the process, the NWMO will continue to work closely with affected communities.

The repository for Canada will be subject to the CNSC's comprehensive licensing system, which covers the entire life cycle of the repository, from site preparation to construction, operation, decommissioning (closure and post-closure), and



Canada Spent Fuel Inventory as of June 30, 2017				
	June 30, 2015	June 30, 2016	June 30, 2017	Net Change over 2016
Wet storage	1,496,518	1,477,471	1,465,360	-12,111*
Dry storage	1,102,470	1,203,354	1,305,558	102,204
Total	2,598,988	2,680,825	2,770,918,	90,093

*More spent fuel was transferred from wet storage to dry storage than was produced during the year, which also happened in 2016.

abandonment (release from CNSC licensing). This stepwise approach will require a license for each phase of the repository life cycle. The process for obtaining a "site preparation" license will be initiated by the NWMO. The NWMO would submit an application for a License to Prepare Site (and possibly construct) to the CNSC. A licensing decision by the CNSC on a repository can be taken only after the successful completion of the environmental assessment, following the process established under the Canadian Environmental Assessment Act (currently under review). During the next five years, the NWMO will also develop transportation plans; transportation of the spent fuel is jointly regulated by the CNSC and Transport Canada.

Financing the program – The owners of the spent fuel provide the funding for the project. These owners are Ontario Power Generation (OPG), New Brunswick Power Corporation, Hydro-Québec, and Atomic Energy of Canada Limited (AECL). Each of these four companies are required to establish independently managed trust funds, and to make annual deposits to ensure the money will be available when needed. As of the end of 2017, the combined trust fund balances were $4.2 billion to cover post-licensing costs of the APM for Canada's existing inventory of spent fuel.

For planning purposes, the NWMO's cost estimate is based on the need to dispose of about 5.2 million bundles. With that assumption, the total lifecycle cost of APM – from the beginning of site selection to completion of the project – is $23 billion in 2015 dollars. The cost to manage the 5.2 million fuel bundles from 2018 onward is $8.9 billion. This cost includes expected investment income and does not include sunk costs.

Nuclear Fuel Waste Projections in Canada – 2017 Update states that about 90,000 spent fuel bundles are generated in Canada on average each year. When a bundle is discharged from a reactor, it is first placed into a spent fuel pool for storage for seven to ten years. After this period, the bundles are placed into dry storage containers, silos, or vaults, which have a minimum design life of 50 years. As of June 30, 2017, approximately 2.8 million spent fuel bundles had been discharged (approximately 55,000 metric tons heavy metal), an increase of approximately 90,000 bundles from the 2016 report (see the table and graph on the previous page). Up to 5.2 million bundles are expected to be produced to the end of the life of the current nuclear generating facilities. If new reactors are built, the potential volume could rise to 7.2 million bundles.

Dry storage was initiated in the 1970s on a small scale at shutdown Atomic Energy of Canada Limited (AECL) prototype reactors. Starting in the 1990s, older spent fuel stored in fuel pools at the reactor sites has been transferred to dry storage on an ongoing basis. In the future, the inventory of spent fuel in wet storage will remain relatively constant since pool storage space is fixed, while inventory of dry storage will continue to grow.

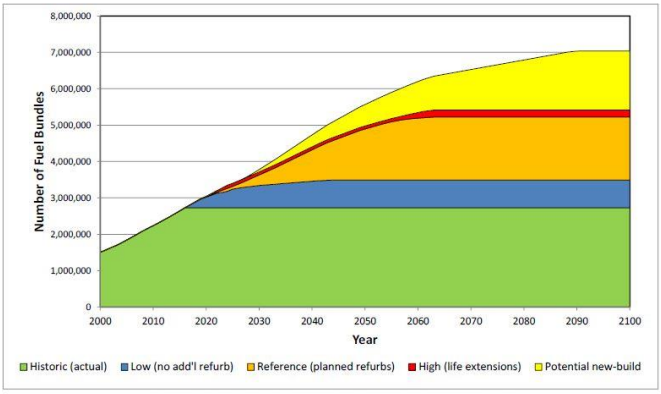


Figure 2: Summary of Projected Used Fuel Inventory

Table 1: Summary of Nuclear Fuel Waste in Canada as of June 30, 2017

Location	Waste Owner	Wet Storage (# bundles)	Dry Storage (# bundles)	TOTAL (# bundles)	Current Status
Bruce A	OPG(2)	331,866	182,784	514,650	- 4 units operational
Bruce B	OPG(2)	352,952	329,462	682,414	- 4 units operational
Darlington	OPG	324,146	208,442	532,588	- 4 units operational. See Note (4).
Douglas Point	AECL	0	22,256	22,256	- permanently shut down 1984
Gentilly 1	AECL	0	3,213	3,213	- permanently shut down 1978
Gentilly 2	HQ	17,965	111,960	129,925	- permanently shut down 2012
Pickering A	OPG	399,703	337,114	736,817	- 2 units operational, 2 units non-operational since 1997 (permanently shut down 2005)
Pickering B	OPG				- 4 units operational
Point Lepreau	NBPN	38,728	103,138	141,866	- operational
Whiteshell	AECL	0	2,268	2,268	- permanently shut down 1985. See Note (1).
Chalk River	AECL	0	4,921	4,921	- mostly fuel from NPD (permanently shut down 1987) with small amounts from other Canadian reactors and research activities.
		Note (3)	Note (3)	Note (3)	- currently under assessment
	TOTAL	***1,465,360***	***1,305,558***	***2,770,918***	

Notes:

AECL = Atomic Energy of Canada Limited
NBPN = New Brunswick Power Nuclear
HQ = Hydro-Québec
OPG = Ontario Power Generation Inc.

(1) 360 bundles of Whiteshell fuel are standard CANDU bundles (from the Douglas Point reactor). The remaining bundles are various research, prototype and test fuel bundles, similar in size and shape to standard CANDU bundles, mainly from the research/prototype WR-1 reactor.

(2) Bruce reactors are leased to Bruce Power for operation. However, OPG is responsible for the used fuel that is produced.

(3) AECL also owns some ~22,000 components of research and development fuels such as fuel elements, fuel pellets and fuel debris in storage at Chalk River. While the total mass of these components is small compared to the overall quantity of CANDU fuel, their varied composition, storage form, dimensions, etc. requires special consideration for future handling. There are also small quantities (a few kg) of non-CANDU fuel associated with several research reactors in Canada.

(4) Darlington is currently undergoing refurbishment, unit-by-unit. The first unit (Unit 2) was shut down for refurbishment in mid-October 2016.

The report also notes the potential for new reactors, including up to four new reactors at OPG's Darlington site. A summary of nuclear fuel characteristics from new reactors, and the total quantity of spent fuel from these reactors is included in the waste projection report. The total additional quantity of spent fuel from the Darlington New Nuclear Project could be up to 1.6 million CANDU fuel bundles (30,000 MTHM) or 10,800 PWR fuel assemblies, depending on the selected reactor type. For planning purposes, the NWMO assumes four new Enhanced CANDU 600 reactor, since that is the only project that has currently received an initial regulatory approval. This reactor type will produce the most spent fuel over its lifetime (1.6 million bundles for 4 reactors).

The graphs included in this article and the data for the table on page 1 are copied from the waste projections report. The strategic plan and the waste projections report may be found at: https://www.nwmo.ca/en/Reports

Top Story

FirstEnergy files deactivation notice for all its nuclear generating plants

On March 28, news broke that FirstEnergy Solutions (FES), a competitive generation subsidiary of FirstEnergy Corp., had notified PJM Interconnection, the regional transmission organization, about its plan to deactivate two nuclear power plants in Ohio and one in Pennsylvania over the course of the next two to three years. FES is working to seek legislative policy solutions as an alternative to deactivation or sale. Plant closures are subject to review by PJM. The US Nuclear Regulatory Commission (NRC) was reportedly notified verbally as well.

The plants scheduled for retirement include:

- Davis-Besse Nuclear Power Station (908 MWe) in Oak Harbor, Ohio, in 2020
- Beaver Valley Power Station (1,872 MWe) in Shippingport, Pennsylvania in 2021
- Perry Nuclear Power Plant (1,268 MWe) in Perry, Ohio, in 2021

The combined capacity of these plants is 4,048 MWe, and together the four reactors provided about 65% of the electricity produced by the FES generating fleet last year.

Don Moul, president of FES Generation Companies and chief nuclear officer, stated, "The decision to deactivate these facilities is very difficult and in no way a reflection on the dedicated, hard-working employees who operate the plants safely and reliably or on the local communities and union leaders who have advocated passionately on their behalf. Though the plants have taken aggressive measures to cut costs, the market challenges facing these units are beyond their control."

He continued, "We call on elected officials in Ohio and Pennsylvania to consider policy solutions that would recognize the importance of these facilities to the employees and local economies in which they operate, and the unique role they play in providing reliable, zero-emission electric power for consumers in both states. We stand ready to roll-up our sleeves and work with policy makers to find solutions that will make it feasible to continue to operate these plants in the future."

According to several media sources, FES filed an application for an order under Section 202c of the Federal Power Act, which gives US Energy Secretary Rick Perry authority to use emergency powers to order PJM Interconnection to negotiate a contract that would compensate the owners of nuclear plants for the benefits they provide, such as reliable energy sources and employment opportunities. PJM reportedly rejected the need for an emergency order to help FirstEnergy.

Industry Calendar

- May 1-3, 2018
  NEI Used Fuel Management Conference
  www.nei.org/conferences/upcoming-conferences
  Savannah International Trade and Convention Center
  Savannah, GA
- June 7-8, 2018
  Decommissioning Strategy Forum
  https://www.exchangemonitor.com/evtx/decommissioning-2018/
  Gaylord Opryland Resort & Convention Center, Nashville, TN
- June 13, 2018
  NWTRB summer 2018 Board meeting
  www.nwtrb.gov
  Idaho Falls, Idaho
- June 17-21, 2018
  2018 ANS Annual Meeting
  www.ans.org/meetings
  Marriott Philadelphia Downtown
  Philadelphia, PA
- October 1-2, 2018
  Nuclear Decommissioning & Used Fuel Strategy Summit
  www.nuclearenergyinsider.com/nuclear-decommissioning-used-fuel/
  Ritz-Carlton Hotel, Charlotte, NC

Details are available at:
https://www.uxc.com/c/data-industry/Calendar.aspx

Vincent Duane, senior vice president at PJM, said the problem is "fundamentally a corporate issue," and was quoted by Reuters as saying, "Nothing we have seen suggests there is any kind of emergency from these units retiring."

The use of such emergency powers related to electricity generation has been minimal. It has only been employed eight times since December 2000, according to DOE, typically only in response to natural disasters or blackouts. Nuclear plants are uniquely situated to handle natural and man-made disruptions to power generation fuel because the plants can store fuel onsite for more than a year. The plants also provide baseload power by operating 24 hours a day.

Both Ohio and Pennsylvania are in a deregulated electricity market where utilities compete to sell power to suppliers through competitive auctions. The low cost of natural gas has caused nuclear power plant operators to face tough competition, leaving nuclear plants at risk of premature closure for economic reasons, even if the units are performing well. FES parent company, FirstEnergy Corp., announced in November 2016 that it would exit the competitive, non-regulated generation due to weak power prices, poor results from capacity auctions, and weak demand forecasts.

News Briefs – Non-US

CNNC selects Holtec transport cask design

Holtec International announced that it has won an international competition to deploy its HI-STAR 100MB transport cask system in China. CNNC selected Holtec's design from among seven bidders from around the world for a tender for the procurement of spent fuel transportation cask systems. The result of the tender was published March 26 on the website, www.chinabidding.com. The bidding process opened on March 1.

The HI-STAR 100MB design is based on the HI-STAR 190 (USNRC docket #70-9373) transportation cask that is made to retrieve large-diameter canisters from nuclear power plants in the US that have on-site storage facilities. The HI-STAR 100MB (USNRC docket #70-9378) will be used to retrieve medium-sized canisters containing spent fuel with higher burnups and shorter cooling times than allowed by the HI-STAR 100 that was licensed by Holtec in 1999. The HI-STAR 100MB also offers the option to transport unpackaged fuel without a canister.

Holtec also envisions using the HI-STAR 100MB at its proposed consolidated interim storage (CIS) facility, HI-STORE CIS, in New Mexico. Holtec's CIS will collect spent fuel from commercial reactor sites across the country and store them temporarily until a final repository solution is operational. The facility is designed to be "canister extraction-friendly," meaning a stored canister can be retrieved and shipped off site in less than one work shift.

Holtec submitted the HI-STAR 100 MB application to the NRC for approval on February 16, 2018.

OPG reaches new milestone at Darlington 2 refurbishment

Ontario Power Generation (OPG) removed the final calandria tube insert (CTI) on March 28, completing another step in the disassembly phase of Darlington Nuclear Generating Station's Unit 2 as the reactor undergoes refurbishment, OPG reported on Thursday.

Calandria tubes sit in the reactor's core, each housing a pressure tube containing nuclear fuel bundles. They are secured at each end by CTIs, a metal ring which forms a mechanical seal. There are 960 CTIs per reactor — one at each end of the 480 calandria tubes. CTIs are released from the tube sheet through induction heating using the CTI release tooling.

OPG used a new production planning tool during CTI removal, which increased efficiency and allowed for the early completion of this project series. The planning tool involved a process map with timed durations for each step in the process, including removal of the components, placing them in flasks, transferring to waste containers, and returning the flasks back to the units.

Perrik Le Dreff of the Darlington Refurbishment team said, "The result was like clockwork since we understood every discrete step of the sequence including the impact of speeding up or slowing down one step and the impact on the rest of the steps."

Completing removal of the CTI means that the calandria tubes themselves can now be removed, another step in dismantling the reactor. Once that is completed, the reactor will undergo an inspection before work begins to rebuild Unit 2.

Refurbishment of Darlington began in October 2016 when Unit 2, the first of the station's four reactors to come online in the 1990s, was safely shut down. Since then, it has been defueled and isolated from the other three units in the operating station. Once complete, new components will be installed and Darlington will be set to generate 30 additional years of non-greenhouse gas emitting power production.

News Briefs – US

University develops robot to help decommission DOE facility

Carnegie Mellon University's (CMU's) Robotics Institute has developed a pair of autonomous robots that will be used to drive through miles of pipes at the Department of Energy's former uranium enrichment plant in Piketon, Ohio to identify uranium deposits on the walls of the pipes. The robot has shown that it can measure radiation levels more accurately from inside the pipe than is possible with external methods. It will save in labor costs as well as reduce risks to workers who would need to perform measurements by hand while in protective gear.

According to CMU's recent press release, DOE officials estimate that the robots could save tens of millions of dollars in completing the characterization of uranium deposits at the Portsmouth Gaseous Diffusion Plant, and maybe up to $50 million in savings at the uranium enrichment plant in Paducah, Kentucky. In addition to the Portsmouth and Paducah plants, the robots could be useful at other DOE sites including the Savannah River Site in Aiken, South Carolina and the Hanford Site in Richland, Washington.

The CMU team, led by William "Red" Whittaker, robotics professor and director of the Field Robotics Center, began the project last year and worked closely with DOE and Fluor-BWXT Portsmouth, the decommissioning contractor, to build a prototype. CMU is building two of the robots, called RadPiper, and will deliver the prototype units to the Portsmouth site in May. DOE has paid CMU $1.4 million to develop the robots.

The uranium deposits must be found in the pipes before DOE can decontaminate, decommission, and demolish the

facility. Identifying the deposits is a "herculean task," as the facility spans 10.6 million square feet of floor space with three large containment enrichment process building that contain more than 75 miles of process pipe. Over the past three years, workers have performed more than 1.4 million measurements of process piping and components manually.

"With more than 15 miles of piping to be characterized in the next process building, there is a need to seek a smarter method," said Rodrigo V. Rimando, Jr., director of technology development for DOE's Office of Environmental Management. "We anticipate a labor savings on the order of an eight-to-one ratio for the piping accomplished by RadPiper." Even with RadPiper, nuclear deposits must be identified manually in some components.

The tetherless robot moves through a pipe on a set of flexible tracks and is equipped with a lidar and fisheye camera to detect obstructions ahead (e.g. closed valves). CMU explained that the robot's disc-collimated sensing instrument uses a standard sodium iodide sensor to count gamma rays. The sensor is positioned between two large lead discs. The lead discs block gamma rays from uranium deposits that lie beyond the one-foot section of pipe that is being characterized at any given time. After completing a run of pipe, the robot automatically returns to its launch point. Integrated data analysis and report generation frees nuclear analysts from time-consuming calculations and makes reports available the same day.

The robots will initially operate in pipes measuring 30 inches and 40 inches in diameter and will characterize radiation levels in each foot-long segment of pipe. The segments found to have potentially hazardous amounts of uranium-235 will be removed and decontaminated. CMU noted that the vast majority of the plant's piping will remain in place and will be demolished safely along with the rest of the facility.

Indian Point 2 begins final refueling outage before retirement

Entergy shut down Indian Point Energy Center Unit 2 on March 19 to begin the 23rd and final routine refueling and maintenance outage for the reactor before it is retired. The last refueling outage for Unit 2 concluded in June 2016 and the reactor has been generating electricity more than 96% of the time since then. Unit 3 remains in service at full power until its final refueling and maintenance outage that is scheduled for next spring.

Entergy is investing more than $75 million in the plant during the outage to ensure it continues to operate safely and reliably until the unit is shut down permanently by April 30, 2020. An additional 1,000 contract workers will supplement the nearly 1,000 full-time Entergy employees during this outage to complete maintenance projects, including comprehensive inspections of baffle bolts on a removable liner inside the reactor; reactor coolant pump seal replacement; fuel oil storage tank repair for one of the unit's three emergency diesel generators; steam generator inspection; and low-pressure turbine blade inspection.

Entergy purchased Indian Point more than 15 years ago and has since invested more than $1.3 billion in safety and reliability improvements. The company announced in January 2017 that it planned to shut down Indian Point Energy Center prematurely as part of a settlement agreement with New York State. In exchange, New York State agreed to drop its legal challenges and support renewal of the operating licenses for the facility.

Indian Point Unit 3 will be permanently shut down by April 30, 2021.

NRC seeks public input on scope of environmental review for Holtec storage facility

The US Nuclear Regulatory Commission (NRC) is inviting public comments on the scope of an environmental impact statement (EIS) for the proposed HI-STORE consolidated interim storage facility for spent nuclear fuel at site in Lea County, New Mexico. On March 30, 2017 Holtec International submitted an application to the NRC for authorization to build and operate the CIS facility (*SpentFUEL* March 31, 2017), and on February 27, 2018, the NRC began its detailed safety, security, and environmental review (*SpentFUEL* March 2, 2018). In the first phase, Holtec intends to store 500 canisters of spent fuel, and eventually store up to 10,000 canisters in the CIS. The NRC will prepare an EIS for this proposed action. Comments must be submitted to the NRC by May 29, 2018.

flyPad

I asked my daughter if she had seen today's newspaper.

"Dad! Newspapers are so old school!" she said while handing me her iPad.

That fly didn't stand a chance! But now I have to buy her a new iPad, so there's that…

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