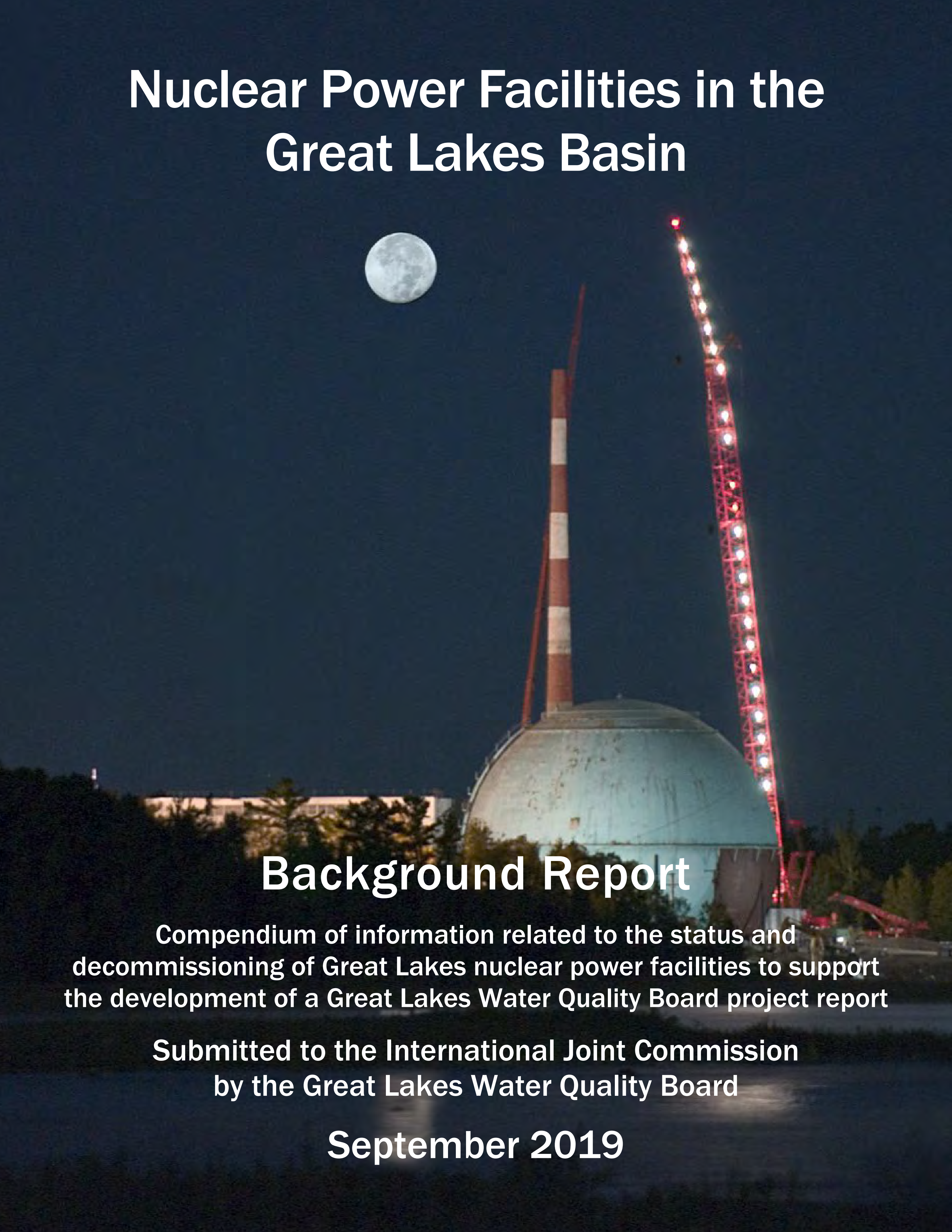
# Nuclear Power Facilities in the Great Lakes Basin



## Background Report

**Compendium of information related to the status and decommissioning of Great Lakes nuclear power facilities to support the development of a Great Lakes Water Quality Board project report**

**Submitted to the International Joint Commission by the Great Lakes Water Quality Board**

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# Acknowledgements

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*For more information on this report, please visit https://ijc.org/en/wqb.*



## Cover Photos

**Front Cover Photo***:* On the shore of Lake Michigan near Charlevoix, Michigan, a 300-foot- (91-meter)-tall crane is positioned to begin dismantling Big Rock Point's 240-foot- (73-meter)-tall ventilation stack. Photo courtesy of Consumers Energy (2004). Used with permission.

**Back Cover Photo***:* A large steam generator is removed from the Zion Nuclear Power Station in Zion, Illinois. Large components were removed after the spent nuclear fuel was relocated to the ISFSI. All the large components were classified as Class A radioactive waste and shipped by rail to the Energy*Solutions* Clive disposal facility located 75 miles (121 kilometers) west of Salt Lake City, Utah, in the state's West Desert. Photo courtesy of Energy*Solutions* (2016). Used with permission.

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# Acronyms and Abbreviations

| | |
|---|---|
| ADAMS | Agency-wide Documents Access and Management System |
| AEA | Atomic Energy Act of 1954 |
| AEC | United States Atomic Energy Commission |
| AECL | Atomic Energy of Canada Limited |
| AEP | American Electric Power |
| ALARA | As Low As Reasonably Achievable |
| BATEA | Best Available Technology Economically Achievable |
| BNGS A | Bruce Nuclear Generating Station A |
| BNGS B | Bruce Nuclear Generating Station B |
| BPR | Big Rock Point |
| Bq | Becquerel = SI unit of radioactivity equal to one disintegration per second |
| BWR | Boiling Water Reactor |
| CAD | Canadian dollars |
| CANDU | Canada Deuterium Uranium (reactor) |
| CE | Consumers Energy Company |
| CEAA | Canadian Environmental Assessment Act |
| CFR | United States *Code of Federal Regulations* |
| CNL | Canadian Nuclear Laboratories |
| CNSC | Canadian Nuclear Safety Commission |
| ComEd | Commonwealth Edison |
| COR | Contracting Officer's Representative |
| CSA | Canadian Standards Association |
| DDP | Detailed Decommissioning Plan |
| DEK | Dominion Energy Kewaunee, Inc. |
| DGR | Deep Geological Repository |
| DOE | United States Department of Energy |
| DNGS | Darlington Nuclear Generating Station |
| DNNP | Darlington New Nuclear Project |
| DPNGS | Douglas Point Nuclear Generating Station |
| DPWMF | Douglas Point Waste Management Facility |
| DTE | DTE Electric Company |
| DWMF | Darlington Waste Management Facility |
| EA | Environmental Assessment |
| EGC | Exelon Generation Company, LLC |
| EIA | United States Energy Information Administration |
| EIS | Environmental Impact Statement |
| ENO | Entergy Nuclear Operations, Inc. |
| ENP | Entergy Nuclear Palisades, LLC |

| | |
|---|---|
| EPA | United States Environmental Protection Agency |
| ERA | Environmental Risk Assessment |
| ESBWR | Economic Simplified Boiling Water Reactor |
| FENOC | FirstEnergy Nuclear Operating Company |
| FES | FirstEnergy Solutions Corporation |
| FY | Fiscal Year |
| GAO | United States Government Accountability Office |
| GLWQA | Great Lakes Water Quality Agreement |
| GTCC | Greater-than-Class-C (waste) |
| GWh | Gigawatt hour = a unit of power equal to one billion ($10^9$) watt hours |
| HLW | High-Level Radioactive Waste |
| IAEA | International Atomic Energy Agency |
| ICRP | International Commission on Radiological Protection |
| IEMP | Independent Environmental Monitoring Program |
| IFB | Irradiated Fuel Bay |
| IJC | International Joint Commission |
| IL | Illinois |
| ILW | Intermediate-Level Radioactive Waste |
| ISFSI | Independent Spent Fuel Storage Installation |
| I&M | Indiana Michigan Power Company |
| JRP | Joint Review Panel |
| KPS | Kewaunee Power Station |
| LLW | Low-Level Radioactive Waste |
| L&ILW | Low- and Intermediate-Level Radioactive Waste |
| MI | Michigan |
| MW | Megawatt = a unit of power equal to one million ($10^6$) watts |
| MWe | Megawatts electric = one million ($10^6$) watts of electric capability |
| MWh | Megawatt hours = a unit of power equal to one million ($10^6$) watt hours |
| MWt | Megawatts thermal = one million ($10^6$) watts of thermal capability |
| NEPA | National Environmental Policy Act |
| NEPB | NextEra Energy Point Beach, LLC |
| NFWA | Nuclear Fuel Waste Act |
| NMP | Nine Mile Point Nuclear Station |
| NRC | United States Nuclear Regulatory Commission |
| NSCA | Nuclear Safety Control Act |
| NY | New York |
| NWMO | Nuclear Waste Management Organization |
| NWPA | Nuclear Waste Policy Act |
| ODCM | Offsite Dose Calculation Manual |
| OH | Ohio |

| | |
|---|---|
| ON | Ontario |
| OPG | Ontario Power Generation |
| OSHA | Occupational Safety and Health Administration |
| PBNP | Point Beach Nuclear Plant |
| PDP | Preliminary Decommissioning Plan |
| PNGS | Pickering Nuclear Generating Station |
| PRDC | Power Reactor Development Company |
| PSDAR | Post Shut Down Activities Report |
| PWMF | Pickering Waste Management Facility |
| PWR | Pressurized Water Reactor |
| REMP | Radiological Environmental Monitoring Program |
| SER | Safety Evaluation Report |
| SNF | Spent Nuclear Fuel |
| SON | Saugeen Ojibway Nation |
| SOR | Statutory Orders and Regulations of Canada |
| SI | International System of Units |
| Sv | Sievert = SI unit of absorbed radiation dose equal to 1 Joule/kilogram |
| TWh | Terawatt hours = a unit of power equal to one trillion ($10^{12}$) watt hours |
| USD | US dollars |
| WI | Wisconsin |
| WQB | Great Lakes Water Quality Board |
| WWMF | Western Waste Management Facility |
| ZNPS | Zion Nuclear Power Station |

# 1. Introduction and Background

The International Joint Commission (IJC) promotes collaboration between Canada and the United States and provides advice to the governments in their efforts to protect, restore and enhance the water quality of the Great Lakes and prevent further degradation of the Great Lakes Basin Ecosystem. Under the Great Lakes Water Quality Agreement (GLWQA), the Great Lakes Water Quality Board (WQB) serves the IJC in an advisory capacity. The WQB has identified decommissioning of nuclear power stations as a priority topic in the Great Lakes basin.

## 1.1 The IJC Boards' Nuclear Studies

The nuclear power era began in Canada and the United States in the 1950s. Because large amounts of water are needed for operation and cooling, all nuclear power plants in the basin were built on the shores of the Great Lakes, where they take in and discharge water. Soon after nuclear power plants started operating, the IJC began studying and reporting to the federal governments the environmental impacts of the nuclear energy lifecycle. From 1976 to 1979, the Radioactivity Subcommittee of the WQB submitted annual reports which described the location of constructed and proposed nuclear power facilities, the nuclear fuel cycle and levels of radioactivity in the Great Lakes. Appendices on radioactivity were common in WQB and Science Advisory Board reports in the '80s and '90s.[1]

In the early '90s, the IJC received numerous letters from the public expressing concern about the accumulation of radioactive waste on the shores of the Great Lakes, requesting further study. In 1995, the IJC authorized a Nuclear Task Force to "review, assess, and report on the state of radioactivity in the Great Lakes."[2] The task force operated under this mandate for five years and produced an inventory of radionuclides for the Great Lakes[3] and a report on the bioaccumulation of radionuclides.[4]

In continuation of its work on radioactive contaminants, in January 2017 the IJC approved the WQB's plan to study the decommissioning of nuclear power plants in the Great Lakes basin.[5]

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[1] To access these historical reports, visit the IJC Digital Archive at the University of Windsor, online at https://scholar.uwindsor.ca/ijcarchive/.

[2] *Nuclear Task Force*. International Joint Commission. https://www.ijc.org/en/ntf.

[3] *Inventory of Radionuclides for the Great Lakes Nuclear Task Force*. International Joint Commission: Nuclear Task Force. December 1997. https://ijc.org/en/inventory-radionuclides-gl-nuclear-task-force

[4] *Report on Bioaccumulation of Elements to Accompany the Inventory of Radionuclides in the Great Lakes Basin*. International Joint Commission: Nuclear Task Force. https://ijc.org/en/report-bioaccumulation-elements-accompany-inventory-radionuclides-great-lakes-basin

[5] According to the EIA, *decommissioning* is the "retirement of a nuclear facility, including decontamination and/or dismantlement."

## 1.2 Project Goal and Objectives

The overall goal of this project is to assess the decommissioning processes and plans for the 38 nuclear reactors at 16 commercial generating stations on 14 sites located within the Great Lakes basin in order to identify potential opportunities to reduce the threats to the Great Lakes environment (water, air, and land). This project will assess the environmental hazards and risks that could result during and after the decommissioning process, the current regulatory regimes in Canada and the United States in order to address the risk, and best practices used in North America and Europe. The work completed will be binational, considering both the Canadian and U.S. portions of the Great Lakes basin.

## 1.3 Document Purpose

The purpose of this document is to compile unbiased background information about nuclear energy production, the nuclear regulators, the decommissioning process, radioactive waste management, and status of the nuclear power facilities in the Great Lakes basin. See Appendix A for more detail on the scope of work.

This background report will be provided as information for the development of a contracted report. The consultant will describe state-of-the-art closure of nuclear facilities as well as analyze the environmental hazards and significant differences in nuclear decommissioning approaches between Canada, Europe, and the United States. This background report and the contracted report will be used by the Legacy Issues Work Group and the WQB to develop its recommendations to the IJC regarding any additional actions that the governments could take to reduce or eliminate threats to the Great Lakes from the release of radioactive contaminants as a result of decommissioning.

## 1.4 Methods

### *1.4.1 Discovery and Sources of Information*

Only publicly available information was used in this report. To ascertain information, the regulators' and operators' websites were thoroughly searched to access specific reports. A list of contact information for the regulators and operators can be found in Appendix B. For nuclear power facilities in Canada, the Canadian Nuclear Safety Commission (CNSC) website[6] discloses information about regulations and licensing information for each nuclear facility. The operators' websites contain annual reports, nuclear performance and environmental reports, financial reports, PowerNews and performance reports, and sustainability reports. Google searches were used to find Preliminary Decommissioning Plan reports. The operators' media relations teams were contacted to request photos and to obtain any missing information.

[6] Canadian Nuclear Safety Commission. https://nuclearsafety.gc.ca/

For nuclear power facilities in the United States, the Nuclear Regulatory Commission (NRC) website[7] has webpages for each licensed nuclear power reactor that contain links to relevant information, including the operating license, annual environmental reports, inspection reports, and event notifications. The Agency-wide Documents Access and Management System (ADAMS)[8] is the official NRC recordkeeping system where Decommissioning Funding reports, Post-Shutdown Activities Reports (PSDARs), Radiological Environmental Operating Reports, Independent Spent Fuel Storage Installation (ISFSI) Annual Radioactive Effluent Release Reports, and License Termination Plans were accessed. The NRC Public Document Room[9] staff was exceptionally helpful in finding these documents and facilitating approvals for those not initially publicly available.

Each nuclear facility's operator was contacted to review and provide feedback on the sections of this report about their licensed facilities.

### *1.4.2 Nuclear Facility Inclusion and Exclusion Criteria*

To be included in this project, the nuclear facilities must be located in the Great Lakes basin and contain nuclear reactors for commercial operation.

#### *1.4.2.1 Great Lakes Basin*

According to the Great Lakes Water Quality Agreement of 2012, the Great Lakes Basin Ecosystem is defined as "the interacting components of air, land, water and living organisms, including humans, and all of the streams, rivers, lakes, and other bodies of water, including groundwater, that are in the drainage basin of the Great Lakes and the St. Lawrence River at the international boundary or upstream from the point at which this river becomes the international boundary between Canada and the United States"[10] (Figure 1-1). Considering administrative divisions, the Great Lakes basin lies within the Province of Ontario and eight U.S. States: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin. For this project, only the commercial nuclear power facilities within the Great Lakes drainage basin were included. Commercial nuclear power facilities within the St. Lawrence River drainage basin or otherwise outside the Great Lakes basin were excluded.[11]

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[7] United States Nuclear Regulatory Commission. https://www.nrc.gov/

[8] *ADAMS Public Documents*. U.S. Nuclear Regulatory Commission. https://www.nrc.gov/reading-rm/adams.html

[9] *Public Document Room*. U.S. Nuclear Regulatory Commission. https://www.nrc.gov/reading-rm/pdr.html

[10] *Great Lakes Water Quality Agreement*. Canada and the United States of America. Article 1(c). 7 September 2012. https://www.ijc.org/en/who/mission/glwqa

[11] The Gentilly Nuclear Generating Station in Bécancour, Québec is the only commercial nuclear power station in the St. Lawrence River watershed and is currently undergoing decommissioning. Due to Lake Michigan's narrow drainage basin in northern Illinois (Figure 1-1), there are four commercial nuclear power stations in the Chicago metropolitan area that are outside the Lake Michigan basin, but are as close as 45 miles (72 kilometers) of Lake Michigan and shown on the Great Lakes Region Nuclear Facilities map (Figure 1-2): Braidwood (45 miles; 72 kilometers), Byron (75 miles; 121 kilometers), Dresden (45 miles; 72 kilometers), and LaSalle (67 miles; 108 kilometers) nuclear generating stations.

#### 1.4.2.2 Commercial Nuclear Generating Stations

According to CNSC and NRC maps, there are numerous nuclear facilities within the Great Lakes basin that are involved in the lifecycle of nuclear power generation, including uranium mines and mill tailings, processing and fuel fabrication facilities, research and test reactors, medical facilities, nuclear power plants, and nuclear waste storage sites (Figure 1-2).[12,13] For this project, the primary inclusion criterion is commercial nuclear generating stations, which are defined as facilities that use nuclear reactors to convert atomic energy into usable nuclear power (i.e., generate electricity) for transmission, distribution, and sale. Nuclear waste management facilities and ISFSIs located on the site of the commercial nuclear generating stations are required by the federal regulators to be included in decommissioning planning and thus are included in this project.

[12] *Maps of nuclear facilities*. Canadian Nuclear Safety Commission. 3 February 2014. http://nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/results.cfm?category=nuclear-power-plants. Accessed 9 July 2018.

[13] *NRC Maps*. U.S. Nuclear Regulatory Commission. 17 August 2018. https://www.nrc.gov/reading-rm/doc-collections/maps/. Accessed 20 August 2018.


Figure 1-1. Map of the Great Lakes basin. Image courtesy of Michigan Sea Grant. Used with permission.

Figure 1-2. Map of the facilities involved in the nuclear energy lifecycle in the Great Lakes region. Image courtesy of Citizens' Clearinghouse on Waste Management and Great Lakes United. Reproduced with permission.

# 2. Nuclear Energy Production and Projections

Electricity is generated from numerous sources (biomass, coal, hydro, nuclear, solar, wind) that comprise a region's electricity mix. Nuclear energy's contribution to the electricity mix of Ontario and the Great Lakes states varies, resulting in divergent levels of impact and importance. The projections of nuclear energy's decline, particularly in the United States, indicate more nuclear stations will be decommissioned soon.

## 2.1 Nuclear Energy Production and Projections in Canada

Canada's National Energy Board estimated that total electricity generation in Canada was 648 terawatt hours (TWh) in 2016. Hydro had the highest share of generation at 59 percent, followed by nuclear at 15 percent, gas/oil/others at 10 percent, coal at 9 percent, and non-hydro renewables (e.g., wind, solar, biomass) at 7 percent.[14]

Commercial nuclear power plants have been producing electricity in Canada since the early 1960s. Today, 19 nuclear reactors are operating at four commercial power stations in Canada, which represent an installed capacity[15] of 13,554 megawatts electric (MWe).[16] There are three operating nuclear power stations in Ontario and one in New Brunswick. Québec's only commercial nuclear power station, Gentilly-2 Nuclear Generating Station on the banks of the St. Lawrence River in Bécancour, permanently closed in December 2012 and is being decommissioned. In 2017, Canada produced 96 TWh of nuclear electricity, which ranked sixth globally.[17]

Ontario, the sole province that contains the Great Lakes basin in Canada, has 18 operating nuclear reactors at three sites, which have 12,894 MWe of installed capacity. In 2017, these three nuclear power stations supplied 90 TWh of electricity,[18] which accounted for 58 percent of the total electricity produced in the province and 94 percent of all nuclear electricity produced in Canada. All three of Ontario's nuclear power stations are in the Great Lakes basin. Ontario currently has no plans to add nuclear capacity to the electricity mix. In 2013, the province deferred the construction of four new nuclear generating units planned for Darlington, due to low electricity demand growth in the province (see *Section 8.1*). In October 2017, Ontario released its

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[14] *Nuclear Generation in Canada*. National Energy Board. 23 August 2018. https://www.neb-one.gc.ca/nrg/sttstc/lctrct/rprt/2018nclrnrg/nclrgnrtn-eng.html. Accessed 3 December 2018.
[15] According to the EIA, *installed capacity* is the "maximum rated output of a generator, prime mover, or other electric power production equipment under specific conditions designated by the manufacturer and is commonly expressed in megawatts (MW)."
[16] *Canada*. International Atomic Energy Agency: Power Reactor Information System. 21 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA. Accessed 22 February 2019.
[17] *Nuclear Generation by Country*. World Nuclear Association. April 2018. http://www.world-nuclear.org/information-library/facts-and-figures/nuclear-generation-by-country.aspx. Accessed 3 December 2018.
[18] *Canada.*

2017 Long Term Energy Plan[19] in which the Government of Ontario recommitted to moving forward with the refurbishment plans for the Bruce and Darlington Nuclear Generating Stations and the shutdown of the Pickering Nuclear Generating Station.[20] Two of Pickering's eight reactors permanently shut down in 2007 and 2008 and are in deferred decommissioning. The single reactor at the Douglas Point Nuclear Generating Station shut down in 1984 and is in deferred decommissioning. Detailed information about each reactor is provided in subsequent sections, which are categorized by the reactor's status.

## 2.2 Nuclear Energy Production and Projections in the United States

The U.S. Energy Information Administration (EIA) estimated that 4,034 TWh of electricity were generated at utility-scale facilities in the United States in 2017. Approximately 63 percent of this electricity generation was from fossil fuels (coal, natural gas, petroleum, and other gases), 20 percent from nuclear energy, and 17 percent from renewable energy sources. An additional 24 TWh of electricity generation was from small-scale solar photovoltaic systems.[21]

Electricity generation from commercial nuclear power plants in the United States began in the late 1950s. At the end of December 2017, the United States had 99 operating commercial nuclear reactors at 61 nuclear power plants in 30 states. There are 20 shutdown commercial nuclear reactors at 18 sites being decommissioned.[22] In 2017, the United States was the world's top nuclear electricity producer by generating 805 TWh, more than double second-ranked France's 379.1 TWh.[23]

In the EIA's *Annual Energy Outlook 2018*, U.S. nuclear power generation capacity is projected to decline from 99.3 gigawatts (GW) to 79.1 GW over the projection period of 2017-2050. This decline in nuclear power generation capacity is due to several factors, including pricing competition in deregulated (i.e., merchant) wholesale electricity markets, growth in wind energy generation, decreasing cost of renewables and natural gas, and nuclear operators' unique expenses.[24]

Nuclear power plants operating in merchant markets are experiencing lower electricity prices, which can, if low enough, result in unprofitable conditions. In fact, roughly half to two-thirds of

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[19] *2017 Long-Term Energy Plan: Delivering fairness and choice*. Glenn Thibeault, Minister of Energy. Government of Ontario. 16 July 2018. https://www.ontario.ca/document/2017-long-term-energy-plan

[20] *Electricity Facts*. Natural Resources Canada. 12 September 2018. https://www.nrcan.gc.ca/energy/facts/electricity/20068. Accessed 3 December 2018.

[21] *Frequently Asked Questions*. U.S. Energy Information Administration. 29 October 2018. https://www.eia.gov/tools/faqs/faq.php?id=427&t=3. Accessed 3 December 2018.

[22] *U.S. Nuclear Industry*. U.S. Energy Information Administration. 1 May 2018. https://www.eia.gov/energyexplained/index.php?page=nuclear_use. Accessed 3 December 2018.

[23] *Nuclear Generation by Country.*

[24] *Annual Energy Outlook 2018: Nuclear Power Outlook*. Michael Scott, U.S. Energy Information Administration. 7 May 2018. https://www.eia.gov/outlooks/aeo/npo.php. Accessed 3 December 2018.

the U.S. nuclear fleet may be operating at a loss in current market conditions.[25] Since 2013, seven nuclear plants have closed. In 2017, four plants reversed their closing decisions after receiving state price support in the form of zero-emission credits, and five additional nuclear plants have also requested state-level price support. Presently, six nuclear plants are scheduled to permanently shut down by 2025 for economic reasons, some in conjunction with necessary major capital improvements required by federal or state regulators.[26]

Among the eight Great Lakes states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin), there are 37 operating nuclear reactors at 23 nuclear power plants that account for 36,152 MWe installed capacity. In 2017, these 37 nuclear reactors supplied 296.3 TWh of electricity, which accounted for 37 percent of the nuclear electricity produced in the United States.[27] The contribution of nuclear energy to each state's electricity mix ranges from 51.8 percent in Illinois to none in Indiana (Table 2-1).

In the U.S.-section of the Great Lakes basin, there are 12 operating nuclear reactors at nine nuclear power stations. Three of those nine nuclear power stations have announced plans to close by 2023. Additionally, four nuclear reactors at three sites have permanently shut down and are currently being decommissioned. Another reactor has been fully decommissioned, and the site was released for unrestricted use. Detailed information about each reactor is provided in subsequent sections, which are categorized by the reactor's status.

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[25] *What's Killing Nuclear Power in the U.S. Electricity Markets?* Jesse Jenkins, MIT Center for Energy and Environmental Policy Research, 2017. http://ceepr.mit.edu/files/papers/2018-001-Brief.pdf

[26] *Annual Energy Outlook 2018: Nuclear Power Outlook*.

[27] *United States of America*. International Atomic Energy Agency: Power Reactor Information System. 21 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US. Accessed 22 February 2019.

**Table 2-1**. Nuclear Energy Production in the Great Lakes Region in 2017

| Province / State | Number of Operating Nuclear Stations | Number of Operating Reactors | Nuclear Capacity (MWe) | Electricity Supplied (GWh) | Province / State's Electricity Production (%)[3,4] |
|---|---|---|---|---|---|
| **Canadian Great Lakes Province**[1] | | | | | |
| Ontario | 3 | 18 | 12,894 | 89,983 | 57.5 |
| **U.S. Great Lakes States**[2] | | | | | |
| Illinois | 6 | 11 | 11,609 | 97,253 | 51.8 |
| Indiana | 0 | 0 | 0 | 0 | 0.0 |
| Michigan | 3 | 4 | 4,140 | 32,388 | 23.8 |
| Minnesota | 2 | 3 | 1,688 | 13,904 | 24.1 |
| New York | 4 | 6 | 5,343 | 42,137 | 34.5 |
| Ohio | 2 | 2 | 2,150 | 17,689 | 10.4 |
| Pennsylvania | 5 | 9 | 10,040 | 83,316 | 41.0 |
| Wisconsin | 1 | 2 | 1,182 | 9,654 | 16.6 |
| **Great Lakes States Total** | **23** | **37** | **36,152** | **296,341** | **-** |
| **Great Lakes Region Total** | **26** | **55** | **49,046** | **386,324** | **-** |

Note: Not all the operating nuclear generating stations in the Great Lakes region are in the Great Lakes basin. Currently, there are 30 operating nuclear reactors at 12 commercial generating stations on 11 sites located within the basin.

Sources: [1] *Canada*. International Atomic Energy Agency: Power Reactor Information System. 21 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA. Accessed 22 February 2019.

[2] *United States of America*. International Atomic Energy Agency: Power Reactor Information System. 21 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US. Accessed 22 February 2019.

[3] *Provincial and Territorial Energy Profiles – Ontario*. National Energy Board. 22 January 2019. http://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/on-eng.html. Accessed 29 January 2019.

[4] *State Profiles and Energy Estimates*. U.S. Energy Information Administration. https://www.eia.gov/state/

# 3. Nuclear Power Regulators

In this section, the regulators of the nuclear power industry in Canada and the United States are described, including the regulatory rules for decommissioning, public involvement, decommissioning strategies, phases of decommissioning, cleanup standards, environmental monitoring, financial guarantees, and limitation of liability.

## 3.1 Canadian Nuclear Safety Commission

Formal regulation of nuclear activities in Canada commenced in 1946 with the coming in to force of the *Atomic Energy Control Act* and the resultant creation of the Atomic Energy Control Board. Subsequently, the *Nuclear Safety and Control Act, 1997* (NSCA) came into force on May 31, 2000, replacing the *Atomic Energy Control Act*. The NSCA established an independent national nuclear regulatory body, the Canadian Nuclear Safety Commission (CNSC), and set the CNSC's mandate, responsibilities, and powers. The CNSC also conducts environmental assessments under the *Canadian Environmental Assessment Act, 2012* (CEAA), implements Canada's bilateral agreement with the International Atomic Energy Agency (IAEA) on nuclear safeguards verification, and strengthens the compensation and civil liability regime for damages that result from a nuclear accident under the *Nuclear Liability and Compensation Act, 2015*.

In addition to the NSCA, other federal acts may apply to the nuclear facilities and activities in Canada. Some of the more important pieces of legislation include nuclear security, environment, transportation, occupational health and safety, and nuclear energy and substances. Succinct descriptions of these pieces of legislation can be found on CNSC website.[28]

The CNSC's specific objectives under the NSCA are to:

- Regulate the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information in order to:
    - Prevent unreasonable risk to the environment and to the health and safety of persons, associated with that development, production, possession or use
    - Prevent unreasonable risk to national security associated with that development, production, possession or use
    - Achieve conformity with measures of control and international obligations to which Canada has agreed.
- Disseminate objective scientific, technical and regulatory information to the public concerning the activities of the CNSC and the effects, on the environment and on the health and safety of persons, of the development, production, possession and use.

[28] *Acts*. Canadian Nuclear Safety Commission. 18 January 2016. https://nuclearsafety.gc.ca/eng/acts-and-regulations/acts/index.cfm. Accessed 3 September 2018.

Assuring compliance with legislation, regulations and licensing requirements is one of the CNSC's core business processes and is carried out through compliance verification and enforcement. Compliance verification includes site inspections and the review of operational activities and licensee documentation. CNSC inspectors are designated and empowered under the NSCA to enforce regulatory requirements.

The CNSC uses a graduated approach to enforcement to encourage and compel compliance and deter future non-compliances. When a non-compliance (or a continued non-compliance) has been identified, CNSC staff assess the significance of the non-compliance, and determine the appropriate enforcement action, based on the CNSC's graduated approach to enforcement.

The CNSC ensures reporting transparency by making all annual compliance reports and regulatory oversight reports available to the public. This includes publicly posting the results of national and international (e.g., Integrated Regulatory Review Service) audits and CNSC responses to those audits. [29]

### *3.1.1 Decommissioning Nuclear Power Plants*

The CNSC regulates the entire lifecycle of nuclear power plants. Decommissioning activities are the actions taken by a licensee at the end of the useful life of the reactor. The decision to stop operating and to decommission is taken solely by the licensee. The CNSC's role is to ensure that decommissioning activities are carried out in accordance with CNSC regulatory requirements to ensure protection of the workers, the public and the environment, and to implement Canada's international commitments. Plans related to the decommissioning of nuclear power plants take, on average, 50 years to complete.[30]

### *3.1.2 Regulations*

The NSCA and its regulations place a requirement on operators of nuclear facilities to make adequate provisions for their safe operation and decommissioning. With reference to decommissioning and waste management, the following regulations under the NSCA have relevance to the decommissioning of a nuclear facility:

- Class I Nuclear Facilities Regulations (SOR/2000-204);
- General Nuclear Safety and Control Regulations (SOR/2000-202); and
- Nuclear Substances and Radiation Devices Regulations (SOR/2000-207).

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[29] *Assessment of the Relevance of the Inclusion of Radionuclides as a Chemical of Mutual Concern under Annex 3 of the Canada-United States Great Lakes Water Quality Agreement*. Canadian Nuclear Safety Commission. September 2017. pp.51-53. http://nuclearsafety.gc.ca/pubs_catalogue/uploads/CNSC-Radionuclides-Chemicals-of-Mutual-Concern-Assessment-ENG.pdf

[30] *Decommissioning of nuclear power plants*. Canadian Nuclear Safety Commission. 3 February 2014. https://www.nuclearsafety.gc.ca/eng/resources/fact-sheets/decommissioning-of-nuclear-power-plants.cfm. Accessed 3 September 2018.

The CNSC identifies the regulatory basis for decommissioning, as defined in the following key references:

- 'Decommissioning Planning for Licensed Activities', Regulatory Guide G-219, June 2000;
- 'Financial Guarantees for the Decommissioning of Licensed Activities', Regulatory Guide G-206, June 2000; and
- 'Licensee Public Information Programs', Regulatory Guide G-217, January 2004.

The guidance indicates the production of a preliminary decommissioning plan (PDP) by the licensees as soon as possible in the lifecycle of the licensed activity. Additionally, the CNSC requires the development and updating of decommissioning plans throughout the facility lifecycle to:

- Identify the impacts of decommissioning and demonstrate that the planned decommissioning activities will remediate all significant impacts and hazards to persons and the environment;
- Ensure compliance with all applicable requirements and criteria; and
- Ensure that the financial responsibility for decommissioning is maintained by the licensee and that appropriate mechanisms are put in place to identify the costs of decommissioning, together with provisions and maintenance of adequate funding to carry out decommissioning operations.

In addition to the publications produced by the CNSC, the Canadian Standards Association (CSA) has produced guidance on the decommissioning of facilities as follows:

- CSA N294, Decommissioning of facilities containing nuclear substances; and
- CSA N292.3, Management of low- and intermediate-level radioactive waste.

Other CSA standards that are relevant to decommissioning are:

- CSA N286, Management system requirements for nuclear power plants;
- CSA N288 series on environmental management for nuclear facilities – in particular:
    - CSA N288.4, Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills
    - CSA N288.5, Effluent monitoring programs at Class I nuclear facilities and uranium mines and mills
    - CSA N288.6, Environmental risk assessments at Class I nuclear facilities and uranium mines and mills;
- CSA N292.0, General principles for the management of radioactive waste and irradiated fuel; and
- CSA N293, Fire Protection for nuclear power plants.

To gain free access to the nuclear-related CSA standards, follow the instructions on the CNSC website.[31]

For environmental regulations, once the operator submits a decommissioning license application, it will be evaluated to determine if an environmental assessment (EA) is required. The CNSC carries out EAs under the CEAA 2012 or the NSCA. Early in the process, CNSC staff determine which EA applies by reviewing the information provided by the applicant or licensee in their application and supporting documentation.

An EA under the CEAA 2012 is a planning and decision-making tool. Its objectives are to minimize or avoid adverse environmental effects before they occur and incorporate environmental factors into decision making for designated projects. An EA under the CEAA 2012 is carried out early in the licensing process (before any licence is granted) and considers the entire proposed lifecycle of a project. It includes information prepared by the applicant and CNSC staff, as well as comments received from Aboriginal groups and the public. The CNSC has developed Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the Canadian Environmental Assessment Act, 2012. The purpose of this document is to inform proponents of the information requirements for the preparation of an environmental impact statement (EIS) for a project that requires an EA under the CEAA 2012. An EIS is a report written by a proponent that presents the technical studies and findings of an EA.

An EA under the NSCA is primarily based on information that the applicant or licensee is required to submit to the CNSC through the established licensing process, such as the licence application and its supporting documentation, and information on environmental protection measures. An EA under the NSCA may also be supported by additional information from research, annual environmental monitoring reports, environmental risk assessments, the CNSC's independent environmental monitoring program (IEMP),[32] and the CNSC's compliance verification activities. An EA report under the NSCA is prepared for a project or activities at the end of the licence term and for which the proposed licence renewal or amendments are not listed in those regulations. The EA report is a summary of the technical assessments for all projects or activities regulated by the CNSC that demonstrate potential interactions with the environment. This is done to ensure that the applicant or licensee will, in carrying on a licensed activity, make adequate provision for the protection of the environment and the health of persons.

An EA will determine if there are any significant effects on human health and the environment. Along with the licensing process under the NSCA, the objective of the EA is to ensure any decommissioning activities are carried out safely and in a manner that protects workers, the

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[31] *How to gain free access to all nuclear-related CSA standards*. Canadian Nuclear Safety Commission. 16 August 2018. https://www.nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents/csa-standards.cfm. Accessed 12 October 2018.

[32] *Independent Environmental Monitoring Program (IEMP)*. Canadian Nuclear Safety Commission. 25 July 2018. http://www.nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/index-iemp.cfm . Accessed 3 August 2018.

public, and the environment. If the EA is approved, the CNSC can consider the operator's license application for decommissioning. The hearing process for the EA and issuance of the decommissioning license provides opportunities for public input.[33]

Other key legislation and regulatory guides include:

- *Impact Assessment Act, 2019;*
    - In June 2018, the Government of Canada introduced proposed legislation to replace the CEAA 2012 with the *Impact Assessment Act*, which broadens the scope of assessments to consider how a proposed project could not only result in environmental impacts, but also health, social and economic impacts, as well as impact on Indigenous peoples, over the long term. Bill C-69 passed the House of Commons in June 2018, passed the Senate in June 2019, and received Royal Assent to become law on June 21, 2019.[34] The *Impact Assessment Act* creates the new Impact Assessment Agency of Canada and repeals the *Canadian Environmental Assessment Act, 2012*.
- *Ontario Environmental Protection Act*;
    - Regulation 347: General – Waste Management
        - §1(1) Radioactive waste is defined as a "hazardous waste"
- *Ontario Water Resources Act*;
- *Ontario Occupational Health and Safety Act*; and
- National Pollutants Release Regulations.

### *3.1.3 Public Involvement*

The CNSC makes decisions on the licensing of major nuclear facilities through a public hearing process as set out in the *Canadian Nuclear Safety Commission Rules of Procedure*. The one- or two-part public hearings for licensing applications typically take place over a 90-day period. The public hearing gives involved parties, members of the public and Indigenous groups an opportunity to be heard before the CNSC. Following a public hearing, the CNSC deliberates and makes its decision. CNSC proceedings are webcast and available for viewing by interested parties.[35] Guidance for Public Information and Disclosure is described in Regulatory Document RD/DG-99.3.

The CNSC is responsible for all recommendations or decisions pertaining to licensing decisions under the NSCA and environmental assessments under the CEAA 2012 consider Aboriginal

[33] *Environmental Assessments*. Canadian Nuclear Safety Commission. 25 September 2018. http://nuclearsafety.gc.ca/eng/resources/environmental-assessments/index.cfm. Accessed 3 December 2018.
[34] *C-69 An Act to enact the Impact Assessment Act and the Canadian Energy Regulator Act, to amend the Navigation Protection Act and to make consequential amendments to other Acts*. Parliament of Canada. https://www.parl.ca/LegisInfo/BillDetails.aspx?Language=E&billId=9630600. Accessed 21 June 2019.
[35] *Watch a public Commission proceeding online*. Canadian Nuclear Safety Commission. 15 March 2018. http://www.nuclearsafety.gc.ca/eng/the-commission/webcasts/index.cfm . Accessed 20 July 2018.

groups' potential or established rights pursuant to the *Constitution Act, 1982*. The CNSC respects these commitments by informing Aboriginal groups of proposed projects, consulting with potentially impacted Aboriginal groups and encouraging participation throughout the licensing process. Aboriginal peoples are also encouraged to bring their concerns before the CNSC. Guidance to Aboriginal Engagement is described in Regulatory Document REGDOC-3.2.2.

The CNSC administers a participant funding program to give the public, Aboriginal groups and other stakeholders the opportunity to request funding to participate in matters related to licensing for major nuclear facilities. The CNSC determines whether to offer participant funding as well as the maximum amount available for each offering. The objectives of the participant funding program are:

- to enhance Aboriginal, public and stakeholder participation in the licensing process
- to help stakeholders bring valuable information to the CNSC through informed and topic-specific interventions related to aspects of licensing

More information about the participant funding program is available on the CNSC website.[36] For information on how the licensees engage with the public, see the Public Information Program section of the licensees' applications for renewal of their operating licence archived on the licensees' websites.

### *3.1.4 Decommissioning Strategies*

The CNSC recommends the following basic alternative strategies to be evaluated for each planning envelope (i.e., a definable part or area of a facility that may be planned in a relatively independent manner):

- **Prompt Decommissioning** – the reactors and stations would be dismantled and the site restored promptly after shutdown;
- **Deferred Decommissioning** – the reactors and stations would be safely stored for several decades after shutdown to allow radiation levels to decay prior to Dismantling & Demolition and Site Restoration.
- ***In-situ* Confinement** – the facility would be secured and the affected portions of the facility abandoned in place; and
- **Phased Decommissioning** – decommissioning would proceed according to a sequence of dismantling activities and periods of Safe Storage, according to the prevailing conditions (e.g., resource availability, safety, environmental and stakeholder conditions). This option would offer a hybrid or combination strategy.

Where a clear strategic preference is not immediately apparent, the CNSC recommends the alternatives strategies be compared using a simple detriment-benefit evaluation method. The

[36] *Participant Funding Program*. Canadian Nuclear Safety Commission. 22 November 2016. http://www.nuclearsafety.gc.ca/eng/the-commission/participant-funding-program/index.cfm. Accessed 14 September 2018.

evaluation method should ensure that the relative advantages and disadvantages of the remaining strategies can be objectively compared in a systematic and traceable fashion. Examples of factors that may be relevant to the evaluation of alternative decommissioning strategies include:[37]

- Forms and characteristics of radioactive and conventional contaminants
- Integrity of containment and other structures over time
- Availability of decontamination and disassembly technologies
- Potential for recycle or reuse of equipment and materials
- Availability of knowledgeable staff
- Potential environmental impacts
- Potential worker or public doses
- End-state objectives and site redevelopment pressures
- Potential revenues, costs and availability funding
- Availability of waste management and disposal capacity
- Regulatory requirements
- Public input

### *3.1.5 Phases of Decommissioning*

According to CSA N294-09, decommissioning generally consists of four phases (Figure 3-1):

a) **Phase 1, Planning for Decommissioning:** This generally begins at the design phase (or as early as possible) and continues throughout the operating life of a nuclear power generation station. A decommissioning strategy and a PDP are developed during this phase. A PDP is required for all licensed activities encompassing a facility's lifecycle and provides the basis for cost estimate for decommissioning. For major facilities, the PDP is required to be updated and reviewed every five years or when requested by the CNSC. The PDP does not authorize the conduct of decommissioning activities.

b) **Phase 2, Preparation for Decommissioning:** This phase begins with the decision to cease operations and begin decommissioning. A detailed decommissioning plan (DDP) is developed during this phase, which is required to be filed with the CNSC prior to decommissioning. The DDP is required for appropriate licensing action and refines and adds procedural and organizational detail to the PDP. The safety case in support of the DDP is the basis for the CNSC staff's recommendation and licensing decision to authorize decommissioning. Once approved, the DDP is incorporated into the licensing basis.

c) **Phase 3, Execution of Decommissioning:** This phase begins with the implementation of the DDP after regulatory approval has been obtained from the CNSC. The activities under this phase include the physical works (i.e., decontamination, Dismantling &

[37] *Decommissioning Planning for Licensed Activities: Regulatory Guide G-219*. Canadian Nuclear Safety Commission. June 2000. p.14. https://nuclearsafety.gc.ca/pubs_catalogue/uploads/G219_e.pdf

Demolition of the facility) and any periods of storage-with-surveillance between interim end states.

d) **Phase 4, Completion of Decommissioning:** This phase involves verifying that all decommissioning activities have been completed satisfactorily, the final end-state has been reached, and all documentation has been completed. Application for a Licence to Abandon is submitted to the CNSC by the licensee at this time.

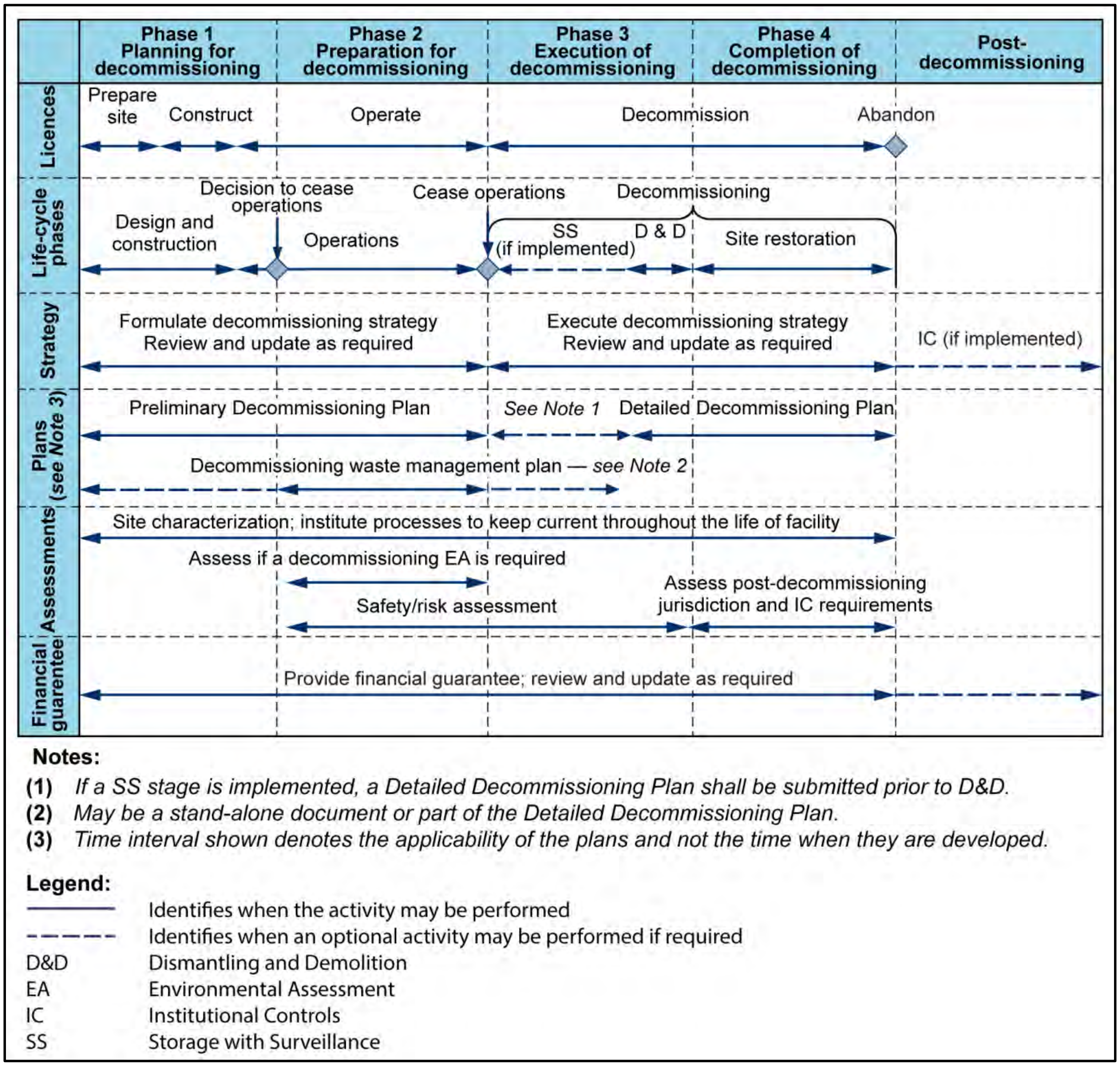


Figure 3-1. Generic phases of decommissioning and indicative timing of key activities in Canada.

Source: Figure 1, CSA N294-09, *Decommissioning of facilities containing nuclear substances*. © 2014 Canadian Standards Association. Reproduced with written permission.

### *3.1.6 Cleanup Standards*

No specific cleanup standards (i.e., release criteria) were able to be found by the researchers. The CNSC and the CSA Group were contacted for comment and replied with the following information. According to CSA N294-09, release criteria should be derived from the proposed end-state (e.g., "restricted use" or "unrestricted use"; and a generic land use such as agricultural, commercial, industrial, institutional, recreational, or residential) and end-state objectives at an appropriate stage of decommissioning planning. The end-state objectives for radiological risk should be consistent with the guidance of the International Commission on Radiological Protection (ICRP) Publication 82: *Protection of the public in situations of prolonged radiation exposure*.

More generally, SOR/2000-203 *Radiation Protection Regulations* codifies the Radiation Protection Program and sets radiation dose limits. For a member of the public, the effective dose limit is 1 mSv per calendar year. The CNSC stated in REGDOC 2.11.1, *Waste Management, Volume III: Assessing the Long-Term Safety of Radioactive Waste Management* that the "long-term safety assessment of a facility or contaminated site should provide reasonable assurance that the radiological dose limit for public exposure (currently 1 mSv/a) will not be exceeded."[38] As a reference, according to the CNSC, the annual average effective dose from natural background radiation is approximately 1.8 mSv in Canada and 2.4 mSv worldwide.[39]

Notably, the CNSC waste and decommissioning framework is currently being modernized,[40,41] including regulatory documents:

- REGDOC-1.1.4, Licence Application Guide: *Licence to Decommission Reactor Facilities* (new)
- REGDOC-1.2.1, *Repositories and Waste Facilities* (new)
- REGDOC-2.11.1, *Waste Programs* (new)
- REGDOC-2.11.2, *Decommissioning Planning* (update to G-219)
- REGDOC-3.3.1, *Financial Guarantees* (update to G-206)

These updated regulatory documents will be published in the next few years and may include specific cleanup standards.[42]

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38 *REGDOC-2.11.1, Waste Management, Volume III: Assessing the Long-Term Safety of Radioactive Waste Management*. Canadian Nuclear Safety Commission. May 2018. https://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/REGDOC-2-11-1-vol3-Assessing-the-Long-Term-Safety-eng.pdf

39 *Natural Background Radiation*. Canadian Nuclear Safety Commission. 19 November 2014. https://nuclearsafety.gc.ca/eng/resources/fact-sheets/natural-background-radiation.cfm. Accessed 14 January 2019.

40 *Canada's Approach to Decommissioning: The Regulator's Perspective*. Canadian Nuclear Safety Commission. 3 October 2017. https://www.nuclearsafety.gc.ca/eng/pdfs/Presentations/CNSC_Staff/2017/20171004-decommissioning-and-dismantling-eng.pdf

41 *The CNSC's Regulatory Framework Plan: Table*. Canadian Nuclear Safety Commission. 22 March 2018. https://nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-framework/regulatory-framework-plan-table.cfm. Accessed 22 August 2018.

42 *Regulatory documents*. Canadian Nuclear Safety Commission. 18 February 2019. http://nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents/index.cfm. Accessed 27 February 2019.

### *3.1.7 Environmental Monitoring*

The CNSC, under the NSCA, is responsible for ensuring that licensed nuclear facilities are operating in a safe manner that ensures the protection of the environment and the health and safety of people. REGDOC-2.9.1, *Environmental Protection: Environmental Principals, Assessments and Protection Measures* describes the CNSC framework and expectations for this mandate area. In accordance with the NSCA and its regulations, and as a requirement of their licences, each licensee is required to develop and maintain an environmental protection program addressing all aspects of its facility or activity with the potential to influence the environment.

The environmental protection program consists of an environmental policy with commitments to the application of as low as reasonably achievable (ALARA) for radionuclides and best available technology economically achievable (BATEA) for hazardous substances, the "polluter pays" and precautionary principles, and the concepts of pollution prevention, sustainable development and adaptive management.

The core elements to an environmental protection program for a major facility must include an:

- environmental risk assessment
- emissions and effluent monitoring program
- environmental monitoring program
- environmental management system

The relationships among these elements are shown in Figure 3-2 along with the corresponding CSA standards addressing the requirements for each element. The process commences with an environmental assessment completed under either the CEAA or the NSCA. An element of this assessment involves the completion of an environmental risk assessment (ERA) consisting of an ecological risk assessment and a human health risk assessment.

The CNSC is responsible to ensure that licensees have effective control measures (e.g., wastewater treatment systems, air pollution control technologies, engineered and administrative barriers and other techniques) in place to prevent or minimize releases to the environment. These preventative and control measures are expected to implement technologies and techniques that would be considered ALARA and BATEA. Release limits are established within the licence along with regulatory action levels. Action levels, set well below licence limits, act as an early warning system to ensure that licensees are carefully monitoring their operation and performance, and to ensure release limits are not reached.

The effluent monitoring program serves to measure the releases of radiological and hazardous substances in air and water to the environment and to ensure releases are below licence release limits. In addition, this program is required to address any additional radiological or hazardous substances identified on a site-specific basis through the ERA that merit monitoring.

An environmental monitoring program is used to measure the concentrations of nuclear and hazardous substances in different environmental media (e.g., air, water, vegetation, foodstuffs and soil) to demonstrate that abiotic and biotic components of the environment and members of the public are protected. The specifics of this monitoring program are determined by regulatory requirements and the results of the site-specific ERA.

The ERA is reviewed and updated periodically (i.e., five years or earlier) with a corresponding re-evaluation of the associated monitoring programs. Revisions to the ERA are informed by the accumulated site knowledge derived from operational experience, monitoring, special investigations, and the incorporation of advances in other knowledge (e.g., scientific). All these elements are managed within a licensee's environmental management system.

In recognition of the fact that protection of the environment in Canada is a shared federal and provincial responsibility, the CNSC cooperates with other jurisdictions and federal departments to protect the environment. Where appropriate, the CNSC may enter into formal arrangements to increase the effectiveness of environmental protection. For example, the CNSC holds memoranda of understanding with other federal departments (e.g., Fisheries and Oceans Canada, Environment and Climate Change Canada, and Health Canada).[43]

Assessments of radiological conditions are an integral part of decommissioning planning and required to be performed throughout the life of an nuclear facility. Radiation surveys are performed prior to construction to establish background conditions as well as during the operational, post-operational, decommissioning, and post-decommissioning stages.[44]

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[43] *Assessment of the Relevance of the Inclusion of Radionuclides as a Chemical of Mutual Concern under Annex 3 of the Canada-United States Great Lakes Water Quality Agreement*. pp.53-55.
[44] *Decommissioning Planning for Licensed Activities: Regulatory Guide G-219*. Canadian Nuclear Safety Commission. June 2000. p.16. https://nuclearsafety.gc.ca/pubs_catalogue/uploads/G219_e.pdf

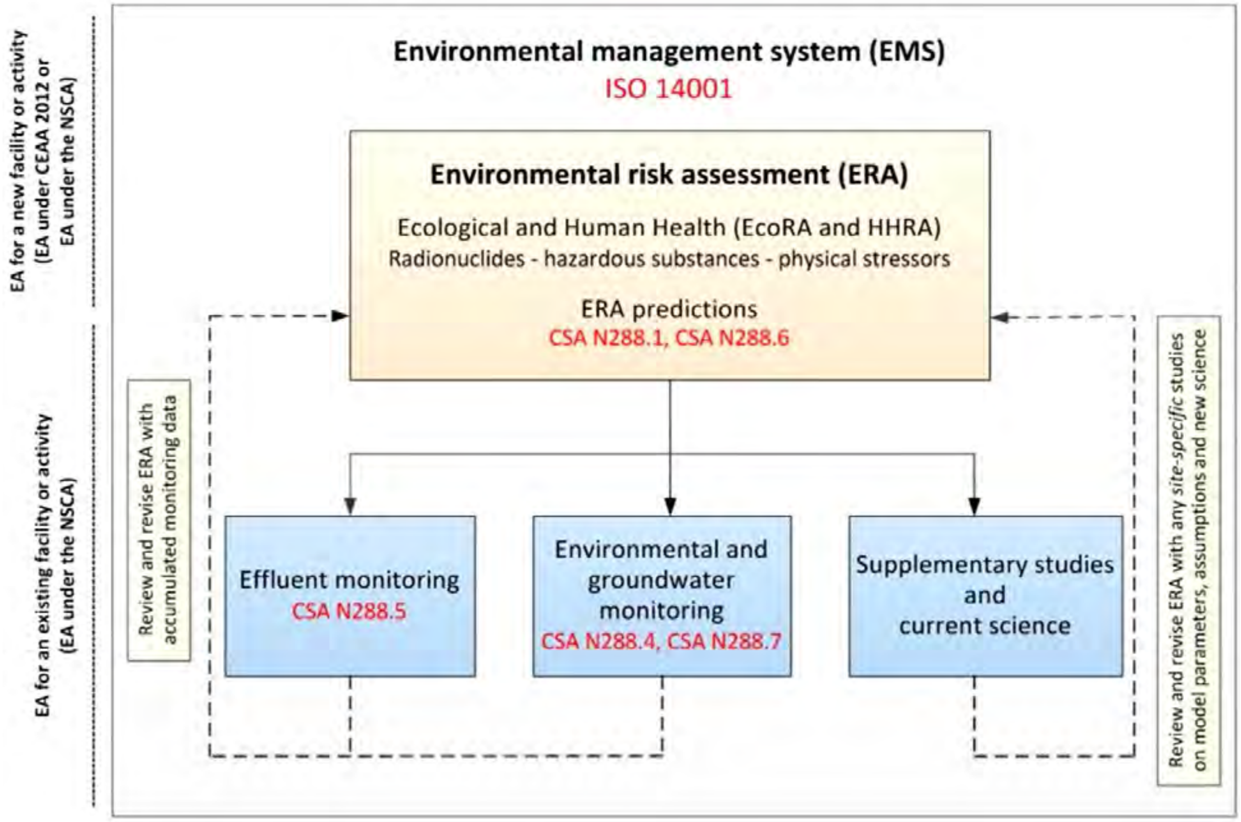


Figure 3-2. Environmental protection framework and the inter-relationship between environmental risk assessment, monitoring, and management.

Source: Figure 2, *Environmental Protection: Environmental Principles, Assessments and Protection Measures: Regulatory document REGDOC-2.9.1, version 1.1.* © 2016 Canadian Nuclear Safety Commission.

### *3.1.8 Financial Guarantees*

The NSCA and its regulations require that applicants and licensees make adequate provisions for the safe operation and decommissioning of existing or proposed operations. Safe operation and decommissioning include the development of acceptable decommissioning plans, the provision of credible estimates of the costs of implementing such decommissioning plans, the provision of corresponding measures to ensure that the costs of decommissioning will be met, and, ultimately, the implementation and completion of accepted decommissioning plans. Financial guarantees must be sufficient to cover the cost of decommissioning work resulting from licensed activities that have taken place prior to the licence period or will take place under the current licence.

Estimates of the costs of implementing proposed decommissioning plans should address all decommissioning activities required during operations and after shutdown, including management or disposal of all wastes, including spent nuclear fuel, monitoring and ongoing maintenance of any institutional controls.

To be acceptable to the CNSC, a funding measure must provide assurance that adequate resources will be available to fund decommissioning activities based on information provided to the CNSC. The financial guarantee must be at arm's length from the licensee and the CNSC must be assured that it or its agents can, upon demand, access or direct adequate funds if a licensee is not available to fulfil its obligations for decommissioning.[45]

Financial guarantees, including acceptance criteria, examples, and administration, are described in detail in Regulatory Guide G-206, *Financial Guarantees for the Decommissioning of Licensed Activities*.

### *3.1.9 Indemnification and Limitation of Liability*

The purpose of the *Nuclear Liability and Compensation Act, 2015* is to govern civil liability and compensation for damage in case of a nuclear incident. The operator's liability is codified in Sections 8-13. For financial provisions, the limit of the operator's liability for damage resulting from a nuclear incident, described in Section 24, is currently $850 million (CAD) and will increase to $1 billion on January 1, 2020. Per Section 28, financial security is to be in the form of insurance with an approved insurer containing only the terms and conditions set out in a standard insurance policy that is approved by the Minister. Per Section 31, the Minister may enter into an indemnity agreement with an operator under which Her Majesty in right of Canada covers any risks that, in the Minister's opinion, would not be assumed by an approved insurer. Per Section 32, the amounts payable by Her Majesty in right of Canada under an indemnity agreement would come from the Nuclear Liability Reinsurance Account.

[45] *Financial Guarantees for the Decommissioning of Licensed Activities: Regulatory Guide G-206*. Canadian Nuclear Regulatory Commission. June 2000. pp.7-9. https://nuclearsafety.gc.ca/pubs_catalogue/uploads/G219_e.pdf

## 3.2 U.S. Nuclear Regulatory Commission

Under the Atomic Energy Act of 1954, as amended (AEA), and the Energy Reorganization Act of 1974, Congress established the NRC to regulate the civilian use of radioactive materials in the United States. The NRC has established a regulatory framework aimed at protecting the public and environment. This framework is composed of several components, including regulations, licensing, guidance to the regulated community, oversight, enforcement, and emergency response. Applicants for an NRC license must meet the applicable regulatory requirements to obtain a license to construct and operate a nuclear reactor, and to otherwise use and possess radioactive material. These regulations are based on established engineering principles for safe plant design and operation. Before issuing a license, the NRC assesses the license application to ensure that safety measures are technically and scientifically sound, all requirements are met, and the appropriate safety systems and radioactive waste processing systems are in place to limit effluent releases to ALARA to protect the public and the environment.

When a nuclear power plant begins operation, the NRC assigns specially trained NRC staff as resident inspectors in permanent positions at the site. These NRC resident inspectors have access to all the site information and provide continual oversight and inspection of the facility. The NRC inspectors investigate whether licensees meet the regulations and the terms of their license to operate safely. When violations are identified, the NRC takes the appropriate enforcement action. The NRC requires licensees to have an emergency response organization which conducts periodic drills to demonstrate readiness in case of a plant emergency. As part of its ongoing oversight, the NRC staff routinely collects and analyzes licensed facility operational experience. The NRC staff uses this information to make appropriate changes to its regulatory framework, on a generic basis, through rulemaking and the issuance of guidance, and on a case-by-case basis, to an individual facility's licensing basis (e.g., changes to license conditions). [46]

The NRC also has a Reactor Decommissioning Inspection Program to fulfill the inspection requirements for the decommissioning of 10 CFR Part 50 power reactor licensees. This inspection program is to be implemented on or shortly after the date the licensee certifies permanent removal from the reactor vessel and is to continue during all part of decommissioning until the license is terminated.[47]

The NRC regulations are codified in Title 10, Chapter I, of the Code of Federal Regulations (CFR),[48] which the U.S. Government Publishing Office maintains and updates annually.[49]

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[46] *U.S. Nuclear Regulatory Commission Response to the Nomination of Radionuclides as Chemicals of Mutual Concern Under Annex 3 of the Great Lakes Water Quality Agreement*. U.S. Nuclear Regulatory Commission. 24 January 2017. pp.4-5. https://www.nrc.gov/docs/ML1633/ML16335A057.pdf

[47] *Decommissioning Power Reactor Inspection Program, Inspection Manual Chapter 2561*. U.S. Nuclear Regulatory Commission. 6 March 2018. https://www.nrc.gov/docs/ML1734/ML17348A400.pdf

[48] *NRC Regulations: Title 10, Code of Federal Regulations*. U.S. Nuclear Regulatory Commission. 25 February 2019. https://www.nrc.gov/reading-rm/doc-collections/cfr/.

[49] *Code of Federal Regulations (Annual Edition): Title 10*. U.S. Government Publishing Office. https://www.govinfo.gov/app/collection/cfr/2018/Title%2010.

### *3.2.1 Decommissioning Nuclear Power Plants*

When a power company decides to close a nuclear power plant permanently, the facility must be decommissioned by safely removing it from service and reducing residual radioactivity to a level that permits release of the property and termination of the operating license. The NRC has strict rules governing nuclear power plant decommissioning, involving cleanup of radioactively contaminated plant systems and structures, and removal of the radioactive fuel. These requirements are aimed at protecting workers and the public during the entire decommissioning process and the public after the license is terminated.[50]

### *3.2.2 Regulations*

The requirements for decommissioning a nuclear power plant are set out in NRC regulations codified in 10 CFR Part 20 Subpart E, and Parts 50.75, 50.82, 51.53, and 51.95. In August 1996, a revised rule went into effect that redefined the decommissioning process and required owners to provide the NRC with early notification of planned decommissioning activities. The rule allows no major decommissioning activities to be undertaken until after certain information has been provided to the NRC and the public.[51]

In accordance with the National Environmental Policy Act of 1969, as amended (NEPA), the NRC develops an Environmental Impact Statement (EIS) for the licensing of any nuclear facility. The typical review includes analysis of impact to air, water, animal life, vegetation, natural resources, and property of historic, archaeological, or architectural significance. The review evaluates cumulative, economic, social, cultural, and other impacts, and environmental justice. The EIS process begins when an applicant submits information to start construction of a nuclear facility. As part of the application, the applicant submits an Environmental Report. The NRC developed regulations that implement NEPA in 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."[52]

States do not regulate any source, by-product, or special nuclear material as defined by the Atomic Energy Act. However, a nuclear power plant must meet all non-nuclear requirements of the state, such as air emissions, hazardous waste, solid waste, Occupational Safety and Health Administration (OSHA) laws and regulations, etc.

### *3.2.3 Public Involvement*

Many components of the NRC's regulatory framework are to be transparent and include opportunities for public comment and participation in the NRC's regulatory process. For

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[50] *Backgrounder on Decommissioning of Nuclear Power Plants*. U.S. Nuclear Regulatory Commission. 15 August 2018. https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/decommissioning.html. Accessed 3 September 2018.
[51] *Ibid.*
[52] *Frequently Asked Questions About NRC's Role Under the National Environmental Policy Act*. U.S. Nuclear Regulatory Commission. 29 December 2017. https://www.nrc.gov/about-nrc/regulatory/licensing/nepa.html Accessed 3 December 2018.

example, the NRC publishes all safety related inspection findings on the agency's public website. Furthermore, the NRC publishes all proposed, substantive regulations in the *Federal Register*[53] for public comment and provides notice of its licensing actions on its public website, and in the case of all reactor licensing actions, in the *Federal Register*. In addition, the NRC provides interested parties an opportunity to request a hearing for all license issuances and amendments.[54]

For the decommissioning process, the public has several opportunities to participate. A public meeting is held in the vicinity of the facility after submittal of a post-shutdown decommissioning activities report (PSDAR) to the NRC. Another public meeting is held when NRC receives the license termination plan. An opportunity for a public hearing is provided prior to issuance of a license amendment approving the plan or any other license amendment request. In addition, when NRC holds a meeting with the licensee, members of the public may observe the meeting (except when the discussion involves proprietary, sensitive, safeguards, or classified information).[55]

For Native American tribal engagement, the NRC has developed and employs the *2017 Tribal Protocol Manual Guidance for NRC Staff*.[56] For historical context, in accordance with the *Presidential Memorandum on Tribal Coordination* issued by President Obama on November 5, 2009,[57] the NRC staff reviewed the agency's various interactions with Native American tribes and published a whitepaper on December 11, 2009.[58] As a continued effort, the NRC developed an internal protocol to guide its future interactions with Native American tribes and published the *Tribal Protocol Manual: Guidance for NRC Employees* in March 2010.

The guiding principles of the NRC's Tribal Policy Statement are:

1. The NRC recognizes the federal trust relationship with and will uphold its trust responsibility to Indian Tribes.
2. The NRC recognizes and is committed to government to government relationship with Indian Tribes.
3. The NRC will conduct outreach to Indian Tribes
4. The NRC will engage in timely consultation
5. The NRC will coordinate with other federal agencies.

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53 *Federal Register: The Daily Journal of the United States Government*. https://www.federalregister.gov

54 *U.S. Nuclear Regulatory Commission Response to the Nomination of Radionuclides as Chemicals of Mutual Concern Under Annex 3 of the Great Lakes Water Quality Agreement*. p.5.

55 *Backgrounder on Decommissioning of Nuclear Power Plants.*

56 *Tribal Protocol Manual*. U.S. Nuclear Regulatory Commission. 10 October 2017. https://www.nrc.gov/about-nrc/state-tribal/tpm.html

57 *Presidential Memorandum on Tribal Consultation*. The White House: Office of the Press Secretary. 5 November 2009. https://obamawhitehouse.archives.gov/the-press-office/memorandum-tribal-consultation-signed-president

58 *U.S. Nuclear Regulatory Commission Interaction with Native American Tribes*. Charles L. Miller, Director of the Office of Federal and State Materials and Environmental Management Programs. 11 December 2009. https://www.nrc.gov/reading-rm/doc-collections/commission/secys/2009/secy2009-0180/2009-0180scy.pdf

6. The NRC will encourage participation by State-Recognized Tribes.

The methods of tribal consultation are described in detail in Section 2.B of the *2017 Tribal Protocol Manual Guidance for NRC Staff*.[59]

### *3.2.4 Decommissioning Strategies*

Licensees may choose from three decommissioning strategies: DECON, SAFSTOR or ENTOMB.

Under DECON (immediate dismantling), soon after the nuclear facility closes, equipment, structures, and portions of the facility containing radioactive contaminants are removed or decontaminated to a level that permits release of the property and termination of the NRC license.

Under SAFSTOR, often considered "deferred dismantling," a nuclear facility is maintained and monitored in a condition that allows the radioactivity to decay; afterwards, the plant is dismantled and the property decontaminated.

Under ENTOMB, radioactive contaminants are permanently encased onsite in structurally sound material such as concrete. The facility is maintained and monitored until the radioactivity decays to a level permitting restricted release of the property. To date, no NRC-licensed facilities have requested this option.

The licensee may also choose to adopt a combination of the first two choices in which some portions of the facility are dismantled or decontaminated while other parts of the facility are left in SAFSTOR. The decision may be based on factors besides radioactive decay, such as availability of waste disposal sites.

Decommissioning must be completed within 60 years of the plant ceasing operations. A time beyond that would be considered only when necessary to protect public health and safety in accordance with NRC regulations.[60]

### *3.2.5 Phases of Decommissioning*

The requirements for nuclear reactor decommissioning activities may be divided into three phases: (1) transition; (2) major decommissioning and storage; and (3) license termination activities.[61]

#### *1. Transition from Operation to Decommissioning*

When a nuclear reactor licensee shuts down the reactor permanently, it must submit a written certification of permanent cessation of operations to the NRC within 30 days. When radioactive

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[59] *2017 Tribal Protocol Manual: Guidance for NRC Staff* (NUREG-2173, Revision 1). U.S. Nuclear Regulatory Commission. 2017. p.15. https://www.nrc.gov/docs/ML1719/ML17193A424.pdf

[60] *Backgrounder on Decommissioning of Nuclear Power Plants.*

[61] *Ibid.*

nuclear fuel is permanently removed from the reactor vessel, the owner must submit another written certification to the NRC, surrendering its authority to operate the reactor or load fuel into the reactor vessel. This eliminates the obligation to adhere to certain requirements needed only during reactor operation. Other requirements are currently eased through exemptions and license amendments; several of these transitional changes will be included in the new regulations under development.

Within two years after submitting the certification of permanent closure, the licensee must submit a PSDAR to the NRC. This report provides a description of the planned decommissioning activities, a schedule for accomplishing them, and an estimate of the expected costs. The report must discuss the reasons for concluding that environmental impacts associated with the site-specific decommissioning activities have already been addressed in previous environmental analyses. Otherwise, the licensee must request a license amendment for approval of the activities and submit to the NRC details on the additional impacts of decommissioning on the environment.

After receiving the report, the NRC publishes a notice of receipt in the *Federal Register*, makes the report available for public review and comment, and holds a public meeting near the plant to discuss the licensee's intentions.

### *2. Major Decommissioning Activities*

Ninety days after the NRC receives the planning report, the owner can begin major decommissioning activities without specific NRC approval. These include permanent removal of such major components as the reactor vessel, steam generators, large piping systems, pumps, and valves.

However, decommissioning activities conducted without specific prior NRC approval must not prevent release of the site for possible unrestricted use, result in there being no reasonable assurance that adequate funds will be available for decommissioning, or cause any significant environmental impact not previously reviewed. If any decommissioning activity does not meet these terms, the licensee is required to submit a license amendment request, which would provide an opportunity for a public hearing.

Initially, the owner can use up to three percent of its set-aside funds for decommissioning planning. The remainder becomes available 90 days after submittal of the planning report unless the NRC staff has raised objections.

### *3. License Termination Activities*

The owner is required to submit a license termination plan within two years of the expected license termination. The plan addresses each of the following: site characterization, remaining site dismantlement activities, plans for site remediation, detailed plans for final radiation surveys for release of the site, updated estimates of remaining decommissioning costs, and a supplement to the environmental report describing any new information or significant environmental changes associated with the final cleanup. Most plans envision releasing the site to the public for unrestricted use, meaning any residual radiation would be below NRC's limits of 25 millirem annual exposure and there would be no further regulatory controls by the NRC. Any plan proposing release of a site for restricted use must describe the site's end use, public consultation, institutional controls, and financial assurance needed to comply with the requirements for license termination for restricted release.

The license termination report requires NRC approval of a license amendment. Before approval can be given, an opportunity for hearing is published and a public meeting is held near the plant site.

The NRC uses a standard review plan (NUREG-1700, Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans) to ensure high quality and uniformity of the license termination plan reviews.

If the remaining dismantlement has been performed in accordance with the approved license termination plan and the NRC's final survey demonstrates that the facility and site are suitable for release, the NRC issues a letter terminating the operating license.

Current updates of all power reactor sites undergoing decommissioning are available on the NRC website.[62] Reactors undergoing decommissioning in the Great Lakes basin are described in section *6. Closed Nuclear Power Stations* of this report.

### *3.2.6 Cleanup Standards*

Following the completion of decontamination, dismantlement and remediation activities, radiological surveys are performed to demonstrate that the dose from any residual radioactivity remaining in as-left structure basements and soils to the unrestricted release criteria as specified in 10 CFR 20.1402, which states:

> A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent to an average member of the critical group that does not exceed 25 millirem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are ALARA. Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.

As a reference, according to the NRC, a U.S. resident receives an average annual radiation exposure from natural sources of about 310 millirem (3.1 mSv). Radon and thoron gases account for two-thirds of this exposure. Cosmic, terrestrial, and internal radiation account for the rest.[63]

[62] *Locations of Power Reactor Sites Undergoing Decommissioning*. U.S. Nuclear Regulatory Commission. 31 December 2018. https://www.nrc.gov/info-finder/decommissioning/power-reactor/ . Accessed 2 January 2019.

### *3.2.7 Environmental Monitoring*

For operating reactors, the licensee is required to submit to the NRC an Annual Radiological Environmental Operating Report and a Radiological Effluent Release Report by May 15 each year for the previous calendar year pursuant to 10 CFR 50.36a(a)(2). These reports specify the quantity of each of the principal radionuclides released to unrestricted areas in liquid and in gaseous effluents during the previous 12 months, including any other information as may be required by the NRC to estimate maximum potential annual radiation doses to the public resulting from effluent releases. If quantities of radioactive materials released during the reporting period are significantly above design objectives, the reports must cover this specifically. Based on these reports and any additional information the NRC may obtain from the licensee or others, the NRC may require the licensee to act as the NRC deems appropriate. These reports are publicly accessible on the NRC webpage for each operating reactor[64] in the Key Documents section via the Plant Environmental Report link.

For ISFSIs, the licensee is required to submit an annual Radiological Environmental Operating Report and an annual ISFSI Radioactive Effluent Release Report pursuant to 10 CFR 72.44. The Radiological Environmental Monitoring Program (REMP) is described in the Offsite Dose Calculation Manual (ODCM) for each licensed facility. These reports are publicly accessible via the NRC ADAMS.[65]

### *3.2.8 Financial Guarantees*

Before a nuclear power plant begins operations, the licensee must establish or obtain a financial mechanism – such as a trust fund or a guarantee from its parent company – to ensure there will be sufficient money to pay for the ultimate decommissioning of the facility. Each nuclear power plant licensee must report to the NRC every two years the status of its decommissioning funding for each reactor or share of a reactor that it owns. The report must estimate the minimum amount needed for decommissioning by using the formulas found in 10 CFR 50.75.[66] These biennial Decommissioning Funding Status Reports include the following information:

1. The minimum decommissioning fund estimate, pursuant to 10 CFR 50.75 (b) and (c)
2. The amount accumulated at the end of calendar year preceding the date of the report for items included in 10 CFR 50.75 (b) and (c)
3. The schedule of the annual amounts remaining to be collected for items in 10 CFR 50.75 (b) and (c)

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63 *Backgrounder on Biological Effects of Radiation*. U.S. Nuclear Regulatory Commission. 22 May 2017. https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/bio-effects-radiation.html/. Accessed 14 January 2019.

64 *Operating Reactors*. U.S. Nuclear Regulatory Commission. 13 December 2018. https://www.nrc.gov/reactors/operating.html/. Accessed 14 December 2018.

65 *ADAMS Public Documents*. U.S. Nuclear Regulatory Commission. https://www.nrc.gov/reading-rm/adams.html

66 *Backgrounder on Biological Effects of Radiation.*

4. The assumptions used regarding escalation in decommissioning cost, rates of earnings on decommissioning fund, and rates of other factors used in funding projection.
5. Any contracts upon which the licensee is relying pursuant to 10 CFR 50.75(e)(1)(v).
6. Any modifications to the current method of providing financial assurance occurring since the last submitted report.
7. Any material changes to the trust agreement.

The NRC formulas in section 10 CFR 50.75(c) include only those decommissioning costs incurred by licensees to remove a facility or site safely from service and reduce residual radioactivity to levels that permit: (1) release of the property for unrestricted use and termination of license; or (2) release of the property under restricted conditions and termination of the license. The cost of dismantling or demolishing non-radiological systems and structures is not included in the NRC decommissioning cost estimates. The costs of managing and storing spent nuclear fuel onsite until transfer to DOE are not included in the cost formulas.

Although there are many factors that affect reactor decommissioning costs, generally they range from $300 million to $400 million (USD). Approximately 70 percent of licensees are authorized to accumulate decommissioning funds over the operating life of their plants. These owners – generally traditional, rate-regulated electric utilities or indirectly regulated generation companies – are not required today to have all of the funds needed for decommissioning. The remaining licensees must provide financial assurance through other methods such as prepaid decommissioning funds and/or a surety method or guarantee. The staff performs an independent analysis of each of these reports to determine whether licensees are providing reasonable "decommissioning funding assurance" for radiological decommissioning of the reactor at the permanent termination of operation.[67]

For management and interim storage of spent fuel (e.g., ISFSI) pursuant to [10 CFR 72.30(c)](), at the time of license renewal and at intervals not to exceed three years, the decommissioning funding plan must be resubmitted with adjustments as necessary to account for changes in costs and the extent of contamination. If the amount of financial assurance will be adjusted downward, this cannot be done until the updated decommissioning funding plan is approved. The decommissioning funding plan must update the information submitted with the original or prior approved plan and must specifically consider the effect of the following events on decommissioning costs:

1. Spills of radioactive material producing additional residual radioactivity in onsite subsurface material.
2. Facility modifications.
3. Changes in authorized possession limits.
4. Actual remediation costs that exceed the previous cost estimate.

67 *Ibid.*

### *3.2.9 Indemnification and Limitation of Liability*

Section 170 of the Atomic Energy Act, "Indemnification and Limitation of Liability" (the Price-Anderson Act or AEA), establishes an indemnification and public liability scheme for damages resulting from nuclear power reactor incidents. Title 10 of the CFR Part 140, "Financial Protection Requirements and Indemnity Agreements," implements the AEA for NRC licensees.

Section 170(b)(1) of the AEA establishes that the amount of primary financial protection required for a nuclear power plant is the amount of liability insurance available from private sources, except that for reactors with less than 100 megawatts electric (MWe), the NRC may require a lesser amount for reactors based on several factors. Such factors include, but are not limited to, the cost of insurance; the size, location, and type of licensed activity; and the nature and purpose of the licensed activity. Section 170(b)(1) of the AEA requires that licensees for reactors above 100 MWe carry the maximum amount of insurance available from private sources and participate in a secondary retrospective insurance plan in a specified amount per facility in the event of a nuclear incident. The NRC is required at least once every five years to adjust these numbers for inflation. As of December 22, 2011, the retrospective premium per reactor per nuclear incident was $111.9 million, with a maximum annual contribution being $17.5 million (USD) per nuclear reactor [AEA, Section 170b.(1) and t]. With 104 nuclear reactors participating in the plan, the total amount of financial protection was approximately $12 billion (USD).

Consistent with the AEA, the regulation at 10 CFR 140.11, "Amounts of Financial Protection for Certain Reactors," states that nuclear reactors designed for the production of 100,000 electrical kilowatts (100 MWe) or more are required to carry $375 million (USD) of liability insurance. Currently, this sum is the maximum amount of liability insurance available from private sources. Section 140.11 also requires that each licensee of a facility above 100 MWe will, in the event of a nuclear incident that results in public liability in excess of the amount of primary liability insurance carried by the licensee where the incident occurred, contribute up to $111.9 million towards public liability and no more than $17.5 million (USD) per reactor within one calendar year.

The AEA requires the NRC to treat a combination of facilities above 100 MWe but below 300 MWe each, with a combined rated capacity of no more than 1,300 MWe, as a single facility for public liability insurance purposes [AEA, Section 170b.(5)(A) and (B)]. The AEA is silent as to a combination of facilities below 100 MWe.

Section 170(c) of the AEA provides the framework for the indemnification of NRC licensees. In those instances where the required financial protection is less than $560 million, the NRC will indemnify that licensee up to $500 million (USD). [68]

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[68] *Insurance and Liability Regulatory Requirements for Small Modular Reactor Facilities*. Johnson, Michael R. 22 December 2011. pp.1-2. https://www.nrc.gov/reading-rm/doc-collections/commission/secys/2011/2011-0178scy.pdf

# 4. Radioactive Waste Management

Radioactive waste is classified and managed differently in Canada and the United States.

## 4.1 Radioactive Waste Management in Canada

The CNSC regulates facilities that process, store or dispose of radioactive waste and the remediation and management of legacy sites. In accordance with Canada's Radioactive Waste Policy Framework developed by Natural Resources Canada, it is the owners of radioactive waste who are responsible for the funding, organization, management, and operation of disposal and other facilities required for their waste.

Radioactive waste can be defined as materials within the CNSC's mandate that contain licensable quantities of nuclear substances for which no future use or benefit is foreseen. Just as there are a wide variety of uses for nuclear substances, the amounts, types, physical forms and hazards of radioactive waste also vary considerably. Consequently, radioactive waste can be subdivided into categories based on its characteristics, including hazard.[69]

### *4.1.1 Radioactive Waste Classification*

To increase clarity and consistency, the CNSC formally adopted the waste categories as defined in CSA N292.0-14, *General Principles for the Management of Radioactive Waste and Irradiated Fuel*, for use in its regulatory framework. CSA N292.0-14 reflects international guidance from the IAEA, including IAEA General Safety Guide GSG-1, *Classification of Radioactive Waste*. CSA N292.0-14 calls for four specific radioactive waste categories. Low-level, intermediate-level, and high-level waste categories are defined by specific constraints based on their overall characterization (Table 4-1). The category of uranium mine and mill tailings is the only proposed waste classification defined by its source.

Low-level radioactive waste (LLW) is generated from hospitals, laboratories and industry, as well as the nuclear fuel production cycle. This waste typically consists of contaminated protective clothing, rags, mops, filters, medical tubes, swabs, needles, syringes, laboratory animal carcasses and tissues, equipment, waste from refurbishment activities such as steam generators, and reactor water treatment residues, which all contain small amounts of short-lived radioactivity. Waste may also be produced during the manufacture of devices such as certain gauges, luminous watches, exit signs and smoke detectors, which contain radioactive material. These wastes are not particularly dangerous to handle if managed properly but must be disposed of more carefully than conventional waste. LLW does not generally require significant shielding during handling and interim storage. Shielding refers to a barrier (e.g., a concrete wall or

[69] DIS-16-03, *Radioactive Waste Management and Decommissioning*. Canadian Nuclear Safety Commission. 13 May 2016. https://nuclearsafety.gc.ca/eng/acts-and-regulations/consultation/comment/d-16-03/index.cfm. Accessed 3 September 2018.

protective clothing) between contaminated waste and workers. LLW may require isolation and containment for periods of up to 300 years. In the long term, LLW may be suitable for surface or near-surface storage; e.g., in a manner similar to that of a municipal landfill but designed for nuclear waste. By volume, about 90 percent of all radioactive waste is considered to be LLW. Despite this, LLW contains just one percent of the radioactivity of all radioactive waste generated.

Intermediate-level radioactive waste (ILW) contains higher amounts of radioactivity and may require special shielding, both in the short- and long-term. It typically comprises resins, chemical sludge, and reactor components from reactor refurbishment or decommissioning. ILW makes up seven percent of the volume of radioactive waste in Canada and contains four percent of the radioactivity of all radioactive waste. Generally, short-lived waste, mainly from reactors, is isolated in engineered, near-surface facilities. Longer-lived waste (e.g., some radioactive sources used in radiation therapy) is stored in shielded surface or near surface facilities. The owners of ILW are responsible for managing the waste they produce. This usually takes place onsite, within the facility. ILW that requires long-term management may also be returned to the manufacturer or transferred to an authorized waste management operator.

Most high-level radioactive waste (HLW) is used fuel from nuclear reactors. Other waste forms derived from irradiated nuclear fuel, such as waste from medical isotope production, can also exhibit similar characteristics and are also considered HLW. Irradiated nuclear fuel also contains significant quantities of long-lived radionuclides, requiring long-term isolation and containment. Irradiated fuel is currently transferred directly to pools of water to assist in cooling for several years. The water also acts as a shield from the radiation. After several years the used fuel is moved to “dry-storage” in shielded above-ground containers stored on the reactor site. HLW is managed by its owners, usually onsite. The inventory of HLW at any site is subject to strict security and verification by both the CNSC and the IAEA. HLW accounts for 95 percent of the total radioactivity of all nuclear waste.[70]

[70] *Ibid.*

**Table 4-1**. CNSC Radioactive Waste Classification

| Limits | Low-Level Waste (LLW) | Intermediate-Level Waste (ILW) | High-Level Waste (HLW) |
|---|---|---|---|
| **Alpha** | < 400 Bq/g average, but not exceeding 4,000 Bq/g for individual packages | No limit | No limit |
| **Long-lived beta/gamma** (C-14, Cl-36, Ni-63, Zr-93, Nb-94, Tc-99, and I-129) | Ranges to tens of kBq/g and may be specific to the site and disposal facility | No limit | No limit; typical levels of $10^4$ to $10^6$ $TBq/m^3$ |
| **Unshielded contact dose rate** | < 2 mSv/h | > 2 mSv/h | No limit |
| **Thermal power** | None | < 2 $kW/m^3$ | No limit |

Source: DIS-16-03, *Radioactive Waste Management and Decommissioning*. Canadian Nuclear Safety Commission. 13 May 2016. https://nuclearsafety.gc.ca/eng/acts-and-regulations/consultation/comment/d-16-03/index.cfm

### *4.1.2 OPG's Proposed Low and Intermediate Level Deep Geologic Repository*

Ontario Power Generation Inc. (OPG) is an Ontario-based electricity generation company whose principal business is the generation of electricity in Ontario. OPG was established under the *Business Corporations Act* (Ontario) and is wholly owned by the Province of Ontario. OPG's nuclear fleet is comprised of the Bruce (see *Section 5.1*), Darlington (see *Section 5.2*), and Pickering Nuclear Generating Stations (see *Section 6.1*).

Since the early 1970s, the low- and intermediate-level radioactive waste (L&ILW) produced as a result of the operation of these facilities has been stored centrally at OPG's Western Waste Management Facility (WWMF) located on the Bruce Nuclear Site in the Municipality of Kincardine, Bruce County, Ontario. OPG and the CNSC consider the existing storage practices to be safe and could be continued safely for many decades. However, given that the wastes remain radioactive for thousands of years, long-term management is required. Consistent with international best practices, OPG's plan for the safe, long-term management of L&ILW produced at its facilities is to develop a deep geologic repository (DGR) capable of safely isolating the waste from people and the environment over the time frame that the wastes remain radioactive (i.e., thousands of years).

Only L&ILW from OPG-owned or operated nuclear generating stations in Ontario would be accepted in the proposed DGR. The DGR facility would manage about 200,000 cubic meters (7,062,933 $ft^3$) of L&ILW. All project activities would be undertaken under the regulatory oversight of the CNSC and other government agencies. The project would be constructed using conventional mining techniques, operated using established radioactive waste management practices, decommissioned using conventional practices and natural processes, and would include mitigation and follow-up as required.

Under a separate process, the Nuclear Waste Management Organization (NWMO) is responsible for implementing Adaptive Phased Management for the long-term management of spent nuclear fuel (see *Section 4.1.3*).

According to OPG's project overview,[71] the DGR project began in 2001 when the Municipality of Kincardine approached OPG to enter preliminary discussions on the long-term management of L&ILW. In late 2005, following completion of an Independent Assessment Study, negotiation of a Host Community Agreement, and community poll indicating support for moving forward with the project, the regulatory approvals process for the DGR was initiated with the submission of the DGR Project Description. In 2010, the DGR's four-year program of studies, investigations and analyses was completed. On January 24, 2012, the Minister of the Environment and the President of the CNSC established the Joint Review Panel (JRP or Panel) to undertake the review of the project under the *Canadian Environmental Assessment Act* and the *Nuclear Safety and Control Act*.

On May 6, 2015, after three years of technical studies and 33 public hearings, the JRP's Environmental Assessment Report was publicly released. According to the report,[72] OPG proposed to construct the DGR approximately 1.2 kilometers (0.75 miles) from the shore of Lake Huron, near the existing WWMF (Figure 4-1). The DGR would be constructed in Ordovician limestone in the Cobourg Formation, which is estimated to be 450 million-year-old rock, at a depth of approximately 680 meters (2,230 feet). The underground facilities would include two shafts, tunnels, emplacement rooms and various underground service areas and installations. The surface facilities would include underground access and ventilation buildings, a waste package receiving building and related infrastructure. The total surface footprint of the DGR would be approximately 30 hectares (74 acres) and the underground facilities would encompass approximately 40 hectares (99 acres).

In their conclusions, the Panel determined that the DGR is the preferred solution for the long-term management of L&ILW where it would be separated from the biosphere by multiple geological barriers, which would be a safer solution over the long term than the current method of storage at the WWMF. The Panel stated that the proposed DGR should proceed sooner rather than later and affirmed that the proposed DGR would not be for the disposal of spent nuclear fuel (i.e., high-level radioactive waste).

The Panel concluded that locating a DGR at the Bruce Nuclear Site is appropriate and not likely to cause significant adverse effects on the water quality or aquatic ecosystems of MacPherson Bay, Lake Huron or the other Great Lakes, provided that mitigation measures, including the Panel's recommendations, are implemented.

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[71] *OPG's Deep Geologic Repository Project for Low & Intermediate Level Waste: L&ILW DGR Overview*. Ontario Power Generation. February 2013. https://www.opg.com/document/dgr-overview-brochure-feb-2013-pdf/.

[72] *Joint Review Panel Environmental Assessment Report – Deep Geologic Repository for Low and Intermediate-level Radioactive Waste Project*. CEAA Reference No. 17520. 6 May 2015. © Her Majesty the Queen in Right of Canada. https://www.ceaa-acee.gc.ca/050/documents/p17520/101595E.pdf

Concerning Aboriginal interests, the Panel acknowledged and encouraged the communication and relationship-building with OPG that was described by Aboriginal groups over the course of the review. The Panel expects that discussions of potential effects on traditional uses and resources will continue as part of the individual agreements entered into between OPG, the Saugeen Ojibway Nation, Métis Nation of Ontario and Historic Saugeen Métis. The Panel also noted CNSC's commitment to ongoing consultation with Aboriginal groups associated with this project.

Overall, the Panel concluded that the project is not likely to cause significant adverse environmental effects, taking into account the implementation of the mitigation measures committed to by OPG together with the mitigation measures recommended by the Panel.

In response to the Joint Review Panel's Environmental Assessment Report, the Canadian government requested additional information from OPG, including the impact on the physical and cultural heritage of the Saugeen Ojibway Nation (SON). OPG has continued to engage in dialogue with the SON, which is expected to make a community decision regarding their support of the proposed DGR around the end of 2019. After the SON's decision, OPG would still require federal approvals of the Environmental Assessment, construction licence, and once built an operating licence.

Pending licensing approval, site preparation and construction of the DGR is anticipated to take approximately eight to ten years to complete, followed by an operations phase. The operations phase would include approximately 35 to 40 years when waste will be emplaced, followed by a period of post-emplacement monitoring to confirm the facility's performance. The decommissioning, and abandonment and long-term performance phases would follow the operations phase, including a period of institutional control for up to 300 years (Figure 4-2).[73]

The construction cost of the DGR is estimated to be approximately $1 billion (2011 CAD). An existing segregated fund established by OPG (Decommissioning Fund), which has been accumulating funds as part of electricity rates, will be used to pay the cost of the DGR Project.[74] To date, approximately $220 million of the construction cost has been incurred for the site studies, project design, consultations and public reviews, and related processes.[75] The project lifecycle cost is estimated to be $2.4 billion (2017 CAD) at the proposed Bruce Nuclear Site. OPG estimated the alternate project sites would cost an additional $1.2 billion to $3.5 billion due to the range of activities that would be required for an alternate location, including a multi-year consent-based siting process, acquisition of land, development and implementation of services to support facility operation, repackaging and transportation, and restarting the regulatory approvals

[73] *OPG's Deep Geologic Repository Project for Low & Intermediate Level Waste: Environmental Impact Statement. Volume 1: Main Report* (00216-REP-07701-00001 R000). Prepared by Golder Associates Ltd. March 2011. https://www.ceaa.gc.ca/050/documents_staticpost/17520/49818/vol1.pdf.
[74] *Ibid.*
[75] Personal communication with Fred Kuntz, Senior Manager, Corporate Relations and Projects Bruce County. Ontario Power Generation. 22 July 2019.

and licensing process. OPG's alternate locations study also demonstrated that there would be more environmental effects of a DGR at an alternate location than the environmental effects of the DGR Project at the Bruce Nuclear Site.[76]

Detailed findings are presented in the Environmental Impact Statement (EIS) and Technical Support Documents. These documents, along with the Preliminary Safety Report (PSR) and supporting documents, can be accessed on the OPG website[77] and the Canadian Environmental Assessment Agency website.[78] A summary of the proposed DGR, including the latest news, licensing progress details, environmental assessments, and regulator responses are publicly available on the CNSC website.[79]

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[76] *OPG's Deep Geologic Repository Project for Low & Intermediate Level Waste: Study of Alternate Locations Main Submission* (00216-REP-07701-00013). December 2016. https://ceaa-acee.gc.ca/050/documents/p17520/116727E.pdf

[77] *Deep Geologic Repository*. Ontario Power Generation. 2019. http://www.opg.com/dgr

[78] *Deep Geologic Repository Project for Low and Intermediate Level Radioactive Waste*. Canadian Environmental Assessment Agency. 9 January 2019. https://www.ceaa.gc.ca/050/evaluations/proj/17520

[79] *Ontario Power Generation Deep Geologic Repository*. Canadian Nuclear Safety Commission. 22 August 2017. http://nuclearsafety.gc.ca/eng/resources/status-of-new-nuclear-projects/deep-geologic-repository/index.cfm. Accessed 17 July 2019.

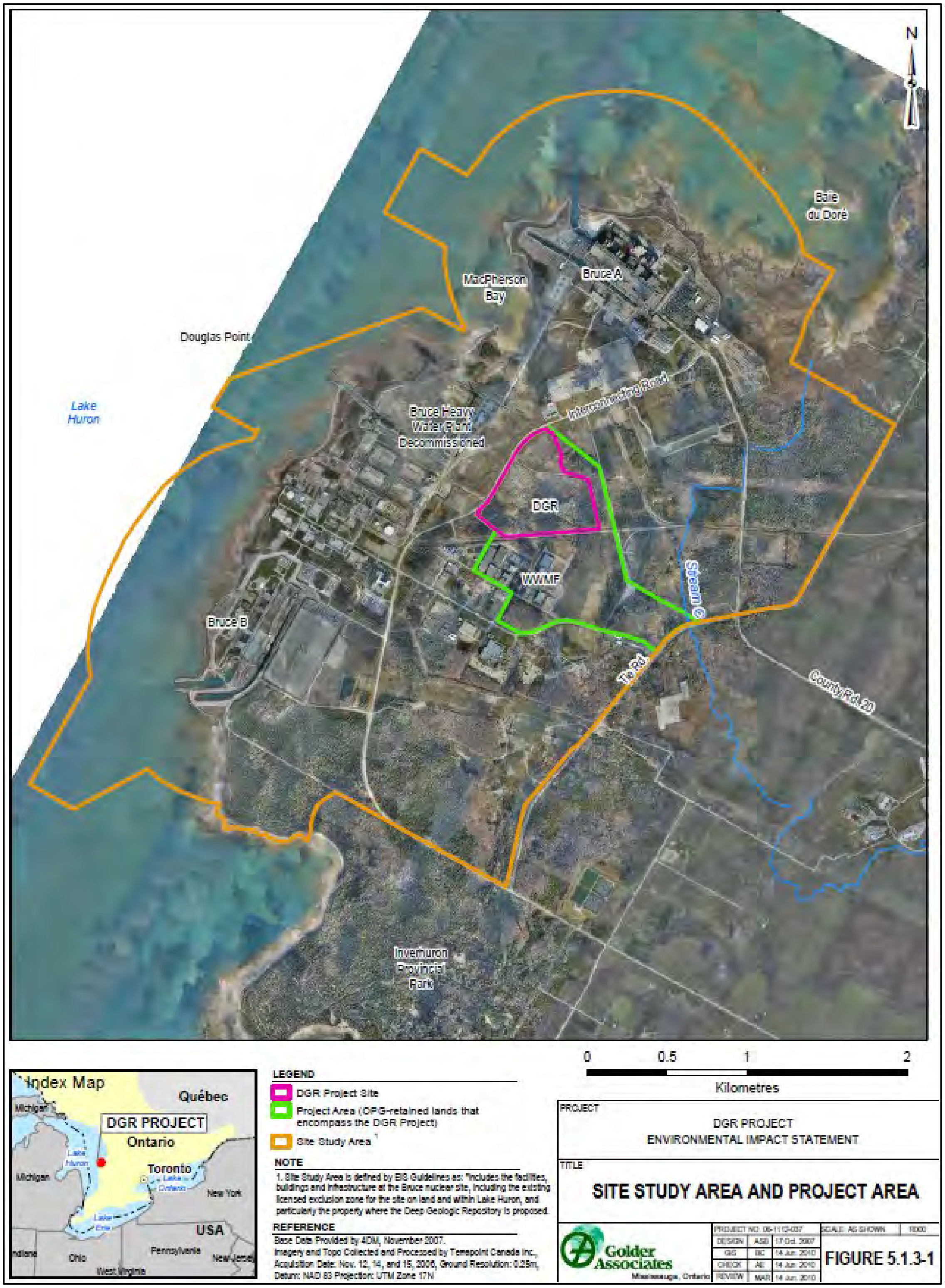


**Figure 4-1**. Ontario Power Generation's Proposed Deep Geologic Repository site study area and project area.

Source: Figure 5.1.3-1, *OPG's Deep Geologic Repository Project for Low & Intermediate Level Waste: Environmental Impact Statement. Volume 1: Main Report* (00216-REP-07701-00001 R000). Prepared by Golder Associates Ltd. March 2011. https://www.ceaa.gc.ca/050/documents_staticpost/17520/49818/vol1.pdf.

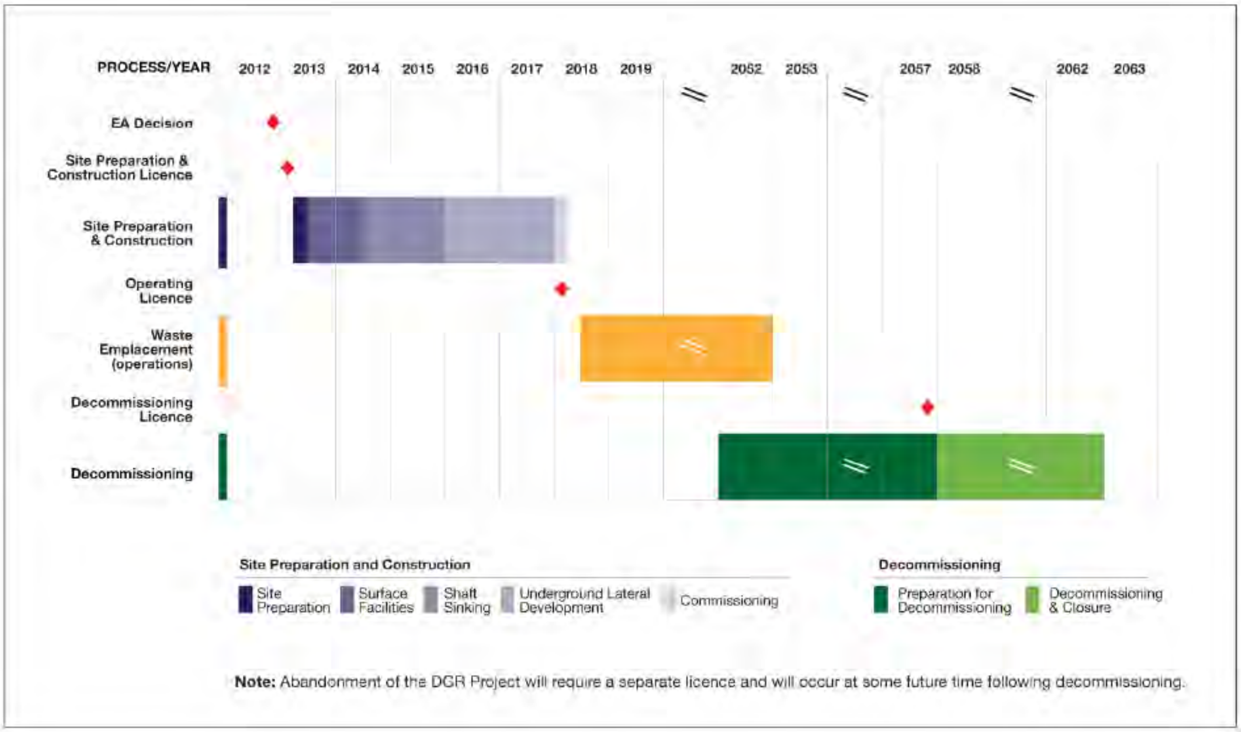


Figure 4-2. Ontario Power Generation's Proposed Deep Geologic Repository Project timeline.

Source: Figure 4.2-1, *OPG's Deep Geologic Repository Project for Low & Intermediate Level Waste: Environmental Impact Statement. Volume 1: Main Report* (00216-REP-07701-00001 R000). Prepared by Golder Associates Ltd. March 2011. https://www.ceaa.gc.ca/050/documents_staticpost/17520/49818/vol1.pdf.

### *4.1.3 Nuclear Waste Management Organization*

The Nuclear Waste Management Organization (NWMO)[80] is responsible for designing and implementing Canada's plan for the safe, long-term management of spent nuclear fuel. The NWMO is a not-for-profit organization established in 2002 by Canada's nuclear electricity producers in accordance with the *Nuclear Fuel Waste Act* (NFWA).[81] The founding members of the NWMO are Ontario Power Generation (OPG), New Brunswick Power Corporation, and Hydro-Québec (HQ). These organizations, along with Atomic Energy of Canada Limited (AECL), are mandated to fund NWMO's operations.

The plan, known as Adaptive Phased Management, emerged from dialogue with specialists and aims to be consistent with international best practice. The plan requires spent nuclear fuel to be contained and isolated in a deep geological repository (DGR). It also calls for a comprehensive process to select an informed and willing host for the project.

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

81 *Nuclear Fuel Waste Act* (S.C. 2002, c. 23). Justice Laws Website. 22 February 2019. https://laws-lois.justice.gc.ca/eng/acts/N-27.7/. Accessed 27 February 2019.

The DGR is being planned to utilize a multiple barrier system, both engineered and natural, to contain and isolate the spent nuclear fuel about 500 meters (1,640 feet) deep, depending on the nature of the geology (Figure 4-3). The goal of the DGR is to protect humans and the environment over the long-term. The spent nuclear fuel is planned to be continuously monitored both during and following operations and to be retrievable for an extended period. The NWMO has stated its commitment to meet or exceed all applicable regulatory standards and requirements for protecting the health, safety, and security of people and the environment.

In May 2010, the NWMO initiated a voluntary site selection process to seek a willing and informed host with suitable geology. The site selection process requires that communities in an area must take the initiative to enter and move through the process. The process is to be collaborative. Interested communities are encouraged to begin a process of study and engagement, involving First Nation and Métis communities, as well as municipalities in the surrounding area. The project goal is to only proceed with interested communities, First Nation and Métis communities, and surrounding municipalities working together to implement it.

By 2012, 22 communities contacted the NWMO to express interest and learn more about the process to be considered as preferred sites for the DGR. Resultant of technical and social assessments, the NWMO narrowed its focus to five communities all located in Ontario: Hornepayne, Huron-Kinloss, Ignace, Manitouwadge, and South Bruce. Of these five communities, Huron-Kinloss, Manitouwadge, and South Bruce are located in the Great Lakes basin, and Hornepayne and Ignace are located just outside the basin (Figure 4-4).

This project represents a significant economic development opportunity for the selected area and is expected to be a $24 billion (CAD) investment over the next 100 years or more. Communities are exploring opportunities to leverage this investment to create related hubs of business activities.

For business planning purposes, the NWMO has estimated the following timeline for the project. By 2022-2023, the NWMO expects to have selected a single site for the DGR. Once a preferred site is selected, the NWMO expects to begin detailed site characterization studies and begin an environmental assessment and licencing process with the CNSC. It is estimated that regulatory approval will take approximately 10 years, and thus a construction licence is assumed to be granted by 2032. The design and construction phase of the project would begin in 2033 and take approximately 10 years to complete. The emplacing of spent nuclear fuel in the repository is assumed to begin between 2040 and 2045. Operations, extended monitoring, and decommissioning is expected to extend over 100 years.

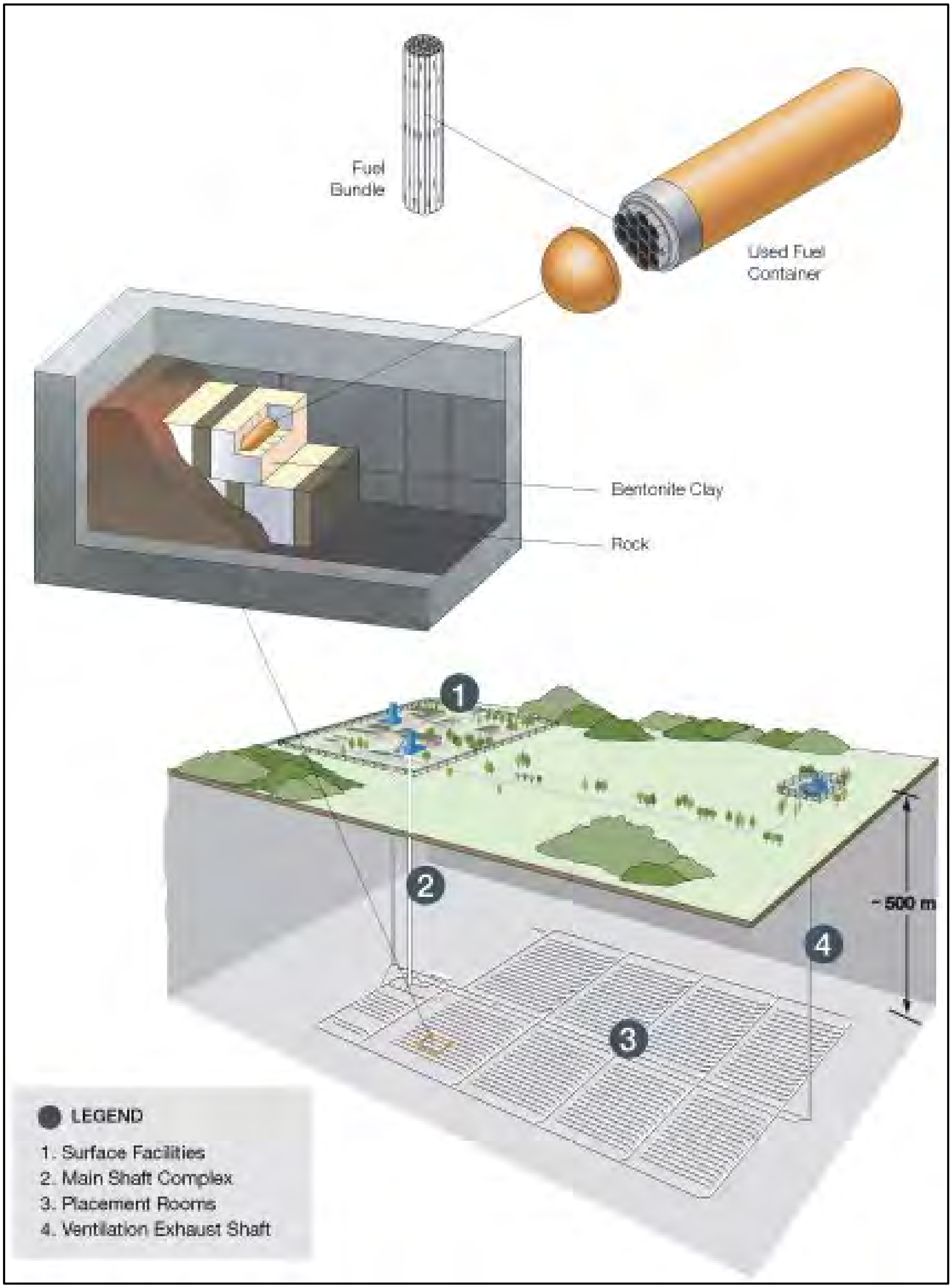


Figure 4-3. Illustration of a deep geological repository.
Source: *Deep Geological Repository Conceptual Design Report Crystalline / Sedimentary Rock Environment* (APM-REP-00440-0015 R001). Noronha, J. © 2016 Nuclear Waste Management Organization.

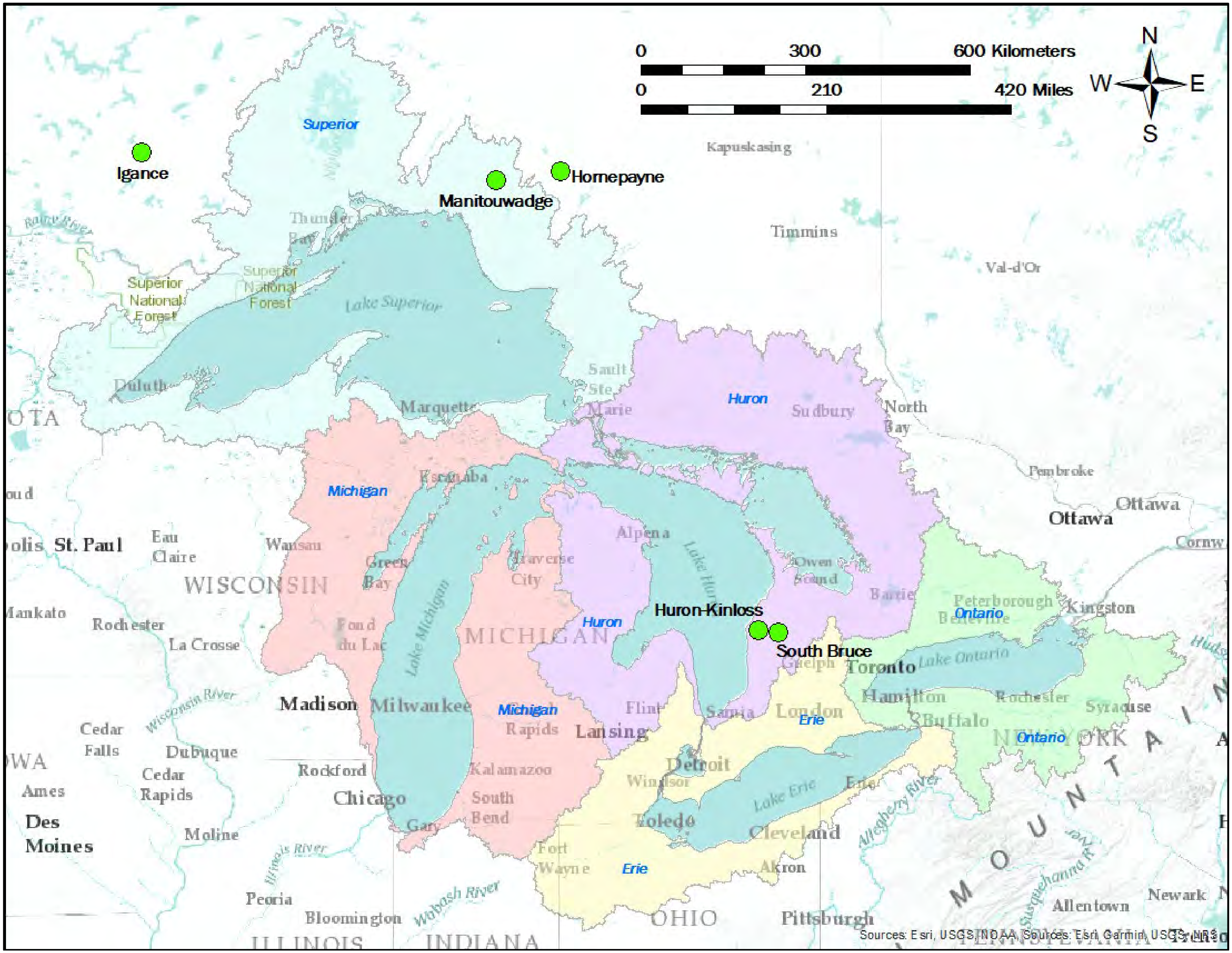


**Figure 4-4.** Map of the five communities under consideration for Canada's deep geological repository in relation to the Great Lakes basin. Credit: Graydon

## 4.2 Radioactive Waste Management in the United States

Under the Atomic Energy Act of 1954 and the Energy Reorganization Act of 1974, the NRC is responsible for protecting the public from sources of ionizing radiation. Title 10 of the *Code of Federal Regulations* delineates the production, utilization, and disposal of radioactive materials and processes. In particular, Part 61 controls the burial of low-level radioactive material and Part 71 defines radioactive material. However, the NRC does not regulate all sources of radioactivity.

### *4.2.1 Low-Level Radioactive Waste Policy Act*

Congress passed the Low-Level Radioactive Waste Policy Act in 1980, declaring the states as being ultimately responsible for the disposition of LLW generated within their own borders. The federal law encouraged the formation of regional groups or compacts to implement this objective safely, efficiently and economically, and set a target date of 1986. With little progress in developing new LLW disposal sites, the Amendments Act of 1985 extended the target, with specific milestones and stiff sanctions for non-compliance. However, the compact process has not resulted in the expected regionalization of LLW disposal. To date, there has been only one new disposal facility licensed to accept all classes of LLW.

There are currently four active, licensed LLW disposal facilities in the United States:[82]

- U.S. Ecology, located in Richland, Washington
  - Is licensed by the State of Washington and accepts Classes A-C waste from the 11 member states of the Northwest and Rocky Mountain Compacts.
- Energy*Solutions* Clive Operations, located in Clive, Utah
  - Is licensed by the State of Utah and accepts Class A waste from all regions of the United States.
- Energy*Solutions* Barnwell Operations, located in Barnwell, South Carolina
  - Is licensed by the State of South Carolina and accepts Classes A-C waste from the 3 member states of the Atlantic Compact.
- Waste Control Specialists, LLC, located in Andrews, Texas
  - Is licensed by the State of Texas and accepts Classes A-C waste from the Texas Compact and from non-compact states.

The Great Lakes states are not all members of the same compact. The states of Indiana, Minnesota, Ohio, and Wisconsin comprise four of the six-member Midwest Compact. The State of Illinois is part of the two-member Central Midwest Compact. The Commonwealth of Pennsylvania is part of the four-member Appalachian Compact. The states of Michigan and New York are not affiliated with any compact.[83] Therefore, the Great Lakes states send their LLW for

[82] *Low Level Radioactive Waste Disposal Facilities*. U.S. Nuclear Regulatory Commission. 10 May 2018. https://scp.nrc.gov/llrw/disposal_facilities.html/. Accessed 15 January 2019.
[83] *Low-Level Waste Compacts*. U.S. Nuclear Regulatory Commission. 9 August 2017. https://www.nrc.gov/waste/llw-disposal/licensing/compacts.html/. Accessed 15 January 2019.

disposal to the Energy*Solutions* Clive Operations in Utah and/or the Waste Control Specialists in Texas.

### *4.2.2 Nuclear Waste Policy Act*

The Nuclear Waste Policy Act of 1982 (NWPA) assigned the responsibility to site, build, and operate a deep geological repository (DGR) for disposal of spent nuclear fuel and high-level radioactive waste created by the commercial nuclear generating plants to the U.S. Department of Energy (DOE). The nuclear waste generators maintain the responsibility to bear the costs of permanent disposal. The NWPA directs the U.S. Environmental Protection Agency (EPA) to develop standards for protection of the general environment from offsite releases of radioactive material in repositories. The NWPA directs the NRC to license the DOE to operate a repository only if it meets EPA's standards and all other relevant requirements. This legislation also created a Nuclear Waste Fund to cover the cost of the program.[84]

### *4.2.3 Radioactive Waste Classification*

The U.S. radioactive waste classification system has two separate sub-systems. One classification sub-system applies to commercial waste and is defined in NRC regulations codified in 10 CFR 60, 61, and 71. The other classification sub-system applies to DOE spent fuel and waste, generated as part of the defense program and regulated by the DOE. The two systems are used for different purposes and different situations, so conflicts do not occur.[85]

Classification of commercial waste is divided into two main categories: high-level radioactive waste (HLW) and low-level radioactive waste (LLW) (Table 4-2). Codified in 10 CFR 60.2, HLW is irradiated reactor fuel (i.e., spent nuclear fuel), and the liquid and solid materials resulting from the reprocessing of spent nuclear fuel. HLW is defined by its origin, not its level of radioactivity. LLW is sub-divided according to its radiological hazard into Class A, B, and C, with Class A being the least hazardous and accounting for 96 percent of LLW. As the waste class and hazard increase, the regulations established by the NRC require progressively greater controls to protect the health and safety of the public and the environment. Wastes that exceed the specific activity of Class C are categorized as Greater-than-Class-C (GTCC) waste and are generally unacceptable for near-surface disposal. There is no lower limit for Class A. Unlike the DOE scheme, there is no separate category for transuranic waste;[86] such waste would be

[84] *Summary of the Nuclear Waste Policy Act*. U.S. Environmental Protection Agency. 7 August 2017. https://www.epa.gov/laws-regulations/summary-nuclear-waste-policy-act/. Accessed 3 December 2018.
[85] *National Waste Programme: International Approaches to Radioactive Waste Classification*. LLW Repository Ltd. October 2016. p.34. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/697667/NWP-REP-134-International-Approaches-to-RW-Classification-Oct-2016.pdf
[86] According to the NRC, *transuranic waste* is "material contaminated with transuranic elements—artificially made, radioactive elements, such as neptunium, plutonium, americium, and others—that have atomic numbers higher than uranium in the periodic table of elements. Transuranic waste is primarily produced from recycling spent fuel or using plutonium to fabricate nuclear weapons."

classified as GTCC waste. For the specific regulations, see Title 10, Section 61.55, of the *Code of Federal Regulations* (10 CFR 61.55), "Waste Classification."

**Table 4-2**. NRC Radioactive Waste Classification

Radioactivity

| | | | | |
|---|---|---|---|---|
| **Commercial Waste** | **High-Level Waste (HLW)** Spent Nuclear Fuel and Highly Radioactive Material from Spent Fuel Processing | | | |
| | **Low-Level Waste (LLW)** Any radioactive waste not classified as HLW or by-product | LLW subdivision based on radiological considerations (concentration of long-lived and short-lived radionuclide on nuclide-specific basis). Must also meet requirements on physical form and characteristics of class. | **Greater-than-Class-C (GTCC)** | Generally unacceptable for near-surface disposal |
| | | | **Class C** | Deeper burial or barriers to intrusion must be effective for 500 years |
| | | | **Class B** | No special disposal provisions |
| | | | **Class A** | Stabilization required if buried with Class B or C waste |
| | **By-products (mill tailings)** Uranium or thorium mill tailings (residual waste from ore after metal extraction) | | | |

Source: Reproduced from Figure 11, *National Waste Programme: International Approaches to Radioactive Waste Classification*. LLW Repository Ltd. October 2016. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/697667/NWP-REP-134-International-Approaches-to-RW-Classification-Oct-2016.pdf

### *4.2.4 Yucca Mountain Nuclear Waste Repository*

The primary site for long-term storage of HLW in the United States was planned to be at the Yucca Mountain site in Nye County, Nevada, on and adjacent to the southwest portion of the Nevada Test Site, approximately 85 miles (137 kilometers) by air northwest of Las Vegas (Figure 4-5). The NRC serves as the independent regulator for the design, construction, operation, and eventual decommissioning of the DGR. After the DOE investigated nine potential sites, Congress amended the Nuclear Waste Policy Act in 1987 to direct the DOE to focus its efforts solely on Yucca Mountain. Since 1987, DOE studied the site, in conjunction with its national laboratories, its private contractors, and other federal agencies such as the U.S. Geological Survey. In addition, DOE was authorized to contract with commercial nuclear reactor operators to take custody of their spent nuclear fuel for disposal at the repository beginning in January 1998. Ultimately, DOE was unable to begin receiving waste by 1998 because of a series of delays due to, among other things, state and local opposition to the construction of a permanent nuclear waste repository in Nevada and technical complexities.[87]

[87] *Yucca Mountain: Information on Alternative Uses of the Site and Related Challenges* (GAO-11-847). U.S. Government Accountability Office. 16 September 2011. https://www.gao.gov/products/GAO-11-847/. Accessed 26 November 2018.

Yucca Mountain was approved by Congress and President Bush in 2002 as the site for the United States' first permanent spent nuclear fuel and HLW geologic repository. In June 2008, the DOE submitted a license application to the NRC seeking authorization to construct a high-level nuclear waste repository at Yucca Mountain. In the application, DOE stated that it planned to open the repository in 2017. The DOE later delayed the date to 2020. On August 5, 2008, the DOE released a revised estimate of the total system lifecycle cost for a repository at Yucca Mountain, which totaled $96.2 billion (2007 USD). Approximately $13.5 billion (2007 USD) had already been incurred since 1983 on studying and developing the Yucca Mountain repository.[88]

In March 2009, Steve Chu, President Obama's Secretary of Energy, announced plans to terminate the Yucca Mountain repository program and instead study other nuclear waste options. Citing opposition from the State of Nevada, the Obama Administration decided to halt the Yucca Mountain project, and no funding has been appropriated for it since FY2010. At the time, the DOE stated the decision to terminate the Yucca Mountain repository program was because it was not a workable option and better solutions to achieve a broader national consensus would be sought. On May 10, 2011, the U.S. Government Accountability Office (GAO) publicly released a report stating the DOE did not cite any technical or safety issues in their decision to terminate the program, but instead, issues of social acceptance.[89]

At about the same time, the Obama Administration directed the DOE to establish a Blue Ribbon Commission of experts to conduct a comprehensive review of policies for managing spent nuclear fuel, including all alternatives for the storage, processing, and disposal of civilian and defense spent nuclear fuel and other radioactive wastes. The *Blue Ribbon Commission on America's Nuclear Future* was published in January 2012 in which a new strategy to manage the nuclear fuel cycle was detailed.[90] One of the strategy's eight key elements was to implement a new, consent-based approach to siting future nuclear waste management facilities. The DOE responded in January 2013 with a waste strategy that called for a consent-based process to select nuclear waste storage and disposal sites and for a surface storage pilot facility to open by 2021.[91]

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[88] *U.S. Department of Energy Releases Revised Total System Life Cycle Cost Estimate and Fee Adequacy Report for Yucca Mountain Project*. U.S. Department of Energy. 5 August 2008. https://www.energy.gov/articles/us-department-energy-releases-revised-total-system-life-cycle-cost-estimate-and-fee/. Accessed 16 January 2019.

[89] *Commercial Nuclear Waste: Effects of a Termination of the Yucca Mountain Repository Program and Lessons Learned* (GAO-11-229). U.S. Government Accountability Office. 8 April 2011. https://www.gao.gov/products/GAO-11-229. Accessed 26 November 2018.

[90] *Blue Ribbon Commission on America's Nuclear Future: Report to the Secretary of Energy*. Lee H. Hamilton and Brent Scowcroft. 26 January 2012. https://www.energy.gov/sites/prod/files/2013/04/f0/brc_finalreport_jan2012.pdf

[91] *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*. U.S. Department of Energy. January 2013. https://www.energy.gov/sites/prod/files/2013%201-15%20Nuclear_Waste_Report.pdf

The DOE issued a *Draft Consent-Based Siting Process* shortly before the end of the Obama Administration in January 2017.[92]

On March 3, 2010, the DOE submitted a motion to the NRC's Atomic Safety and Licensing Board to withdraw its license application with prejudice, a term described by the DOE to mean the Yucca Mountain site would be excluded from further consideration as a repository site. On June 29, 2010, the licensing board denied DOE's motion, ruling that DOE was obligated under the NWPA to continue with the licensing effort. The board noted that, even if the NRC approved the license application, there was no guarantee the Yucca Mountain repository would ever be constructed for any number of reasons, including congressional action changing the law or a decision by Congress not to fund the proposed repository. In the meantime, DOE took steps to dismantle the Yucca Mountain repository program by September 30, 2010.[93]

On August 13, 2013, a federal appeals court ordered the NRC to continue the Yucca Mountain licensing process with previously appropriated funds.[94] In response, the NRC issued the final volumes of the Yucca Mountain Safety Evaluation Report (SER), which provided the NRC staff's determination that the repository would meet all applicable standards. However, the staff said upon completing the SER that the NRC should not authorize construction of the repository until all land and water rights requirements were met and a supplement to DOE's environmental impact statement were completed,[95] which the NRC finished in May 2016.[96]

The Trump Administration included funding to restart Yucca Mounting licensing in its FY2018 and FY2019 budget submissions to Congress, but the funding was not included in the enacted appropriations measures for either year. The House had approved the requested funding for FY2018 and $100 million (USD) more than the request for FY2019, but the Senate approved no funding either year. The enacted versions did not include the Yucca Mountain funding.[97] Thus, the Yucca Mountain project remains on hold. Consequently, HLW will remain stored in onsite ISFSIs until a DOE site becomes available.

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[92] *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste*. U.S. Department of Energy. 12 January 2017. https://www.energy.gov/sites/prod/files/2017/01/f34/Draft%20Consent-Based%20Siting%20Process%20and%20Siting%20Considerations.pdf

[93] *Yucca Mountain: Information on Alternative Uses of the Site and Related Challenges* (GAO-11-847).

[94] U.S. Court of Appeals for the District of Columbia Circuit, In re: Aiken County et al., No. 11-1271, writ of mandamus, 13 August 2013. https://www.cadc.uscourts.gov/internet/opinions.nsf/BAE0CF34F762EBD985257BC6004DEB18/$file/11-1271-1451347.pdf

[95] *NRC Publishes Final Two Volumes of Yucca Mountain Safety Evaluation* (15-005). U.S. Nuclear Regulatory Commission. 29 January 2015. https://www.nrc.gov/docs/ML1502/ML15029A543.pdf

[96] *Supplement to the U.S. Department of Energy's Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (NUREG-2184, Final Report). U.S. Nuclear Regulatory Commission. May 2016. https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2184/. Accessed 15 January 2019.

[97] *Nuclear Energy: Overview of Congressional Issues* (R42853). Congressional Research Service. 16 November 2018. https://crsreports.congress.gov/product/pdf/R/R42853/. Accessed 15 January 2019.

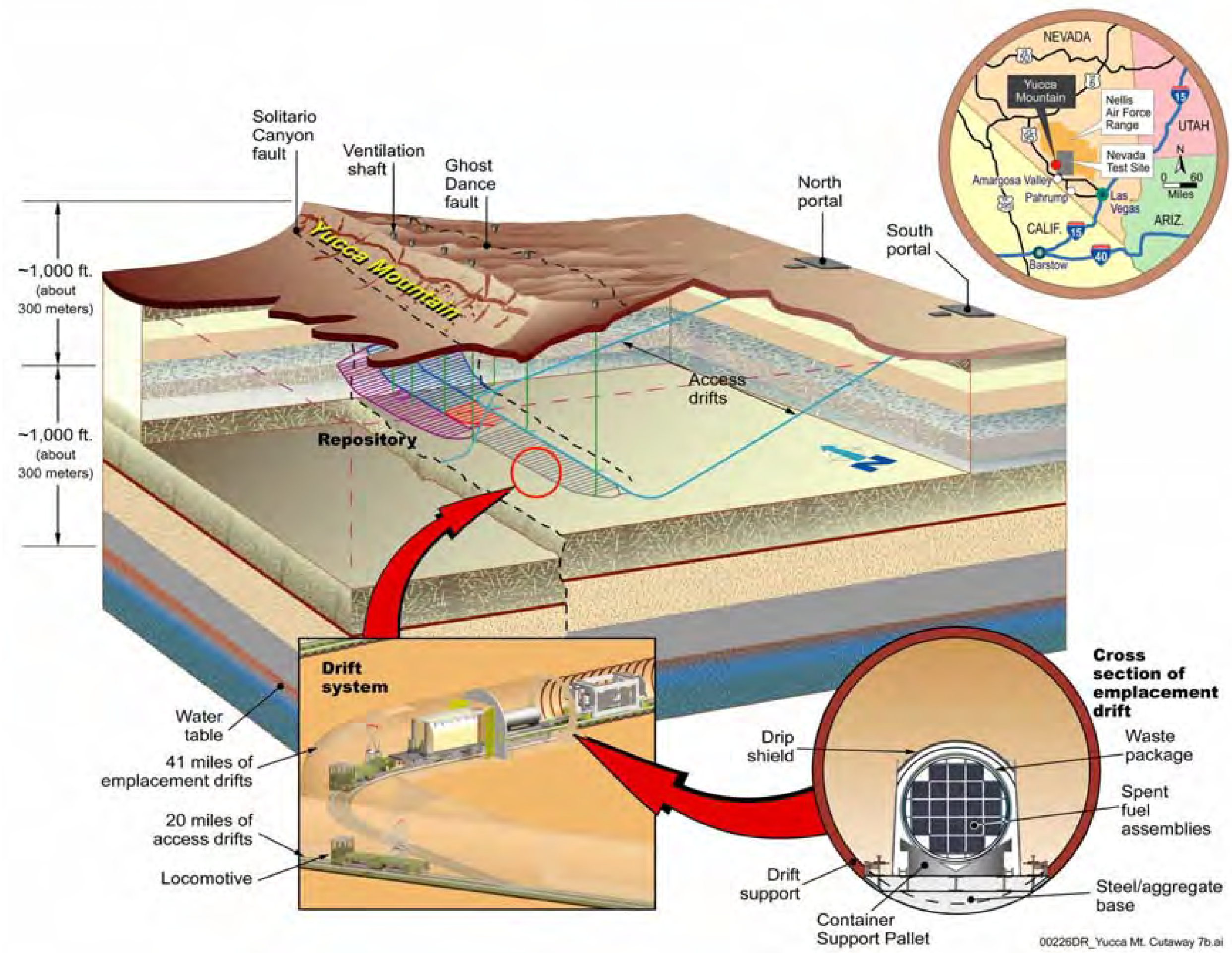


Figure 4-5. Illustration of the Yucca Mountain deep geological repository.
Source: *Yucca Mountain: The Most Studied Real Estate on the Planet.* Report to the Chairman, Senator James M. Inhofe, U.S. Senate Committee on Environment and Public Works, Majority Staff. March 2006.

## 4.3 Global Perspective on DGRs

According to the World Nuclear Association, 30 countries around the world currently operate about 450 nuclear reactors, the world's second largest source of low-carbon electricity, trailing only hydroelectric power.[98] Currently, there are 10 existing nuclear waste repositories deeper than 50 meters (164 feet) that receive L&ILW:

98 *Nuclear Power in the World Today*. World Nuclear Association. February 2019. https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx. Accessed 22 July 2019.

- Asse II, Germany
- Morselben, Germany
- Waste Isolation Pilot Project (WIPP), New Mexico, USA
- Onkala, Finland
- Loviisa, Finland
- KORAD, South Korea
- Bratrstvi, South Korea
- Richard, Czech Republic
- SKB Forsmark, Sweden
- National Radioactive Waste Repository, Hungary

Another DGR is under construction in Konrad, Germany, and more DGRs are being explored in Argentina, Belgium, Canada, China, Czech Republic, Finland, France, Japan, Netherlands, South Africa, Sweden, the United Kingdom, and the United States.[99]

However, there is still no system in place for the permanent disposal of the spent nuclear fuel (i.e., high-level radioactive waste). While numerous countries are considering DGRs, Finland is the only country that has begun the construction of a DGR for the final disposal of its spent nuclear fuel.[100] Sweden is reviewing a license application for the future spent fuel DGR at Forsmark.[101] The license application for France's Cigéo DGR is expected to be submitted by the end of 2018 and construction to begin in 2020.

**Photo 4.3-1** - An access tunnel 450 meters (1,476 ft) below the surface within the ONKALO deep geologic repository in Olkiluoto, Finland. The tunnel is 5.5 meters (18 ft) wide and 6.3 meters (21 ft) high. Photo courtesy of Posiva (2014).

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[99] *Responsible Waste Management: OPG Briefings in Michigan*. 2 July 2019. Ontario Power Generation.
[100] *Solving the Back End: Finland's Key to the Final Disposal of Spent Nuclear Fuel*. Chatzis, Irena. International Atomic Energy Agency: Department of Nuclear Energy. 18 October 2018. https://www.iaea.org/newscenter/news/solving-the-back-end-finlands-key-to-the-final-disposal-of-spent-nuclear-fuel. Accessed 26 November 2018.
[101] *The Spent Fuel Repository*. SKB. 2 March 2018. https://www.skb.com/future-projects/the-spent-fuel-repository/. Accessed 22 July 2019.

## 4.4 Radioactive Waste Estimates at Closure

In 2018, Natural Resources Canada published an inventory of radioactive waste in Canada as of December 31, 2016. Among the four nuclear generating stations in the Canadian-section of the Great Lakes basin that store HLW (Bruce A&B, Darlington, Pickering A&B, and Douglas Point), there were 2,400,287 spent nuclear fuel bundles, which have an estimated volume of 9,801 cubic meters (346,119 $ft^3$) and contain 47,201 metric tons (52,030 US tons) of uranium (Table 4-3). Included in the report were projections of radioactive wastes in 2019, 2050, and 2100 based on life expectancy of existing nuclear reactors, including announced refurbishment and life extension plans (Table 4-4). The total projected volume and mass of HLW at the four nuclear generating stations in the Canadian-section of the Great Lakes basin for 2019 was 11,084 cubic meters (391,428 $ft^3$) weighing 53,380 metric tons (58,841 US tons), for 2050 was 18,512 cubic meters (653,746 $ft^3$) weighing 88,868 metric tons (97,960 US tons), and for 2100 was 20,085 cubic meters (709,296 $ft^3$) weighing 96,367 metric tons (106,226 US tons).

In the United States, the DOE published an inventory of spent nuclear fuel in dry storage at nuclear power facilities on August 22, 2016. Among the 12 nuclear power stations in the U.S.-section of the Great Lakes basin, there were 10,743 spent fuel assemblies stored in 265 casks. Projected estimates of radioactive wastes (e.g., amount of spent nuclear fuel assemblies, GTCC waste, and storage casks) at nuclear power stations in the United States may be included in ISFSI Decommissioning Funding Plans that are submitted by licensees to the NRC pursuant to 10 CFR 72.30. At the projected time of decommissioning for the 12 nuclear power facilities in the U.S.-section of the Great Lakes basin, the estimated amount of HLW is 52,190 spent fuel assemblies stored in 1,064 casks and an additional 31 casks storing GTCC waste (Table 4-5). The HLW is expected to be stored onsite at each facility's ISFSI until HLW is accepted for long-term storage by the DOE, which the operators assume will not occur for several decades in the future.

**Photo 4.4-1** – At the Bruce Nuclear Generating Stations, each reactor has 480 designated fuel channels, which hold 5,760 fuel bundles. Each fuel bundle stays in the reactor for 12 to 20 months, depending on where it is located. Once removed, a used fuel bundle is transferred to the primary and secondary fuel bays where it cools for 10 years before it is cool enough to be placed in a dry storage container. It is then transferred to Ontario Power Generation's Western Waste Management Facility, which is located on the Bruce Nuclear Site, for long-term, above-ground storage until a permanent repository becomes available. Photo courtesy of Bruce Power. Used with permission.

**Table 4-3.** High-Level Radioactive Waste Inventory at Canadian Nuclear Reactors in the Great Lakes Basin in 2016

| Company - Site name | Reactor status as of December 2016 | Nuclear fuel waste generated in 2016 (2016 accumulation rate) | | | Onsite nuclear fuel waste inventory to December 31, 2016 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Dry storage | Wet storage | Total storage | | | | |
| | | Fuel bundles | Est. volume | | Fuel bundles | Fuel bundles | Fuel bundles | Est. volume | | Uranium | |
| | | | $m^3$ | $ft^3$ | | | | $m^3$ | $ft^3$ | Metric tons | US tons |
| OPG - Bruce A | Operating | 18,439 | 74 | 2,613 | 168,576 | 335,654 | 504,230 | 2,017 | 71,230 | 9,551 | 10,528 |
| OPG - Bruce B | Operating | 22,344 | 89 | 3,143 | 321,782 | 349,442 | 671,224 | 2,685 | 94,820 | 12,824 | 14,136 |
| OPG - Darlington | Operating | 21,669 | 87 | 3,072 | 192,314 | 332,514 | 524,828 | 2,099 | 74,125 | 10,066 | 11,096 |
| OPG - Pickering A | 2/4 units operating | 5,260 | 21 | 742 | 75,461 | 263,709 | 339,170 | 1,357 | 47,922 | 6,739 | 7,429 |
| OPG - Pickering B | Operating | 11,600 | 46 | 1,624 | 251,451 | 137,128 | 338,579 | 1,554 | 54,879 | 7,721 | 8,511 |
| AECL - Douglas Point | Shutdown and partially decommissioned | 0 | 0 | 0 | 22,256 | 0 | 22,256 | 89 | 3,143 | 300 | 330 |
| **Total HLW** | | **79,312** | **317** | **11,194** | **1,031,840** | **1,418,447** | **2,400,287** | **9,801** | **346,119** | **47,201** | **52,030** |

Acronyms: AECL = Atomic Energy of Canada Limited; OPG = Ontario Power Generation

Unit conversions: Volume: 1 cubic meter ($m^3$) = 35.3 cubic feet ($ft^3$); Mass: 1 metric ton = 1,000 kilograms = 1.1 US tons = 2,205 pounds

Note: Totals are affected by unit conversions and rounding.

Source: Adapted with permission from Table 4, *Inventory of Radioactive Waste in Canada 2016*. Natural Resources Canada. © 2018 Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/uranium-nuclear/17-0467%20Canada%20Radioactive%20Waste%20Report_access_e.pdf.

**Table 4-4.** High-Level Radioactive Waste Projections at Canadian Nuclear Reactors in the Great Lakes Basin

| Company - Site Name | HLW inventory 2019 | | | | | HLW inventory 2050 | | | | | HLW inventory 2100 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fuel bundles | Est. volume | | Mass | | Fuel bundles | Est. volume | | Mass | | Fuel bundles | Est. volume | | Mass | |
| | | $m^3$ | $ft^3$ | Metric tons | US tons | | $m^3$ | $ft^3$ | Metric tons | US tons | | $m^3$ | $ft^3$ | Metric tons | US tons |
| OPG - Bruce A | 588,773 | 2,355 | 83,166 | 11,152 | 12,293 | 1,141,400 | 4,566 | 161,247 | 21,619 | 23,831 | 1,242,398 | 4,970 | 175,514 | 23,532 | 25,940 |
| OPG - Bruce B | 759,571 | 3,038 | 107,286 | 14,512 | 15,997 | 1,411,201 | 5,645 | 199,351 | 26,962 | 29,721 | 1,661,142 | 6,645 | 234,666 | 31,738 | 34,985 |
| OPG - Darlington | 593,323 | 2,373 | 83,802 | 11,380 | 12,544 | 1,170,007 | 4,680 | 165,273 | 22,441 | 24,737 | 1,212,280 | 4,849 | 171,241 | 23,252 | 25,630 |
| OPG - Pickering A | 363,885 | 1,456 | 51,418 | 7,230 | 7,970 | 379,487 | 1,518 | 53,608 | 7,540 | 8,312 | 379,487 | 1,518 | 53,608 | 7,540 | 8,312 |
| OPG - Pickering B | 443,149 | 1,773 | 62,613 | 8,805 | 9,706 | 503,527 | 2,014 | 71,124 | 10,005 | 11,029 | 503,527 | 2,014 | 71,124 | 10,005 | 11,029 |
| AECL - Douglas Point | 22,256 | 89 | 3,143 | 300 | 331 | 22,256 | 89 | 3,143 | 300 | 331 | 22,256 | 89 | 3,143 | 300 | 331 |
| **Total HLW** | **2,770,957** | **11,084** | **391,428** | **53,380** | **58,841** | **4,627,878** | **18,512** | **653,746** | **88,868** | **97,960** | **5,021,090** | **20,085** | **709,296** | **96,367** | **106,226** |

Acronyms: AECL = Atomic Energy of Canada Limited; OPG = Ontario Power Generation

Unit conversions: Volume: 1 cubic meter ($m^3$) = 35.3 cubic feet ($ft^3$); Mass: 1 metric ton = 1,000 kilograms = 1.1 US tons = 2,205 pounds

Note: Totals are affected by unit conversions and rounding.

Source: Adapted with permission from Table 6, *Inventory of Radioactive Waste in Canada 2016*. Natural Resources Canada. © 2018 Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/uranium-nuclear/17-0467%20Canada%20Radioactive%20Waste%20Report_access_e.pdf

**Table 4-5.** High-Level Radioactive Waste Inventory in Dry Storage at ISFSIs in the U.S.-Section of the Great Lakes Basin

| Site Name | HLW Inventory as of August 22, 2016 | | Projected HLW Inventory at Decommissioning | | | |
|---|---|---|---|---|---|---|
| | SNF Assemblies | Storage Casks Containing SNF | Reference Year | SNF Assemblies | Storage Cask Quantity | |
| | | | | | Containing SNF | Containing GTCC |
| Big Rock Point[1] | 441 | 7 | 2006 | 441 | 7 | 1 |
| Davis-Besse Nuclear Plant[2] | 72 | 3 | 2020 | 1,529 | 43 | 4 |
| Donald C. Cook Nuclear Plant[3] | 896 | 28 | 2037 | 6,552 | 205 | 6 |
| Enrico Fermi Nuclear Station[4] | 408 | 6 | 2045 | 6,528 | 96 | 4 |
| FitzPatrick Nuclear Plant[5] | 1,428 | 21 | 2034 | 6,314 | 93 | NA |
| Kewaunee Power Plant[6] | 448 | 14 | 2017 | 1,335 | 38 | NA |
| Nine Mile Point Nuclear Station[5] | 1,464 | 24 | 2046 | 14,291 | 234 | NA |
| Palisades Nuclear Plant[1] | 1,096 | 42 | 2022 | 2,082 | 63 | 5 |
| Point Beach Nuclear Plant[7] | 1,120 | 39 | 2033 | 3,616 | 85 | 2 |
| Perry Nuclear Power Plant[2] | 952 | 14 | 2021 | 5,393 | 80 | 5 |
| R.E. Ginna Nuclear Plant[5] | 192 | 6 | 2029 | 1,883 | 59 | NA |
| Zion Power Station[8] | 2,226 | 61 | 2014 | 2,226 | 61 | 4 |
| **Total** | **10,743** | **265** | **-** | **52,190** | **1,064** | **31** |

Acronyms: GTCC = Greater-than-Class-C waste; HLW = High-Level Radioactive Waste; NA = Not Available; SNF = Spent Nuclear Fuel

Source of HLW Inventory as of August 22, 2016:

Adapted from Table A-1, *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2/.

Sources for HLW Projected Inventory at Decommissioning:

[1] *ISFSI Decommissioning Funding Plans* (10 CFR 72.30). Entergy Nuclear Operations, Inc. 17 December 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18351A478

[2] *Triennial ISFSI Decommissioning Funding Plans*. First Energy Nuclear Operating Company. 17 December 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18351A161

[3] *Decommissioning Study of the D.C. Cook Nuclear Power Plant* (Revision 0). Knight Cost Engineering Services, LLC. 21 January 2016. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18341A134

[4] *Fermi 2 ISFSI Decommissioning Funding Plan Update*. DTE Energy. 30 March 2017. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML17089A789

[5] *International Joint Commission Request for NRC Assistance in Obtaining Projected HLW Estimates for Nuclear Power Plants Operated by Exelon Generation Company*. U.S. Nuclear Regulatory Commission. 24 January 2019. Accession Number = ML18340A0451.

[6] *Kewaunee Power Station Revision to Post-Shutdown Activities Report.* Dominion Energy Kewaunee, Inc. 25 April 2014. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14118A382

[7] *Decommissioning Funding Status Reports / ISFSI Financial Assurance Update*. Florida Power and Light Company. 30 March 2017. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML17093A722

[8] *License Termination Plan, Revision 2*. Zion*Solutions*, LLC. 7 February 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18052A857

# 5. Operating Nuclear Generating Stations

The first nuclear generating station to begin commercial operation in the Great Lakes basin was Consumers Energy's Big Rock Point, the world's first high power-density boiling water reactor (BWR). Commercial operation of Big Rock Point began March 29, 1963. Three years later, the Enrico Fermi Atomic Power Plant (Fermi-1) fast breeder reactor began commercial operation on August 7, 1966, followed by the Douglas Point Nuclear Generating Station, the first commercial-scale Canada Deuterium Uranium (CANDU) reactor, which began commercial operation on September 26, 1968.

In total, 38 nuclear reactors at 16 commercial generating stations on 14 sites were constructed and generated electricity in the Great Lakes basin (Figure 1-2). Of those, there are 21 current or former nuclear reactors at four generating stations on three sites in Ontario, which 12 of those nuclear reactors are at two sites on the north shore of Lake Ontario near Toronto and nine reactors are at two generating stations on the Bruce Nuclear Site on the east shore of Lake Huron. In the US-section of the basin, there are 17 current or former nuclear reactors at 12 generating stations on 11 sites. Of those, four nuclear reactors are at three generating stations on two sites along the south shore of Lake Ontario, four reactors are at three sites on the shores of Lake Erie, and nine reactors are at six sites on the shores of Lake Michigan. There are not any commercial nuclear reactors in the Lake Superior drainage basin.

Currently, there are 30 operating nuclear reactors at 12 generating stations on 11 sites in the Great Lakes basin (Table 5-1). Of those, there are 18 operating nuclear reactors at three sites in Ontario, which 10 of those nuclear reactors are at two sites on the north shore of Lake Ontario near Toronto and eight reactors are at the Bruce Nuclear Site on the east shore of Lake Huron. In the US-section of the basin, there are 12 operating nuclear reactors at nine generating stations on eight sites. Of those, four nuclear reactors are at three generating stations on two sites along the south shore of Lake Ontario, three reactors are at three sites on the shores of Lake Erie, and five reactors are at three sites on the shores of Lake Michigan.

Currently operating nuclear generating stations without closure plans are described here, and stations that have plans to close or have already shut down are described in the subsequent sections.

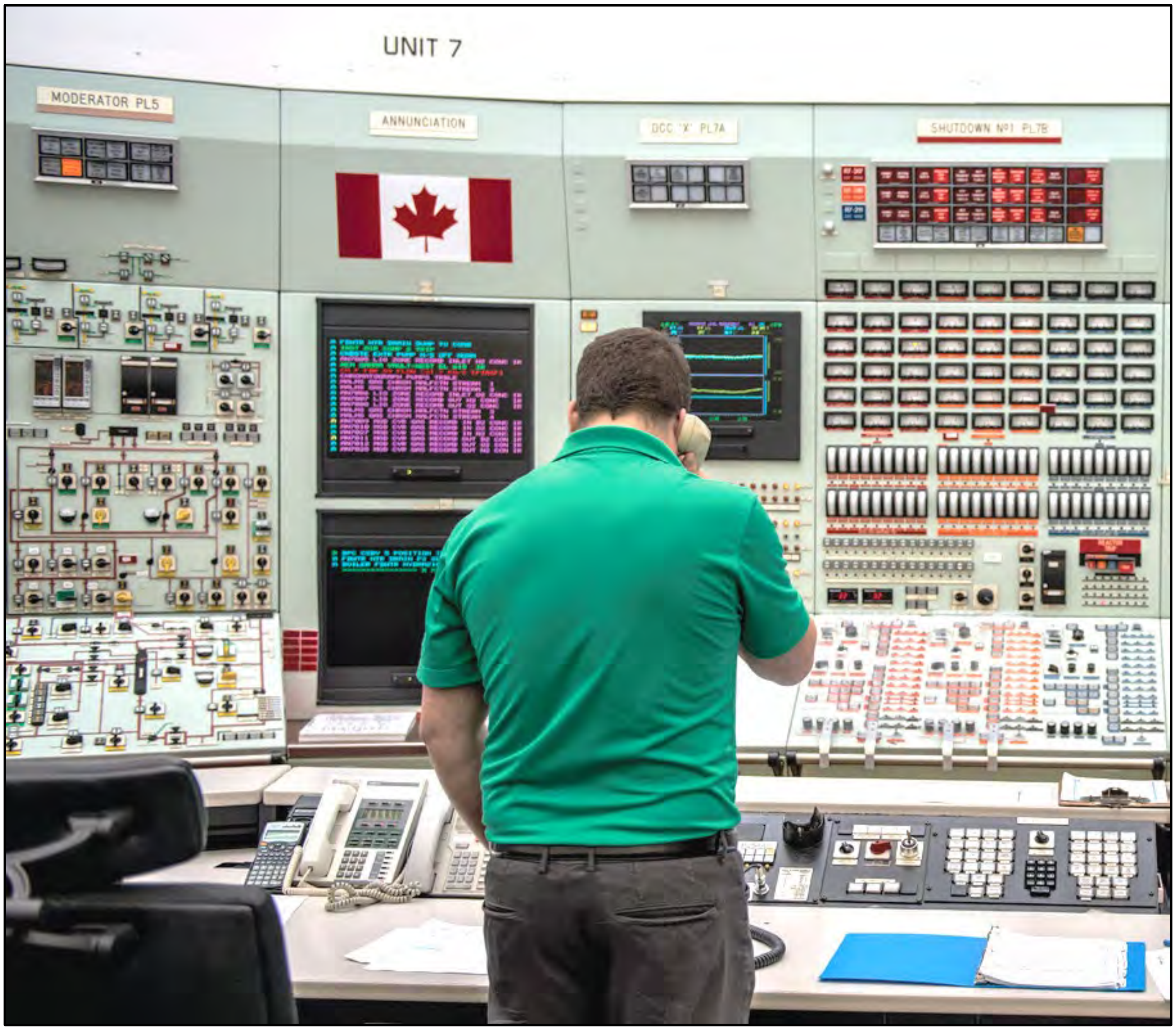

**Photo 5.0-1**. An operator works in the control room of the Bruce Nuclear Generating Station Unit 7 in Kincardine, Ontario. Photo courtesy of Bruce Power. Used with permission.

**Table 5-1.** Operating Nuclear Generating Stations in the Great Lakes Basin

| Site Name | Location | Current Licensee | Operating License - Issued | Operating License - Renewed | Operating License - Expires | Capacity (MWe) | Decommissioning Planning Report | Estimated Decommissioning Cost (in millions) |
|---|---|---|---|---|---|---|---|---|
| Bruce Nuclear Generating Stations | Kincardine, ON | | | | | | | 2015 CAD |
| Bruce A: Units 1-4 | | Bruce Power | 1977 | 1 Oct 2018 | 31 Sept 2028 | 6,232 | Dec 2016 | $2,840 |
| Bruce B: Units 5-8 | | | | | | | | $2,810 |
| Western Waste Management Facility | | Ontario Power Generation | | 1 June 2017 | 31 May 2027 | - | Dec 2016 | $111.7 to $118.1 |
| Darlington Nuclear Generating Station | Clarington, ON | Ontario Power Generation | | | | | | 2015 CAD |
| 4 Reactor Units | | | 1990 | 1 Jan 2016 | 30 Nov 2025 | 3,512 | Dec 2016 | $3,360 |
| Darlington Waste Management Facility | | | Nov 2007 | 13 March 2013 | 30 April 2023 | - | Dec 2016 | $18.35 |
| Davis-Besse Nuclear Power Station | Oak Harbor, OH | FirstEnergy Solutions Co. | | | | | | 2017 USD |
| Unit 1 | | | 22 Apr 1977 | 8 Dec 2015 | 22 Apr 2037 | 894 | 24 Mar 2017 | $467.40 |
| ISFSI | | | | | | - | 17 Dec 2018 | $6.07 |
| Donald C. Cook Nuclear Plant | Bridgman, MI | Indiana Michigan Power Co. | | | | | | 2015 USD |
| Unit 1 | | | 25 Oct 1974 | 30 Aug 2005 | 25 Oct 2034 | 1,009 | | $1,634 |
| Unit 2 | | | 23 Dec 1977 | 30 Aug 2005 | 23 Dec 2037 | 1,060 | 21 Jan 2016 | |
| ISFSI | | | | | | - | | $56.95 |
| Enrico Fermi Nuclear Station | Newport, MI | DTE Electric Co. | | | | | | 2018 USD |
| Unit 2 | | | 15 July 1985 | 15 Dec 2016 | 20 March 2045 | 1,141 | 28 Mar 2019 | $1,290 |
| Unit 3 - approved but not constructed | | | 30 April 2015 | - | | 1,600 | - | - |
| ISFSI | | | | | | - | 30 Mar 2017 | $9.26 |
| James A. FitzPatrick Nuclear Power Plant | Scriba, NY | Exelon Corp | | | | | | 2018 USD |
| Unit 1 | | | 17 Oct 1974 | 8 Sept 2008 | 17 Oct 2034 | 853 | 1 April 2019 | $656.95 |
| ISFSI | | | | | | - | | $10.27 |

**Table 5-1**. Operating Nuclear Generating Stations in the Great Lakes Basin (continued)

| Site Name | Location | Current Licensee | Operating License - Issued | Operating License - Renewed | Operating License - Expires | Capacity (MWe) | Decommissioning Planning Report | Estimated Decommissioning Cost (in millions) |
|---|---|---|---|---|---|---|---|---|
| Nine Mile Point Nuclear Station | Scriba, NY | Exelon Corp | | | | | | 2018 USD |
| Unit 1 | | | 26 Dec 1974 | 31 Oct 2006 | 22 Aug 2029 | 626 | | $626.97 |
| Unit 2 | | | 2 July 1987 | 31 Oct 2006 | 31 Oct 2046 | 1,287 | 1 April 2019 | $699.30 |
| ISFSI | | | | | | - | | $13.57 |
| Palisades Nuclear Power Plant | Covert, MI | Entergy Nuclear Operations, Inc. | | | | | | 2018 USD |
| Unit 1 | | | 21 Feb 1971 | 17 Jan 2007 | 24 Mar 2031 | 787 | 29 March 2019 | $480.43 |
| ISFSI | | | | | | - | | $8.00 |
| Perry Nuclear Power Plant | Perry, OH | FirstEnergy Solutions Co. | | | | | | 2016 USD |
| Unit 1 | | | 18 Mar 1986 | - | 18 Mar 2026 | 1,240 | 24 Mar 2017 | $651.90 |
| ISFSI | | | | | | - | 17 Dec 2018 | $10.24 |
| Pickering Nuclear Generating Station | Pickering, ON | Ontario Power Generation | | | | | | 2015 CAD |
| PNGS A: Units 1-4 (Units 2-3 are deactivated)<br>PNGS B: Units 5-8 | | | 1971 | 1 Sept 2018 | 31 Aug 2028 | 3,094 | Dec 2016 | $5,190 |
| Pickering Waste Management Facility | | | | 1 April 2018 | 31 August 2028 | - | Dec 2016 | $29.82 |
| Point Beach Nuclear Plant | Two Rivers, WI | NextEra Energy Point Beach, LLC | | | | | | 2018 USD |
| Unit 1 | | | 5 Oct 1970 | 22 Dec 2005 | 5 Oct 2030 | 595 | | $447.28 |
| Unit 2 | | | 8 Mar 1973 | 22 Dec 2005 | 8 Mar 2033 | 597 | 25 Mar 2019 | $427.28 |
| ISFSI | | | | | | - | | $8.43 |
| R.E. Ginna Nuclear Power Plant | Ontario, NY | Exelon Corp | | | | | | 2018 USD |
| Unit 1 | | | 19 Sept 1969 | 19 May 2004 | 18 Sept 2029 | 582 | 1 April 2019 | $457.78 |
| ISFSI | | | | | | - | | $6.63 |

## 5.1 Bruce Nuclear Generating Stations

**Photo 5.1-1** – Located in Bruce County, Ontario, the Bruce Nuclear Generating Stations are photographed from above Lake Huron. Captured during a restart, Bruce A is pictured in the foreground after the Heavy Water Plant was dismantled. Bruce B produces a puff of steam along the shoreline in the background. The white dome of the Douglas Point containment building is visible along the shoreline between Bruce A and B. Photo courtesy of Bruce Power (2006). Used with permission.

The Bruce Nuclear Generating Stations (BNGS) are located on the east shore of Lake Huron in the Municipality of Kincardine, Bruce County, Ontario. All the facilities on the Bruce Nuclear Site occupy 932 hectares (2,303 acres) and approximately 8 kilometers (5 miles) of lake frontage. The Bruce Nuclear Site is owned by Ontario Power Generation (OPG) and operates under a long-term leasing agreement with the Province of Ontario.

Bruce A (BNGS A) contains four CANDU reactors (Units 1-4) that started commercial operation between September 1977 and January 1979. Bruce B (BNGS B) also contains four CANDU reactors (Units 5-8) that started commercial operation between September 1984 and May 1987. The combined eight reactors have an installed capacity of 6,288 MWe and have supplied an average of 45,134 GWh of electricity annually since Units 2 and 3 returned to service 2012. Over its lifetime, BNGS has supplied 1,357.95 TWh of electricity.[102]

### *5.1.1 Previous Temporary Shutdown and Refurbishment Plans*

In the late-1990s, the former Ontario Hydro (broken up by the passage of the Energy Competition Act of 1998 by the Legislative Assembly of Ontario) made a business decision to lay-up BNGS A. Unit 2 was shut down in October 1995, followed by Unit 1 in October 1997, Unit 4 in March 1998 and Unit 3 in April 1998. The station was placed in a state consistent with the Electric Power Research Institute specifications for plant lay-up. The nuclear systems were maintained in a standard state for shutdown reactors, with essentially all the systems left in service. Bruce Power, a private company, was formed in 2001, and OPG leased portions of the Bruce Nuclear Site (including both BNGS A and BNGS B) to Bruce Power, which immediately unveiled plans to restart Units 3 and 4. Unit 4 returned to service on October 7, 2003, and Unit 3 returned to service on January 8, 2004. Units 1 and 2 were refurbished and returned to service in 2012.

OPG retains ownership and responsibility for the eventual decommissioning of the two stations after defueling and dewatering by Bruce Power. In addition, OPG owns and operates the Western Waste Management Facility (WWMF) adjacent to the stations. On September 27, 2018, the CNSC approved Bruce Power's request to renew the operating licence, which became valid on October 1, 2018, and will expire on September 30, 2028. With this licence renewal, the CNSC authorized Bruce Power to undertake licensed activities related to the refurbishment of BNGS Units 3 to 8 through its planned Major Component Replacement Project, which will take place from 2020 to 2033.[103]

### *5.1.2 Decommissioning Plan and Radioactive Waste Estimate*

As of December 2016, the expected end-of-life for BNGS A and B (assuming the completion of planned refurbishment and 30-year nominal. operating life post-refurbishment) are:

| | |
|---|---|
| Unit 1 – 2043 | Unit 5 – 2062 |
| Unit 2 – 2043 | Unit 6 – 2058 |
| Unit 3 – 2061 | Unit 7 – 2063 |
| Unit 4 – 2062 | Unit 8 – 2063 |

For planning purposes, OPG has chosen the Deferred Decommissioning strategy, in which the reactors and stations would be stored for several decades after shutdown (Safe Storage) to allow

[102] *Canada*. International Atomic Energy Agency: Power Reactor Information System. 21 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA. Accessed 22 February 2019.
[103] *CNSC renews Bruce Power's nuclear power reactor operating licence for the Bruce Nuclear Generating Station*. Canadian Nuclear Safety Commission. 27 September 2018. https://www.canada.ca/en/nuclear-safety-commission/news/2018/09/cnsc-renews-bruce-powers-nuclear-power-reactor-operating-licence-for-the-bruce-nuclear-generating-station.html. Accessed 3 September 2018.

radiation levels to decay prior to Dismantling & Demolition and Site Restoration. The estimated volumes of low- and intermediate-level waste (L&ILW) generated through the decommissioning of BNGS A and BNGS B are 56,741 cubic meters (2,003,790 $ft^3$) of LLW and 6,999 cubic meters (247,167 $ft^3$) of ILW (Table 5-2).

OPG plans to place L&ILW generated during decommissioning in their proposed L&ILW deep geological repository (DGR) to be located in the municipality of Kincardine, on the current Bruce Nuclear Site (see *Section 4.1.2*). Upon approval by the CNSC, the OPG L&ILW DGR is expected to be in service by 2026 with an initial capacity of 200,000 cubic meters (7,062,933 $ft^3$) of packaged waste. This initial volume is expected to be sufficient for operational waste derived from OPG-owned facilities. For decommissioning waste to be accommodated in the DGR, an expansion of 200,000 cubic meters (7,062,933 $ft^3$) would be required, which is assumed to occur between 2039 and 2043.[104]

For HLW management, the spent nuclear fuel will be transferred from the Irradiated Fuel Bays (IFBs) to a permanent spent nuclear fuel disposal facility, which is expected to be available no earlier than 2043 (see *Section 4.1.3*). As of December 31, 2016, Natural Resources Canada reported the HLW inventory stored onsite at BNGS A were 504,230 fuel bundles, which had an estimated volume of 2,017 cubic meters (71,230 $ft^3$) and contained 9,551 metric tons (10,528 US tons) of uranium. Stored onsite at BNGS B, there were 671,224 fuel bundles, which had an estimated volume of 2,684 cubic meters (94,785 $ft^3$) and contained 12,824 metric tons (14,136 US tons) of uranium (Table 4-3).[105]

As of December 2016, site restoration of BNGS A was assumed to occur from 2092-2095. Site restoration of BNGS B was assumed to occur from 2096-2099. The cost associated with decommissioning the BNGS A and BNGS B were estimated at $2.84 billion and $2.81 billion (2015 CAD), respectively (Table 5-1).

As of December 2016, approval from the CNSC to begin decommissioning of the WWMF L&ILW facilities is anticipated to be received in 2073 and decommissioning activities completed by 2075. For the WWMF used fuel dry storage facility, the licence to begin decommissioning is anticipated to be received in 2099 and site restoration of the entire WWMF site completed by 2100. OPG anticipates receiving the Licence to Abandon from the CNSC in 2101. The cost associated with decommissioning the WWMF was estimated to be between $111.7 million and $118.1 million (2015 CAD) (Table 5-1).[106]

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[104] *Preliminary Decommissioning Plan – Bruce Nuclear Generating Stations A and B*. Ontario Power Generation. December 2016. Rev. 2. https://www.opg.com/generating-power/nuclear/Documents/06819-PLAN-00960-00001_BNGS_PDP.pdf

[105] *Inventory of Radioactive Waste in Canada 2016*. Natural Resources Canada. 2018. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/uranium-nuclear/17-0467%20Canada%20Radioactive%20Waste%20Report_access_e.pdf

[106] *Preliminary Decommissioning Plan – Bruce Nuclear Generating Stations A and B*.

**Table 5-2.** Estimated Volumes of L&ILW Generated During the Decommissioning of BNGS A & B

| Reactor Unit | | Low-Level Radioactive Waste (LLW) | | Intermediate-Level Radioactive Waste (ILW) | |
|---|---|---|---|---|---|
| | | $m^3$ | $ft^3$ | $m^3$ | $ft^3$ |
| BNGS A | Unit 1 | 5,527 | 195,184 | 813 | 28,711 |
| | Unit 2 | 5,525 | 195,114 | 813 | 28,711 |
| | Unit 3 | 5,444 | 192,253 | 813 | 28,711 |
| | Unit 4 | 5,443 | 192,218 | 813 | 28,711 |
| | Unit 0 (common services) | 5,753 | 203,165 | 205 | 7,240 |
| | **Total*** | 27,692 | 977,934 | 3,456 | 122,048 |
| BNGS B | Unit 5 | 5,592 | 197,480 | 835 | 29,488 |
| | Unit 6 | 5,608 | 198,045 | 835 | 29,488 |
| | Unit 7 | 5,586 | 197,268 | 835 | 29,488 |
| | Unit 8 | 5,589 | 197,374 | 835 | 29,488 |
| | Unit 0 (common services) | 6,673 | 235,655 | 205 | 7,240 |
| | **Total*** | 29,049 | 1,025,856 | 3,543 | 125,120 |
| **Grand Total*** | | **56,741** | **2,003,790** | **6,999** | **247,167** |

* May not add due to rounding

Source: Adapted from Table 4-2, *Preliminary Decommissioning Plan - Bruce Nuclear Generating Stations A and B*. Ontario Power Generation. December 2016. https://www.opg.com/generating-power/nuclear/Documents/06819-PLAN-00960-00001_BNGS_PDP.pdf.

**Photo 5.1-2** – Bruce Power reached a deal with the Ontario government to refurbish its reactors as part of its Major Component Replacement (MCR). The CNSC approved the MCR project in September 2018, which will take place from 2020 to 2033. Photo courtesy of Bruce Power (2016). Used with permission.

## 5.2 Darlington Nuclear Generating Station

Photo 5.2-1 – Located on the shore of Lake Ontario in Durham Region, Ontario, the Darlington Nuclear Generating Station began commercial operations in 1990. Photo courtesy of Ontario Power Generation (2011). Used with permission.

The Darlington Nuclear Generating Station (DNGS) is located on the north shore of Lake Ontario in the Municipality of Clarington, Durham Region, Ontario, approximately 70 kilometers (43 miles) east of Toronto, ON. DNGS is comprised of a land parcel of 485 hectares (1,198 acres) plus additional water lot areas of 17 hectares (42 acres) extending into Lake Ontario to accommodate the water intake tunnel and the discharge pipe. DNGS has a total lake frontage of approximately 3.2 kilometers (2 miles).

DNGS contains four CANDU reactors that have an installed capacity of 3,512 MWe. The first unit (Unit 2) entered commercial service on October 9, 1990, followed by Unit 1 on November 14, 1992, Unit 3 on February 14, 1993, and Unit 4 on June 14, 1993. Since 2000, DNGS has supplied an average of 26,763 GWh of electricity annually. Over its lifetime, DNGS has supplied 670.19 TWh of electricity.[107]

OPG owns and is licensed by the CNSC to operate the station. The most recent license was issued on January 1, 2016 and will expire November 30, 2025. OPG also owns and operates the

[107] *Canada*. International Atomic Energy Agency: Power Reactor Information System. 21 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA. Accessed 22 February 2019.

Darlington Nuclear Waste Management Facility (DWMF), a Class 1B nuclear facility, located at the Darlington Site. Additionally, OPG submitted an application to the CNSC for a proposed project to construct and operate four new nuclear reactors (see *Section 8.1*).

As of December 2016, refurbishment of the DNGS units is planned, with each unit refurbishment outage being three to four years in length:

- Unit 1 – 2021-2024
- Unit 2 – 2016-2020
- Unit 3 – 2019-2023
- Unit 4 – 2023-2026

The expected end-of-life for the four reactors (assuming the completion of planned refurbishment and 30-year nominal operating life post-refurbishment) are:

- Unit 1 – 2053
- Unit 2 – 2049
- Unit 3 – 2052
- Unit 4 – 2055

### *5.2.1 Decommissioning Plan and Radioactive Waste Estimate*

For planning purposes, OPG has chosen the Deferred Decommissioning strategy. The estimated volumes of radioactive waste generated through the decommissioning of DNGS are 47,042 cubic meters (1,661,273 $ft^3$) of LLW and 3,547 cubic meters (125,261 $ft^3$) of ILW (Table 5-3). The ultimate disposal of L&ILW is expected to be at the planned OPG L&ILW DGR in Kincardine, Ontario, which is expected to begin service by 2026 (see *Section 4.1.2*).[108]

For HLW management, the used fuel from the reactors is planned to be initially stored in the Irradiated Fuel Bays (IFBs) for a 10-year cooling period after which the used fuel will be loaded into the dry storage containers and transported to the interim used fuel storage facility (i.e., the DWMF) until a permanent disposal facility becomes available (see *Section 4.1.3*). As of December 31, 2016, Natural Resources Canada reported the HLW inventory stored onsite at DNGS were 524,828 fuel bundles, which had an estimated volume of 2,099 cubic meters (74,125 $ft^3$) and contained 10,066 metric tons (11,096 US tons) of uranium (Table 4-3).[109]

As of December 2016, the Dismantling & Demolition of DNGS is assumed to commence between 2083 and 2086. Site Restoration of DNGS is assumed to occur from 2090-2093. After the Site Restoration phase is completed, OPG will apply to the CNSC for a Licence to Abandon.

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108 *Preliminary Decommissioning Plan – Darlington Nuclear Generating Station*. Ontario Power Generation. December 2016. Rev. 2. https://www.opg.com/generating-power/nuclear/Documents/NK38-PLAN-00960-10001_DNGS_PDP.pdf

109 *Inventory of Radioactive Waste in Canada 2016*. Natural Resources Canada. 2018. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/uranium-nuclear/17-0467%20Canada%20Radioactive%20Waste%20Report_access_e.pdf

The cost associated with decommissioning the DNGS was estimated at $3.36 billion (2015 CAD) (Table 5-1).

As of December 2016, the Dismantling & Demolition of the DWMF is assumed to commence in 2085 and will take approximately two years to complete. Site Restoration of the DWMF is expected to be completed in 2086. OPG assumes that a Licence to Abandon will be received in 2087. The cost associated with decommissioning the DWMF was estimated at $18.35 million (2015 CAD) (Table 5-1).[110]

**Table 5-3.** Estimated Volumes of L&ILW Generated During the Decommissioning of DNGS

| DNGS Unit | Low-Level Radioactive Waste (LLW) | | Intermediate-Level Radioactive Waste (ILW) | |
|---|---|---|---|---|
| | $m^3$ | $ft^3$ | $m^3$ | $ft^3$ |
| Unit 1 | 8,954 | 316,208 | 836 | 29,523 |
| Unit 2 | 8,815 | 311,299 | 836 | 29,523 |
| Unit 3 | 8,802 | 310,840 | 836 | 29,523 |
| Unit 4 | 8,791 | 310,451 | 836 | 29,523 |
| Unit 0 (common services) | 11,681 | 412,511 | 205 | 7,240 |
| **Total*** | **47,042** | **1,661,273** | **3,547** | **125,261** |

* May not add due to rounding

Source: Adapted from Table 4-2, *Preliminary Decommissioning Plan - Darlington Nuclear Generating Station*. Ontario Power Generation. December 2016. https://www.opg.com/generating-power/nuclear/Documents/NK38-PLAN-00960-10001_DNGS_PDP.pdf.

[110] *Preliminary Decommissioning Plan – Darlington Waste Management Facility*. Ontario Power Generation. December 2016. Rev. 4. https://www.opg.com/generating-power/nuclear/Documents/00044-PLAN-00960-00001_DWMF_PDP.pdf

Photo 5.2-2 – Darlington's Reactor Building No.2 and Vacuum Building as they were being constructed on the shore of Lake Ontario. Photo courtesy of Ontario Power Generation (1984). Used with permission.

## 5.3 Donald C. Cook Nuclear Plant

Photo 5.3-1 – Located on the shore of Lake Michigan in Berrien County, Michigan, the Cook Nuclear Plant began commercial operations in 1975. Photo courtesy of American Electric Power (August 2014). Used with permission.

The Donald C. Cook Nuclear Plant is located on the east shore of Lake Michigan near the City of Bridgman in Lake Charter Township, Berrien County, Michigan, approximately 13 miles (21 kilometers) south of Benton Harbor, MI. The Cook Plant occupies 650 acres (263 hectares) and approximately 0.75 miles (1.2 kilometers) lake frontage. The tract is part of the world's largest formation of freshwater dunes.[111]

The Cook Plant, owned by American Electric Power (AEP), contains two Westinghouse four-loop PWRs (Cook-1 and Cook-2) and an ISFSI that are licensed individually by the NRC. Construction of Cook-1 began March 25, 1969, initial criticality[112] was achieved January 18, 1975, and commercial operations began August 28, 1975.[113] Construction of Cook-2 began

[111] *Cook Plant: About Us*. Indiana Michigan Power. 2018. http://www.cookinfo.com/About.aspx. Accessed 3 September 2018.
[112] According to the NRC, *criticality* is "the normal operating condition of a reactor, in which nuclear fuel sustains a fission chain reaction. A reactor achieves criticality (and is said to be critical) when each fission event releases a sufficient number of neutrons to sustain an ongoing series of reactions."
[113] *Cook-1*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=653. Accessed 15 February 2019.

March 25, 1969, initial criticality was achieved March 10, 1978, and commercial operations began July 1, 1978.[114] Construction cost $3.352 billion (2007 USD).[115]

Indiana Michigan Power Company (I&M), a subsidiary of AEP, was issued the original operating license for Cook-1 on October 25, 1974, was renewed on August 30, 2005, and will expire on October 25, 2034. Cook-1 is licensed to be operated at a maximum power level of 3,304 MW thermal and has an installed capacity of 1,045 MW electric. Since 2000, Cook-1 has supplied an average of 6,993 GWh of electricity annually. Over its lifetime, Cook-1 has supplied 263.45 TWh of electricity, corresponding to a capacity factor[116] of 69.1 percent.[117]

I&M was issued the original operating license for Cook-2 on December 23, 1977, was renewed on August 30, 2005, and will expire on December 23, 2037. Cook-2 is licensed to be operated at a maximum power level of 3,468 MW thermal and has an installed capacity of 1,168 MW electric. Since 2000, Cook-2 has supplied an average of 8,261 GWh of electricity annually. Over its lifetime, Cook-2 has supplied 262.96 TWh of electricity, corresponding to a capacity factor of 70.7 percent.[118]

### *5.3.1 Decommissioning Plan and Spent Nuclear Fuel Estimate*

As of January 21, 2016, an updated study of the DECON with indefinite on-site dry storage decommissioning scenario produced a decommissioning cost estimate of $1.634 billion (2015 USD). In addition, the plan included an annual cost of $4.91 million per year of post-decommissioning spent fuel storage and $56.95 million for the eventual decommissioning of the ISFSI.[119] As of December 31, 2016, the combined NRC minimum decommissioning cost estimate, pursuant to 10 CFR 50.75(b) and (c), was $979.8 million (2016 USD) (Table 5-1). However, the combined decommissioning trust fund balance was only $877.7 million, but I&M expects this balance to exceed the NRC minimum decommissioning cost estimates at the time both units are shut down.[120]

Both reactors are planned to be decommissioned in series following shut down upon license expiration in 2034 and 2037. Decommissioning of the site is planned to be completed in 2047, which is 112 months after the shutdown of Cook-2. Spent fuel is planned to remain onsite in dry

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114 *Cook-2*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=654. Accessed 15 February 2019.
115 *Michigan Nuclear Profile 2010*. U.S. Energy Information Administration. 26 April 26. https://www.eia.gov/nuclear/state/archive/2010/michigan/. Accessed 15 February 2019.
116 According to the IAEA, *capacity factor* is the "actual energy output of an electricity-generating device divided by the energy output that would be produced if it operated at its rated power output for the entire year."
117 *Cook-1*.
118 *Cook-2*.
119 *Decommissioning Study of the D.C. Cook Nuclear Power Plant* (Revision 0). Knight Cost Engineering Services, LLC. 21 January 2016. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18341A134. Accessed 18 January 2019.
120 *Donald C. Cook Nuclear Plant Units 1 and 2: Decommissioning Funding Status Report*. Indiana Michigan Power. 21 March 2017. https://www.nrc.gov/docs/ML1708/ML17081A443.pdf. Accessed 10 January 2019.

storage until a DOE facility begins accepting the HLW. The maximum number of spent fuel assemblies stored at the ISFSI at any given time would be approximately 6,552 requiring 205 storage casks. In addition to the spent fuel, the GTCC waste would be stored at the ISFSI requiring an additional six casks.[121] As of August 22, 2016, the DOE inventory indicated there were 896 spent fuel assemblies in dry storage contained in 28 casks (Table 4-5).[122]

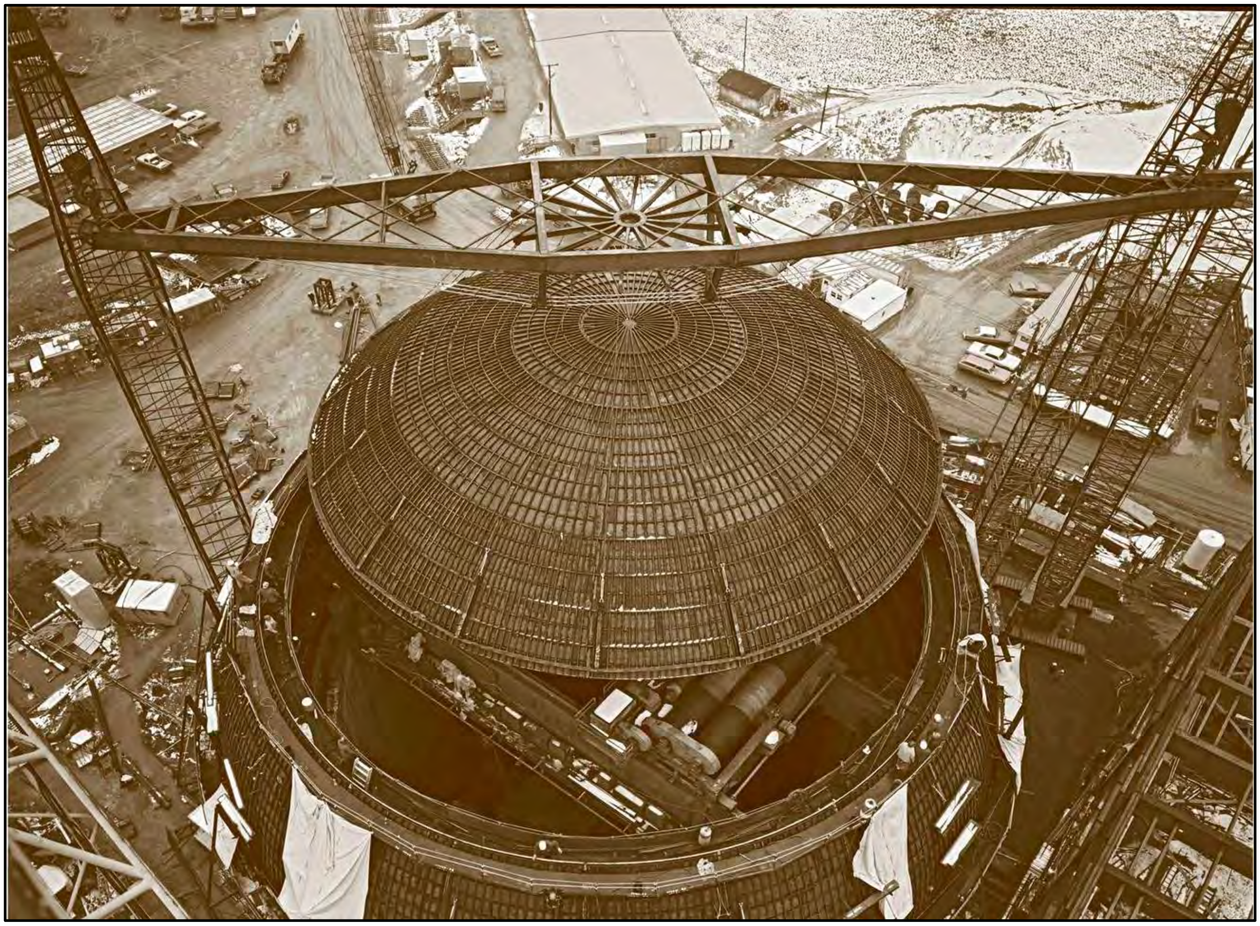

**Photo 5.3-2** – Located on the shore of Lake Michigan near Bridgman, Michigan, the cap of the Cook Nuclear Plant Unit 1 Containment Building is captured being lowered into place during construction. Photo courtesy of American Electric Power (circa 1970). Used with permission.

[121] *Decommissioning Study of the D.C. Cook Nuclear Power Plant* (Revision 0). p.31

[122] *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the US Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.

**Photo 5.3-3** – The complete Unit 2 turbine-generator was replaced in 2016 in a $250 million (USD) project. Photo courtesy of American Electric Power (2016). Used with permission.

## 5.4 Enrico Fermi Nuclear Station

**Photo 5.4-1**– Located on the shore of Lake Erie in Monroe County, Michigan, the Enrico Fermi Nuclear Station (Fermi-2) began commercial operations in 1988. Swan Creek is seen beyond the rising steam from the pair of cooling towers. Photo courtesy of DTE Energy (2012). Used with permission.

The Enrico Fermi Nuclear Station Unit 2 (Fermi-2) is located on the west shore of Lake Erie's western basin in Frenchtown Charter Township, Monroe County, Michigan, approximately 25 miles (40 kilometers) northeast of Toledo, OH. The remnants of the Enrico Fermi Atomic Power Plant Unit 1 (Fermi-1) are located on the site, which collectively occupies 1,260 acres (510 hectares) and approximately 1.8 miles (2.9 kilometers) of lake frontage. The Detroit River International Wildlife Refuge manages 650 acres (263 hectares) of the Fermi site. For information about Fermi-1, see *Section 7.1 Enrico Fermi Atomic Power Plant*. For information about Fermi-3, see *Section 8.2 DTE's Proposed New Reactor at Fermi*.

The DTE Electric Company (DTE) owns and operates Fermi-2, a General Electric Type 4 BWR. Construction on Fermi-2 begin in September 1972 and cost $6.11 billion (2007 USD).[123] Initial criticality was achieved on June 21, 1985 and commercial operations began January 23, 1988.[124]

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[123] *Michigan Nuclear Profile 2010*. U.S. Energy Information Administration. 26 April 26. https://www.eia.gov/nuclear/state/archive/2010/michigan/. Accessed 15 February 2019.
[124] *Fermi-2*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=674. Accessed 15 February 2019.

The NRC issued DTE the original operating license for Fermi-2 on July 15, 1985, was renewed on December 15, 2016, and will expire on March 20, 2045. Fermi-2 is licensed to be operated at a maximum power level of 3,486 MW thermal and has an installed capacity of 1,122 MW electric. Since 2000, Fermi-2 has supplied an average of 8,098 GWh of electricity annual. Over its lifetime, Fermi-2 has supplied 216.14 TWh of electricity, corresponding to a capacity factor of 76.3 percent.[125]

### *5.4.1 Spent Nuclear Fuel Estimate and Decommissioning Fund Estimates*

As of August 22, 2016, the DOE inventory indicated there were 408 spent fuel assemblies in dry storage contained in 6 casks.[126] As of March 30, 2017, approximately 6,528 spent fuel assemblies contained in 96 casks were estimated to be required upon operating license expiration (Table 4-5).[127]

As of December 31, 2016, the decommissioning cost estimate for the ISFSI with a 25 percent contingency was $8.9 million (2016 USD). The funds for the ISFSI decommissioning were reported to be placed in a separate account in the Fermi-2 nuclear decommissioning trust fund and the account held approximately $2.2 million (2016 USD).[128] As of December 31, 2018, the minimum decommissioning fund estimate for Fermi-2 was $1.12 billion (2018 USD) (Table 5-1) and the decommissioning trust fund amount was $1.29 billion with approximately $3 million being collected each year for decommissioning.[129]

125 *Fermi-2.*
126 *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.
127 *Fermi 2 ISFSI Decommissioning Funding Plan Update* (10 CFR 72.30). DTE Energy Company. 30 March 2017. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML17089A789. Accessed 10 August 2018.
128 *Ibid.*
129 *Decommissioning Funding Status Report for Fermi 2*. DTE Energy Company. 28 March 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19087A224. Accessed 25 June 2019.


**Photo 5.4-2** – Operators train in the control room simulator of DTE's Enrico Fermi Nuclear Station near Newport, MI. Photo courtesy of DTE Energy. Used with permission.

## 5.5 James A. FitzPatrick Nuclear Power Plant & Nine Mile Point Nuclear Station

Photo 5.5-1. Located on the shore of Lake Ontario in Oswego County, New York, the FitzPatrick and Nine Mile Point nuclear power plants are owned and operated by Exelon Corp. Photo courtesy of Exelon.

The James A. FitzPatrick Nuclear Power Plant and Nine Mile Point Nuclear Station (NMP) are located on a shared site along the southeast shore of Lake Ontario in the Town of Scriba, Oswego County, New York, approximately 6 miles (10 kilometers) northeast of the City of Oswego, NY. The FitzPatrick plant contains a single General Electric Type 4 BWR and an ISFSI, and the NMP contains two General Electric BWRs (NMP-1 and NMP-2) and an ISFSI that are licensed individually by the NRC. The reactors and support buildings occupy 1,600 acres (647 hectares) and 2.1 miles (3.4 kilometers) of shoreline. The FitzPatrick site occupies the east sector of the NMP site, approximately 0.57 miles (0.92 kilometers) east of NMP-1. NMP-2 is located between NMP-1 and the FitzPatrick site.[130]

### *5.5.1 James A. FitzPatrick Nuclear Power Plant*

The FitzPatrick Plant is owned by Exelon FitzPatrick, LLC and licensed by the NRC to be operated by Exelon Generation Company, LLC (EGC). Construction of FitzPatrick began September 1, 1968 and cost $1.065 billion (2007 USD).[131] Initial critical was achieved on November 17, 1974 and commercial operations began July 28, 1975.[132]

The original operating license was issued on October 17, 1974, was renewed on September 8, 2008, and will expire on October 17, 2034. On March 3, 2017, the NRC approved the license

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130 *2017 Annual Radiological Environmental Operating Report*. Exelon Generating Co., LLC. 7 May 2018. https://www.nrc.gov/docs/ML1812/ML18127B699.pdf

131 *New York Nuclear Profile 2010*. U.S. Energy Information Administration. 26 April 2012. https://www.eia.gov/nuclear/state/archive/2010/newyork/. Accessed 15 February 2019.

132 *FitzPatrick*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=668. Accessed 15 February 2019.

transfer from Entergy Nuclear Operations (ENO) to EGC.[133] FitzPatrick is licensed to be operated at a maximum power level of 2,536 MW thermal and has an installed capacity of 813 MW electric. Since 2000, FitzPatrick has supplied an average of 6,651 GWh of electricity annually. Over its lifetime, FitzPatrick has supplied 231.50 TWh of electricity, corresponding to a capacity factor of 77.3 percent.[134]

#### *5.5.1.1 Spent Nuclear Fuel Estimate and Decommissioning Fund Estimates*

No estimate of the HLW to be stored at the FitzPatrick ISFSI upon decommissioning was found in the publicly available documents submitted by EGC to the NRC. EGC was contacted several times and declined to provide an estimate. The IJC requested the NRC obtain an updated estimate of spent nuclear fuel upon FitzPatrick's operating license expiration. In a letter dated January 24, 2019, the NRC estimated that approximately 6,314 spent nuclear fuel assemblies contained in 93 storage casks will be required upon license expiration in 2034.[135] As of August 22, 2016, the DOE inventory indicated there were 1,428 spent fuel assemblies in dry storage contained in 21 casks (Table 4-5).[136]

As of December 31, 2018, the minimum decommissioning fund estimate was $656.95 million and the ISFSI obligation was $10.27 million (2018 USD) (Table 5-1). The amount of decommissioning trust funds accumulated was $837.71 million.[137]

### *5.5.2 Nine Mile Point Nuclear Station*

Construction of NMP-1 began April 12, 1965 and cost $804.7 million (2007 USD).[138] Initial criticality was achieved on September 5, 1969 and commercial operations began December 1, 1969.[139] Construction of NMP-2 began August 1, 1975 and cost $8.529 billion (2007 USD).[140]

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[133] *NRC Approves License Transfer of FitzPatrick Nuclear Plant*. U.S. Nuclear Regulatory Commission. 3 March 2017. https://www.nrc.gov/docs/ML1706/ML17062A563.pdf

[134] *FitzPatrick*.

[135] *International Joint Commission Request for NRC Assistance in Obtaining Projected HLW Estimates for Nuclear Power Plants Operated by Exelon Generation Company*. U.S. Nuclear Regulatory Commission. 24 January 2019. Accession Number = ML18340A0451.

[136] *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.

[137] *Report on the Status of Decommissioning Funding for Reactors and Independent Spent Fuel Storage Installations*. Exelon Generation Company, LLC. 1 April 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19091A140. Accessed 25 June 2019.

[138] *New York Nuclear Profile 2010.*

[139] *Nine Mile Point-1*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=607. Accessed 15 February 2019.

[140] *New York Nuclear Profile 2010.*

Initial criticality was achieved May 23, 1987 and commercial operations began March 11, 1988.[141]

NMP-1 is owned by Exelon Generation Company, LLC (EGC), and NMP-2 is owned by EGC (82 percent) and the Long Island Power Authority (18 percent). On March 25, 2014, the NRC approved the transfer of operating authority of NMP-1 and NMP-2 to EGC from Nine Mile Point Nuclear Station, LLC.[142]

The original operating license for NMP-1 was issued on December 26, 1974, was renewed on October 31, 2006, and will expire on August 22, 2029. NMP-1 is licensed to be operated at a maximum power level of 1,850 MW thermal and has an installed capacity of 613 MW electric. Since 2000, NMP-1 has supplied an average of 4,913 GWh of electricity annually. Over its lifetime, NMP Unit 1 has supplied 186.19 TWh of electricity, corresponding to a capacity factor of 73.6 percent.[143]

The original operating license for NMP-2 was issued on July 2, 1987, was renewed on October 31, 2006, and will expire on October 31, 2046. NMP-2 is licensed to be operated at a maximum power level of 3,988 MW thermal and has an installed capacity of 1,277 MW electric. Since 2000, NMP-2 has supplied an average of 9,486 GWh of electricity annually. Over its lifetime, NMP-2 has supplied 249.92 TWh of electricity, corresponding to a capacity factor of 84.2 percent.[144]

#### *5.5.2.1 Spent Nuclear Fuel Estimate and Decommissioning Fund Estimates*

No estimate of the HLW to be stored at the NMP ISFSI upon decommissioning was found in the publicly available documents submitted by EGC to the NRC. EGC was contacted several times and declined to provide an estimate. The IJC requested the NRC obtain an updated estimate of spent nuclear fuel upon NMP's operating licenses expiration dates. In a letter dated January 24, 2019, the NRC estimated that approximately 14,291 spent nuclear fuel assemblies contained in 234 storage casks will be required upon license expiration in 2046.[145] As of August 22, 2016, the DOE inventory indicated there were 1,464 spent fuel assemblies in dry storage contained in 24 casks (Table 4-5).[146]

As of December 31, 2018, the minimum decommissioning fund estimate for NMP-1 was $624.97 million (2018 USD) and ISFSI obligation was $6.78 million. However, the amount of decommissioning trust funds accumulated was only $622.19 million. The minimum

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[141] *Nine Mile Point-2*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=711. Accessed 15 February 2019.
[142] *Nine Mile Point Nuclear Power Station, Unit Nos. 1 and 2*. U.S. Nuclear Regulatory Commission. 1 April 2014. https://www.nrc.gov/docs/ML1409/ML14091A323.pdf
[143] *Nine Mile Point-1*.
[144] *Nine Mile Point-2*.
[145] *International Joint Commission Request for NRC Assistance in Obtaining Projected HLW Estimates for Nuclear Power Plants Operated by Exelon Generation Company*.
[146] *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development.*

decommissioning trust fund for the EGC portion (82 percent) of NMP-2 was $573.43 million and ISFSI obligation of $5.56 million. However, the amount of decommissioning trust funds accumulated was only $390.62 million. The minimum decommissioning trust fund for the Long Island Power Authority portion (18 percent) of NMP-2 was $125.87 million and ISFSI obligation of $1.22 million (Table 5-1). However, the amount of decommissioning trust funds accumulated was only $125.0 million.[147]

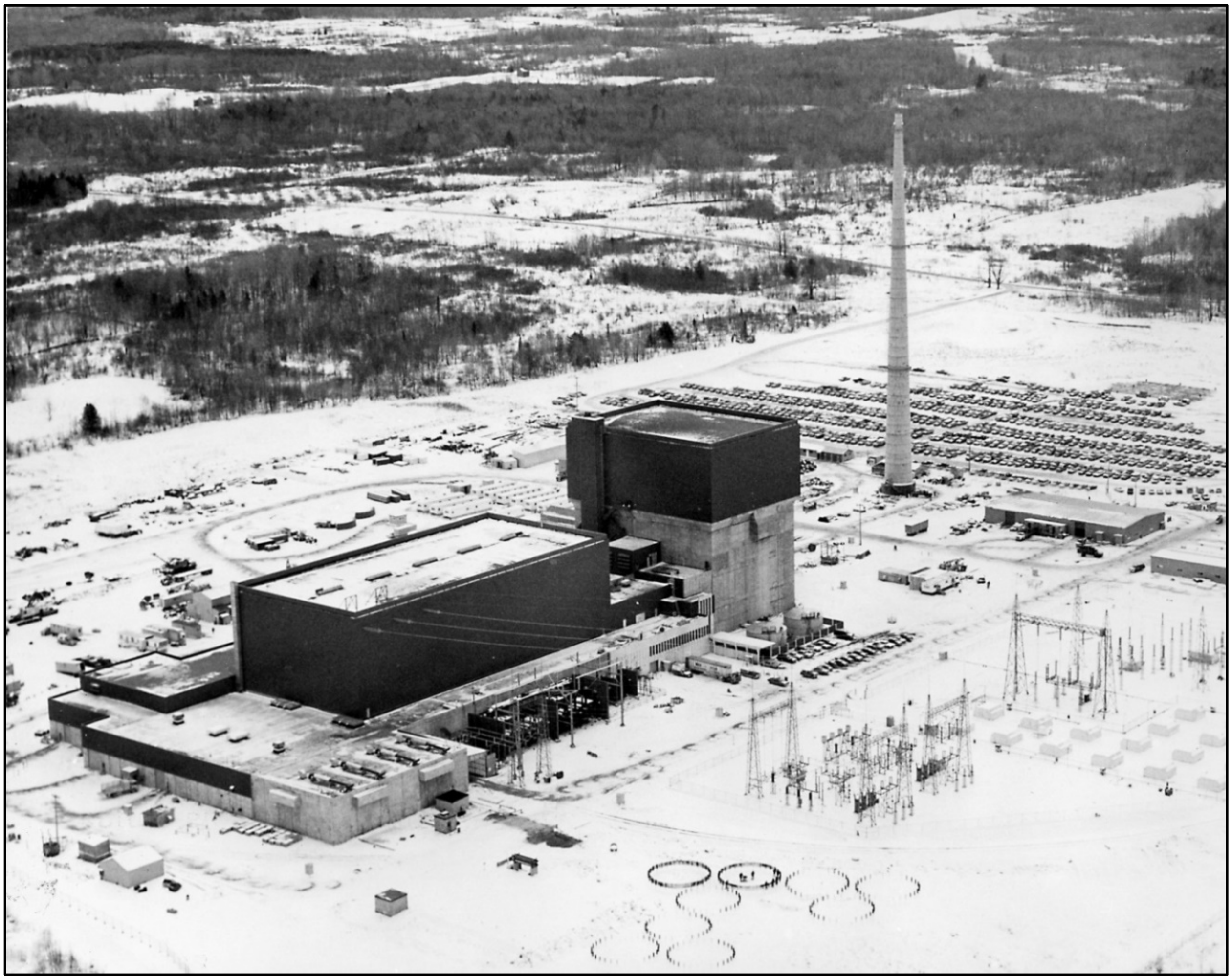

**Photo 5.5-2** – Originally designed as an 821 MWe plant, the FitzPatrick Nuclear Power Plant was scheduled for completion in 1973. The New York State Power Authority reported that the plant was 80 percent completed at the time of this photograph was captured. Photo courtesy of the U.S. Department of Energy: flickr (circa 1973). Public domain.

[147] *Report on Status of Decommissioning Funding for Reactors and Independent Spent Fuel Storage Installations*. Exelon Generation Company, LLC. 1 April 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19091A140. Accessed 25 June 2019.

## 5.6 Point Beach Nuclear Plant

**Photo 5.6-1** – Located on the shore of Lake Michigan in Manitowoc County, Wisconsin, the Point Beach Nuclear Plant began commercial operations in 1970. Photo courtesy of the U.S. Army Corps of Engineers: Great Lakes Oblique Imagery (April 2012). Public domain.

The Point Beach Nuclear Plant (PBNP) is located on the west shore of Lake Michigan near the town of Two Creeks in Manitowoc County, Wisconsin, approximately 13 miles (21 kilometers) north-northeast of Manitowoc, WI and 30 miles (48 kilometers) southeast of Green Bay, WI. The PBNP occupies approximately 1.2 miles (1.9 kilometers) of lake frontage and 1,260 acres (510 hectares) of land, which approximately 60 percent is licensed to farmers who use the land to grow various crops.[148]

The PBNP is currently owned and licensed to be operated by NextEra Energy Point Beach, LLC (NEPB), a subsidiary of NextEra Energy Resources, LLC. The PBNP contains two Westinghouse two-loop pressurized water reactors (PWRs) (Point Beach-1 and Point Beach-2) and an ISFSI that are licensed individually by the NRC. Construction of Point Beach-1 began July 19, 1967, initial criticality was achieved November 2, 1970, and commercial operations

[148] *2017 Annual Monitoring Report*. NextEra Energy Point Beach, LLC. 30 April 2018. https://www.nrc.gov/docs/ML1812/ML18120A234.pdf

began December 21, 1970.[149] Construction of Point Beach-2 began July 25, 1968, initial criticality was achieved May 30, 1972, and commercial operations began October 1, 1972.[150] Construction cost $589.1 million (2007 USD).[151]

The original operating license for Point Beach-1 was issued on October 5, 1970, was renewed on December 22, 2005, and will expire on October 5, 2030. Point Beach-1 is licensed to be operated at a maximum power level of 1,800 MW thermal and has an installed capacity of 591 MW electric. Since 2000, Point Beach-1 has supplied an average of 4,267 GWh of electricity annually. Over its lifetime, Point Beach-1 has supplied 170.94 TWh of electricity, corresponding to a capacity factor of 81.4 percent.[152]

The original operating license for Point Beach-2 was issued on March 8, 1973, was renewed on December 22, 2005, and will expire on March 8, 2033. Point Beach-2 is licensed to be operated at a maximum power level of 1,800 MW thermal and has an installed capacity of 591 MW electric. Since 2000, Point Beach-2 has supplied an average of 4,274 GWh of electricity annually. Over its lifetime, Point Beach-2 has supplied 169.90 TWh of electricity, corresponding to a capacity factor of 84.2 percent.[153]

### *5.6.1 Spent Nuclear Fuel Estimate and Decommissioning Fund Estimates*

As of August 22, 2016, the DOE inventory indicated there were 1,120 spent fuel assemblies in dry storage contained in 39 casks.[154] As of March 30, 2017, approximately 3,616 spent fuel assemblies contained in 87 dry storage casks and an additional two casks for GTCC waste were projected to be required upon the operating licenses expiration dates (Table 4-5).[155]

As of March 25, 2019, the minimum decommissioning fund estimate for Point Beach-1 was $447.28 million (2018 USD). However, the decommissioning trust fund balance was $401.73 million, but NEPB projects the fund will be $544.88 million at shutdown after calculating a two percent real rate of return as allowed by the NRC. The minimum decommissioning fund estimate for Point Beach-2 was $447.28 million. However, the decommissioning trust fund balance was $378.52 million, but NEPB projects the fund will be $538.51 million at shutdown after

149 *Point Beach-1*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=622. Accessed 15 February 2019.
150 *Point Beach-2*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=644. Accessed 15 February 2019.
151 *Wisconsin State Nuclear Profile 2010*. U.S. Energy Information Administration. 26 April 2012. https://www.eia.gov/nuclear/state/archive/2010/wisconsin/. Accessed 15 February 2019.
152 *Point Beach-1*.
153 *Point Beach-2*.
154 *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.
155 *Decommissioning Funding Status Reports / Independent Spent Fuel Storage Installation (ISFSI) Financial Assurance Update.* Florida Power & Light Company. 30 March 2017. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML17093A722. Accessed 10 August 2018.

calculating a two percent real rate of return as allowed by the NRC. The ISFSI decommissioning cost estimate with a 25 percent contingency was $8.43 million (2018 USD) and was assumed to be incurred in year 2075 (Table 5-1).[156]

Photo 5.6-2 – The Point Beach Nuclear Power Plant was formerly operated by Wisconsin Electric Power Co. and Wisconsin Michigan Power Co. Photo courtesy of the U.S. Department of Energy: flickr (circa 1973). Public domain.

156 *Decommissioning Funding Status Reports / Independent Spent Fuel Storage Installation Financial Assurance Update.* Florida Power and Light. 25 March 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19088A130. Accessed 25 June 2019.

## 5.7 Robert Emmett Ginna Nuclear Power Plant

**Photo 5.7-1** – Located on the shore of Lake Ontario in Wayne County, New York, the R.E. Ginna Nuclear Power Plant began commercial operations in 1970. Photo courtesy of the U.S. Army Corps of Engineers: Great Lakes Oblique Imagery (April 2012). Public domain.

The R.E. Ginna Nuclear Power Plant is located on the south shore of Lake Ontario in the Town of Ontario, Wayne County, New York, approximately 20 miles (32 kilometers) northeast of Rochester, NY. The Ginna Plant occupies approximately 426 acres (172 hectares) and approximately 0.75 miles (1.2 kilometers) of lake frontage.[157]

The Ginna Plant is currently owned and operated by Exelon Generation Company, LLC (EGC), a subsidiary of Constellation Energy Nuclear Group, LLC. The Ginna Plant contains a single Westinghouse two-loop PWR and an ISFSI that are licensed individually by the NRC. Construction began April 25, 1966 and cost $346.15 million (2007 USD).[158] Initial criticality was achieved November 8, 1969 and commercial operations began July 1, 1970.[159]

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157 *Ginna Nuclear Power Plant*. Exelon Generation. 2017. http://www.exeloncorp.com/locations/Documents/Ginna%20Fact%20Sheet%20-%202017.pdf
158 *New York Nuclear Profile 2010*. U.S. Energy Information Administration. 26 April 2012. https://www.eia.gov/nuclear/state/archive/2010/newyork/. Accessed 15 February 2019.
159 *Ginna*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=609. Accessed 15 February 2019.

The original operating license for the PWR was issued on September 19, 1969, was renewed on May 19, 2004, and will expire on September 18, 2029. The Ginna Plant is licensed to be operated at a maximum power level of 1,775 MW thermal and has an installed capacity of 580 MW electric. Since 2000, Ginna has supplied an average of 4,476 GWh of electricity annually. Over its lifetime, Ginna has supplied 176.39 TWh of electricity, corresponding to a capacity factor of 84.5 percent.[160]

### *5.7.1 Spent Nuclear Fuel Estimates and Decommissioning Fund Estimates*

No estimate of the HLW to be stored at the Ginna ISFSI upon decommissioning was found in the publicly available documents submitted by EGC to the NRC. EGC was contacted several times and declined to provide an estimate. The IJC requested the NRC obtain an updated estimate of spent nuclear fuel upon Ginna's operating license expiration. In a letter dated January 24, 2019, the NRC estimated that approximately 1,883 spent nuclear fuel assemblies contained in 59 storage casks will be required upon license expiration in 2029.[161] As of August 22, 2016, the DOE inventory indicated there were 192 spent fuel assemblies in dry storage contained in 6 casks (Table 4-5).[162]

As of December 31, 2018, the minimum decommissioning fund estimate was $457.78 million (2018 USD) and the ISFSI obligation was $6.63 million (Table 5-1). However, the decommissioning trust fund amount was only $453.70 million, but EGC expects a two percent annual real rate of return as allowed by the NRC.[163]

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160 *Ginna*.

161 *International Joint Commission Request for NRC Assistance in Obtaining Projected HLW Estimates for Nuclear Power Plants Operated by Exelon Generation Company*. U.S. Nuclear Regulatory Commission. 24 January 2019. Accession Number = ML18340A0451.

162 *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.

163 *Report on the Status of Decommissioning Funding for Reactors and Independent Spent Fuel Storage Installations*. Exelon Generation Company, LLC. 1 April 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19091A140. Accessed 25 June 2019.

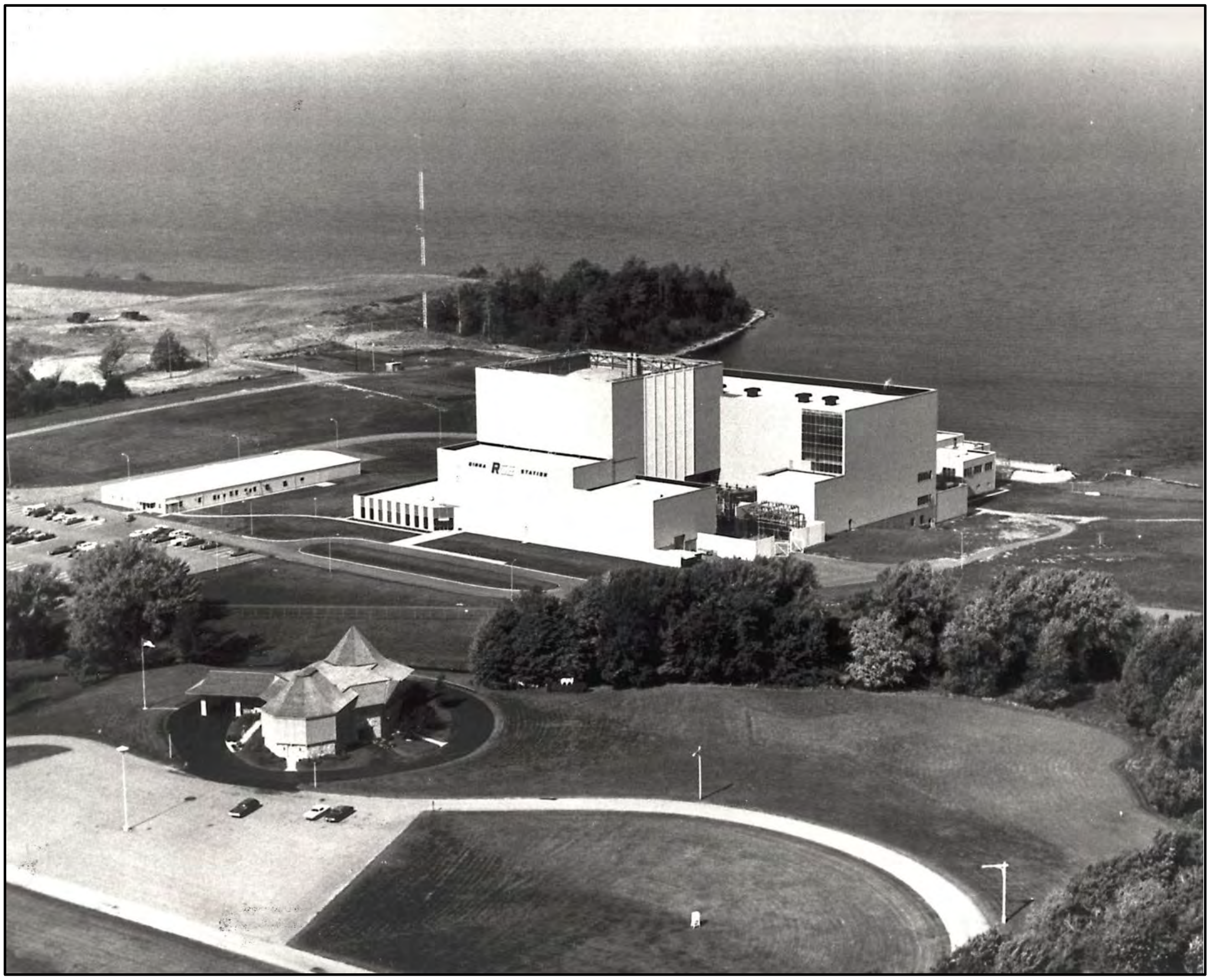

**Photo 5.7-2 –** View of the Robert Emmett Ginna Nuclear Power Plant on the south shore of Lake Ontario at Ontario, New York. Originally designed as a 420 MWe plant, RE Ginna was formerly owned by the Rochester Gas and Electric Company and began operation in 1969. Photo courtesy of the U.S. Department of Energy: flickr (circa 1974). Public domain.

# 6. Early Closure Announcements

Due to the combination of financial challenges of sustained low natural gas prices, market liberalization, and renewable energy subsidies, nine nuclear reactors at four sites in the Great Lakes basin are still operating but have announced closures before their operating license expiration, which will require early decommissioning (Table 5-1).


**Photo 6.0-1** – A new reactor head is moved in preparation for installation at the Davis-Besse Nuclear Power Station located near Oak Harbor, Ohio. FirstEnergy Solutions announced on March 28, 2018, that three nuclear power plants, including Davis-Besse, would close in the next three years. However, with the recent passage of Ohio House Bill 6, FirstEnergy Solutions is in the process to rescind the deactivation orders for its Perry and Davis-Besse nuclear power stations on the south shore of Lake Erie in Ohio. Photo courtesy of FirstEnergy Solutions (October 2011). Used with permission.

## 6.1 Pickering Nuclear Generating Station

**Photo 6.1-1** – Located on the shore of Lake Ontario in the Durham Region, Ontario, the Pickering Nuclear Generating Station began commercial operations in 1971 and is scheduled to close in 2024. Photo courtesy of Ontario Power Generation (2009). Used with permission.

The Pickering Nuclear Generating Station (PNGS) is located on the north shore of Lake Ontario at Moore Point in the Town of Pickering, Durham Region, Ontario, approximately 32 kilometers (20 miles) northeast of downtown Toronto, ON. PNGS occupies a land area of 240 hectares (600 acres) and approximately 3.4 kilometers (2.1 miles) of lake frontage.[164]

OPG owns and is licensed by the CNSC to operate the PNGS. The PNGS contains eight CANDU reactors. The first four CANDU reactors (PNGS A) went into service in 1971. In 1997, these reactors were placed in voluntary lay-up as part of what was then Ontario Hydro's nuclear improvement program. In September 2003, Unit 4 was returned to commercial operation followed by Unit 1 in November 2005. Units 2 and 3 remain shut down. Units 5 to 8 (PNGS B) began first operating in 1983 and continue to operate today. Since 2006, the six operating reactors have an installed capacity of 3,094 MWe combined and have supplied an average of

[164] *Preliminary Decommissioning Plan – Pickering Nuclear Generating Stations A & B*. Ontario Power Generation. December 2016. Rev. 2. https://www.opg.com/generating-power/nuclear/Documents/P-PLAN-00960-00001_PNGS_PDP.pdf

45,134 GWh of electricity annually. Over its lifetime, PNGS has supplied 864.04 TWh of electricity.[165]

### *6.1.1 Closure Announcement*

On August 8, 2018, the CNSC renewed the Nuclear Power Reactor Operating Licence for the PNGS. The licence is valid from September 1, 2018 until August 31, 2028. The CNSC also authorized OPG to operate PNGS Units 5 to 8 to a maximum of 295,000 equivalent full power hours. OPG intends to cease commercial operation of the PNGS on December 31, 2024. This will be followed by a post-shutdown activities and stabilization stage until 2028. The commercial operation of any PNGS reactor unit beyond 2024 would require authorization from the CNSC.[166]

### *6.1.2 Radioactive Waste Estimates and Decommissioning Plan*

For planning purposes, the expected decommissioning strategy is Deferred Decommissioning. The estimated volumes of L&ILW generated through the decommissioning of PNGS are 62,016 cubic meters (2,190,074 $ft^3$) of LLW and 6,102 cubic meters (215,490 $ft^3$) of ILW (Table 6-1). The ultimate disposal of the L&ILW is expected to be at the proposed OPG L&ILW DGR in Kincardine, Ontario, which is assumed to begin service by 2026.[167]

As of December 31, 2016, Natural Resources Canada reported the HLW inventory stored onsite at PNGS A was 339,170 fuel bundles, which had an estimated volume of 1,357 cubic meters (47,922 $ft^3$) and contained 6,739 metric tons (7,429 US tons) of uranium. Stored onsite at PNGS B, there were 388,579 fuel bundles, which had an estimated volume of 1,554 cubic meters (54,879 $ft^3$) and contained 7,721 metric tons (8,511 US tons) of uranium (Table 4-3).[168]

As of December 2016, Site Restoration of PNGS A is assumed to occur from 2061-2064. Site Restoration of PNGS B is assumed to occur from 2061-2065. The cost associated with decommissioning the PNGS is estimated at $5.19 billion (2015 CAD) (Table 5-1).[169]

OPG also owns and operates the Pickering Waste Management Facility (PWMF), a Class 1B nuclear facility, located at the Pickering Nuclear Site. As of December 2016, the Dismantling & Demolition of the PWMF is assumed to commence in 2055 and Site Restoration is expected to be completed in 2056. OPG assumes that a Licence to Abandon will be received in 2057. The

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165 *Canada*. International Atomic Energy Agency: Power Reactor Information System. 21 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA. Accessed 22 February 2019.

166 *CNSC Renews Ontario Power Generation's Nuclear Power Reactor Operating Licence for the Pickering Nuclear Generating Stations*. Canadian Nuclear Safety Commission. 8 August 2018. https://www.canada.ca/en/nuclear-safety-commission/news/2018/08/cnsc-renews-ontario-power-generations-nuclear-power-reactor-operating-licence-for-the-pickering-nuclear-generating-station.html. Accessed 10 August 2018.

167 *Preliminary Decommissioning Plan – Pickering Nuclear Generating Stations A & B*.

168 *Inventory of Radioactive Waste in Canada 2016*. Natural Resources Canada. 2018. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/uranium-nuclear/17-0467%20Canada%20Radioactive%20Waste%20Report_access_e.pdf

169 *Preliminary Decommissioning Plan – Pickering Nuclear Generating Stations A & B*.

cost associated with decommissioning the PWMF was estimated at $29.82 million (2015 CAD) (Table 5-1).[170]

**Table 6-1.** Estimated Volumes of L&ILW Generated During the Decommissioning of PNGS A & B

| PNGS A and B Units | Low-Level Radioactive Waste (LLW) | | Intermediate-Level Radioactive Waste (ILW) | |
|---|---|---|---|---|
| | $m^3$ | $ft^3$ | $m^3$ | $ft^3$ |
| Unit 1 | 6,224 | 219,799 | 714 | 25,215 |
| Unit 2 | 5,375 | 189,816 | 711 | 25,109 |
| Unit 3 | 5,375 | 198,816 | 711 | 25,109 |
| Unit 4 | 6,220 | 219,657 | 714 | 25,215 |
| Unit 5 | 5,342 | 188,651 | 758 | 26,769 |
| Unit 6 | 5,338 | 188,510 | 758 | 26,769 |
| Unit 7 | 5,338 | 188,510 | 758 | 26,769 |
| Unit 8 | 5,342 | 188,651 | 758 | 23,769 |
| Unit 0 (common services) | 17,462 | 616,665 | 217 | 7,663 |
| **Total*** | **62,016** | **2,190,074** | **6,102** | **215,490** |

* May not add due to rounding

Source: Adapted from Table 4-2, *Preliminary Decommissioning Plan - Pickering Nuclear Generating Stations A & B*. Ontario Power Generation. December 2016. https://www.opg.com/generating-power/nuclear/Documents/P-PLAN-00960-00001_PNGS_PDP.pdf.

[170] *Preliminary Decommissioning Plan – Pickering Waste Management Facility*. Ontario Power Generation. December 2016. https://www.opg.com/generating-power/nuclear/Documents/92896-PLAN-00960-00001_PWMF_PDP.pdf

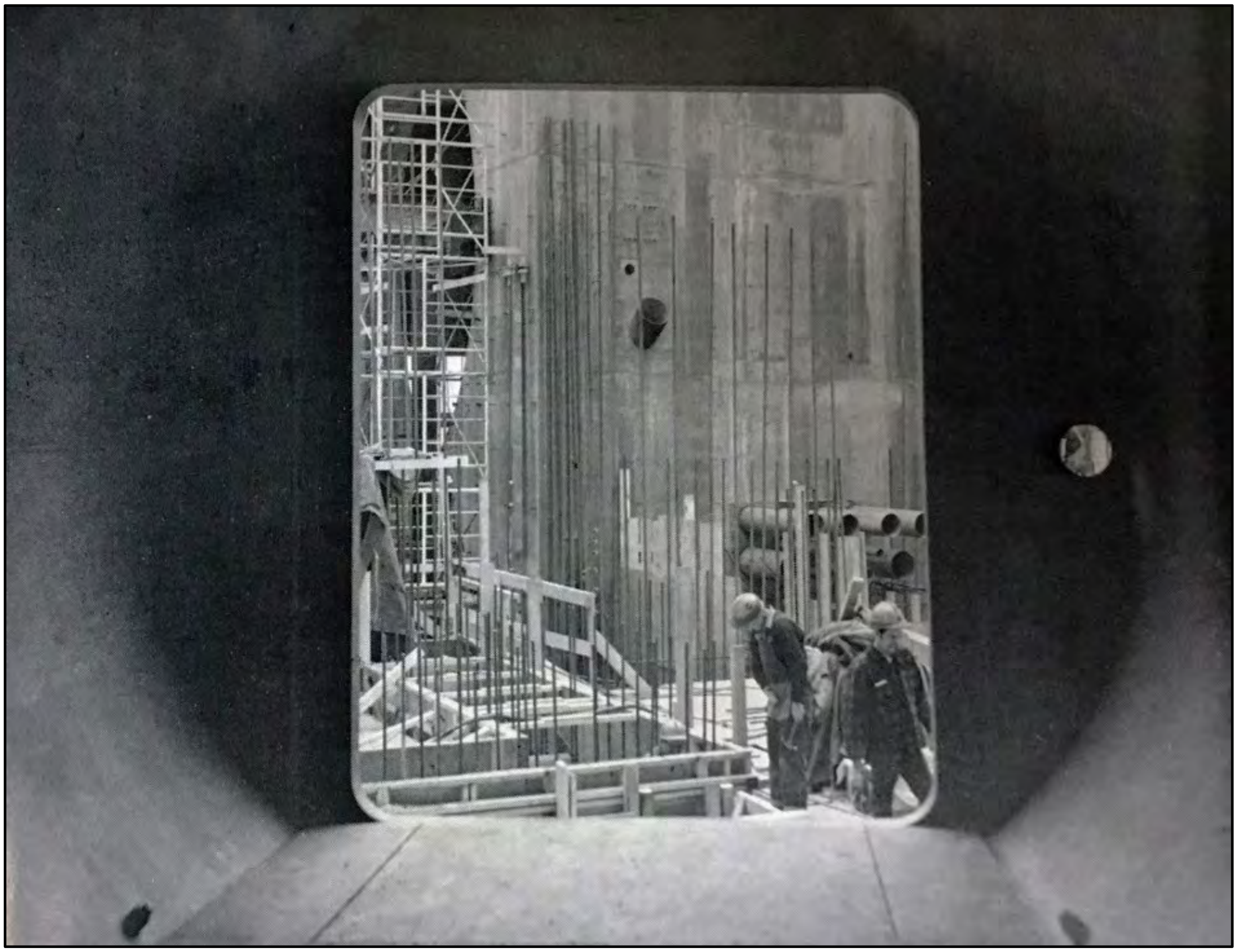

**Photo 6.1-2** – Peering through a portal at the Pickering Nuclear Generating Station while under construction. Photo courtesy of Ontario Power Generation (circa 1968). Used with permission.

## 6.2 Davis-Besse Nuclear Power Station

**Photo 6.2-1** – Located on the shore of Lake Erie in Ottawa County, Ohio, the Davis-Besse Nuclear Power Station began commercial operations in 1978 and is scheduled to close in 2020, which is 17 years before license expiration. Photo courtesy of FirstEnergy Solutions. Used with permission.

The Davis-Besse Nuclear Power Station is located on the south shore of Lake Erie's western basin in Carroll Township, Ottawa County, Ohio, approximately 21 miles (34 kilometers) east of Toledo, OH. Davis-Besse occupies 954 acres (386 hectares), and in conjunction with the US Fish and Wildlife Service, maintains the adjacent 733 acres (297 hectares) of Navarre Marsh wetlands as part of the Ottawa National Wildlife Refuge.[171]

Davis-Besse contains a single Babcock & Wilcox two-loop PWR and an ISFSI. Construction of Davis-Besse began September 1, 1970 and cost $2.221 billion (2007 USD).[172] Initial criticality was achieved August 12, 1977 and commercial operations began July 31, 1978.[173]

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171 *Davis-Besse Nuclear Power Station*. FirstEnergy Generation. 2018.
https://fes.com/content/dam/fes/about/files/plantfactsheets/davis-besse-plant--facts-at-a-glance.pdf
172 *Ohio Nuclear Profile 2010*. U.S. Energy Information Administration. 26 April 2012.
https://www.eia.gov/nuclear/state/archive/2010/ohio/. Accessed 15 February 2019.
173 *Davis Besse-1*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019.
https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=676. Accessed 15 February 2019.

The reactor and ISFSI are licensed individually by the NRC to be operated by FirstEnergy Nuclear Operating Company (FENOC) and FirstEnergy Nuclear Generation, LLC, both subsidiaries of FirstEnergy Solutions Corporation (FES). The original operating license was issued on April 22, 1977, was renewed on December 8, 2015, and will expire on April 22, 2037. Davis-Besse is licensed to be operated at a maximum power level of 2,817 MW thermal and has an installed capacity of 894 MW electric. After the reactor was restarted in 2004, Davis-Besse has supplied an average of 6,852 GWh of electricity annually. Over its lifetime, Davis-Besse has supplied 217.10 TWh of electricity, corresponding to a capacity factor of 70.7 percent.[174]

### *6.2.1 Nuclear Safety Incident and Response*

On March 5, 2002, maintenance workers at the Davis-Besse discovered a football-sized void in the reactor vessel head. The NRC reported that the void, caused by corrosion, did not cause a reactor accident, and did not actually cause any problems while the reactor was operating. The near failure of one of three barriers between the reactor fuel and the environment, however, is still considered a serious nuclear safety incident by the NRC. FENOC committed to keep Davis-Besse shut down until the reactor vessel head had been replaced and the company implemented safety culture changes at the plant to maintain safety as the top priority. The NRC fined FirstEnergy $5.45 million (USD), the largest fine in NRC history, for the violations that led to the corrosion. FirstEnergy also paid $28 million (USD) in fines under a settlement with the U.S. Department of Justice. While the NRC confirmed the plant was ready to restart in 2004, the agency continued extra inspections through 2009. These included reviews of 20 independent assessments of Davis-Besse by third-party organizations. The NRC also inspected the reactor vessel and reviewed the results of FirstEnergy's inspections from early 2005. The NRC reported that inspectors paid particular attention to FirstEnergy's commitment to increase their focus on safety culture and encourage a safety conscious work environment. In 2009, the NRC was satisfied that FirstEnergy had addressed the organizational problems that had allowed such a serious incident to occur.[175]

### *6.2.2 Early Closure Announcement and Subsidizing Legislation*

On March 28, 2018, FES notified PJM Interconnection, the regional transmission organization and competitive wholesale electricity market, that several of its generating facilities, including the Davis-Besse Nuclear Power Station, would be deactivated due to severe economic challenges in the competitive energy market and expected to cease Davis-Besse's operations on May 31, 2020.[176] Three days later, FES, its subsidiaries and FENOC filed voluntary petitions for Chapter

[174] *Davis Besse-1*.
[175] *Backgrounder on Improvements Resulting From Davis-Besse Incident*. U.S. Nuclear Regulatory Commission. 5 July 2018. https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/davis-besse-improv.html. Accessed 26 February 2019.
[176] *FirstEnergy Solutions Files Deactivation Notice for Three Competitive Nuclear Generating Plants in Ohio and Pennsylvania*. FirstEnergy Solutions. 28 March 2018. https://www.prnewswire.com/news-

11 Restructuring with the U.S. Bankruptcy Court in the Northern District of Ohio in Akron.[177] Since then, Davis-Besse continued normal operations as FES pursued legislative policy solutions to subsidize operational expenses as an alternative to deactivation or sale. States of Illinois, New Jersey, and New York have already adopted zero-emission credit programs that subsidize their nuclear power plants helping them to be economical viable.[178]

On July 23, 2019, Ohio Governor Mike DeWine signed House Bill 6 into law, which created the Ohio Clean Air Program.[179] This program will provide subsidies to electricity generators that meet the "clean air" emissions standards, including solar, wind, nuclear, natural gas, and coal plants. Of the $170 million (USD) the fund is estimated to raise each year, approximately $150 million is expected to be paid to FES for its Davis-Besse and Perry Nuclear Power Plants beginning with quarterly payments in April 2021 and running through 2027. The money for the plants is subject to an annual review, so the subsidy could be reduced or eliminated in future years if it is deemed to be no longer necessary.[180] This subsidy is expected to allow these plants to continue operating past their announced closure dates.

On July 24, 2019, FES stated that it will begin the process to rescind the deactivation orders for its Perry and Davis-Besse plants and begin preparations for the Davis-Besse's mandatory refueling in the spring of 2020.[181]

### *6.2.3 Spent Nuclear Fuel Estimate and Decommissioning Fund Estimates*

As of December 17, 2018, approximately 1,529 spent fuel assemblies contained in 43 casks and an additional 4 casks containing GTCC waste were estimated to be required upon reactor deactivation on May 31, 2020 and subsequent decommissioning.[182] As of August 22, 2016, the DOE inventory indicated there were 72 spent fuel assemblies in dry storage contained in 3 casks (Table 4-5).[183]

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releases/firstenergy-solutions-files-deactivation-notice-for-three-competitive-nuclear-generating-plants-in-ohio-and-pennsylvania-300621346.html. Accessed 8 January 2019.

[177] *Restructuring Information*. FirstEnergy Solutions. 31 March 2018. https://www.fes.com/content/fes/home/restructuring.html. Accessed 24 July 2019.

[178] *Zero-Emission Credits*. Nuclear Energy Institute. April 2018. https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/zero-emission-credits-201804.pdf

[179] *House Bill 6*. The Ohio Legislature: 133rd General Assembly. 2019. https://www.legislature.ohio.gov/legislation/legislation-summary?id=GA133-HB-6. Accessed 24 July 2019.

[180] *Ohio Gov DeWine signs controversial nuke subsidy bill*. John Funk, Utility Dive. 23 July 2019. https://www.utilitydive.com/news/breaking-ohio-passes-controversial-nuke-subsidy-bill-by-one-vote/559342/. Accessed 24 July 2019.

[181] *FirstEnergy Solutions announces it will refuel at Davis-Besse*. Daniel Carson, Fremont News-Messenger. 24 July 2019. https://www.thenews-messenger.com/story/news/local/2019/07/24/firstenergy-solutions-announces-refuel-davis-besse-nuclear-power-station/1822494001/. Accessed 1 August 2019.

[182] *Triennial ISFSI Decommissioning Funding Plans*. FirstEnergy Nuclear Operating Company. 17 December 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18351A161. Accessed 4 February 2019.

[183] *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning

As of December 31, 2016, the minimum decommissioning fund estimate for Davis-Besse was $467.4 million (2016 USD) and the amount accumulated in the external trust fund was $552.4 million.[184] The ISFSI decommissioning cost estimate with a 25 percent contingency was $6.07 million (2018 USD) and the value of the provisional fund with the exclusive purpose to accumulate and hold funds for the decommissioning of the ISFSI was $10.21 million. The spent fuel management plan is based in general upon completion of spent fuel receipt by the DOE in year 2059.[185]

**Photo 6.2-2** – The reactor pressure vessel at the Davis-Besse Nuclear Power Station shows a buildup of boric acid deposits from leaking nozzles (not shown). Plant operators later discovered the acid had corroded part of the pressure vessel head, triggering a two-year shut down to repair the damage. This photo was taken during the refueling outage at Davis-Besse in 2000. Photo courtesy of the U.S. Nuclear Regulatory Commission: flickr (2000). Public domain.

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Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.

[184] *Submittal of the Decommissioning Funding Status Reports*. FirstEnergy Nuclear Operating Company. 24 March 2017. https://www.nrc.gov/docs/ML1708/ML17083B221.pdf

[185] *Triennial ISFSI Decommissioning Funding Plans*.

**Photo 6.2-3** – One of Davis-Besse's two new steam generators is transported across the site in preparation for installation. Photo courtesy of FirstEnergy Solutions (March 2014). Used with permission.

## 6.3 Perry Nuclear Power Plant

**Photo 6.3-1** – Located on the shore of Lake Erie in Lake County, Ohio, the Perry Nuclear Power Plant Training Building is pictured in the foreground and the cooling towers are visible in the background. Perry began commercial operations in 1987 and is scheduled to close in 2021, which is 5 years before license expiration. Photo courtesy of FirstEnergy Solutions (May 2011). Used with permission.

The Perry Nuclear Power Plant is located on the south shore of Lake Erie's central basin in Perry Township, Lake County, Ohio, approximately 35 miles (56 kilometers) northeast of Cleveland, OH. Perry occupies 1,100 acres (445 hectares) and approximately 0.8 miles (1.3 kilometers) of lake frontage. The property has more than 850 acres (344 hectares) of natural forests and marshes that provide diverse habitat for area wildlife.[186]

Perry contains a single General Electric Type 6 BWR and an ISFSI. Construction of Perry began October 1, 1974 and cost $6.024 billion (2007 USD).[187] Initial criticality was achieved on June 6, 1986 and commercial operations began November 18, 1987.[188]

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[186] *Perry Nuclear Power Plant*. FirstEnergy Generation. 2018. https://fes.com/content/dam/fes/about/files/plantfactsheets/perry-plant-facts-at-a-glance.pdf

[187] *Ohio Nuclear Profile 2010*. U.S. Energy Information Administration. 26 April 2012. https://www.eia.gov/nuclear/state/archive/2010/ohio/. Accessed 15 February 2019.

[188] *Perry-1*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=725. Accessed 15 February 2019.

The reactor and ISFSI are individually licensed by the NRC to be operated by FENOC and FirstEnergy Nuclear Generation, LLC, both subsidiaries of FirstEnergy Solutions Corporation (FES). The operating license was issued on March 18, 1978 and will expire on March 18, 2026. Perry is licensed to be operated at a maximum power level of 3,758 MW thermal and has an installed capacity of 1,256 MW electric. Since 2000, Perry has supplied an average of 9,397 GWh of electricity annually. Over its lifetime, Perry has supplied 257.16 TWh of electricity, corresponding to a capacity factor of 80.8 percent.

### *6.3.1 Early Closure Announcement and Subsidizing Legislation*

On March 28, 2018, FES notified PJM Interconnection, the regional transmission organization and competitive wholesale electricity market, that several of its generating facilities, including the Perry Nuclear Power Station, would be deactivated due to severe economic challenges in the competitive energy market and expected to cease Perry's operations on May 31, 2021.[189] Three days later, FES, its subsidiaries and FENOC filed voluntary petitions for Chapter 11 Restructuring with the U.S. Bankruptcy Court in the Northern District of Ohio in Akron.[190] Since then, Perry continued normal operations as FES pursued legislative policy solutions to subsidize operational expenses as an alternative to deactivation or sale. States of Illinois, New Jersey, and New York have already adopted zero-emission credit programs that subsidize their nuclear power plants helping them to be economical viable.[191]

On July 23, 2019, Ohio Governor Mike DeWine signed House Bill 6 into law, which created the Ohio Clean Air Program.[192] This program will provide subsidies to electricity generators that meet the "clean air" emissions standards, including solar, wind, nuclear, natural gas, and coal plants. Of the $170 million (USD) the fund is estimated to raise each year, approximately $150 million is expected to be paid to FES for its Davis-Besse and Perry Nuclear Power Plants beginning with quarterly payments in April 2021 and running through 2027. The money for the plants is subject to an annual review, so the subsidy could be reduced or eliminated in future years if it is deemed to be no longer necessary.[193] This subsidy is expected to allow these plants to continue operating past their announced closure dates.

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189 *FirstEnergy Solutions Files Deactivation Notice for Three Competitive Nuclear Generating Plants in Ohio and Pennsylvania*. FirstEnergy Solutions. 28 March 2018. https://www.prnewswire.com/news-releases/firstenergy-solutions-files-deactivation-notice-for-three-competitive-nuclear-generating-plants-in-ohio-and-pennsylvania-300621346.html. Accessed 8 January 2019.
190 *Restructuring Information*. FirstEnergy Solutions. 31 March 2018. https://www.fes.com/content/fes/home/restructuring.html. Accessed 24 July 2019.
191 *Zero-Emission Credits*. Nuclear Energy Institute. April 2018. https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/zero-emission-credits-201804.pdf
192 *House Bill 6*. The Ohio Legislature: 133rd General Assembly. 2019. https://www.legislature.ohio.gov/legislation/legislation-summary?id=GA133-HB-6. Accessed 24 July 2019.
193 *Ohio Gov DeWine signs controversial nuke subsidy bill*. John Funk, Utility Dive. 23 July 2019. https://www.utilitydive.com/news/breaking-ohio-passes-controversial-nuke-subsidy-bill-by-one-vote/559342/. Accessed 24 July 2019.

On July 24, 2019, FES stated that it will begin the process to rescind the deactivation orders for its Perry and Davis-Besse plants and begin preparations for the Davis-Besse's mandatory refueling in the spring of 2020.[194]

### *6.3.2 Spent Nuclear Fuel Estimate and Decommissioning Fund Estimates*

As of December 17, 2018, approximately 5,393 spent fuel assemblies contained in 80 casks and an additional 5 casks containing GTCC waste were estimated to be required upon reactor deactivation on May 31, 2021 and subsequent decommissioning.[195] As of August 22, 2016, the DOE inventory indicated there were 952 spent fuel assemblies in dry storage contained in 14 casks (Table 4-5).[196]

As of December 31, 2016, the minimum decommissioning fund estimate for Perry was $651.9 million (2016 USD) (Table 5-1). However, the amount accumulated in an external trust fund was only $515.5 million.[197] The ISFSI decommissioning cost estimate with a 25 percent contingency was $10.24 million (2018 USD) and the value of provisional trust with the exclusive purpose to accumulate and hold funds for decommissioning the ISFSI was $10.21 million. The spent fuel management plan is based in general upon completion of spent fuel receipt by the DOE in the year 2060.[198]

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194 *FirstEnergy Solutions announces it will refuel at Davis-Besse*. Daniel Carson, Fremont News-Messenger. 24 July 2019. https://www.thenews-messenger.com/story/news/local/2019/07/24/firstenergy-solutions-announces-refuel-davis-besse-nuclear-power-station/1822494001/. Accessed 1 August 2019.
195 *Triennial ISFSI Decommissioning Funding Plans*. FirstEnergy Nuclear Operating Company. 17 December 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18351A161. Accessed 4 February 2019.
196 *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.
197 *Submittal of the Decommissioning Funding Status Reports*. FirstEnergy Nuclear Operating Company. 24 March 2017. https://www.nrc.gov/docs/ML1708/ML17083B221.pdf
198 *Triennial ISFSI Decommissioning Funding Plans*.

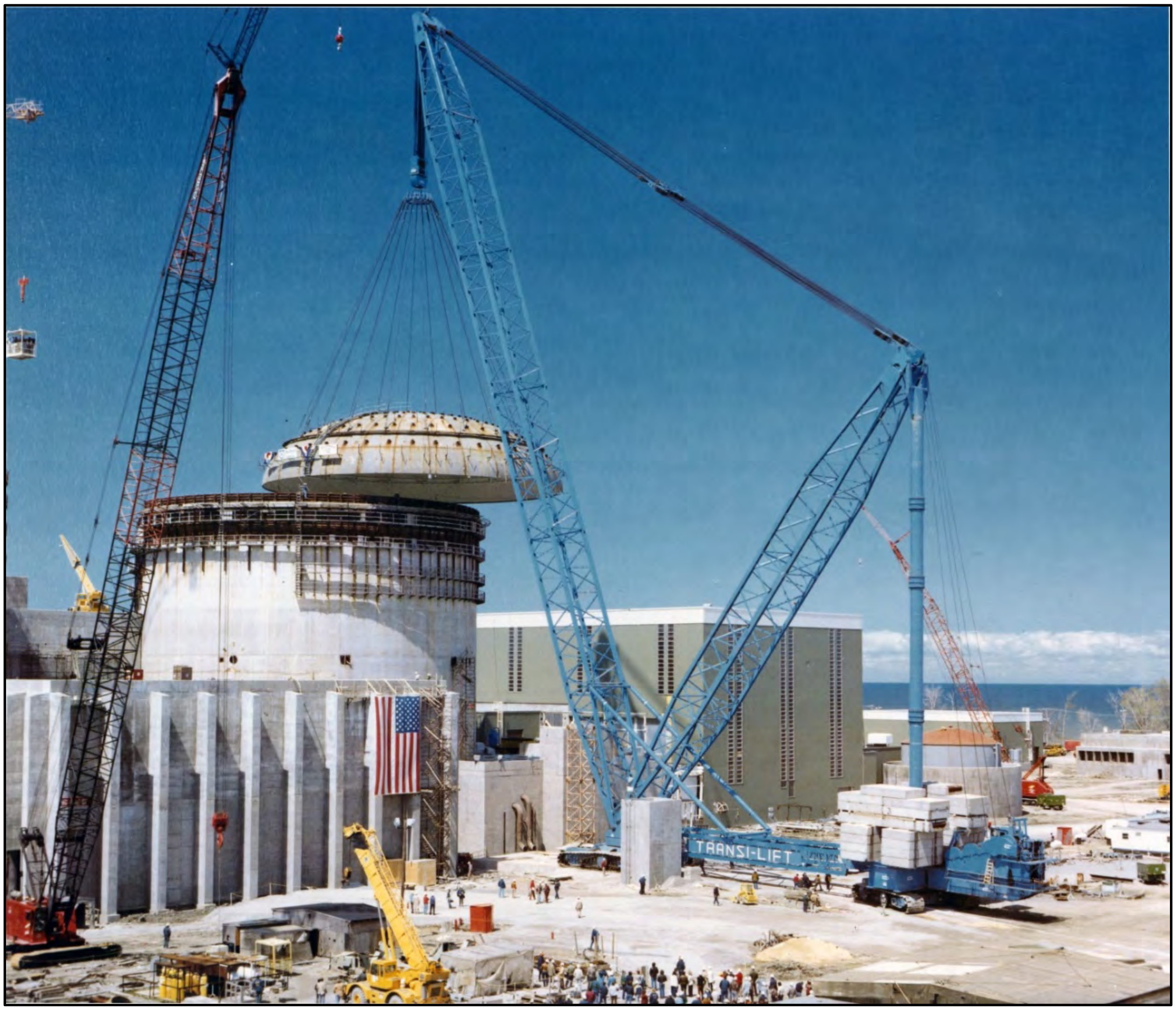

**Photo 6.3-2** – The dome is set on Perry's Unit 1 Containment Building during construction. Photo courtesy of FirstEnergy Solutions (May 1981). Used with permission.

## 6.4 Palisades Nuclear Power Plant

Photo 6.4-1 – Located on the shore of Lake Michigan in Van Buren County, Michigan, the Palisades Nuclear Power Plant began commercial operations in 1971 and is scheduled to close in April 2022, which is 9 years before license expiration. With steam rising, the cooling units are visible to the south (right) of the reactor containment building. Photo courtesy of Entergy Nuclear Palisades. Used with permission.

The Palisades Nuclear Power Plant is located on the east shore of Lake Michigan in western Covert Township, Van Buren County, Michigan, which is approximately 6 miles (10 kilometers) south of South Haven, MI and 45 miles (72 kilometers) west of Kalamazoo, MI. Palisades occupies 432 acres (175 hectares) and approximately 1 mile (1.6 kilometers) of lake frontage.[199]

Palisades contains a single Combustion Engineering two-loop PWR and an ISFSI that are licensed individually by the NRC. Construction began March 14, 1967 and cost $630 million

199 *Palisades Power Plant*. Entergy Corporation. 2018. http://www.entergy-nuclear.com/plant_information/palisades.aspx. Accessed 3 September 2018.

(2007 USD).[200] Initial criticality was achieved May 24, 1971 and commercial operations began December 31, 1971.[201]

The NRC issued the original operating license to Consumers Energy Company (CE) on February 21, 1971 and was renewed on February 21, 1991. On January 17, 2007, the NRC transferred the operating license to Entergy Nuclear Palisades, LLC (ENP) and Entergy Nuclear Operations, Inc. (ENO), which will expire on March 24, 2031. Palisades is licensed to be operated at a maximum power level of 2,565.4 MW thermal and has an installed capacity of 805 MW electric. Since 2000, Palisades has supplied an average of 5,928 GWh of electricity annually. Over its lifetime, Palisades has supplied 204.26 TWh of electricity, corresponding to a capacity factor of 70.5 percent.[202]

On April 11, 2007, Entergy completed the plant purchase from Consumers Energy Company for $380 million (2007 USD), which included the Big Rock Point ISFSI site, approximately 107 acres (43 hectares) in Charlevoix County, Michigan.[203]

### *6.4.1 Early Closure Announcement*

On August 1, 2018, Entergy Corp. announced their agreement to sell the Palisades Nuclear Power Plant and the BRP ISFSI to a Holtec International subsidiary for accelerated decommissioning. The transaction is subject to approval by the NRC and is not expected to occur until 2023 after its planned shutdown in April 2022, nine years ahead of license expiration.[204]

### *6.4.2 Spent Fuel Estimate and Decommissioning Plan*

As of December 17, 2018, approximately 2,082 spent fuel assemblies contained in 63 casks and an additional 5 casks containing GTCC waste were estimated to be required upon decommissioning.[205] As of August 22, 2016, the DOE inventory indicated there were 1,096 spent fuel assemblies in dry storage contained in 42 casks (Table 4-5).[206]

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200 *Michigan Nuclear Profile 2010.* U.S. Energy Information Administration. 26 April 2012. https://www.eia.gov/nuclear/state/archive/2010/michigan/. Accessed 15 February 2019.

201 *Palisades*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=616. Accessed 15 February 2019.

202 *Ibid.*

203 *Palisades Power Plant*.

204 *Entergy Agrees to Post-Shutdown Sale of Pilgrim, Palisades Nuclear Power Plants to Holtec International for Decommissioning*. Entergy Corporation. 1 August 2018. https://www.prnewswire.com/news-releases/entergy-agrees-to-post-shutdown-sale-of-pilgrim-palisades-nuclear-power-plants-to-holtec-international-for-decommissioning-300689839.html. Accessed 3 September 2018.

205 *ISFSI Decommissioning Funding Plans* (10 CFR 72.30). Entergy Nuclear Operations, Inc. 17 December 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18351A478. Accessed 22 February 2019.

206 *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.

As of December 31, 2018, the minimum decommissioning fund estimate for Palisades was $480.43 million (2018 USD) and the decommissioning cost estimate for the ISFSI was $8.0 million. However, the decommissioning trust fund amount was $443.63 million.[207]

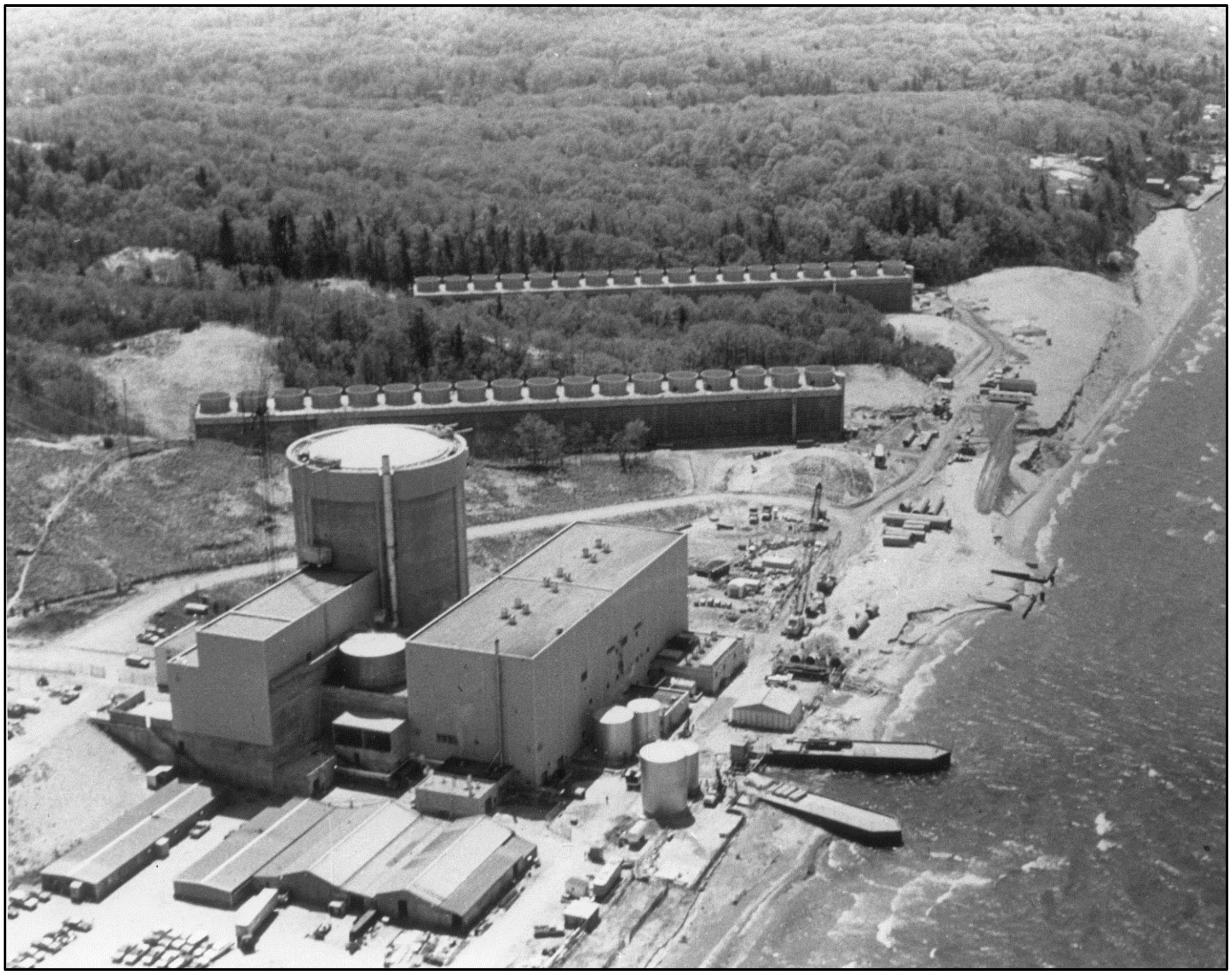

**Photo 6.4-2** – The Palisades Nuclear Power Plant was built and operated by the Consumers Power Company of Michigan until 2007 when the license was transferred to Entergy Nuclear Palisades. Photo courtesy of the U.S. Department of Energy: flickr (circa 1974). Public domain.

[207] *Decommissioning Funding Status Report*. Entergy Nuclear Operations, Inc. 28 March 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19087A318. Accessed 25 June 2019.

# 7. Permanently Shut Down Nuclear Reactors

Since the first nuclear power station in the Great Lakes basin began commercial operations in 1963, eight nuclear reactors at six sites have been permanently shut down. Only one of those nuclear sites has been fully decommissioned and released for unrestricted use (Table 7-1).

Photo 7.0-1 – At the Zion Nuclear Power Station, containment Units 1 and 2 are all that remain, and demolition of both units has started. All sources of radioactivity have been removed from the units prior to demolition. Demolition of the containment units will be accomplished by chipping away from the bottom up and is estimated to take 60 days for each unit. Photo courtesy of Energy*Solutions* (May 2018). Used with permission.

**Table 7-1.** Permanently Shut Down Nuclear Reactors in the Great Lakes Basin

| Plant | Location | Current Licensee | License Status | Operation Dates | Annual Radiological Environmental Operating Report | Decommissioning Planning Report | License Termination Plan (LTP) | Site Restoration Completion Date |
|---|---|---|---|---|---|---|---|---|
| Big Rock Point | Charlevoix, MI | | | 29 Mar 1963 to 29 Aug 1997 | | | Revision 3 17 July 2013 | |
| Greenfield - 435 acres (176 ha) | | Consumers Energy | Released | | N/A | | | 8 Jan 2007 |
| ISFSI - 107 acres (43 ha) | | Entergy Nuclear Operations | ISFSI | 2003 to present | 20 April 2018 | 17 Dec 2018 | | |
| Douglas Point Nuclear Generating Station | Kincardine, ON | Canadian Nuclear Laboratories (CNL) | | | | 22 June 2018 | | |
| Unit 1 | | | SAFSTOR | 26 Sept 1968 to 4 May 1984 | | | | 2059 |
| Enrico Fermi Atomic Power Plant | Newport, MI | DTE Electric Co. | | | 30 April 2019 | 29 Mar 2019 | Revision 4 29 June 2011 | |
| Unit 1 | | | SAFSTOR | 7 Aug 1966 to 29 Nov 1972 | | | | 2032 |
| Pickering Nuclear Generating Station | Pickering, ON | Ontario Power Generation | | | 2018 | Dec 2016 | | 2065 |
| Unit 2 | | | SAFSTOR | 30 Dec 1971 to 31 Dec 1997 | | | | |
| Unit 3 | | | SAFSTOR | 1 June 1972 to 29 Dec 1997 | | | | |
| Kewaunee Power Station | Carlton, WI | Dominion Energy Kewaunee, Inc | | | 31 Dec 2018 | 23 March 2018 | | 4 Dec 2073 |
| Unit 1 | | | SAFSTOR | 16 June 1974 to 7 May 2013 | | | | |
| ISFSI | | | ISFSI | 2009 to present | | | | |
| Zion Nuclear Power Station | Zion, IL | Zion*Solutions*, LLC | | | May 2019 | | Revision 2 7 Feb 2018 | 20 Sept 2020 |
| Unit 1 | | | DECON | 31 Dec 1973 to 13 Feb 1998 | | | | |
| Unit 2 | | | DECON | 17 Sept 1974 to 13 Feb 1998 | | | | |
| ISFSI | | | ISFSI | 2013 to present | | | | |

## 7.1 Enrico Fermi Atomic Power Plant

**Photo 7.1-1** – Located in Monroe County, Michigan, the Enrico Fermi Atomic Power Plant (Fermi-1) was constructed on the west shore of Lake Erie. Fermi-1, a sodium-cooled fast-breeder reactor, was the first nuclear reactor to begin construction in the Great Lakes basin. Fermi-1 began commercial operations in 1966 and was closed in 1972. Photo courtesy of DTE Energy (circa 1956). Used with permission.

The first reactor to be decommissioned was Enrico Fermi Atomic Power Plant Unit 1 (Fermi-1) in November 1972. Fermi-1 is located on the west shore of Lake Erie's western basin in Frenchtown Charter Township, Monroe County, Michigan, approximately 25 miles (40 kilometers) northeast of Toledo, OH. The current Fermi site occupies 1,260 acres (510 hectares) and approximately 1.8 miles (2.9 kilometers) of lake frontage. The Detroit River International Wildlife Refuge manages 650 acres (263 hectares) of the Fermi site. For information about Fermi-2, see *Section* 5.*4 Enrico Fermi Nuclear Station*. For information about Fermi-3, see *Section 8.2 DTE's Proposed New Reactor at Fermi*.

The Enrico Fermi Breeder Reactor Project was formally organized in 1955 as the Power Reactor Development Company (PRDC) with 34 companies participating. On August 4, 1956, the US Atomic Energy Commission (AEC) granted the PRDC the construction permit to build the reactor. Fermi-1 was the largest fast-neutron reactor built at that time. Fermi-1 was cooled by sodium and operated at essentially atmospheric pressure. The reactor was designed for a maximum power level of 430 MW thermal; however, the maximum power level with the first core loading (Core A) was 200 MW thermal (66 MW electric). The primary system was filled with sodium in December 1960 and initial criticality was achieved August 23, 1963.[208] Commercial operations began August 7, 1966.[209]

### *7.1.1 Nuclear Safety Incident and Permanent Shutdown*

On October 5, 1966, during a controlled power ascension, a zirconium plate at the bottom of the reactor vessel became loose and blocked sodium coolant flow to some fuel subassemblies. Two of the 105 fuel subassemblies started to melt. Radiation monitors alarmed, and the operators manually scrammed the reactor. On December 15, 1968, the Atomic Power Development Associates, Inc. issued a report to the PRDC and the AEC that no fission products (i.e., radioactive contaminants) escaped the reactor building and did not cause any public safety hazard. The damage to the reactor and fuel assemblies took nearly four years to repair.[210] By May 1970, the reactor was ready to resume operation, but a sodium explosion delayed startup until July of that year. In October 1970, the reactor finally reached a power level of 200 MW thermal. During 1971, Fermi-1 only generated 19.4 GWh of electricity corresponding to an average capacity factor of only 3.4 percent. Therefore, the PRDC declined to purchase additional uranium fuel to continue plant operations. In August 1972, upon denial of an extension of the operating license, shut down of the plant was initiated. The decision to decommission the plant was made on November 27, 1972.[211] All fuel and blanket subassemblies were shipped offsite by May 15, 1973. The non-radioactive secondary sodium system was drained, and the sodium sent to Fike Chemical Company. The radioactive primary sodium was stored in storage tanks and in 55-gallon drums until the sodium was shipped to a DOE site in Idaho in 1984.[212] Fermi-1 was officially decommissioned on December 31, 1975.

### *7.1.2 Decommissioning Fund Estimates and Paid Expenses*

Fermi-1 is currently owned by DTE Energy. The current license status is SAFSTOR and expires in 2025. At a future date, decommissioning will be continued for the purpose of removing the remaining residual radioactive material and terminating the Fermi-1 license. As of December 31, 2018, the minimum decommissioning fund estimate for Fermi-1 with a contingency of 30

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[208] *Fast Reactor Development in the United States*. Cochran, Thomas B., Feiveson, Harold A., and von Hippel, Frank. *Science & Global Security, 17:109-131.* 1 November 2009. DOI: 10.1080/08929880903445514
[209] *Fermi-1*. International Atomic Energy Agency: Power Reactor Information System. 25 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=602. Accessed 26 February 2019.
[210] *Report on the Fuel Melting Incident in the Enrico Fermi Atomic Power Plant on October 5, 1966* (APDA-233). Prepared for Power Reactor Development Company by Atomic Power Development Associates, Inc. 15 December 1968. https://www.osti.gov/biblio/4766757/. Accessed 14 September 2018.
[211] *Fast Reactor Development in the United States*.
[212] *Fermi – Unit 1*. U.S. Nuclear Regulatory Commission. 19 July 2018. https://www.nrc.gov/info-finder/decommissioning/power-reactor/enrico-fermi-atomic-power-plant-unit-1.html. Accessed 23 July 2018.

percent was $22.5 million (2018 USD). The market value of the Fermi-1 trust fund was $2.8 million, which is $19.7 million below the estimated remaining costs. A DTE Energy guarantee of $20 million was chosen as the assurance method for the shortfall. The total cost of Fermi-1 decommissioning activities and SAFSTOR maintenance since the initial decommissioning in 1972 through 2018 was $85.4 million (2018 USD). However, no money was spent on decommissioning activities in 2018.[213]

**Photo 7.1-2** – The Enrico Fermi Atomic Power Plant (Fermi-1) was operated by the Power Reactor Development Company from 1966 to 1972. Fermi-1 is currently owned by DTE Energy. The current license status is SAFSTOR and expires in 2025. Photo courtesy of the U.S. Army Corps of Engineers: Great Lakes Oblique Imagery (April 2012). Public domain.

213 *Decommissioning Funding Status Report for Fermi 1*. DTE Energy Company. 29 March 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19088A250. Accessed 25 June 2019.

## 7.2 Douglas Point Nuclear Generating Station

Photo 7.2-1 – Located on the shore of Lake Huron at the Bruce Power site in Bruce County, Ontario, the Douglas Point Nuclear Generating Station officially began commercial operations in 1968 and was closed in 1984. Douglas Point is seen in the foreground and the Bruce B Nuclear Generating Station is pictured in the background. Photo courtesy of Atomic Energy of Canada Limited (September 2011). Used with permission.

The Douglas Point Nuclear Generating Station (DPNGS) is located on the east shore of Lake Huron in the municipality of Kincardine, Bruce County, Ontario, on the Bruce Nuclear Site. DPNGS, built and owned by Atomic Energy of Canada Limited (AECL), was Canada's first full-scale nuclear power plant and the second CANDU pressurized heavy water reactor.

Construction of the single 704 MW thermal (206 MW electric) prototype CANDU reactor began February 1, 1960, and initial criticality was achieved November 15, 1966. DPNGS began supplying electricity to the grid on January 7, 1967, and officially began commercial operations on September 26, 1968.

Ontario Hydro operated DPNGS for AECL from September 26, 1968, until the reactor was permanently shut down on May 4, 1984. Over its 17 years of commercial service, DPNGS supplied an average of 950 GWh of electricity annually for a lifetime total of 15.63 TWh, corresponding to a capacity factor of 55.6 percent.[214]

[214] *Douglas Point*. International Atomic Energy Agency: Power Reactor Information System. 25 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=40. Accessed 26 February 2019.

### *7.2.1 Decommissioning Activities*

Douglas Point was the second rector in the Great Lakes basin to be permanently shut down. Decommissioning of the reactor began in 1986, and the transfer of spent fuel from wet storage in the reactor pool to a dedicated dry storage facility was completed in 1988.[215] Now, the Douglas Point Waste Management Facility (DPWMF) is located on the site of the former DPNGS co-located with the Bruce Nuclear Generating Stations. The DPNGS and DPWMF have been maintained in Phase 2 – the Storage-with-Surveillance phase – of a Deferred Decommissioning program. Consequently, the DPWMF is closed to the receipt of new wastes.

On November 3, 2014, AECL launched Canadian Nuclear Laboratories (CNL), a wholly owned subsidiary. CNL is now responsible for the CNSC licence for the DPNGS facility and decommissioning.[216] The CNSC issued CNL the licence for the DPWMF on October 22, 2014 and will expire on December 31, 2034.[217] As of April 1, 2018, CNL anticipates beginning final decommissioning in 2059. The proposed end-state of the site is a brownfield restored for industrial use consistent with the rest of the Bruce Nuclear Site.[218]

### *7.2.2 Spent Nuclear Fuel Inventory*

As of December 2016, Natural Resources Canada reported the HLW inventory stored onsite at DPNGS was 22,256 fuel bundles, which had an estimated volume of 89 cubic meters (3,143 $ft^3$) and contained 300 metric tons (330 US tons) of uranium (Table 4-3).[219]

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[215] *Canadian Nuclear Laboratories: Progress Update for CNL's Prototype Waste Facilities, Whiteshell Laboratories and the Port Hope Area Initiative*. Canadian Nuclear Safety Commission. 22 June 2018. http://nuclearsafety.gc.ca/eng/the-commission/meetings/cmd/pdf/CMD18/CMD18-M30.pdf

[216] *Launch of Canadian Nuclear Laboratories*. Quinn, Patrick. Canadian Nuclear Energy Alliance. 30 October 2014. http://www.cnl.ca/en/home/news-and-publications/news-releases/2014/141030.aspx. Accessed 3 September 2018.

[217] *2017 Annual Compliance Report for Douglas Point and Gentilly-1 Waste Facilities*. Canadian Nuclear Laboratories. http://www.cnl.ca/site/media/Parent/2017-Annual-Compliance-Report-DP&Gen.pdf

[218] *Canadian Nuclear Laboratories: Progress Update for CNL's Prototype Waste Facilities, Whiteshell Laboratories and the Port Hope Area Initiative*.

[219] *Inventory of Radioactive Waste in Canada 2016*. Natural Resources Canada. 2018. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/uranium-nuclear/17-0467%20Canada%20Radioactive%20Waste%20Report_access_e.pdf

**Photo 7.2-2** – Construction of Douglas Point, Canada's first full-scale nuclear power plant, began in 1960 on the east shore of Lake Huron. Photo courtesy of Atomic Energy of Canada Limited (circa 1961). Used with permission.

## 7.3 Big Rock Point

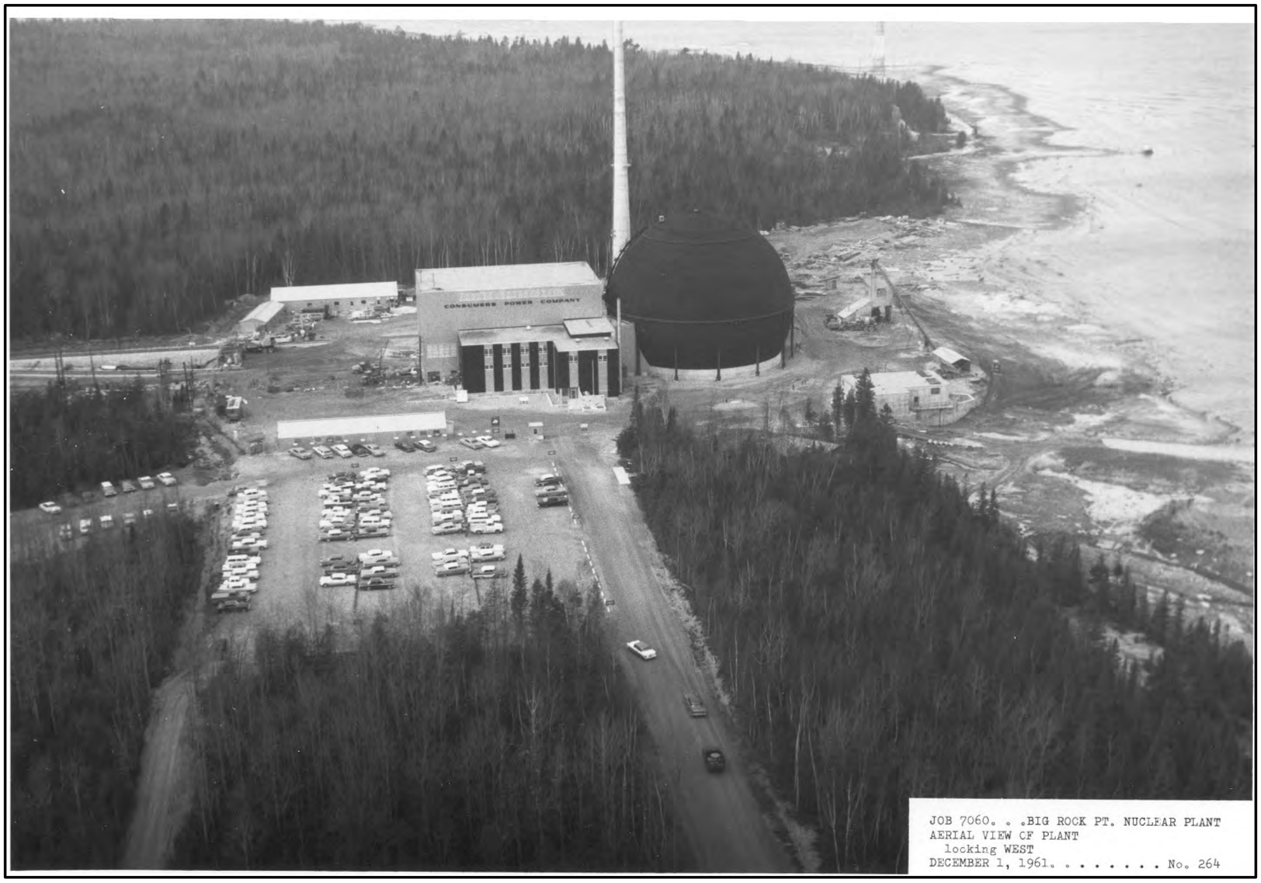


**Photo 7.3-1** – Located on the shore of Lake Michigan in Charlevoix County, Michigan, the Big Rock Point Nuclear Plant began commercial operation on March 29, 1963, the first nuclear reactor to reach this milestone in the Great Lakes basin. Big Rock Point operated for 34 years before being permanently shut down in 1997. Photo courtesy of Consumers Energy (December 1961). Used with permission.

Big Rock Point (BRP) is located on the south shore of Little Traverse Bay on Lake Michigan in Hayes Township, Charlevoix County, Michigan, approximately 12 miles (19 kilometers) west of Petoskey, MI. BRP occupies approximately 564 acres (228 hectares) and approximately 1.5 miles (2.4 kilometers) of lake frontage.[220]

Owned by Consumers Energy Company (CE), BRP was the first commercial nuclear power plant to begin operations in the Great Lakes basin and the fifth in the United States. The General Electric BWR was rated for 240 MW thermal and was built by Bechtel Corporation. Construction of BRP began May 1, 1960, and initial criticality was achieved September 27, 1962. BRP began supplying electricity to the grid on December 8, 1962, and officially began commercial operations on March 29, 1963. BRP permanently shut down on August 29, 1997, ending 34 years of electric power generation as the nation's oldest and longest running nuclear

[220] *Big Rock Point License Termination Plan, Revision 3*. Entergy Nuclear Operations, Inc. 17 July 2013. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML13204A012. Accessed 17 July 2018.

plant at that time. Over its lifetime, BRP supplied an average of 375 GWh of electricity annually for a lifetime total of 12.74 TWh, corresponding to a capacity factor of 64.1 percent.[221]

### *7.3.1 Spent Nuclear Fuel Inventory*

BRP was the third reactor in the Great Lakes basin to be decommissioned. CE decided to close BRP because of its relatively small size (67 MW electric) was likely to make it too expensive to operate in an increasingly competitive environment. Fuel was transferred to the spent fuel pool by September 20, 1997. On March 26, 2003, the 441 spent fuel assemblies and GTCC waste were transferred to dry storage in the ISFSI located onsite. The ISFSI consists of seven concrete casks (each containing the spent fuel canister), one concrete cask containing the GTCC waste, and a 75-foot (23 m) by 99-foot (30 m) reinforced concrete pad that the eight concrete casks stand vertically on.[222] As of August 22, 2016, the DOE inventory indicated there were 441 spent fuel assemblies in dry storage contained in seven casks (Table 4-5).[223]

### *7.3.2 Decommissioning Activities and Decommissioning Fund Estimates*

As of March 2004, the estimated cost to decommission BRP was $439.4 million (expenditure year USD).[224] All systems and structures not needed for the ISFSI were removed and the site remediation was completed on August 29, 2006. On January 8, 2007, the NRC approved CE's request to release approximately 435 acres (176 hectares) for unrestricted use (i.e., greenfield condition). The remaining 107 acres (43 hectares) includes the ISFSI and continues to be under license by the NRC.[225]

On April 6, 2007, the NRC approved the transfer of the operating license for the BRP ISFSI from CE to Entergy Nuclear Palisades, LLC (ENP) and Entergy Nuclear Operations, Inc. (ENO). After the fuel is removed from the site to a DOE facility, the ISFSI will be decommissioned and the ISFSI license terminated.[226] As of December 31, 2018, the decommissioning cost estimate

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221 *Big Rock Point*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=601. Accessed 15 February 2019.
222 *ISFSI Decommissioning Funding Plans* (10 CFR 72.30). Entergy Nuclear Operations, Inc. 17 December 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18351A478. Accessed 22 February 2019.
223 *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.
224 *Big Rock Point Plant – Post Shutdown Decommissioning Activities Report (PSDAR); Revision 4*. Consumers Energy. 31 March 2005. https://www.nrc.gov/docs/ML0509/ML050940217.pdf
225 *Big Rock Point – Release of Land from Part 50 License for Unrestricted Use*. U.S. Nuclear Regulatory Commission. 8 January 2007. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML063410361. Accessed 17 July 2018.
226 *NRC Staff Approves Big Rock Point ISFSI License Transfer* (No. 07-045). U.S. Nuclear Regulatory Commission. 10 April 2007. https://www.nrc.gov/docs/ML0710/ML071000477.pdf

for the ISFSI was $2.57 million (2018 USD).[227] As of December 31, 2018, the projected costs to manage spent fuel until DOE removal (using an assumed date of 2039) was $47.89 million (2018 USD) and ongoing costs have been paid for out of ENP operating funds.[228]

On August 1, 2018, Entergy Corp. announced their agreement to sell the BRP ISFSI site to a Holtec International subsidiary, a nuclear decommissioning specialist. The transaction is subject to approval by the NRC and is not expected to occur until 2023.[229]


**Photo 7.3-2** – The Independent Spent Fuel Storage Installation (ISFSI) at Big Rock Point is currently licensed to Entergy Nuclear Palisades, LLC (ENP). There are 441 spent fuel assemblies contained in six casks and one cask contains Greater-than-Class-C (GTCC) waste. Photo credit: Graydon, with permission from ENP (July 2018).

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227 *Decommissioning Funding Status Report*. Entergy Nuclear Operations, Inc. 28 March 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19087A318. Accessed 25 June 2019.
228 *Status of Funding for Managing Irradiated Fuel for Year Ending December 31, 2018*. Entergy Nuclear Operations, Inc. 28 March 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19087A276. Accessed 25 June 2019.
229 *Entergy Agrees to Post-Shutdown Sale of Pilgrim, Palisades Nuclear Power Plants to Holtec International for Decommissioning*. Entergy Corporation. 1 August 2018. https://www.prnewswire.com/news-releases/entergy-agrees-to-post-shutdown-sale-of-pilgrim-palisades-nuclear-power-plants-to-holtec-international-for-decommissioning-300689839.html. Accessed 3 September 2018.

**Photo 7.3-3** – Remediation of the Big Rock Point site was completed in August 2006. In January 2007, the U.S. Nuclear Regulatory Commission (NRC) approved Consumers Energy's request to release 435 acres (176 ha) for unrestricted use. The Independent Spent Fuel Storage Installation (ISFSI), seen in the background, continues to be under license by the NRC until the spent fuel is transferred to a U.S. Department of Energy location for permanent disposal. Photo courtesy of the U.S. Army Corps of Engineers: Great Lakes Oblique Imagery (April 2012). Public domain.

## 7.4 Zion Nuclear Power Station

**Photo 7.4-1** – Located on the shore of Lake Michigan in Lake County, Illinois, the Zion Nuclear Power Station operated from 1973 until 1998. This photo captures the facility just prior to the start of dismantling operations. Photo courtesy of Energy*Solutions* (October 2010). Used with permission.

The Zion Nuclear Power Station (ZNPS) is located on the west shore of Lake Michigan in the eastern portion of the City of Zion in Lake County, Illinois, approximately 40 miles (64 kilometers) north of Chicago, IL and 42 miles (68 kilometers) south of Milwaukee, WI. Bisecting the Adeline Jay Geo-Karis Illinois Beach State Park, the ZNPS property occupies approximately 331 acres (134 hectares) and approximately 0.6 miles (1 kilometer) of lake frontage.[230]

ZNPS consisted of two Westinghouse four-loop 1,040 MW electric PWRs and was licensed by the NRC to be operated by Commonwealth Edison (ComEd). Construction of Zion-1 began December 26, 1968, and initial criticality was achieved on June 19, 1973. Zion-1 began supplying electricity to the grid on June 28, 1973 and officially began commercial operation on December 31, 1973.[231] Construction of Zion-2 began December 1, 1968, and initial criticality

[230] *License Termination Plan* (Revision 2). Zion*Solutions*, LLC. 7 February 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18052A857. Accessed 9 August 2018.
[231] *Zion-1*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=640. Accessed 15 February 2019.

was achieved December 24, 1973. Zion-2 first began supplying electricity to the grid on December 26, 1973 and officially began commercial operation on September 17, 1974.[232] ComEd ceased operation of both reactor units on February 13, 1998. The two ZNPS reactors are tied as the fourth reactors in the Great Lakes basin to permanently shut down. Through 25 years of commercial operation, Zion-1 supplied an average of 4,977 GWh of electricity annually for a lifetime total of 124.41 TWh, corresponding to a capacity factor of 57.4 percent.[233] Zion-2 supplied an average of 5,413 GWh of electricity annually for a lifetime total of 124.50 TWh, corresponding to a capacity factor of 59.2 percent.[234]

### *7.4.1 Decommissioning Activities*

On March 9, 1998, transfer of all fuel assemblies to the spent fuel pool was completed, and the reactors were placed in a SAFSTOR condition (a period of safe storage of the stabilized and defueled facility).[235] In 2000, the licenses were transferred from ComEd to Exelon Nuclear Generation, LLC (Exelon). On September 1, 2010, the licenses were transferred from Exelon to Zion*Solutions*, LLC, a subsidiary of Energy*Solutions*, Inc., for decommissioning. Decommissioning operations began October 1, 2010.

The ISFSI, which occupies approximately 5 acres (2 hectares), was constructed onsite and became operational in December 2013. All 61 dry cask storage canisters (containing 2,226 spent fuel assemblies) and four GTCC waste canisters were transferred to the ISFSI by January 10, 2015. As of August 22, 2016, DOE inventory indicated there were 2,226 spent fuel assemblies in dry storage contained in 61 casks (Table 4-5).[236]

As of January 31, 2018, all onsite above grade structures have been demolished except for the two containment domes, the wastewater treatment facility, the discharge valve houses, and the upper surfaces of the forebay. The demolition of the remaining above grade structures was scheduled for completion by May 2018. The final structures to be demolished were the containment buildings, which were removed in November 2018.

As of December 31, 2018, the cumulative amount spent on decommissioning was $651.5 million (2018 USD), and the decommissioning trust fund balance was $8.7 million. However, the estimated costs to complete decommissioning were $24 million and the projected costs to manage the irradiated fuel were $4.5 million, which results in a shortfall of $19.8 million. The

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232 *Zion-2*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=646. Accessed 15 February 2019.
233 *Zion-1*.
234 *Zion-2*.
235 *License Termination Plan* (Revision 2).
236 *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.

NRC has requested and Zion*Solutions* has provided additional information to explain this shortfall of funds.[237]

Due to the completion of decontamination, dismantlement and remediation activities, radiological surveys are being performed and final status survey reports have been submitted to the NRC to demonstrate that the dose from any residual radioactivity remaining in as-left structure basements and soils at ZNPS (excluding the ISFSI) to the unrestricted release criteria as specified in 10 CFR 20.1402. Pending approval by the NRC, the 10 CFR Part 50 license will be reduced to the area around the ISFSI site and the site transferred back to Exelon. Zion*Solutions* agreements with Exelon include rights that will enable Zion*Solutions* to return the decontaminated site and transfer the ISFSI, spent fuel, remaining GTCC waste, and associated NRC licenses to Exelon by September 1, 2020. Once these transfers are accomplished, Exelon would maintain the irradiated fuel, including ongoing financial responsibility, until its transfer to the DOE for its ultimate disposition.[238]

**Photo 7.4-2** – Moving at 2 mph (0.9 $ms^{-1}$), crews move the first 75-ton (68-metric ton) cask of spent fuel to the ISFSI. The transfer of the 61 casks of spent fuel to the ISFSI was completed in 366 days, a company record. Photo courtesy of Energy*Solutions* (January 2014). Used with permission.

[237] *Revised Report on Status of Decommissioning Funding for Shutdown Reactors.* Zion*Solutions*, LLC. 13 June 2019. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19168A029. Accessed 25 June 2019.
[238] *Ibid.*

## 7.5 Kewaunee Power Station

Photo 7.5-1 – Located on the shore of Lake Michigan in Kewaunee County, Wisconsin, the Kewaunee Power Station began commercial operations in 1974. KPS closed in 2013 and is currently in the SAFSTOR phase of decommissioning. The completion of all decommissioning activities and site restoration is projected to be December 2073. Photo courtesy of the U.S. Army Corps of Engineers: Great Lakes Oblique Imagery (April 2012). Public domain.

The Kewaunee Power Station (KPS) is located on the west shore of Lake Michigan in the Town of Carlton, Kewaunee County, Wisconsin, approximately 27 miles (43 kilometers) southeast of Green Bay, WI. The KPS occupies approximately 908 acres (367 hectares) and approximately 2 miles (3.1 kilometers) of lake frontage.[239]

Dominion Energy Kewaunee, Inc. (DEK) owns and was licensed by the NRC to operate KPS. KPS contains a single Westinghouse two-loop PWR (1,772 MWt capacity) with supporting facilities. Construction of KPS began on August 6, 1968 and cost $756.15 million (2007

[239] *Kewaunee Power Station: Post-Shutdown Decommissioning Activities Report*. Dominion Energy Kewaunee, Inc. 25 April 2014. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14118A382. Accessed 23 July 2018.

USD).[240] Initial criticality was achieved March 7, 1974. The NRC issued the operating license on December 21, 1973 and commercial operations began June 16, 1974.

### *7.5.1 Decommissioning Activities*

KPS is the most recent reactor in the Great Lakes basin to be decommissioned. The permanent cessation of reactor operation occurred on May 7, 2013, and the reactor was defueled on May 14, 2013. Through 40 years of commercial operation, KPS supplied an average of 3,752 GWh of electricity annually for a lifetime total of 150.08 TWh, corresponding to a capacity factor of 84.0 percent.[241]

As of April 25, 2014, approximately 1,335 spent fuel assemblies contained in 38 casks were estimated to be required upon decommissioning.[242] As of August 22, 2016, the DOE inventory indicated there were 448 spent fuel assemblies in dry storage contained in 14 casks (Table 4-5).[243] On June 15, 2017, KPS completed the transfer of spent fuel from its spent fuel pool to its ISFSI.[244]

The decommissioning approach that DEK selected for KPS was the SAFSTOR method. Under the SAFSTOR method, the objective is to place the facility in a safe and stable condition and maintained in that state allowing levels of radioactivity to decrease through radioactive decay, followed by decontamination and dismantlement. Pursuant to 10 CFR 50.82(a)(3), decommissioning must be completed within 60 years of cessation of operations. As of April 25, 2014, the completion of all decommissioning activities and approval of site restoration is projected to be December 4, 2073 and estimated to cost $846.1 million (2012 USD).[245] As of December 31, 2017, the total of decommissioning expenditures already incurred was $251.84 million (expenditure-year USD).[246]

240 *Wisconsin State Nuclear Profile 2010.* U.S. Energy Information Administration. 26 April 2012. https://www.eia.gov/nuclear/state/archive/2010/wisconsin/. Accessed 15 February 2019.
241 *Kewaunee*. International Atomic Energy Agency: Power Reactor Information System. 14 February 2019. https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=647. Accessed 15 February 2019.
242 *Kewaunee Power Station: Post-Shutdown Decommissioning Activities Report*.
243 *Dry Storage Cask Inventory Assessment: Fuel Cycle Research & Development* (FCRD-NFST-2014-000602, Revision 2). Prepared for the U.S. Department of Energy: Nuclear Fuels Storage and Transportation Planning Project by Robert H. Jones Jr (SRNL). 22 August 2016. https://www.energy.gov/ne/downloads/dry-storage-cask-inventory-assessment-revision-2. Accessed 3 August 2018.
244 *2017 Annual Radiological Environmental Operating Report: Kewaunee Power Station*. Dominion Energy Kewaunee, Inc. 31 December 2017. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18142A521. Accessed 3 August 2018.
245 *Kewaunee Power Station: Post-Shutdown Decommissioning Activities Report*.
246 *Decommissioning Funding Status Report for KPS*. Dominion Energy Kewaunee, Inc. 23 March 2018. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML18092A082. Accessed 3 August 2018.

**Photo 7.5-2** – The Kewaunee Nuclear Power Plant near Carlton, Wisconsin, in its early years of operation. Photo courtesy of the U.S. Department of Energy: flickr (circa 1975). Public domain.

# 8. Proposed New Nuclear Power Reactors

License applications for new nuclear reactors in the Great Lakes basin have been submitted for:

- Darlington Nuclear Generating Station in Bowmanville, Ontario, for four new reactors
- Fermi, Unit 3 in Monroe County, Michigan, for one new reactor

## 8.1 OPG's Proposed New Reactors at Darlington

In June 2006, the Ontario Ministry of Energy directed Ontario Power Generation to begin the approvals process for the installation and operation of four new nuclear reactors at the existing Darlington Nuclear Site on the north shore of Lake Ontario in the Municipality of Clarington, Ontario. On September 20, 2006, OPG submitted an application to the CNSC for a licence to prepare the Darlington B site. OPG's proposed Darlington New Nuclear Project (DNNP) included the preparation of the site; construction of up to four new reactors and associated facilities; the operation and maintenance of the reactors and related facilities for approximately 60 years, including the management of conventional and radioactive waste; and, the decommissioning and eventual abandonment of the nuclear reactors and associated facilities. The Project would be expected to generate up to 4,800 megawatts of electricity for delivery to the Ontario grid, with an initial need of 2,000 megawatts.

In April 2007, OPG submitted its Project Description and Environmental Assessment to the CNSC. On September 30, 2009, OPG submitted its Environmental Impact Statement to the CNSC. On October 30, 2009, the Minister of the Environment and the Governor in Council appointed a three-member Joint Review Panel (JRP or Panel), in consultation with the President of the CNSC, to assess the environmental effects of the Project and included public review and comment period. After nearly two years of technical studies, 15 public hearings and Aboriginal Engagement, the Panel published its Environmental Assessment Report on August 25, 2011 and concluded that the Project is not likely to cause significant adverse environmental effects, provided the Panel's recommendations are implemented. Per the Panel's recommendations, OPG completed additional cost-benefit analyses for a cooling tower and once-through condenser cooling water systems, as required by the CNSC.[247]

On August 17, 2012, the CNSC issued OPG a nuclear power reactor Site Preparation Licence for a period of 10 years. This Licence authorizes OPG to undertake a range of site preparation activities, including clearing and grubbing of vegetation, excavation and grading of the site, installation of service and utilities, construction of administrative and support buildings, and other activities. However, in December 2013, citing lower than planned power consumption growth combined with a strong supply situation, the Government of Ontario, through the 2013

[247] *Joint review panel: Darlington new nuclear power plant*. Canadian Nuclear Safety Commission. 3 February 2014. http://nuclearsafety.gc.ca/eng/the-commission/joint_review_panel/darlington/index.cfm. Accessed 25 July 2019.

Long-Term Energy Plan, directed OPG to defer the construction of new nuclear reactors at the Darlington Generation Station, but also requested OPG maintain the Site Preparation Licence granted by the CNSC.[248]

In May 2014, Greenpeace Canada, Lake Ontario Waterkeeper, Northwatch and the Canadian Environmental Law Association filed an application for judicial review before the Federal Court of Canada challenging the adequacy of the federal Environmental Assessment conducted by the Joint Review Panel and challenging the Site Preparation Licence issued by the CNSC to OPG. The Court allowed the application for judicial review and ordered the Environmental Assessment be returned to the Joint Review Panel for further consideration. Consequently, the Licence was set aside. This decision was appealed by the CNSC and OPG, and on September 10, 2015, the Federal Court of Appeal set aside the judgement of the Federal Court of Canada, thereby dismissing the application for judicial review. In November 2015, an application for leave to appeal the Federal Court of Appeal's decision was filed with the Supreme Court of Canada. In April 2016, the Supreme Court decided to not grant leave to appeal the Federal Court of Appeal's decision and upheld the Environmental Assessment and the CNSC's decision to issue the Licence. Thus, OPG maintains the Site Preparation Licence issued by the CNSC, which is valid until August 17, 2022.[249]

Since Ontario's 2013 Long-Term Energy Plan directed OPG to defer construction of the new nuclear reactors, OPG has not received any further direction to proceed with project activities. OPG considers the DNNP site to be a significant asset for the Province of Ontario because it is the only site in Canada with an accepted Environmental Assessment and an approved Site Preparation Licence for new nuclear reactors. Therefore, OPG has informed the CNSC of its intention to renew the Site Preparation Licence before its expiration in 2022.[250]

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248 *Mid-Term Report on Results of Compliance Activities and Performance of Ontario Power Generation's Darlington New Nuclear Project* (CMD 18-M55.1) – Commission Meeting. Canadian Nuclear Safety Commission. 13 December 2018. http://nuclearsafety.gc.ca/eng/the-commission/meetings/cmd/pdf/CMD18/CMD18-M55-1.pdf.
249 *Darlington New Nuclear Project*. Canadian Nuclear Safety Commission. 28 April 2016. http://nuclearsafety.gc.ca/eng/resources/status-of-new-nuclear-projects/darlington/index.cfm. Accessed 25 July 2019.
250 *Ibid.*

## 8.2 DTE's Proposed New Reactor at Fermi

On April 30, 2015, the NRC approved the Combined License for DTE to construct and operate a GE-Hitachi Economic Simplified Boiling Water Reactor (ESBWR) (Figure 8-1) at the existing Fermi Nuclear Power Plant in Monroe County, Michigan. The ESBWR is a 1,600 MW electric reactor that includes passive safety features to cool down the reactor after an accident without the need for electricity or human intervention. If built, this ESBWR would become the most powerful (i.e., generate the most energy) single generating unit in the United States.[251] However, DTE has announced that it has not committed to constructing the new reactor.[252]

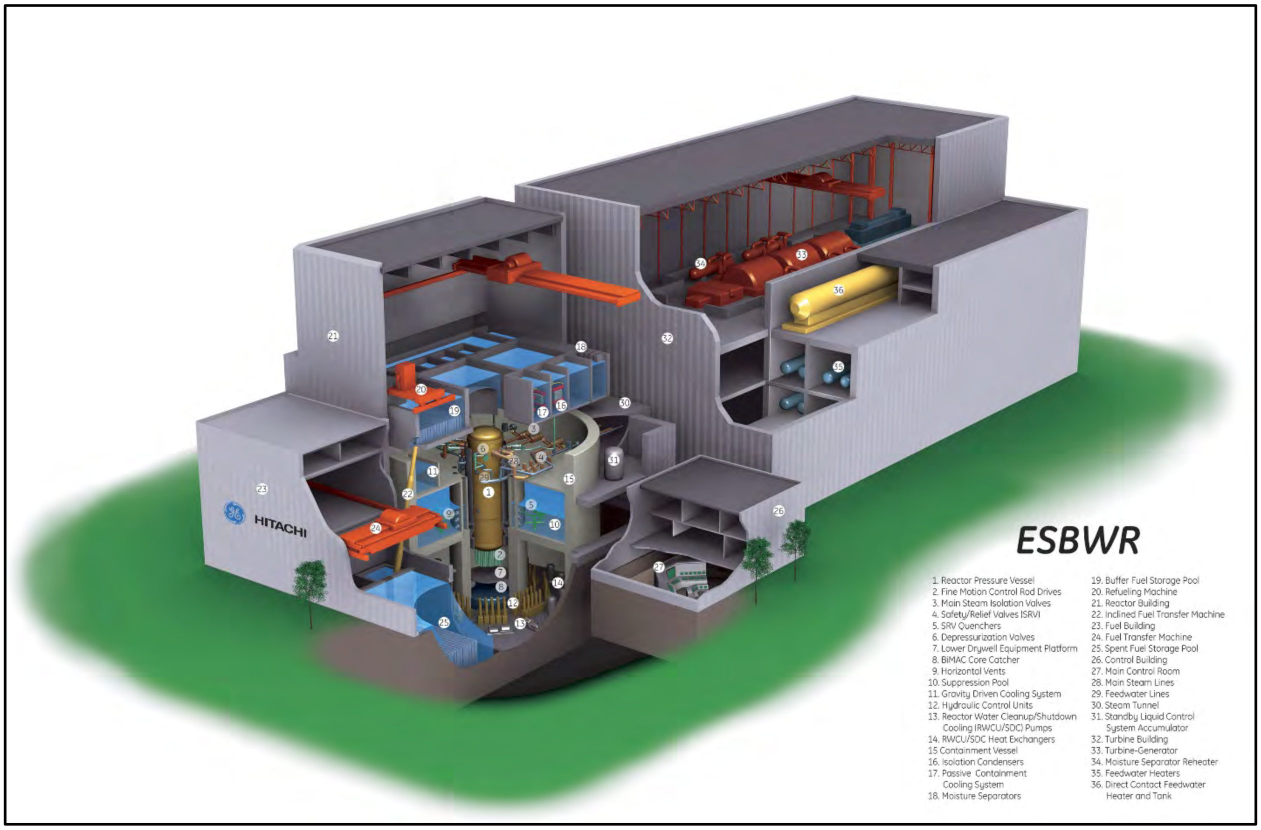


**Figure 8-1** – The NRC certified the Economic Simplified Boiling Water Reactor (ESBWR) design in October 2014. The ESBWR, designed by GE-Hitachi Nuclear Energy, is a single-cycle, boiling-water reactor, with a rated power of 4,500 MW thermal. Image courtesy of GE-Hitachi.

[251] *NRC Concludes Hearing on Fermi New Reactor, Combined License to be Issued* (No: 15-030). U.S. Nuclear Regulatory Commission. 30 April 2015. https://www.nrc.gov/docs/ML1512/ML15120A302.pdf.

[252] *Fermi 2 Power Plant: The Future of Nuclear Plant Development*. DTE Energy. 2019. https://www.newlook.dteenergy.com/wps/wcm/connect/dte-web/home/about-dte/common/fermi2. Accessed 24 July 2019.

# Appendix A – Background Report Objectives

**IJC Research on the State of Nuclear Decommissioning Issues and the applicable Nuclear Regulatory Regime in the Great Lakes Region**.

IJC staff will produce a report with background information for this project. This background report will synthesize information about the nuclear power plants and reactor units in the hydrologic boundary of the Great Lakes basin with information on:

a. Plant status (e.g., operational, closed, scheduled for closure, being refurbished, etc.)
b. Date of actual or planned closure.
c. The status of closure plans, including dismantling, decommissioning, and site cleanup.
d. The status of regulatory plan approval as applicable.
e. Plans for new nuclear power plants or units within the Great Lakes basin that may require additional closures in the future.
f. Estimates of high-level, intermediate, and low-level radioactive wastes that are likely to be involved at the time of closure, both in the power plant and in onsite waste storage or disposal facilities.
g. A description of the types of decommissioning actions that have been taken at each closed facility or unit, or actions planned to be taken at nuclear power currently operating or planned to be built. This includes a listing of who is responsible for:
    i. decommissioning the facility,
    ii. on-going monitoring after decommissioning,
    iii. any additional remediation that may be needed at a later point; and
    iv. how long that responsibility lies with the same entity (government or commercial) after closure, including any shifts in who is responsible.
h. A description of the role of the Great Lakes States, Ontario, First Nations, Tribes, Métis, municipalities, and public engagement in the process associated with developing and approving closure plans.
i. A review of the nuclear regulatory regimes in the United States and Canada that includes a description of the regulatory regime addressing the approval of nuclear dismantling, decommissioning, and related activities in the U.S. and Canada. This includes a description of the regulatory rules and/or guidelines for decommissioning, including cleanup standards, bond requirements, liability limitations, and on-going environmental monitoring.

This background report will be provided as information for the development of a contracted report. The consultant will describe state-of-the-art closure of nuclear facilities as well as analyze the environmental hazards and significant differences in nuclear decommissioning approaches between Canada, Europe, and the United States. This background report and the contracted report will be used by the Legacy Issues Work Group and the WQB to develop its recommendations to the IJC regarding any additional actions that the governments could take to eliminate or reduce threats to the Great Lakes from the release of radioactive contaminants as a result of decommissioning.

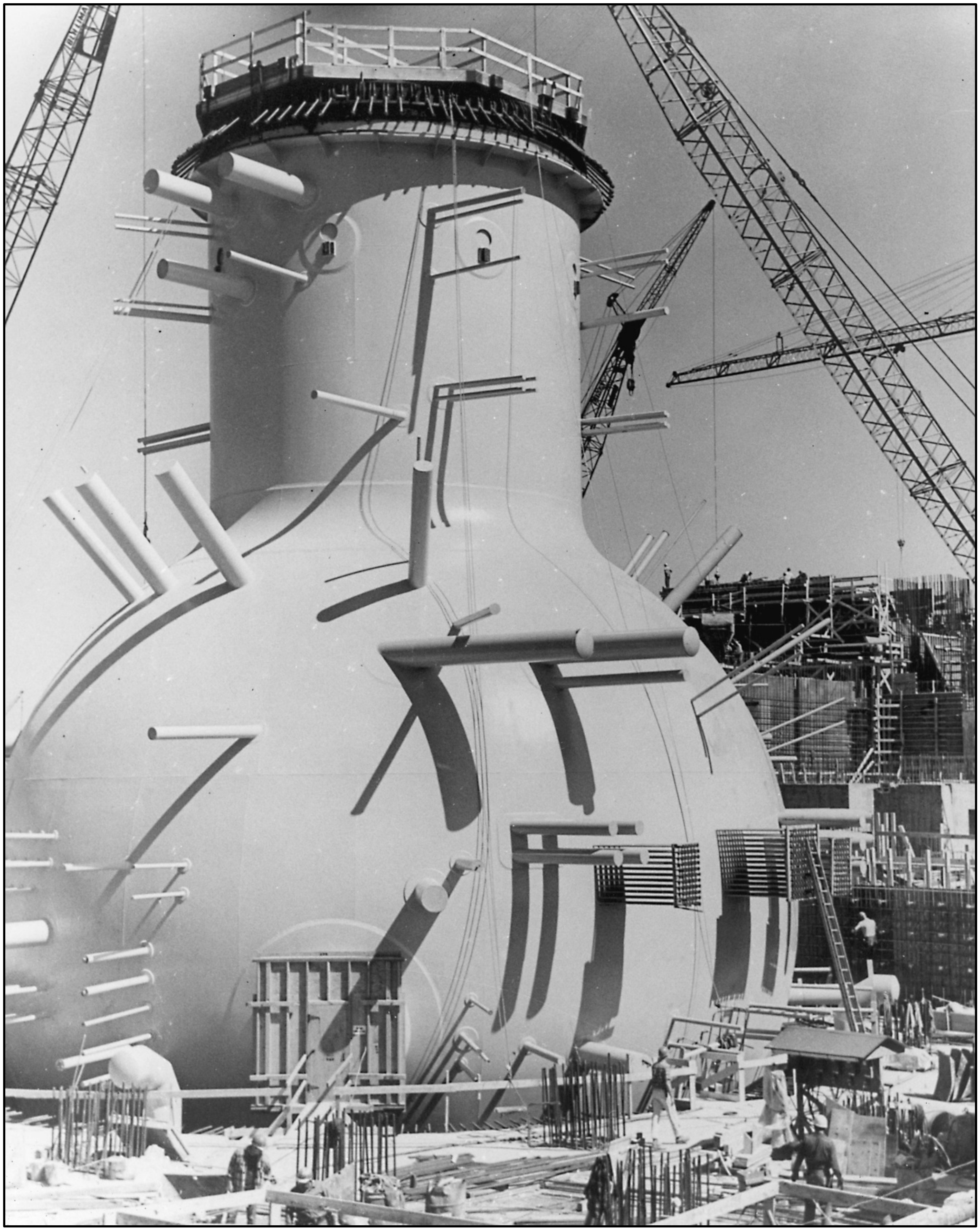

**Photo A.A-1** – At the Nine Mile Point Nuclear Power Plant, this 130-foot- (40-meter)-tall pressure vessel houses the reactor built by General Electric for the Niagara Mohawk Power Corporation. Photo courtesy of the U.S. Department of Energy (circa 1966). Public domain.

# Appendix B – Contact Information

## Contact Information for the Nuclear Operators

### *American Electric Power: Indiana-Michigan Power*

*Donald C. Cook Nuclear Plant*

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*Bruce Nuclear Generating Stations*

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### ***EnergySolutions***

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### ***Entergy Nuclear Palisades***

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### ***Nuclear Waste Management Organization***

*Canada's spent nuclear fuel deep geological repository organization*

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### ***Ontario Power Generation***

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**Photo A.B-1** – Cranes were used to lift rebar and concrete for the construction of the Vacuum Building at the Darlington Nuclear Generating Facility. Photo courtesy of Ontario Power Generation (circa 1983). Used with permission.

## Contact Information for the Nuclear Regulators

### *Canadian Nuclear Safety Commission*

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Contact Us webpage: http://nuclearsafety.gc.ca/eng/contact-us/index.cfm

*News Room*

Webpage: http://nuclearsafety.gc.ca/eng/resources/news-room/index.cfm

### *U.S. Nuclear Regulatory Commission*

*Office of International Programs*

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*News Releases*

Webpage: https://www.nrc.gov/reading-rm/doc-collections/news/

*NRC Library*

Webpage: https://www.nrc.gov/reading-rm.html

Agency-wide Documents Access and Management System (ADAMS)

Webpage: https://www.nrc.gov/reading-rm/adams.html

Public Document Room (PDR)

Phone: 301-415-4737 or 1-800-397-4209

Facsimile: 301-415-3548

Email: pdr.resource@nrc.gov

Webpage: https://www.nrc.gov/reading-rm/pdr.html

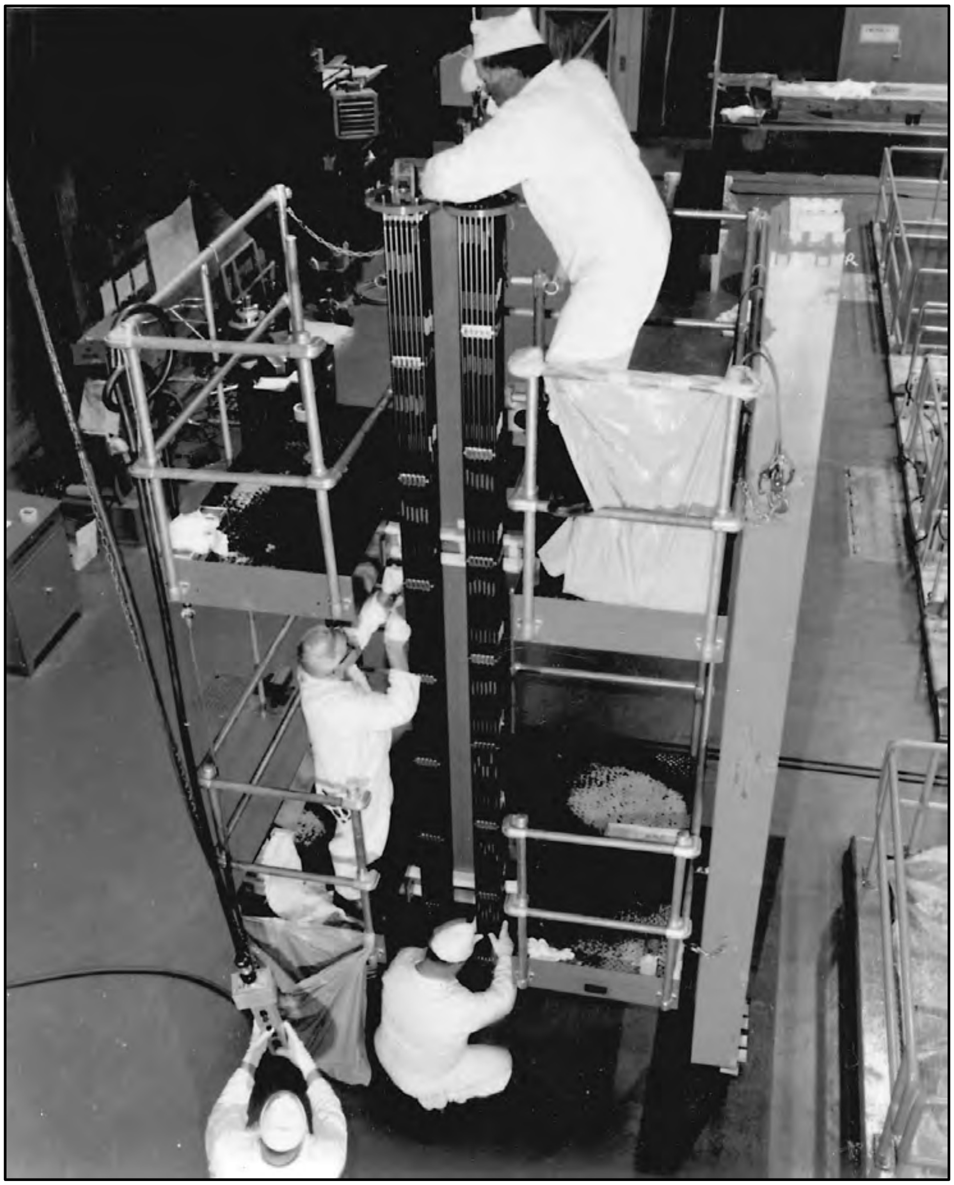

**Photo A.B-2** – Technicians prepare uranium fuel bundles for loading at Niagara Mohawk Power Corporation's Nine Mile Point Nuclear Station near Oswego, New York on Lake Ontario. Photo courtesy of the U.S. Department of Energy (Circa 1970). Public domain.


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