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Mémoire de Northwatch

In the Matter of the

À l'égard d'

Ontario Power Generation Inc.

Ontario Power Generation Inc.

Application for a licence to construct one BWRX-300 reactor at the Darlington New Nuclear Project Site (DNNP)

Demande visant à construire 1 réacteur BWRX-300 sur le site du projet de nouvelle centrale nucléaire de Darlington (PNCND)

Commission Public Hearing
Part-2

Audience publique de la Commission
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Northwatch Comments on Ontario Power Generation Inc.'s Application for a Licence to Construct BWRX-300 reactor(s) at Darlington Nuclear Generating Station

NORTHWATCH

November 2024

Ref. 2024-H-03

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Précis

The documentation submitted by OPG either does not include or inadequately addresses the information areas required in an application to construct a nuclear reactor in Canada.

Northwatch has made several requests of the Commission, which singly and in combination have the objective of requiring that Ontario Power Generation provide the necessary information and that the licensing review be carried out in a manner which is information-based and provides an opportunity for the public and Indigenous peoples to fully and fairly engage in the review process.

Introduction

Overview

Ontario Power Generation is intending to construct four of the GE-Hitachi BWRX-300 boiling water reactors at the site of the Darlington Nuclear Generating Station on the north shore of Lake Ontario, 70 kilometres east of Toronto.

The BWRX – 300e is a “small modular reactor” designed by GE Hitachi. It is cooled and moderated by low-pressure, light-water with what the proponent describes as “distinctive safety feature of natural cooling of the core without reliance on electrical pumps to circulate water and remove decay-heat in the event of reactor shutdown”.

The fuel is UO2, enriched to an average of 3.4% 235-U.

It is a tenth-generation version of the U.S. NRC-licensed, 1,520 MWe ESBWR. As such, many of the components, e.g., fuel and moderator/coolant, have already been in use for decades, which GE-Hitachi claims provides considerable operational experience and knowledge of materials properties and their response to intense radiation fields. However, the BWRX-300 reactor has not yet been constructed or operated anywhere, and it is unclear where this reactor lands on the continuum from idea to concept to design to deliverable. It must also be noted that its predecessor design by GE-Hitachi, the ESBWR[1] has never been constructed and is more than five times larger in electrical output. The BWRX-300 is also the only boiling water reactor under development in Canada or the United States.[2]

While some much earlier versions of this reactor type have been employed elsewhere, the only commercial reactors that have operated in Canada have been the heavy-water CANDU reactors, which use a different fuel, have a different operating system, and generate reactor fuel wastes which are very different in characteristics and in dimensions. As such, the selection of the BWRX-300 is a significant departure for Ontario Power Generation and for Canada more generally.

Ontario Power Generation announced the selection of the 300-megawatt (MWe) BWRX-300 reactor in December 2021. According to OPG, their preliminary schedule is to complete construction of the first reactor by 2028 with commercial operation in 2029.

[1] https://aris.iaea.org/PDF/BWRX-300_2020.pdf
[2] https://www.energy.gov/ne/articles/first-us-small-modular-boiling-water-reactor-under-development

Northwatch's Interest

Northwatch is a public interest organization concerned with environmental protection and social development in northeastern Ontario. Founded in 1988 to provide a representative regional voice in environmental decision-making and to address regional concerns with respect to energy, waste, mining and forestry related activities and initiatives, we have a long term and consistent interest in the nuclear chain, and its serial effects and potential effects with respect to northeastern Ontario, including issues related to uranium mining and refining, nuclear power generation, and various nuclear waste management initiatives and proposals as they may relate or have the potential to affect the lands, waters and/or people of northern Ontario.

Northwatch has a dual mandate that includes public interest research, education and advocacy to promote environmental awareness and protection of the environment, and the support and promotion of public participation in environment-related decision-making.

Northwatch is interested in Ontario Power Generation's proposed approach to nuclear waste management and containment over various time frames. Northwatch's issues and concerns relate to the generation and management of the nuclear wastes that will result from Ontario Power Generation's operations. The wastes of concern include those wastes which will result from continued and future reactor operation, including and particularly – in this case – the novel wastes from the BWRX-300 reactors which Ontario Power Generation has selected for construction, operation and decommissioning at the Darlington Nuclear Generating Station.

Given Ontario Power Generation's established practice of transferring radioactive wastes from the Darlington NGS to the Western Waste Management Facility on the eastern shore of Lake Huron, and given the OPG-controlled Nuclear Waste Management Organization's current investigation of the Revell area between Ignace and Dryden in Kenora District in northern Ontario as a potential burial location for high level nuclear (irradiated) fuel waste and potentially other radioactive wastes - including wastes generated through the construction, operation and decommissioning of so-called "small modular reactors" – all licensing stages related to the development of new reactors at the DNN are of direct interest to Northwatch.

Project Licensing History for the Darlington New Nuclear Project

In 2007 Ontario Power Generation (OPG) considered nine reactor designs under offer or development by six different vendors: the EC6 and ACR-1000 from AECL, the EPR from Areva, the ABWR and ESBWR from GE Hitachi, the OPR1000 and APR1400 from KHNP, the US-APWR from Mitsubishi, and the AP-1000 from Westinghouse.

In March 2008, Infrastructure Ontario (IO) issued a competitive Request for Proposal (RFP) for a new nuclear power station in Ontario and four vendors were invited to participate in the RFP process: AECL (the ACR-1000), Areva (the EPR), GE-Hitachi (the ESBWR) and Westinghouse (the AP1000). GE-Hitachi chose not to participate in the process.

In September 2009 Ontario Power Generation submitted an Application for a Licence to Prepare a Site (LTPS) and an Environmental Impact Statement (EIS) for the Darlington New Nuclear Project (DNNP). In response to an August 2010 information request from the Joint Review Panel (JRP) reviewing OPG's EIS, OPG provided information to the JRP about the Enhanced CANDU 6 (EC6) heavy water reactor, in consultation with the EC6 vendor, AECL.

The Joint Review Panel carried out an environmental assessment review and hearing in the absence of a selected reactor design or the detailed information that would - presumably – have been under consideration in an actual environmental assessment of an identified reactor design. Northwatch was an intervenor in the public hearing, providing expert and general submissions in writing and participating throughout the hearing.

The JRP released its report on August 25, 2011 and presented 67 recommendations in its report, including recommendation #1: "*The Panel understands that prior to construction, the Canadian Nuclear Safety Commission will determine whether this environmental assessment is applicable to the reactor technology selected by the Government of Ontario for the Project. Nevertheless, if the selected reactor technology is fundamentally different from the specific reactor technologies bounded by the plant parameter envelope, the Panel recommends that a new environmental assessment be conducted*."

The Government of Canada supported this recommendation, stipulating as follows:

> *"Any RA (Regulatory Authority) under the CEAA will need to determine whether the future proposal by the proponent is fundamentally different from the specific reactor technologies assessed by the JRP and if a new EA is required under the CEAA."*

In 2013 the Government of Ontario deferred the procurement of large new nuclear reactors at the Darlington site.

Between 2019 and 2021 OPG reviewed several different concepts or conceptual designs for various "small modular reactor technologies", and in December 2021 announced that it had selected the BWRX-300 as the technology to be deployed at the DNNP site.

Prior to their December 2021 announcement of their selected reactor design, OPG had sought and received a renewal of their site preparation license for the Darlington New Nuclear Project.

On October15, 2020 CNSC announced a public hearing on the renewal of Ontario Power Generation Inc.'s nuclear power reactor site preparation licence for the Darlington New Nuclear

Project.[3] Northwatch intervened in that license review process and objected to the license being renewed at that time for a number of reasons, including the absence of a selected reactor design; at that time, OPG's reactor selection decision and its announcement was thought to be imminent, which it was. On October 12, 2021 the CNSC announced the Commission's decision to renew the nuclear power reactor site preparation licence issued to Ontario Power Generation Inc.[4] Ontario Power Generation announced the selection of the 300-megawatt (MWe) BWRX-300 reactor in December 2021.

In October 2022 Northwatch received notifications from the Canadian Nuclear Safety Commission that the CNSC would be holding "webinars on the upcoming licensing review of the Darlington New Nuclear Project" and that Indigenous Nations and communities, members of the public and stakeholders were invited to review and comment on two OPG documents related to the Darlington New Nuclear Project, namely the "*Use of Plant Parameters Envelope to Encompass the Reactor Designs Being Considered for the Darlington Site*" and "*Darlington New Nuclear Project Environmental Impact Statement Review Report for Small Modular Reactor BWRX-300*".

CNSC staff described the purpose of that consultation as being "to enable the Canadian Nuclear Safety Commission (CNSC) to gather feedback early in the licensing process for Ontario Power Generation's (OPG) Darlington New Nuclear Project (DNNP). Feedback received during this stage will help the CNSC to better understand this project."[5] Northwatch participated in the online sessions and provided written comments.

On April 3, 2023 the Canadian Nuclear Safety Commission issued a notice[6] that it would hold a hearing in January 2024 on the applicability of the Darlington New Nuclear Project environmental assessment and plant parameter envelope to OPG's selected reactor technology, the BWRX-300. The purpose of the hearing was for the Commission to consider and decide on OPG's application for a licence to construct one BWRX-300 reactor for its DNNP. Although the EA for the DNNP considers up to four reactor units, the application before the Commission is purportedly limited to one reactor unit. Northwatch submitted written comments and participated in the hearing.

Northwatch's analysis was that OPG and CNSC were attempting to persuade the Commission that the <u>effects</u> of the different reactor technology would not be fundamentally different from the

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[3] CNSC CMD Ref.2021-H-04
[4] CNSC DEC 21-H4, as posted at https://api.cnsc-ccsn.gc.ca/dms/digital-medias/Decision-OPGDNPP-June10-11-e.pdf/object
[5] As found at https://www.letstalknuclearsafety.ca/dnnp-pre-licensing-consultation 19 March 2023
[6] CNSC CMD Ref. 2024-H-02

effects of the reactors considered in the 2011 hearing, whereas the Government decision had clearly set out that a new environmental assessment would be required if the technology was fundamentally different. Neither OPG or CNSC tried to persuade the Commission that the technology was not fundamentally different.

On April 22, 2024 the CNSC announced the Commission's decision that the existing environmental assessment for the Darlington New Nuclear Project (DNNP) is applicable to the General Electric Hitachi BWRX-300 reactor.

On June 27, 2024 the CNSC issued a notice that it would hold a 2-part public hearing on Ontario Power Generation Inc.'s application for a licence to construct one BWRX-300 reactor for its Darlington New Nuclear Project, with Day 1 in October 2024 with submissions restricted to CNSC staff and Ontario Power Generation and Day 2 of the public hearing in January 2025. The stated purpose of the hearing is for the Commission to consider and decide on OPG's application for a licence to construct one BWRX-300 reactor for its DNNP.[7] The early EA for the DNNP assumed up to four large reactor units, but in this public licensing review the Commission is limiting its consideration to one small reactor unit.

Ontario Power Generation's application for a licence to construct the BWRX-300 reactor(s) at the Darlington Nuclear Generating Statin is the subject of this submission.

[7] CNSC CMD Ref. 2024-H-03

Review of OPG's Application for a Licence to Construct

According to the CNSC's own rules (REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2) OPG's application must contain the following information:

- A technical description of the reactor, including layout and design and design features
- Site characteristics, including exclusion zones, emergency planning, other radiological sources (such as the four CANDU reactors and large nuclear waste facilities on the same site)
- Safety issues and aspects related to the reactor design and operation, including criticality issues, security concerns, reactors safety systems,
- Radioactive waste and hazardous waste treatment systems
- The potential for severe accidents, probabilistic safety assessments
- Radiation sources, monitoring, and protection and radiological impacts
- Environmental monitoring
- Handling of radioactive and hazardous waste, including storage and disposal
- Decommissioning and End of Life Aspects, including financial guarantees

The application submitted by OPG either does not include or inadequately addresses these required topics.

Northwatch's review is not comprehensive and has been largely limited to our key area of interest, i.e the generation and management of radioactive wastes. This scoping reflects our own geography, mandate and capacity constraints, and does not in any way imply that those topics which we have not included have been satisfactorily addressed by Ontario Power Generation.

Our comments on the application are based on our review of the October 2022 Application for a Licence to Construct a Reactor Facility, and the Commission Member Documents prepared by Canadian Nuclear Safety Commission and Ontario Power Generation (CMDs 24-H2 and 24-H2.1) and both date signed June 28, 2024) as well as on select documents, including but not limited to the Preliminary Safety Analysis Report published in 2022 for the BWRX-300.

Technical Description of the Reactor

According to *REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2* OPG's application must contain a technical description of the reactor, including layout and design and design features.

The application filed by OPG lacks sufficient description and details of many aspects of the reactor layout and design features.

There are several graphic depictions of the BWRX-300 unit and the site layout included in the application and OPG's commission member document, including some – such as Figures 3 and 4 in the CMD – that are of such poor quality that they are very difficult to read and to identify the components being depicted.

Figure 5 in OPG's CMD is the most "readable" of the graphic presentations and identifies two features of the BWRX layout related to nucleaer waste and its management: the "Radwaste Building" and the "Proposed Spent Fuel Storage" (but not the "Fuel Pool"). Figure 8 identifies the "Fuel Pool", but not the Radwaste Building or Proposed Spent Fuel Storage.

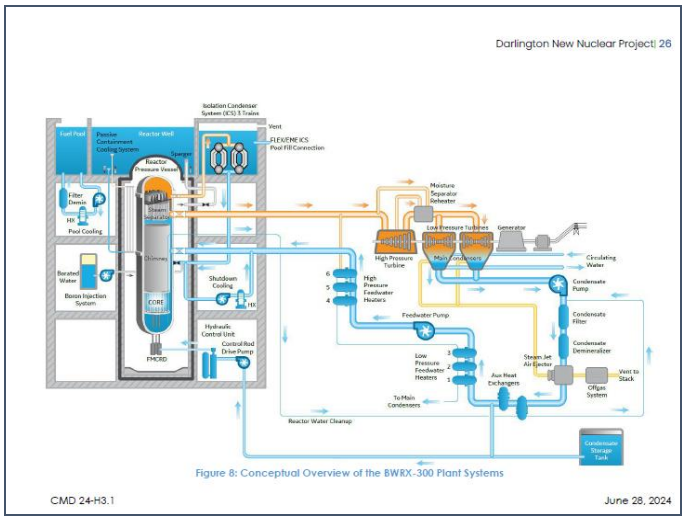


Figure 5: An Artist Rendition of a Potential BWRX-300 Layout

OPG's application very generically describes the Radwaste Building (RWB) as "housing equipment associated with the handling, processing, and packaging of solid and liquid radioactive waste generated by the nuclear facility"[8]. The description of the Radioactive Waste Building Structure is similarly limited. The description of the actual structure is as follows: *Its structure consists of reinforced concrete walls and floor slabs supported on a shallow reinforced concrete mat foundation with roof joists and composite roof decking. The lateral force resisting system of the structure consists of concrete shear walls, concrete floors, and a composite roof deck acting as a diaphragm.*[9]

As summarized above, the Application provides no description of those aspects of the building most related to its function as the location of radioactive wastes, such as shielding, robustness from extreme weather or malevolent acts, or the design and security of the actual waste containers being housed.

The applications description of Spent Fuel Storage and Handling is similarly deficient. The application states that the spent fuel is removed from the reactor and initially stored in the Fuel Pool until the decay

[8] DNNP Construction Licence Application, Ontario Power Generation, October 2022, pages 28 and 134
[9] DNNP Construction Licence Application, Ontario Power Generation, October 2022, page 142

heat reduces to the appropriate level and then loaded into a dry canister in the pool, and then moved to the refuel floor cask washdown pad for processing and before transfer to an interim storage facility.[10]

The application provides no design description of the spent fuel pool, or of the dry storage containers into which the waste will be transferred. While OPG may be able to argue – albeit weakly – that the design of the dry storage containers may be a matter for the operating license stage, no argument can be convincingly made that a detailed description of the spent fuel pool should not be included in the application to construct. The spent fuel pool is part of the reactor layout, part of the reactor design, and a detailed description of the spent fuel pools is not included in the application to construct.

The application does argue that the construction of the on-site dry storage facility will be part of a separate licence application but stages that "the general approach is briefly described here". However, the description is limited to simply stated that the wastes will be transferred and moved to dry storage, and provides no description of the dry storage facility or the dry storage containers.[11]

While some additional information provided in the form of a very general description of the Fuel Pool Cooling and Cleanup system, Criticality Protection through maintaining physical distance and Radiation Monitoring, the application lacks sufficient detail in each of these important aspects of reactor design.[12] For example, the application states that "the fuel pool, reactor pool, and surrounding concrete walls are designed to ensure the area dose rate is maintained within specification"[13] but provides no description of each of those features, the basis for their design, or the basis for determining that these design features – singly and in combination – are adequate to the challenge of limiting dose.

REQUEST: That the Commission deny the application to construct on the basis of OPG having provided inadequate information about their reactor design, including the design, design features and design basis for those parts of the site layout related to radioactive waste and its containment, including the Radwaste Building, the Spent Fuel Storage and the Fuel Pool

Site Characteristics

According to *REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2* OPG's application must contain a description of site characteristics, including exclusion zones, emergency planning, other radiological sources. (such as the four CANDU reactors and large nuclear waste facilities on the same site)

In Section 3.1 of the license to construct application OPG describes their site characterization, and in Section 3.1.7. the application does acknowledge that baseline radiation and radioactivity includes natural background, background from anthropogenic sources (fallout from nuclear testing and releases from other nuclear sites) and releases from the Darlington Nuclear Generating Station (DNGS) (app, page 54) In Section 3.1.8 the application claims that OPG remains active in monitoring land use within 10 km of the DN site to determine whether there are any proposed land uses that would be of concern from the perspective of sensitive land uses such as day care, hospital, or retirement home locating within the vicinity of the DN site. (page 54).

[10] DNNP Construction Licence Application, Ontario Power Generation, October 2022, page 219
[11] DNNP Construction Licence Application, Ontario Power Generation, October 2022, page 219
[12] DNNP Construction Licence Application, Ontario Power Generation, October 2022, page 220
[13] DNNP Construction Licence Application, Ontario Power Generation, October 2022, page 221

Notably absent from the site description is that the proposed location of the first of four boiling water reactors next door to the already operating four-unit Darlington Nuclear Generating Station, and immediately adjacent to the sizeable Darlington Waste Management Facility (DWMF) and its proposed expansion of additional waste storage buildings between the current facility and Lake Ontario.

Renewal of the Darlington Waste Management Facility Operating Licence WFOL-W4-355.01/2023

Figure 2: Nuclear Sustainability Services - Darlington

Source: CMD: 23-H9.1, OPG DWMF License Renewal, 2023

Figure 2: Photograph of DN Site Illustrating DNNP Site Boundary

Source: OPG CMD 24-H3.1, page 15

REQUEST: That the Commission defer further consideration of the application to construct until such time as OPG has provided evidence of how their site selection appropriately considered how the adjacency of the proposed boiling water reactor created an additional risk factor for the Darlington Waste Management Facility and vice versa and demonstrated that construction of the boiling water reactor in such close proximity to the DWMF does not create additional risk for the waste facilities, including as a result of accidents arising with or malevolent acts directed at the BWRX-300.

Reactor Design and Safety Issues

According to *REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2* OPG's application must contain a discussion of safety issues and aspects related to the reactor design and operation, including criticality issues, security concerns, reactors safety systems.

With respect to reactor design, we found sections of Ontario Power Generation's material to be more promotional than informative in nature. For example, in their June 2024 Commission Member Document OPG writes that *"Where possible, the BWRX-300 design allows for in-factory modular construction."* [14]

At least in theory, where possible, that might be the case. But it is clearly not the case at this point in time for the reactor which is the subject of this application for a license to construction because it is the single and sole reactor on order, so there will be no factory line production, no mass manufacturing. These are promotional statements and are not appropriate to what should be a detailed and technical description.

Similarly, the statements that the LTC Application "demonstrates that the regulatory requirements are satisfied commensurate with the stage of design and continue to be confirmed as part of the

[14] CMD 24-H3.1, page 75

design process, some specific design and safety analysis deliverables have been committed to CNSC staff as future deliverables once the detailed design is complete"[15] is an attempt at persuasion but is not information.

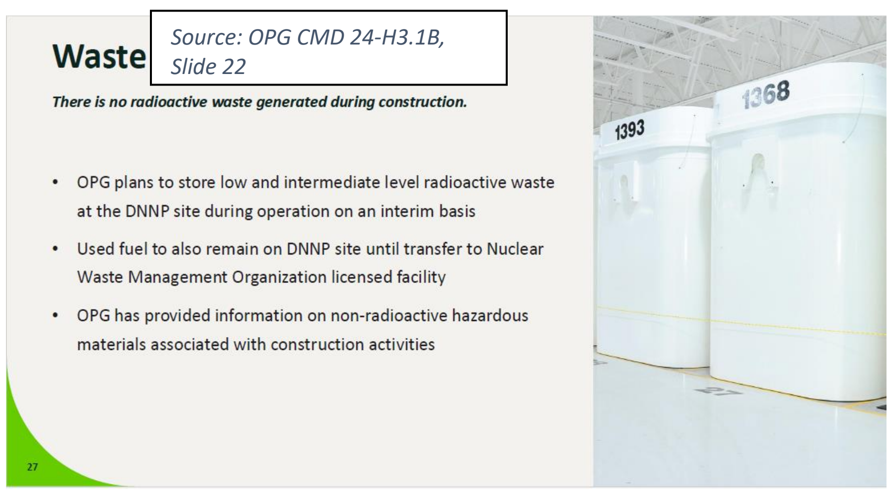
OPG further argues that it will :*ensure that all commitments made during the LTC Application review are completed prior to the start of the relevant construction activities under a Licence to Construct." What these statements confirm is that OPG has applied for a licence to construct a reactor prior to having completed the reactor design or the construction plan. This is not acceptable to the public, and should not be acceptable to the Commission, despite the willingness of CSNC staff to replace the Commission in their decision-making role.*

Reflecting on the progression of this licensing process, OPG successfully gained approval of a an environmental assessment of a reactor without selecting a reactor design in 2011, then was exempted from the requirement to undergo an environmental assessment process if the selected design was fundamentally different despite having selected a fundamentally different technology, and now are proposing that they be granted license to construct a reactor prior to having presented a complete reactor design or construction plan.

REQUEST: That the Commission defer further consideration of the application to construct until such time as OPG has submitted a complete reactor design and construction plan and met all the requirements of REGDOC-1.1.2

Radioactive Waste

According to *REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2* OPG's application must contain a description of radioactive waste and hazardous waste treatment systems and a discussion of the handling of radioactive and hazardous waste, including storage and disposal.



OPG acknowledges in the commission member document that the scope of their proposed activities under the application for a license to construct includes the construction of the Reactor Building and the radioactive waste building and auxiliaries.[16]

OPG argues in their application that "the BWRX-300 design minimizes its environmental impact by…Maintaining a low waste signature for both conventional and radioactive waste. This is accomplished using advanced design and construction methods that reduce waste during

[15] CMD 24-H3.1, page 77
[16] CMD 24-H3.1, Section 1.3, "Scope", page 10

construction as well as the amount of irradiated material for decommissioning. In addition, the design requires fewer operational and maintenance activities that generate waste."[17] However, it has been shown by scholars that SMRs in general are not beneficial for waste stream management and disposal due to the simple fact that they are smaller, and thus neutron leakage is higher.[18]

While Section 2.2 of the CMD includes a brief description of the fuel, the fuel assembly and the fuel cycle, there is no description of this same fuel after it has been irradiated and become high-level nuclear waste, or of the management structures that must be constructed – under this license application – to house the resulting waste.

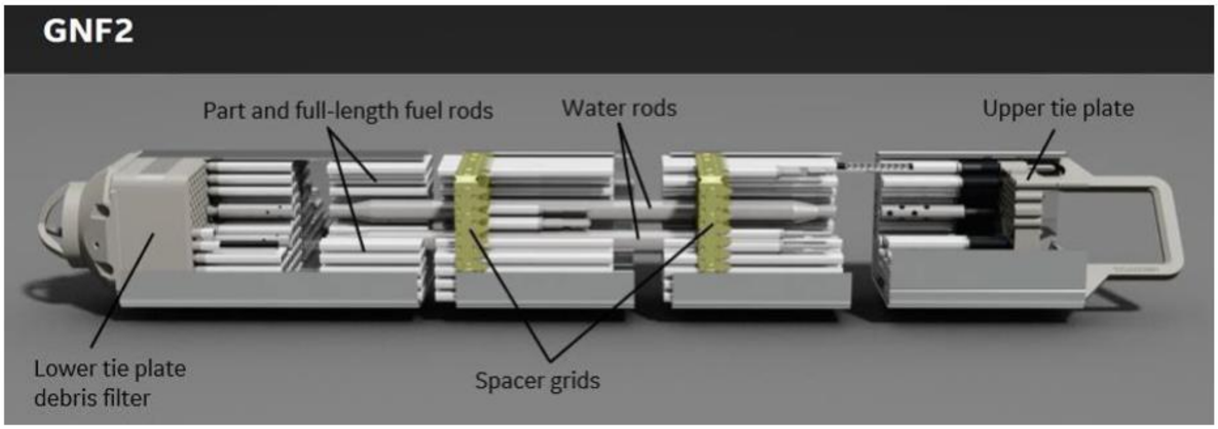


Figure 13: GNF2 Fuel Bundle

Figure 1: OPG CMD page 38

In Section 4.11 of the CMD, titled "Waste Management", OPG argues that because the activities to be licensed under the DNNP LTC will not involve the generation of radioactive wastes the handling of radioactive wastes is not a licensed activity under this application, but claims that "information is provided for how these wastes will be managed and stored through the lifecycle of the BWRX-300 at the DNNP site."

Sufficient information is not provided. In fact, what is provided is limited to very broad claims about OPG's waste management program more generally (not specific to the BWRX-300 construction and operation) and a statement that "for the DNNP, OPG will have a similar program to ensure that spent fuel, low and intermediate level radioactive waste and non-radioactive hazardous substances and waste are handled, processed, transported and stored in accordance with the applicable federal, provincial and municipal regulations and authorizations."

This is not a description of the waste management systems and structures.

[17] DNNP Construction Licence Application, Ontario Power Generation, October 2022, Page 36

[18] Krall, L.M., Macfarlane, A.M., Ewing, R.C., 2022. Nuclear waste from small modular reactors. Proceedings of the National Academy of Sciences 119, e2111833119. doi:10.1073/pnas. 2111833119.

Similarly, the description of "Radioactive Waste" in Section 4.11.2 is overly general, and quite generic. There is no description of interim storage – or the interim storage facilities that would be constructed – in this section.[19]

The CMD describes OPG as having "carefully considered the two options for the interim storage of low and intermediate level waste (L&ILW) that were assessed in and remain bounded by the EA: the construction of onsite licensed storage structures, and off-site transportation to a licensed facility" and states that they will proceed with interim storage of L&ILW onsite at a licensed facility, followed by relocation to permanent offsite licensed L&ILW disposal facilities.[20]

The CMD states that for "the management of used fuel, OPG will utilize a similar process that is used at the existing Pickering and Darlington Nuclear Generating Stations which process is also used in the nuclear industry as the preferred method for safe and economical storage of used fuel" and that "the used fuel from all reactors in Ontario is currently stored in Spent Fuel Bays and dry storage facilities at the stations where the fuel was used."

Ontario Power Generation does not acknowledge or address the very different dimensions and characteristics of the irradiated fuel waste that will be generated by the BWRX-300 reactor versus the CANDU reactors which have been the design for operations at Pickering and Darlington. The very general statements about following past practices are particularly meaningless given that the BWRX-300 is a fundamentally different technology and it will produce irradiated fuel waste which has many fundamental differences from the CANDU waste and so from the operating experience OPG seeks to reference.

OPG claims in their CMD that "the dry fuel storage practices will reflect the fundamental safety aspects related to criticality, radiation exposure, heat control, containment and retrievability" but has provided no information or evidence to support that claim. Moreover, it appears in Figure 4 in CMD 24-H3.1 that the (future) used fuel storage facility is outside the protected area.

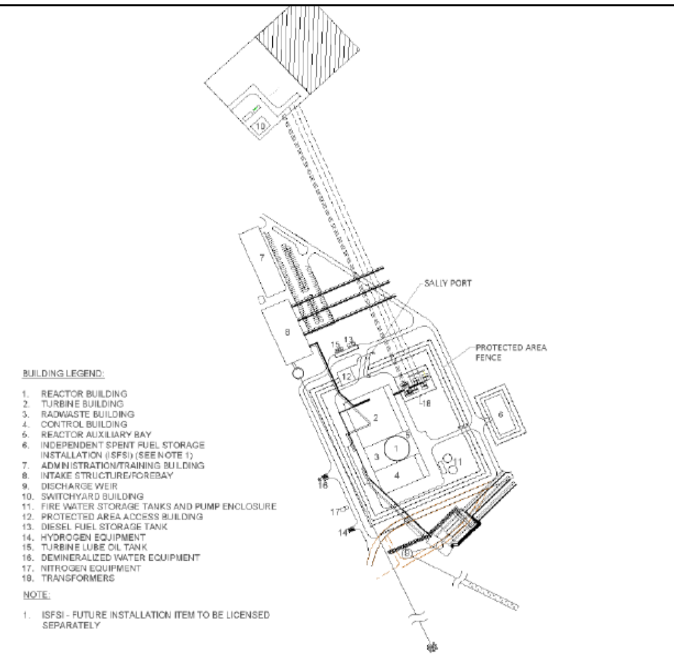


Figure 4: Detailed view of Preliminary Layout of Single BWRX 300 Unit

Figure 2: OPG CMD 24-H3.1, page 17

REQUEST: That the Commission defer further consideration of the application to construct until such time as OPG has submitted addressed the gaps and deficiencies in their application with respect to radioactive waste management and its facilities, including the design details of those facilities which will

[19] OPG CMD 24-H3.1, page 102-103
[20] OPG CMD 24-H3.1, page 103

be constructed prior to operation commencing, and adjustment of the site configuration to correct the current placement of the future fuel waste storage being outside the protected area.

In the application itself, presumably based on its argument that no waste will be generated during construction and so long term waste management falls outside the scope of the license to construct, OPG limits its discussion of the long-term management of radioactive waste to the statement that “Long-term management of DNNP’s used nuclear fuel will be planned as part of the Nuclear Waste Management Organization’s (NWMO) Adaptive Phased Management program.” [21]

Northwatch finds this statement to be appropriate. It does not claim successes the NWMO has not – and may not – achieve, and it does not provide details of a project which OPG itself has argued is outside the scope of the LTC.

It is quite a different case in OPG’s CMD, where they devote a considerable amount of text to the promotion of the NWMO’s current effort to site a deep geological repository for high-level nuclear waste and to describing the NWMO, as of October 2023, now being “also responsible for developing a consent-based siting process for a DGR for intermediate-level and non-fuel high-level radioactive waste.” [22]

In the CMD OPG also adopts the NWMO’s mix and match game, stating both that the deep geological repository which NWMO is attempting to develop and site under their “Adaptive Phased Management Plan” will “can accommodate the long-term storage of the BWRX-300 spent fuel and this small increase in volume” and that “NWMO is also exploring the potential to include any future used fuel from SMRs and new nuclear in the same repository that will manage the intermediate-level waste and non-fuel high-level waste”.

Northwatch first became aware of this shell game the NWMO is playing through remarks NWMO made to the Canadian Nuclear Association in February 2024 and has noted the increasing frequency and flexibility of the NWMO’s “whack a hole” approach since that time. It demonstrates that the NWMO’s plans are fluid, flexible, and should be recognized as being for illustrative purposes only.

OPG chooses in their CMD to further stray out of the narrow scope of the application for he license to construct – so narrow, OPG argued, that it excluded the management of the radioactive wastes that would be generated and must be housed within the nuclear generating complex – to describe OPGs transportation plans with a random collection of statements about OPG’s transportation packages, shipments of enriched fuel (but not by OPG), and declarations that “the shipments of fresh and spent enriched fuel for the BWRX-300 will be in accordance with the CNSC Packaging and Transport of Nuclear Substances Regulations, 2015 and the Nuclear Security Regulations”.[23]

REQUEST: that the Commission make a determination as to whether the long-term management of radioactive waste is within the scope of this license review; if it is within scope, require OPG or their subsidiary NWMO to provide a detailed and technical description of the management approach, system

[21] DNNP Construction Licence Application, Ontario Power Generation, October 2022, page 219
[22] OPG CMD 24-H3.1, page 105
[23] OPG CMD 24-H3.1, page 112

and designs to be employed and allow supplementary submissions from the public intervenors after such information has been provided.

Accidents and Safety Assessments

According to *REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2* OPG's application must contain a discussion of the potential for severe accidents, probabilistic safety assessments.

In their CMD OPG claims that the BWRX-300 design provides physical features to ensure the facility is protected against malevolent acts to prevent potential release of radioactivity or energy to the public and environment but provides no evidence to support such a claim. OPG further states that "the BWRX-300 development includes a security by design approach from the early stages of design that uses sound engineering principles to demonstrate that within an acceptable margin of confidence sufficient capabilities are available to perform the above functions over a wide range of threats"[24] but again provide no evidence. The CMD goes on to argue that "the details of the design relating to security systems and structures are considered Prescribed Information and as such were provided directly to CNSC Staff for review" thus certainly any public scrutiny of this important area of assessment.

REQUEST: That the Commission make publicly available evidence provided by OPG that the BWRX-300 design includes physical features to ensure the facility is protected against malevolent acts to prevent potential release of radioactivity, with any redactions necessary for security purposes.

Radiation and Radiological Impacts

According to *REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2* OPG's application must contain a description of radiation sources, monitoring, and protection and radiological impacts.

While this subject area was outside Northwatch's primary area of assessment, we noted with concern that while the license application acknowledged that "designing to meet the Radiation Protection Objective begins with a comprehensive identification of radiation sources"[25] no such comprehensive listing or identification of radiation sources was included in the application. This need for a comprehensive identification of radiation sources was similarly identified in OPG's CMD[26] and similarly missing from the information provided.

We note that under the heading of "Radiation Protection" in OPG's CMD it is stated that "the objective for BWRX-300 radiation protection is to keep radiation exposures within regulatory limits and As Low as Reasonably Achievable (ALARA), while accounting for social and economic factors."[27] We acknowledge that the "principle" of ALARA is generally accepted by the CNSC, we also wish to note that there is a discomfort with this "objective" in the public. A key issue is the subjective nature of that qualifier "economic and social factors taken into account". As "low as achievable" is more in line with public

[24] OPG CMD 24-H3.1, Page 83-84
[25] DNNP Construction Licence Application, Ontario Power Generation, October 2022, page 113
[26] OPG CMD 24-H3.1, page 63
[27] OPG CMD 24-H3.1, Page 82

expectations. The adder of "reasonably" introduces a measure of subjectivity and value judgement. The further addition of "while accounting for social and economic factors" adds utilitarianism to subjectivity, reducing it from a principle to a proxy for the protection of human health and the environment.

Environmental Protection and Monitoring

According to *REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2* OPG's application must contain a description of the environmental monitoring methods and systems, and means to identify, control and monitor all releases of radioactive and hazardous substances and effects on the environment from facilities or as the result of licensed activities.

While this subject area was outside Northwatch's primary area of assessment, we wish to draw to the Commission's attention what we consider to be a fundamental flaw in how OPG has stated their Environmental Protection Objective:

> *The BWRX-300 is designed to account for the Environmental Protection Objective by ensuring that <u>reasonably practical measures</u> are taken to protect the environment during the construction and operation of the reactor facility and to mitigate the consequences of an event. The safety analysis confirms that the design includes effective provisions to <u>limit, control, treat and monitor releases</u> to the environment and minimize the generation of radioactive and hazardous wastes*.[28] (emphasis added)

Two questions arise from this stating of the Environmental Protection Objective:

- what is the measure of "reasonable practical" in reference to measures to be taken to protect the environment? Who determines what is "reasonable" or what is "practical"? Are these determinations made based on human health? Are the made based on respect of the environmental imperative? Or is the determination based on cost or on operational expediency? What is the Commission's understanding of this objective? Based on what assumptions or measures is the Commission determining whether this objective, as stated, is sufficiently protective of human health and the environment, as per the Commission's regulatory responsibilities?
- Is it satisfactory to the Commission – and to the public – that the design provisions will simply "limit, control, treat and monitor releases to the environment" rather than avoiding or preventing those releases?

Decommissioning

According to *REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Reactor Facility, Version 2* OPG's application must contain a description of decommissioning and end of life aspects, including financial guarantees.

[28] OPG CMD 24-H3.1, Page 63

In its application for construction, OPG states that "Preliminary Decommissioning Plans (PDPs) will be prepared and submitted it to the CNSC for acceptance for each stage of the DNNP lifecycle"[29], that "The PDP for the construction phase will be prepared to the requirements of REGDOC-2.11.2, Decommissioning [R-113] and will describe the end state of the facility after decommissioning, for CNSC acceptance" and that "PDPs for both the as-built facility and end-of-life will be submitted as part of the LTC Application supporting materials[R-32]."

The License to Construct application is to describe the decommissioning plans, rather than simply indicate that preliminary decommissioning plans will be prepared at a later date.

Ontario Power Generation has provided the CNSC with two preliminary decommissioning plans, one for "as built" and one for "end of life", and both dated March 2023, and while the information presented in these documents were not included in the application – as required – they similarly failed to meet the REGDOC requirements, and contain internal contradictions.

In the section 2.4, titled "DECOMMISSIONING STRATEGY", OPG sets out the following:

> *7) Underground metal and concrete piping will be excavated for survey and removed, <u>if necessary</u>. Uncontaminated materials beyond one meter below grade will be left in place, while contaminated materials that exceed the site release criteria will be removed and disposed of appropriately.*
>
> *8) Sub-surface structures will be surveyed for contamination, decontaminated if required and, consistent with international practices, dismantled to a 'nominal removal depth' of one meter below grade, backfilled with concrete rubble and/or soil and graded over. If contamination is present beyond one meter depth, OPG will be responsible to remediate until the respective screening levels are met. Additionally, the one-meter depth allows for the placement of both gravel for drainage and topsoil for erosion control through the establishment of vegetation and provides significant attenuation of any residual gamma radionuclides that may remain within the site release limits. At-grade foundation slabs exceeding one meter in thickness will be abandoned in place and covered with a one-meter-thick layer of backfill*[30]
>
> *10) 'Clearance Levels' based on guidance provided in CSA N292.5, "Guideline for the exemption or clearance from regulatory controls of materials that contain, or potentially contain, nuclear substances", July 2011 (reaffirmed 2016) (Ref. 38) will be developed prior to the decommissioning. These criteria will standardize the approach for segregation of the decommissioning wastes into those requiring long-term management and those that can be recycled, left on site or disposed of in conventional waste facilities*[31]

Issues include:

[29] DNNP Construction Licence Application, Ontario Power Generation, October 2022, Section 4.11.4 Decommissioning Practices, page 253

[30] Preliminary Decommissioning Plan Darlington New Nuclear Project - End Of Life, NK054-PLAN-00960-00007-R000 2023-03-17, page 5

[31] Preliminary Decommissioning Plan Darlington New Nuclear Project - End Of Life, NK054-PLAN-00960-00007-R000 2023-03-17, page 5

- Decisions to remove materials will be made based on site release criteria that has not been presented, and so is not subject to public comment or Commission consideration as part of this license application
- It is unclear how materials below one meter will be evaluated, and to what depth
- Decisions to remove material below one meter are reliant on screening levels which are not stated (or not yet developed)
- The plan relies on gravel, topsoil and vegetation for “attenuation of any residual gamma radionuclides”
- foundation slabs exceeding one meter in thickness will be abandoned in place and covered with a one-meter-thick layer of backfill; no estimate of contamination is identifies as being a requirement
- the development of Clearance Levels is deferred until some unidentified time in the future “prior to the decommissioning”
- the preliminary plan identifies that some decommissioning wastes will be left on site but provides no description of the management strategy of facilities for these wastes[32]

In the Preliminary Decommissioning Plan OPG defines “In situ decommissioning” as being “to place the facility, location or site, or portions thereof, in a safe and secure condition in which some or all of the radioactive contaminants are disposed of in place, which may result in the creation of a waste disposal site” and then states that “OPG has not considered In-situ decommissioning as there are no exceptional circumstances associated with the DNNP that would warrant its use”.[33]

While OPG is declaring that it has not considered in-situ decommissioning, as noted above there are several elements of their decommissioning plan which create the possibility of materials be left in place which, de facto, is in-situ decommissioning.

Northwatch supports an approach of managing radioactive wastes at or near the point of generation. However, the long-term management of waste at the point of generation is distinctly different from either an in-situ “decommissioning” approach which simply leaves the wastes or contaminated materials in place, unmanaged and unremediated.

As per above, REGDOC-1.1.2 directs that OPG’s application must contain financial guarantees. In contrast, Section 2.14 of the preliminary decommissioning plan states that decommissioning costs are provided separately, and details of the financial guarantee will be provided for future licensing stages.[34]

REQUEST: prior to completing their consideration of the OPG application for a license to construct and rendering their decision, the Commission must ensure that the public has ready access to the preliminary decommissioning plans, that the preliminary decommissioning plans provide sufficient information, resolve internal conflicts and contain costs estimates and details of both the amount and the means of calculating the financial guarantee, and there is a public comment opportunity with respect to the PDPs and financial guarantee.

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[32] Preliminary Decommissioning Plan Darlington New Nuclear Project - End Of Life, NK054-PLAN-00960-00007-R000 2023-03-17, page 5

[33] Preliminary Decommissioning Plan Darlington New Nuclear Project - End Of Life, NK054-PLAN-00960-00007-R000 2023-03-17, page 49

[34] Preliminary Decommissioning Plan Darlington New Nuclear Project - End Of Life, NK054-PLAN-00960-00007-R000 2023-03-17, page 75

Conclusions

As outlined earlier in this submission, the documentation submitted by OPG either does not include or inadequately addresses the information areas required in an application to construct a nuclear reactor in Canada.

Northwatch has made several requests of the Commission, which singly and in combination have the objective of requiring that Ontario Power Generation provide the necessary information and that the licensing review be carried out in a manner which is information-based and provides an opportunity for the public and Indigenous peoples to fully and fairly engage in the review process.

The requests made in the body of this submission are:

REQUEST: That the Commission deny the application to construct on the basis of OPG having provided inadequate information about their reactor design, including the design, design features and design basis for those parts of the site layout related to radioactive waste and its containment, including the Radwaste Building, the Spent Fuel Storage and the Fuel Pool

REQUEST: That the Commission defer further consideration of the application to construct until such time as OPG has provided evidence of how their site selection appropriately considered how the adjacency of the proposed boiling water reactor created an additional risk factor for the Darlington Waste Management Facility and vice versa and demonstrated that construction of the boiling water reactor in such close proximity to the DWMF does not create additional risk for the waste facilities, including as a result of accidents arising with or malevolent acts directed at the BWRX-300.

REQUEST: That the Commission defer further consideration of the application to construct until such time as OPG has submitted a complete reactor design and construction plan and met all the requirements of REGDOC-1.1.2

REQUEST: That the Commission defer further consideration of the application to construct until such time as OPG has submitted addressed the gaps and deficiencies in their application with respect to radioactive waste management and its facilities, including the design details of those facilities which will be constructed prior to operation commencing, and adjustment of the site configuration to correct the current placement of the future fuel waste storage being outside the protected area.

REQUEST: that the Commission make a determination as to whether the long-term management of radioactive waste is within the scope of this license review; if it is within scope, require OPG or their subsidiary NWMO to provide a detailed and technical description of the management approach, system and designs to be employed and allow supplementary submissions from the public intervenors after such information has been provided.

REQUEST: That the Commission make publicly available evidence provided by OPG that the BWRX-300 design includes physical features to ensure the facility is protected against malevolent acts to prevent potential release of radioactivity, with any redactions necessary for security purposes.

REQUEST: prior to completing their consideration of the OPG application for a license to construct and rendering their decision, the Commission must ensure that the public has ready access to the preliminary decommissioning plans, that the preliminary decommissioning plans provide sufficient information, resolve internal conflicts and contain costs estimates and details of both the amount and the means of calculating the financial guarantee, and there is a public comment opportunity with respect to the PDPs and financial guarantee.

In summary, Northwatch is requesting that the Commission deny OPG their application. In the alternative, we request that the Commission deny OPG their application until such time as all matters may be given due consideration, the public and Indigenous peoples have the opportunity for an additional intervention after the required information has been made available.

All of which is respectfully submitted by Northwatch on November 11th, 2024.

For return correspondence contact Northwatch at northwatch@nortwatch.org.

Northwatch – Appendix 1 – 2024-H-03

BOKU
Institute of Safety
and Risk Sciences

Peculiarities in Chapter 11 and Chapter 15 of the Preliminary Safety Analysis Report of the BWRX-300 Nuclear Reactor

November 2024

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Peculiarities in Chapter 11 and Chapter 15 of the Preliminary Safety Analysis Report of the BWRX-300 Nuclear Reactor

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Contents

1 Introduction

Ontario Power Generation (OPG) is proposing to construct four BWRX-300 reactors at the Darlington Nuclear Generating Station, 70 km west of Toronto on the north shore of Lake Ontario. OPG is seeking to delay the detailed address of nuclear waste management until the operating license (now at the construction license stage) so the information on radioactive wastes and OPG's proposed management continues to be limited.

2 Background and Method

The BWRX-300 is a small modular reactor (SMR) designed by GE Hitachi Nuclear Energy. It is a boiling water reactor (BWR), which is a type of light water reactor (LWR). Currently, there are 41 BWR with a power level of about 1 Gigawatt (GWe) each in operation (IAEA, 2024).

The BWRX-300 is designed to produce approximately 300 Megawatts of electrical power (MWe). It utilizes natural circulation for cooling. According to GE Hitachi, it represents a significant advancement in nuclear technology, aiming to provide a more cost-effective, safe, and flexible solution for generating nuclear power. Its promoters argue that this design leverages the extensive operational experience and proven technology of previous BWRs while incorporating innovative features to enhance its performance and safety.

The BWRX-300 comes with the same promises as other small modular reactors: its smaller size and modular construction should allow for shorter construction times and reduced initial capital investment. The modular approach also might enable factory fabrication of components, which could improve quality control and reduce construction risks and delays. The realism of these claims is beyond the scope of this report and is discussed elsewhere, e.g., in Pistner et al. (2021), Lyman (2013), and Ramana (2021).

The BWRX-300 uses several passive safety systems, such as natural circulation for cooling. These systems rely on natural physical principles, such as gravity and natural circulation, to maintain safe operation and cooling of the reactor core without the need for active mechanical components or operator intervention.

The purpose of this report is to highlight peculiarities in the operational radioactive waste information and the preliminary safety analysis. To this end, the information on the BWRX-300 is compared with the information in the final safety analysis reports for a large BWR.

The Economic Simplified Boiling Water Reactor (ESBWR) is a Generation III+ nuclear reactor design developed by General Electric Hitachi Nuclear Energy. It is an advanced boiling water reactor (BWR) that uses light water as both coolant and neutron moderator. The ESBWR operates with a direct cycle, where water is boiled directly in the reactor core to produce steam, which then drives the turbines connected to electrical generators. A key feature of the ESBWR is its passive safety systems, which rely on natural circulation and gravity to maintain core cooling and containment integrity without the need for active mechanical pumps or operator intervention.

The ESBWR has a simplified design with fewer components and systems compared to earlier BWR models. It is one of the predecessors of the BWRX-300. It is designed to produce approximately 1,600 MWe of electrical power, making it suitable for large-scale electricity generation. The U.S. Nuclear Regulatory Commission (NRC) granted design approval in September 2014.

Unless stated otherwise, information and values are taken from the Final Safety Analysis Report for the ESBWR (Hitachi, 2014) and the Preliminary Safety Analysis Report published in 2022 for the BWRX-300 (Hitachi, 2022a).

3 Management of Radioactive Waste

The following section looks at the concentration of radionuclides in the coolant water during normal and design basis operation. It further touches two other aspects regarding the potential waste generation of the BWRX-300.

3.1 Radioactive Source Terms

Chapter 11 of the PSAR, titled "Management of Radioactive Waste," provides detailed information on the radioactive source terms in reactor water and steam. These values serve as the design basis for radioactive waste management systems during operation and are crucial during accidents that may lead to radioactive releases from the reactor core into the environment or containment structures. These radioactive materials can include fission products, activation products, and transuranic elements.

During normal operation, release rates into the environment are typically very low due to stringent containment measures and the use of multiple barriers, such as fuel cladding, the reactor vessel, and the containment building. However, there is always a certain release rate of radionuclides into the water and steam, even under normal conditions. Radionuclides in a nuclear reactor are primarily produced by the fission of fissile materials in the fuel rods and by the activation of other materials. Fission products can escape from the fuel rods into the coolant through imperfections or breaches in the fuel cladding. Neutrons produced during fission can interact with the coolant itself, as well as with structural materials and impurities in the reactor, making formerly stable nuclides radioactive through a process called activation. Consequently, there is always a certain concentration of radionuclides in the primary coolant circuit. Typically, these radionuclides are confined within this system. However, if there is a leak in the system, radionuclides might be transferred to the secondary coolant circuit. In the event of a controlled or accidental release, radionuclides can be released into the environment.

In this chapter of the report, we look at the source terms for relevant isotopes for the BWRX-300. Hereby, two source terms are presented. The first source term is a realistic model, which is based on the American Nuclear Standard Source Term Specifications (ANSI) and American Nuclear Society (ANS) 18.1 (ANS, 2020). It is referred to as the normal operation source term. It is derived from measured nuclide concentrations during operation of BWRs and adjusted to the BWRX-300 and the ESBWR using parameters given in Table 1. Normal operation refers to the routine functioning of the reactor under standard conditions, where all systems operate within specified limits and no significant safety issues arise.

Parameter	ESBWR	BWRX-300
Thermal Power, MWth	4500	870
Reactor Mass, kg	3.06e5	1.23 e5
Water clean-up systems Flow Rate (kg/hr)	8.76e4	about 1% steam flow rate
Steam Flow Rate (kg/hr)	8.76e6	5.03e5

Table 1: Parameters for Source Term Adjustment for the ESBWR and the BWRX-300

Concentrations are given for various nuclides and group of nuclides such as noble gases, fission products, or activation products in the safety analysis reports. We focus on three different nuclides:

- Strontium-90 (Sr-90) is important in nuclear reactors' release rates due to its long half-life and high radiotoxicity. As a byproduct of nuclear fission, Sr-90 can be released during reactor operations or accidents. It mimics calcium and accumulates in bones, posing significant health risks, including bone cancer and leukemia.

- Iodine-131 (I-131) is crucial due to its high radioactivity and potential health risks. I-131 is a byproduct of nuclear fission with a short half-life of about 8 days, emitting beta and gamma radiation. It can be released during reactor operations or accidents and is readily absorbed by the thyroid gland, increasing the risk of thyroid cancer and other disorders. Other iodine isotopes have shorter half lives and are thus of less relevance.

- Barium-137m (Ba-137m, "m" for excited state of the nuclide) is listed together with Cesium-137 (Cs-137) in nuclear power plants because Ba-137m is a decay product of Cs-137. Cs-137 undergoes beta decay to form Ba-137m, a metastable isotope of barium. Ba-137m then releases gamma radiation as it transitions to its stable form, Ba-137. Monitoring both isotopes is crucial for radiation safety and environmental monitoring, as Cs-137 is a significant fission product with a long half-life, and its decay to Ba-137m contributes to the overall radiation levels.

The concentrations in the water of the primary cooling circuit for the ESBWR and the BWRX-300 according to the respective safety analysis reports are given in Table 2. The values for both reactors were obtained by adapting the ANSI/ANS-18.1 Source Term Standard. The equilibrium concentration scales with the radionuclide input rate to coolant, which in turn primarily scales with the reactor thermal power.

From the table, one will recognize two anomalies: First, the difference between the concentrations of Sr-90 and I-131 in the primary coolant of the ESBWR and BWRX-300 is about the factor 100 or two orders of magnitude. This is not the difference in reactor thermal power. Equilibrium concentrations further scale with the inverse of the reactor water mass. Even though the BWRX-300 has a rather high volume of primary coolant, it seems rather unlikely that this could account for such a huge difference. Second, the concentration of Cs-137/Ba-137m is almost the same. This again strengthens the point that there seems to be more going into the calculation than stated in the BWRX-300 Preliminary Safety Analysis Report.

Nuclide Unit	ESBWR MBq/g	BWRX-300 MBq/g
Strontium-90	1.8e-7	4.6e-9
Iodine-131	1.2e-4	2.7e-6
Cesium-137/Ba-137m	1.9e-6	1.3e-6

Table 2: The concentration of relevant nuclides in the water of the ESBWR and the BWRX-300 during normal operation. For Sr-90 and I-131 concentrations are significantly lower for the BWRX-300.

Design basis, on the other hand, encompasses the set of conditions and events that a reactor is engineered to withstand without significant release of radioactive materials. This includes, among others, potential accidents and equipment failures. While normal operation focuses on maintaining safe, efficient performance, the design basis is intended to ensure the reactor's resilience and safety under a wide range of hypothetical scenarios, providing a robust framework for protecting public health and the environment.

For the ESBWR, design bases concentrations are also derived using the ANSI/ANS-18.2 standards. For the BWRX-300, however, it is stated that the GEH clad defect model is used. A reference from 1973 is given as a basis for system and shielding requirements (Skarpelos and Gilbert, 1973). In this reference, lots of historical leakage rates are given as well. It is not clear why this model is referenced in the Preliminary Safety Analysis Report for the BWRX-300, but not in the Final Safety Analysis Report for the ESBWR. The concentrations in the primary coolant water for both reactors as given in the safety analysis reports are listed in Table 3.

Nuclide Unit	ESBWR MBq/g	BWRX-300 MBq/g
Strontium-90	1.3e-6	3.2e-6
Iodine-131	8.6e-4	1.9e-3
Cesium-137/Ba-137m	1.3e-5	8.7e-4

Table 3: Design basis concentration of relevant nuclides in the water of the ESBWR and the BWRX-300. For Sr-90 and I-131, concentrations for the BWRX-300 are about twice as high. For Cesium-137/Ba-137, the concentration for the BWRX-300 is more than 60 times as high.

Again, Cesium-137/Ba-137m stands out: while for Sr-90 and I-131 the concentrations in the coolant are about twice as high for the BWRX-300, they are more than sixty times as high for Cesium-137/Ba-137m. This cannot be explained easily by simply using a different calculation method.

The design basis concentrations for the ESBWR are higher than the normal operation concentrations, by about one order of magnitude. For the BWRX-300, design basis concentrations of I-131 and Cs-137/Ba-137m are orders of magnitude higher than normal operation conditions. The influence of the water clean-up system is unclear. For the BWRX-300, it is stated that the planned condensate filters and demineralization (CFD) system represents the best available technology economically achievable and will be at least equivalent to existing coolant clean-up systems in operating BWRs. At the current stage, its effectiveness is unclear.

When using ANSI/ASN 18.1, the fraction of nuclides removed by the CFD system is included in the equilibrium concentration calculation. For the effectiveness of the CFD, more precisely, the nuclide-dependent removal rate parameters, the text in the PSAR refers to Table 11.1-3. However, no nuclide-dependent parameters are given in this table. For the ESBWR, these values are given for iodine, Rb, and Cs, and all others. According to the above explanation, it is likely that the same values are assumed for the BWRX-300, but this is not explicitly stated. But this does not fit the tabled valued. The higher design basis concentrations could be explained by the fact that the CFD system is assumed not to be in operation. Nevertheless, a decontamination system that reduces the concentration by two orders of magnitude would be excellent. So there must be other factors influencing the concentrations.

3.2 Nuclear Waste generated by SMRs

On a more general note, in the Ontario Power Generation DNNP Construction License Application from October 2022, it is stated that the BWRX-300 is "maintaining a low waste signature for both conventional and radioactive waste. This is accomplished using advanced design and construction methods that reduce waste during construction, as well as the amount of irradiated material for decommissioning." (Ontario Power Generation, October 2022, p. 36) It is not clear what kind of methods those are supposed to be. However, it has been shown by scholars that SMRs in general are not beneficial for waste stream management and disposal due to the simple fact that they are smaller, and thus neutron leakage is higher (Krall et al., 2022).

On page 45 of the construction license, it is further argued that the construction of the facility does not require the handling of radioactive materials. Even though this is technically correct, it should be stressed that constructing a facility without planning to use it when finished does not make sense at all. The facility to be built is a nuclear power reactor. Operating nuclear power reactors inevitably uses radioactive material and produces nuclear waste. Logically and practically, the construction of nuclear power plants requires the construction of waste handling facilities and concepts on how to deal with the resulting nuclear waste.

4 Safety Analysis

4.1 Methods in Safety Analysis

Traditionally, safety analysis is based on deterministic methods. Deterministic safety analysis (DSA) looks at specified initiating events and assesses plant behavior (IAEA, 2010; Johnson and Ma, 2022). Conservative assumptions such as the single failure criterion are used: even if the most powerful safety system fails, are the other ones able to fulfill the task. The so-called postulated initiating events (PIEs) are, for example, turbine shutdown or loss of feedwater heating. Each event is analyzed individually. The safety analysis report shows that each event has consequences that are acceptable in terms of the likelihood of the event occurring. The list of PIEs developed with the technology of nuclear power plants. However, not all events might occur in all reactor designs.

In contrast, probabilistic safety analysis (PSA) is a method to identify accident scenarios and estimate the risk presented by a facility (NEA, 2009; IAEA, 2010). While in the case of DSA it must be demonstrated that precisely specified failure sequences are mastered, in the case of PSA it is sufficient for the total risk from several different failure paths to remain below a limit. Due to the inherent uncertainties, the probabilistic safety analysis is seen as an add-on to the deterministic safety analysis only (Petrangeli, 2006).

This approach is not followed thoroughly for the BWRX-300: Certain events such as the "Loss of Vital DC Bus" are not covered in the deterministic safety analysis as done for the ESBWR but only using probabilistic safety analysis - without further explanation.

4.2 Redundancy and Diversity of Safety Systems

A central safety system of the BWRX-300 is the Isolation Condenser System. This passive system uses heat exchangers in the reactor pressure vessel (RPV), from which excess heat is transported by natural circulation to heat exchangers in isolation condenser pools above the RPV. This system is triple redundant, i.e. three independent ICS trains end in three separate, but interconnected water pools. According to its specifications, a single ICS is able to supply sufficient cooling in all considered accident sequences. This follows the logic, that e.g. one train may be shutdown for maintenance and a second train may fail in the accident, leaving a single (sufficient) train operational. However, there is no indication that the ICS trains apply a diverse design, i.e. they are identical. A diverse design is usually required to prevent the failure of all redundant systems, e.g. due to a similar fault in all assemblies. Further, since the IC pools are interconnected by large pipes with valves, an accident is conceivable in which the water supply of the pools is exhausted too quickly due to damage to one of the pools and opening of the connecting valves, causing all ICS to fail.

4.3 Comparison of Events

The following section compares the events investigated for the ESBWR and the BWRX-300 in order to identify differences and further possible weaknesses. These are divided into Anticipated Operational Occurrences (AOO) and Design Basis Accidents (DBA).

4.3.1 Comparison of Anticipated Operational Occurrences Events

The direct comparison of Anticipated Operational Occurrences shows a more detailed approach for the ESBWR (see Table 4).

Further, the different design of the BWRX-300 makes a direct comparison of the events "Closure of One Main Steamline Isolation Valve" and "Closure of One Main Steam Reactor Isolation Valve" not possible, since in the latter case the valve is attached directly to the reactor vessel and no relief valves are used. These differences also moves the event "Closure of All Main Steam Reactor Isolation Valves and Feedwater Isolation" of the BWRX-300 to the DBA category, while "Closure of All Main Steamline Isolation Valves" of the ESBWR is an AOO. This is similar for "Loss of All Feedwater Flow" and "Feedwater Pump Trip – One Pump".

ESBWR	BWRX-300
Decrease In Core Coolant Temperature	
Loss Of Feedwater Heating	Loss Of Feedwater Heating
Increase In Reactor Pressure	
	Generator Load Rejection or Turbine Trip
Closure of One Turbine Control Valve	
Generator Load Rejection With Turbine Bypass	
Generator Load Rejection With a Single Failure in the Turbine Bypass System	
Turbine Trip With Turbine Bypass	
Turbine Trip With a Single Failure in the Turbine Bypass System	
Closure of One Main Steamline Isolation Valve	Closure of One MSRIV
Closure of All Main Steamline Isolation Valves	*similar DBA event*
Loss of Condenser Vacuum	Loss of Condenser Vacuum (LOCV)
Loss of Shutdown Cooling Function of RWCU/SDC	
	Loss-of-Preferred Power (LOPP)
Reactivity and Power Distribution Anomalies	
Control Rod Withdrawal Error During Startup	
Control Rod Withdrawal Error During Power Operation	
Increase in Reactor Coolant Inventory	
	Inadvertent Isolation Condenser Initiation – One Train (IICI-1)
Inadvertent Isolation Condenser Initiation	
Runout of One Feedwater Pump	
Decrease in Reactor Coolant Inventory	
Opening of One Turbine Control or Bypass Valve	
Loss of Non-Emergency AC Power to Station Auxiliaries	*DBA event*
Loss of All Feedwater Flow	
	Feedwater Pump Trip – One Pump

Table 4: Comparison of Postulated Initiating Events for Anticipated Operational Occurrences between the ESBWR and the BWRX-300 reactor design.

Inadvertent Control Rod Withdrawal is not analyzed since "a protection function of Automatic Thermal Limits Monitor (ATLM) initiates a control rod block" (p 15-16).

Due to the design differences, "Loss of Non-Emergency AC Power to Station Auxiliaries", which is as initiating event identical to "Loss-of-Preferred Power (LOPP)" and indicates an offsite power failure is an AOO for the ESBWR, but a DBA event for the BWRX-300. The resulting sequences differ accordingly.

4.3.2 Comparison of Design Basis Accident events

Comparison of the analyzed Design Base Events shows that "Control Rod Manipulation Errors" and "Control Rod Drop Accidents" were analyzed in detail for the ESBWR, but deemed of little relevance for the BWRX-300. These accidents may lead to damage to the fuel rods and release of radioactivity. While release outside of the containment is unlikely in these cases, it is unclear why it is practically ignored in the safety analysis of the BWRX-300.

The "Fuel Handling Accident" is categorized as a non-reactor group DEC event, but analysis are done similar to the ESBWR, with almost identical results.

"Inadvertent Shutdown Cooling System Function Operation" and "Inadvertent Opening of a Depressurization Valve" are addressed in detail for the ESBWR but ignored without explanation for the BWRX-300.

4.3.3 Selected Events

Three selected events are discussed in more detail for illustration.

Closure of One Main Steam Reactor Isolation Valve

In case of the closure of the main steam reactor isolation valve stops the flow of steam from the reactor to the turbine. It isolates the reactor core, thus preventing potential release of radioactive materials. At the same time, it also hinders the cooling of the reactor core. This event is of interest, since it results in the highest peak cladding temperature and peak vessel pressure. This might result in severe damage to those components. It is considered as AOO and, when the reactor SCRAM fails, as Design Extension Condition.

The sequence for events in case of the Anticipated Operational Occurrences is as follows (citation from Chapter 15):

- *One MSRIV closes causing RPV pressure and power to increase*
- *Scram occurs on MSRIV position*
- *Reactor Level Control (RLC) controls levels*
- *Second MSRIV in the second steam line closes on leak detection indication (this is assumed because it makes the event more severe)*
- *One ICS train initiates on high RPV pressure ([...] a single ICS train is capable of controlling pressure and removing decay heat as demonstrated in the pressure increase DBA analysis)*
- *Controlled state achieved*

The DEC case is identical, only with additional fail of the SCRAM. As can be seen, the safety relies solely on the ICS, which is as explained above, triple redundant, but not diverse. To our knowledge, no alternative system for decreasing the RPV pressure exist.

ESBWR	BWRX-300
Loss of Feedwater Heating	Common Cause Failure – Loss of Feedwater Heater
Feedwater Controller Failure – Maximum Flow Demand	Feedwater Flow Increase – All Pumps
AOO event	Common Cause Failure - Loss of FW Flow
Pressure Regulator Failure – Opening of All Turbine Control and Bypass Valves	Reactor Pressure Vessel Pressure Control Open
Pressure Regulator Failure – Closure of All Turbine Control and Bypass Valves	RPV Pressure Control Downscale
Generator Load Rejection With Total Turbine Bypass Failure	Generator Load Rejection or Turbine Trip
Turbine Trip With Total Turbine Bypass Failure	Generator Load Rejection or Turbine Trip
Control Rod Withdrawal Error During Refueling	
Control Rod Withdrawal Error During Startup With Failure of Control Rod Block	
Control Rod Withdrawal Error During Power Operation with ATLM Failure	
Fuel Assembly Loading Error, Mislocated Bundle	Fuel Loading Error (FLE)
Fuel Assembly Loading Error, Misoriented Bundle	Fuel Loading Error (FLE)
Inadvertent Shutdown Cooling System Function Operation	
Inadvertent Opening of a Safety Relief Valve	*not applicable*
Inadvertent Opening of a Depressurization Valve	
Stuck Open Safety Relief Valve	*not applicable*
Liquid-Containing Tank Failure	
	Inadvertent Isolation Condenser Initiation - All Trains
similar AOO event	Closure of All MSRIVs and FW Isolation
AOO event	Loss-of-Preferred Power (LOPP)

Table 5: Comparison of Postulated Initiating Events for Design Basis Accidents between the ESBWR and the BWRX-300 reactor design.

ESBWR	BWRX-300
Fuel Handling Accident	
Loss-of-Coolant Accident Inside Containment	Feedwater Pipe Break Inside the Containment, Conservative Case
Main Steamline Break Accident Outside Containment	Large Main Steam Pipe Break Outside the Containment
Control Rod Drop Accident	
Feedwater Line Break Outside Containment	Large Feedwater Pipe Break Outside the Containment
Failure of Small Line Carrying Primary Coolant Outside Containment	Small Breaks Outside the Containment
Reactor Water Cleanup/Shutdown Cooling System Line Failure Outside Containment	
	Large Isolation Condenser Pipe Breaks Outside the Containment
	Large Isolation Condenser Pipe Breaks Inside the Containment
	Main Steam Pipe Breaks Inside the Containment, Conservative Case
	Small Steam and Liquid Pipe Breaks Inside the Containment
Spent Fuel Cask Drop Accident	

Table 6: Comparison of Postulated Initiating Events for Design Basis Accidents between the ESBWR and the BWRX-300 reactor design.

Closure of All Main Steam Reactor Isolation Valves and Feedwater Isolation

The closure of all main steam reactor isolation valves and feedwater isolation is critical to prevent radioactive steam and coolant from escaping the reactor core into the environment, ensuring containment and protecting safety systems during abnormal or emergency conditions. According to the PSAR, the sequence would be as follows:

- *Closure of all MSRIV and FW isolation valves*
- *Scram occurs on high neutron flux*
- *After scram, immediate challenge to cladding and RCPB integrity is over*
- *An ICS train initiates on high pressure. The first IC train fails to actuate (assumed single failure). One of the two remaining trains is sufficient to control pressure*
- *Controlled state achieved*

Again, RPV pressure is controlled through the ICS, no alternative means to control this sequence exist.

Interfacing Systems LOCA

An "Interfacing Systems Loss of Coolant Accident" (ISLOCA) is a type of accident where there is a breach in the boundary between two different cooling circuits. This can lead to a loss of coolant from one system into another, affecting cooling of the reactor core.

While for the similar ESBWR two ISLOCA paths have been identified, for the BWRX-300, one ISLOCA is considered *"practically eliminated"*. It is not clear how this is achieved, as the two designs appear to differ only marginally in this respect.

5 Conclusion

In the following, we describe some peculiarities that came to our eye when scanning through the available information on operational waste management and safety analysis for the BWRX-300. This list does not claim to be exhaustive.

Comparing concentrations of radionuclides in the coolant of BWRX-300 and ESBWR leads to questions.

Chapter eleven presents an estimation of the source term of radionuclides in the reactor coolant. This source term is estimated once using realistic methods (normal operation source term), and once estimated using conservative methods (design basis source term).

Information on operation source terms in coolant water is derived using standard source terms, which are roughly scaled according to the power levels of the reactor. However, questions arise when comparing those source terms with the ESBWR source term:

In normal operation, the concentration of Strontium-90 and Iodine-131 is two orders of magnitude lower for the BWRX-300 than for the ESBWR, but the concentration of Cesium-137/Barium-137m is in the same order of magnitude, which cannot be explained by the difference in power levels of the reactor.

The method to derive design basis source terms in coolant water differs from the method used for the GEH ESBWR reactor. The difference in normal and design basis source term is several orders of magnitude for the BWRX-300, unlike in the ESBWR. It is not clear where this difference is coming from. This should be further investigated.

Lack of diversity for the Isolation Condenser System

Important safety functions such as pressure reduction in the reactor coolant system should be redundant and diverse. Although the Isolation Condenser System in the BWRX-300 is triple redundant (3x100%), it is not diverse, i.e. a common fault in the individual systems or in the shared components (interconnected water pools) could cause a complete failure. For several initiating events in the safety analysis, the reactor is brought in a safe state by single Isolation Condenser which is sufficient to provide adequate cooling capacity. There is no additional system to reduce excess pressure in the reactor pressure vessel. The ESBWR on the other hand features safety relief valves at the steam lines, which are capable of blowing steam into the containment. This system was removed in the design of the BWRX-300. A closer examination should be conducted to determine the extent to which the concepts of redundancy *and* diversity are implemented in other critical safety systems as well.

Certain postulated initiating events that are analyzed using deterministic safety analysis for the ESBWR are only analyzed using probabilistic safety analysis for the BWRX-300. This fact is of interest since using DSA it must be shown for each initiating event separately that it can be managed. In a PSA, only the overall resulting risk of the facility is of importance. It is not stated in the PSAR why for those respective events no deterministic analysis is done.

The list of events for the safety analysis of the BWRX-300 is reduced

For the BWRX-300, the list of analyzed initiating event is shorter than for the ESBWR. One example are fuel handling accidents, which might lead to local increase in reactivity and thus heat production. During fuel handling accidents, fuel elements are not positioned correctly and/or at the planned position in the core. Those events are considered relevant for the similarly designed ESBWR, but not analyzed for the BWRX-300. There is no conclusive explanation as to which changes in the design justify this.

A List of Abbreviations

Abbreviation	Meaning
AOO	Anticipated Operational Occurrences
CFD System	Condensate Filters and Demineralization System
DBA	Design Basis Accident
DEC	Design Extension Conditions
ESBWR	Economic Simplified Boiling Water Reactor
FSAR	Final Safety Analysis Report
FW	Feedwater
ICS	Isolation Condenser System
LOCA	Loss of Coolant Accident
MSRIV	Main Steamline Reactor Isolation Valve
OPG	Ontario Power Generation
PIE	Postulated Initiating Events
PHWR	Pressurized Heavy Water Reactor
PSAR	Preliminary Safety Analysis Report
RCPB	Reactor Coolant Pressure Boundary

Table 7: List of Abbreviations

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